Quality aspects of the Norwegian cause of death statistics

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Thesis for the degree of Philosophiae Doctor (PhD)
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1. The scientific environment

The work of this thesis was conducted at:

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Department of Global Public Health and Primary Care, University of Bergen.

UNIVERSITY OF BERGEN
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2. Acknowledgements

This study has been a lengthy journey, but I have also had the opportunity to meet many people that have – in various ways – helped and inspired me in the process.

I would first like to thank my supervisors – Geir Sverre Braut, G. Cecilie Alfsen and Stein Emil Vollset, and, for some time, Marta Ebbing. All very competent, albeit extremely different both in scientific background and in personal attitude. I am especially indebted to Geir Sverre; I have always enjoyed our discussions, whether they were related to the present research or not. I am also grateful to the other co-authors: Anne Gro Pedersen and Gerhard Sulo.

I have not had any external funding or scholarship for this work. The head of the departments, especially Susanne Buhr-Wildhagen in Stavanger, have tried to allocate some time for research between the daily routine, for which I am deeply grateful. The consequence has been more workload on my closest colleagues; I appreciate your good-will. Co-workers in all professions have shown their support and interest, even if I suspect that the other researchers at the department consider me an exotic animal.

I learned a lot during the time I worked at the Cause of Death Registry, especially from the nosologists (medical coders). They taught me the basics of cause of death registration and coding, participated in the query part of paper II, and were good discussion partners.

I have also had fruitful discussions with local police officers, attorneys, and judges concerning the systems for and purposes of death investigation.

My deepest thanks gos to my family: my dear wife Bente and our children Ludvig and Sunniva. They have endured my physical and mental absence. Bente has given unlimited support as well as good advice and cautions, when needed.

"What counts most cannot be counted!"

3. Introduction

For the largest part of my professional life, I have worked with causes of death. As a forensic pathologist and histopathologist, I perform autopsies to ascertain the cause and manner of death and convey my opinions to the police, health care professionals, and next-of-kin. The autopsy results are also reported to the Norwegian Cause of Death Registry, to be implemented in the official cause of death statistics. For some years I worked at the said Registry, assisting in coding of death certificates, giving advice for quality control, and production of statistics. A substantial part of my job was to communicate with users of cause of death data: researchers, government officials, NGOs (non-governmental organizations), and media. I gained valuable knowledge on production and utilization of cause of death data, both on individual and group level. There are strengths and weaknesses in the death registration system and the quality of the data, and the quality of the analyses and research cannot be better than the ingoing data. It is therefore important to have a grasp on the data quality, including if the quality is better or worse in some population segments. Frequent questions from the users of cause of death data are some variants of: "How can I know if the data are correct? If not – what is the **real** cause of death?" When formal validation studies are lacking, the extent of unsuitable diagnostic codes ("garbage codes") can be used as one parameter of data quality. If many deaths are coded with garbage codes, then the information value of the cause of death data is reduced. Knowledge of the extent of the use of garbage codes, both in general and in specific segments of the population, can indicate where there are flaws in the data quality.

Autopsies, both forensic and non-forensic, give valuable information on the cause(s) of death. If the frequency of autopsies is too low, there is a risk that the registered cause of death will be incomplete or wrong. In case of forensic autopsies, this may lead to insufficient investigation of unnatural deaths. If there are systematic differences between population segments (such as geographical regions), this may

introduce spurious shifts in the cause of death statistics. These are important aspects when discussing the use of forensic autopsies in the society, both for legal and public health reasons.

In this thesis, I present investigations on some quality aspects of the Norwegian cause of death statistics, related to the use of garbage codes for the underlying cause of death, as well as an analysis of the pattern of use of forensic autopsies.

In order to understand the “why”, “how”, and “wherefore” of the current conception for understanding and registration causes of death, it is necessary to be familiar with the historical processes leading up to today’s system. Therefore, the thesis starts with a historical overview and discussion of core concepts.

4. Abstract

4.1 Data quality in Norwegian cause of death statistics

Information on all-cause and cause-specific mortality in a population are considered fundamental public health indicators. It is used for surveillance of causes of death, production of national and international statistics, for research and quality improvement. It is the underlying cause of death (the condition that started the sequence of events leading to death) that conveys most information for public health purposes. The quality of the produced cause of death statistics and the analyses using these data is no better than the quality of the ingoing data material. This thesis presents some quality aspects of the Norwegian cause of death statistics. The Norwegian Cause of Death Registry is the main data source for the studies.

In deaths in Norway, the cause of death is registered based on information on the death certificate. The information is supplemented by the autopsy report, if an autopsy has been performed. The diagnoses are registered according to the international classification system ICD-10, but not all diagnostic codes carry adequate information. Some codes only describe the circumstances, such as “sudden death” or terminal complications that might be the result of a number of different condition (“multi organ failure”). Codes that do not convey sufficient information on the underlying cause of death are called garbage codes. If a large proportion of the deaths is assigned a garbage code, the information value of the cause of death statistics is reduced. The information value increases if it is possible to ascertain which diagnoses that are hidden behind the garbage codes. The international Global Burden of Disease Study has developed advanced statistical methods to come closer to more complete cause of death statistics, a process called redistribution.

In the first part of the study, we investigated the use of garbage codes in the Norwegian Cause of Death Registry in the years 1996-2019. We found that 29% of the deaths were assigned a garbage code, 14% in the group with lowest information

value (major garbage codes). During the study period, the proportion of deaths assigned a less serious (minor) garbage code decreased, but not the proportion with the most serious garbage codes. The proportion of garbage codes was higher in the oldest age group and in deaths outside health care institutions, and lower where an autopsy had been performed. The garbage code proportions are similar in Denmark and Sweden, but lower in Finland and the United Kingdom. The prevalence of garbage codes is the most important quality issue in the Norwegian cause of death statistics.

In the second part of the study, we performed an in-depth analysis of the use of one specific garbage code. The ICD-10 code X59 is used in external cause deaths (injuries, poisonings) where the information on the circumstances is missing (e.g. whether the injury was caused by a traffic accident or a fall). In the study period 2005-2014 this information was lacking in 26% of the deaths with an external cause. Most of these occurred in elderly persons with a fracture in the hip region. Based on the deaths with adequate information, we developed a statistical method that could be applied on the deaths lacking information. The results indicate that more than 95% of the X59 deaths are accidental falls, and a query to the certifying doctors in 2015 supports this view. Our results indicate that the real mortality from accidental falls in Norway is more than twice as high as shown in the official statistics.

A forensic autopsy is part of the police investigation in possible unnatural deaths, but the autopsy results are also important supplementary information to the cause of death statistics. This is especially relevant in external cause deaths and unexpected deaths outside health care institutions. In the third part of the study, we investigated the use of forensic autopsies in Norway in the years 1996-2017. We found that a forensic autopsy had been carried out in 4.1% of all deaths, but the proportion varied between police districts, from 0.9-7.8%, and this variation persisted throughout the study period. The differences could only partly be explained by geographical factors, such as the size of the population of the municipality and the distance from the place of death to the autopsy facility. Other factors are probably important, such as local

traditions and guidelines. If there are unjustified differences in the use of forensic autopsies between police districts, there is a risk that unnatural deaths will not be adequately investigated, and it might introduce spurious shifts in the cause of death statistics.

4.2 Datakvaliteten i den norske dødsårsaksstatistikken

Opplysninger om dødelighet og dødsårsaker i en befolkning regnes som grunnleggende folkehelsedata. De brukes for å overvåke dødsårsaker og se på endringer over tid, gir grunnlag for nasjonal og internasjonal statistikk, brukes i forskning og for planlegging og kvalitetsarbeid i helse- og omsorgstjenestene. Det er den underliggende dødsårsaken (den tilstanden som startet rekken av hendelser som førte til døden) som gir mest informasjon for folkehelseformål. Kvaliteten av den statistikken som produseres og de analysene som blir gjort er ikke bedre enn kvaliteten av dataene som brukes. I denne avhandlingen presenteres studier av noen kvalitetsaspekter i den norske dødsårsaksstatistikken. Datamaterialet til studiene kommer i all hovedsak fra det norske dødsårsaksregisteret.

Ved alle dødsfall i Norge blir dødsårsaken registrert ut fra opplysninger på legeerklæring om dødsfall (dødsmelding/dødsattest). Der det er gjort en obduksjon brukes obduksjonsresultatene for å supplere opplysningene på dødsmeldingen. Diagnosene registreres i henhold til det internasjonale kodeverket ICD-10, men ikke alle diagnosene der har like god informasjonsverdi om den underliggende dødsårsaken. Det kan for eksempel være diagnoser som bare sier noe om omstendighetene rundt dødsfallet («plutselig død») eller angir en komplikasjon som kan skyldes mange ulike tilstander («multiorgansvikt»). Slike diagnoser har blitt kalt «skrotkoder» (på engelsk «garbage codes»). Dersom en stor del av dødsfallene har slike diagnoser vil den samlede informasjonsverdien av dødsårsaksstatistikken bli dårlig. Det er nyttig dersom det er mulig å finne ut hvilke dødsårsaker som er skjult bak skrotkodene. Den internasjonale Global Burden of Disease Study (GBD) har

utviklet avanserte statistiske metoder for å komme nærmere en mer fullstendig dødsårsaksstatistikk. Denne prosessen kallen redistribusjon.

I den første delstudien undersøkte vi forekomsten av skrotkoder i det norske Dødsårsaksregisteret i perioden 1996-2019. Vi fant at 29 % av alle dødsfall hadde fått en skrotkode, 14 % hadde fått en kode i gruppen med minst informasjonsverdi (alvorlige skrotkoder). I løpet av studieperioden var det ikke tegn til at det ble mindre bruk av de alvorligste skrotkodene, men det var en nedgang i bruken av de minst alvorlige kodene. Det var høyere bruk av skrotkoder i de eldste aldersgruppene og ved dødsfall utenfor helseinstitusjon, og lavere der det hadde blitt gjort en obduksjon. Forekomsten er i samme størrelsesorden som i for eksempel Danmark og Sverige, men lavere enn i Finland og Storbritannia. Den høye forekomsten av skrotkoder er den alvorligste kritikken av datakvaliteten i Dødsårsaksregisteret i Norge.

I den andre delstudien så vi nærmere på bruken av en enkelt skrotkode i Norge. Koden X59 brukes for dødsfall på grunn av en ytre årsak (skader, forgiftninger) der det ikke er opplysninger om hva som var årsaken til skaden (for eksempel om det var en trafikkulykke eller et fall). I perioden 2005-2014 manglet disse opplysningene i 26 % av alle dødsfall med en ytre årsak. De fleste av disse var hos eldre personer med brudd i hofteregionen. På bakgrunn av de dødsfallene der man hadde fått gode opplysninger utviklet vi en statistisk metode som kunne brukes på dødsfallene som manglet opplysninger. Resultatene tyder på at mer enn 95 % av X59-dødsfallene egentlig var fallulykker, og dette ble støttet av en spørreundersøkelse i 2015 til legene som hadde fylt ut slike dødsmeldinger. Resultatene våre tyder på at den reelle dødeligheten av fallulykker i Norge er mer enn dobbelt så høy som det som fremkommer i den offisielle statistikken.

En rettsmedisinsk obduksjon er en del av politiets etterforskning ved mulig unaturlige dødsfall, men obduksjonsresultatene er også viktige bidrag til dødsårsaksstatistikken. Dette gjelder særlig dødsfall på grunn av ytre årsak og plutselige og uventede dødsfall som skjer utenfor helseinstitusjon. I den tredje delstudien undersøkte vi

bruken av rettsmedisinske obduksjoner i Norge i perioden 1996-2017. Vi fant at 4,1 % av alle dødsfall hadde blitt rettsmedisinsk undersøkt, men andelen varierte fra 0,9-7,8 % i ulike politidistrikter, og ulikheten ble ikke mindre i løpet av studieperioden. Forskjellene kunne bare delvis forklares med geografiske faktorer, slik som ulikheter i folketall og avstanden fra dødssted til obduksjonssted. Trolig spiller andre faktorer inn, slik som lokale tradisjoner og retningslinjer. Vi konkluderte med at dersom det er ubegrunnede forskjeller i bruk av rettsmedisinske obduksjoner mellom politidistrikt, så øker det risikoen for at unaturlige dødsfall ikke blir godt nok undersøkt, og det kan føre til feil i dødsårsaksstatistikken.

5. List of publications

I. Ellingsen CL, Alfsen GA, Ebbing M, Pedersen AG, Sulo G, Vollset SE, Braut GS.
Garbage codes in the Norwegian Cause of Death Registry 1996-2019.
BMC Public Health. 2022 Jul 7;22(1):1301. doi: 10.1186/s12889-022-13639-w

II. Ellingsen CL, Ebbing M, Alfsen GC, Vollset SE.
Injury death certificates without specification of the circumstances leading to the fatal injury – the Norwegian Cause of Death Registry 2005-2014.
Popul Health Metr. 2018 Dec 24;16(1):20. doi: 10.1186/s12963-018-0176-2

III. Ellingsen CL, Alfsen GC, Braut GS.
Forensic autopsies in Norway 1996-2017: A retrospective study of factors associated with deaths undergoing forensic autopsy.
Scand J Public Health. 2022 Jun;50(4):424-31. doi: 10.1177/1403494821997208. Epub 2021 Mar 8

(Note that the sequence of papers refers to their place in the thesis and not the order of publication.)

6. Contents

7. The purpose of cause of death statistics

Information on all-cause and cause-specific mortality are considered fundamental public health indicators (4-7). To cite from the regulation concerning the Norwegian Cause of Death Registry, the purpose of the registry is to provide data for surveillance of causes of death and temporal changes of these, national and international statistics, research, and quality assurance in the health sector (8). Information on cause(s) of death can be of value by itself or as a means for other research or analyses. There are studies that indicate that countries with well-functioning vital statistics systems in general have better health in the population, even after adjusting for differences in gross domestic product (9). Worldwide, about one-third of the deaths are not registered at all. Of those who are registered, up to half are not given a cause of death or only a non-informative cause (10, 11).

The starting point is (almost always) knowledge of the particulars of a death in an individual person: the sex, the age at the time of death, the place of and circumstances around the death, and of course the cause(s) of death. If we are interested only in this specific person, this information might be sufficient. Examples here are information to the next-of-kin, feedback to the treating physicians, and information to the police in case of a possible unnatural death. If cause of death data is used in linkage studies or as end-point in follow-up studies, it is also necessary to have individual-level information on the deceased persons. If one investigates a specific death or use data for linkage studies, missing or incorrect information obviously influences the outcome of the analyses.

For public health purposes, aggregated information on group level is more important than information on each person. This might sound counter-intuitive, as group-level data is the sum of the data on all the individuals concerned. Nevertheless, group-level information can still be of considerable value, even if the records for some of the persons are missing or wrong.

8. A short history of cause of death statistics

„Wer nicht von dreitausend Jahren
Sich weiß Rechenschaft zu geben,
Bleib im Dunkeln unerfahren,
Mag von Tag zu Tage leben.“
(Johann Wolfgang von Goethe (1749 – 1832), Westöstlicher Diwan)

Registration and classification of causes of death did not appear as a fully developed framework, rather as the result of a century-long process. There is no reason to believe that the present concept and system will be the final one. To better understand where we are and perhaps the possibilities for future improvement, it is necessary to know something about the background. This is not intended to be a comprehensive historical account, just to present some important waypoints and examples.

8.1 The earliest history – censuses and parish registers

In this context, with census we mean an enumeration of the population in a realm. There are several accounts of censuses from early civilizations, more than 1000 years BC; among these are China, Egypt and Greece. The purpose was probably for taxation, enrolment of soldiers, and planning the need of food supplies. In the Roman Empire, there was a system with regular censuses (12).

A census is like a cross-sectional survey. It takes a snapshot of the situation, but does not say much about the dynamics of the population – the number of births and deaths, and even less about the causes of death. The long history of censuses nevertheless shows that humankind has considered it important to have some kind of overview of the population.

In southern parts of Europe (present-day Italy and France), there are accounts of parish registers back to the 14th and 15th centuries (13, 14). They contained records on baptisms (but not births), marriages, and burials (but not deaths), along with other information regarding the events in the parish. In Denmark (and later Norway), parish registers (ministerial books) were instigated at the end of the 16th century, and were

mandatory from 1685. The oldest surviving parish register ("kirkebok") in Norway stems from 1623 (Andebu).

Fig. 8.1.1. The ministerial book from Andebu 1623-1738.
(Reprinted with permission from Arkivverket Norway.)

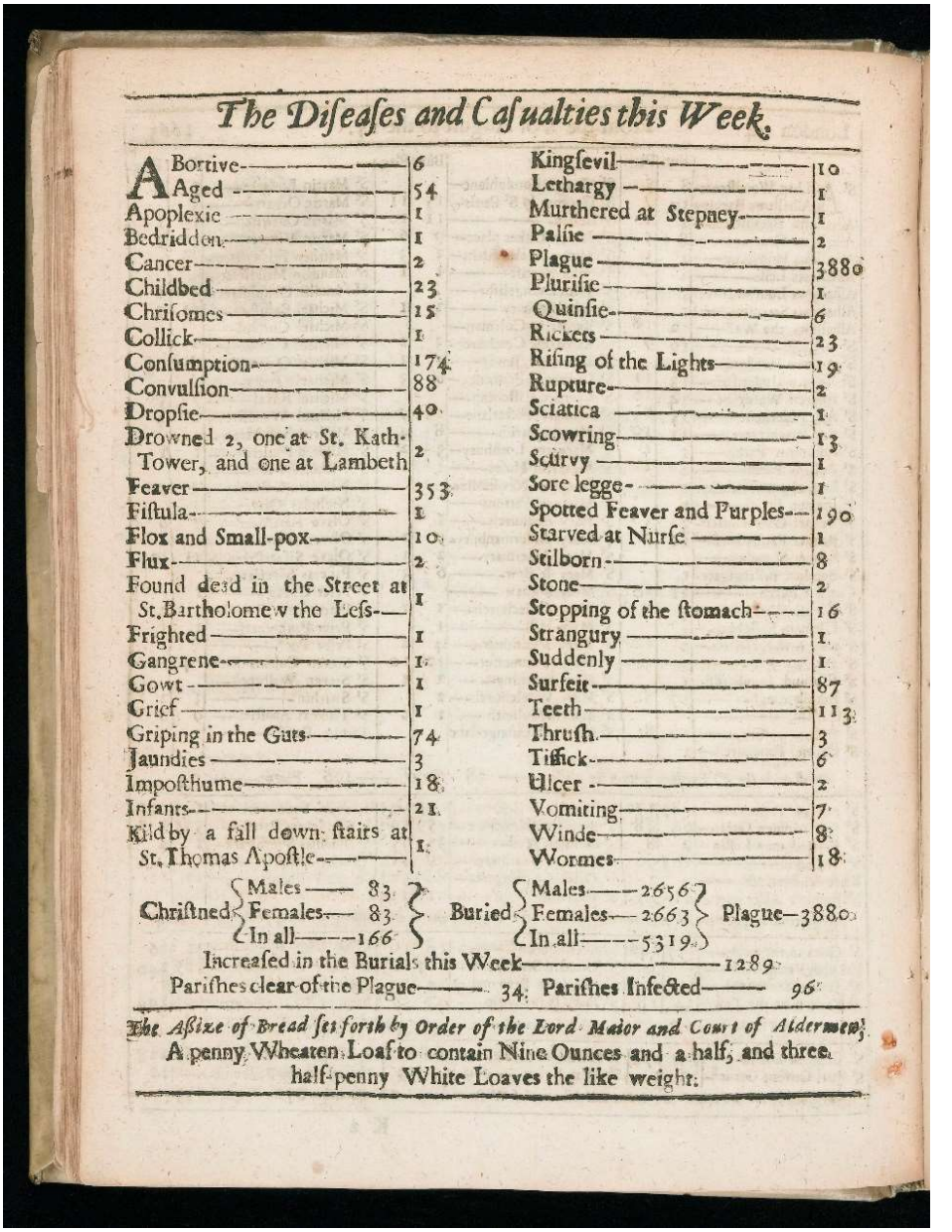
In some cases (after 1820) did the parish registers also contain information on the causes of death.

The first census-like counting in Norway was the census of males in 1663-66 (15). The first "real" census stems from 1769, and the first nominative census, where all persons were registered by name, was held in 1801. From 1815, with a few exceptions, there have been censuses in Norway every 10 years (16). The National Population Register, established 1964, is based on the census from 1960. A consequence of a well-functioning population register is that one does not have to rely on censuses for information on the size and composition of the population (16).

8.2 Cause of death registrations and registries

There are accounts of registrations of deaths from the middle of the 15th century in Italy (14, 17). The cities established health boards, mainly to fight plague epidemics. Before a body could be buried, a death certificate issued by a physician or a barber-surgeon was required to be filed.

Among the earliest systematic collections of causes of death are the Bills of Mortality in London, starting in 1532. These were lists of burials with the name of the deceased, the parish, and the cause of death, with special emphasis on the plague (17, 18). The cause of death was decided by searchers (known as "wise women"), after they had viewed the body. In difficult cases, they might consult a physician. Once a week, a general account was published by the Worshipful Company of Parish Clerks. For the particular week presented in the illustration, 3880 of the 5319 deaths (73%) were caused by the plague, showing the impact on the society. Some of the cause groups are broad and general, while others are highly specific and evidently ad hoc ("Kild by a fall down stairs at St. Thomas Apostle").



The Diſeaſes and Caſualties this Week.

Abortive	6	Kingſevil	10
Aged	54	Lethargy	1
Apoplexie	1	Murthered at Stepney	1
Bedridden	1	Paliſie	2
Cancer	2	Plague	3880
Childbed	23	Pluriſie	1
Chriſomes	15	Quinſie	6
Collick	1	Rickets	23
Conſumption	174	Riſing of the Lights	19
Convulſion	88	Rupture	2
Dropſie	40	Sciatica	1
Drowned 2, one at St. Kath. Tower, and one at Lambeth	2	Scowring	13
		Scurvy	1
Feaver	353	Sore legge	1
Fiſtula	1	Spotted Feaver and Purples	190
Flox and Small-pox	10	Starved at Nurſe	1
Flux	2	Stilborn	8
Found dead in the Street at St. Bartholomew the Leſs	1	Stone	2
		Stopping of the ſtomach	16
Frighted	1	Strangury	1
Gangrene	1	Suddenly	1
Gowt	1	Surfeit	87
Grief	1	Teeth	113
Griping in the Guts	74	Thruſh	3
Jaundies	3	Tiſſick	6
Impoſthume	18	Ulcer	2
Infants	21	Vomiting	7
Kild by a fall down ſtairs at St. Thomas Apoſtle	1	Winde	8
		Wormes	18

Chriſtned { Males 83, Females 83, In all 166 } Buried { Males 2656, Females 2663, In all 5319 } Plague 3880

Increaſed in the Burials this Week 1289

Pariſhes clear of the Plague 34. Pariſhes Infected 96

The Aſſize of Bread ſet forth by Order of the Lord Maior and Court of Aldermen:
A penny Wheaten Loaf to contain Nine Ounces and a half, and three half-penny White Loaves the like weight.

Fig 8.2.1. Bills of Mortality Aug. 15-22, 1665. Wellcome Library, London. (Creative Commons licence)

John Graunt (1620-1674) compiled and analysed data from the Bills of Mortality. He noted that few who read the weekly bills made serious use of them, apart from gossiping about the burials. Graunt summarized the bills into tables by season, year, and geographical region. He reported time trends for certain diseases, and discussed the effect of misclassification. He also made important contributions to the methods of demography (19).

With the establishment of Tabellverket in 1749, Sweden has the oldest continuous national population registration system (20). The reports from the parsons on births, deaths and causes of death were based on information in the parish registers, submitted on preprinted forms. In the first period, the parsons could choose from a list of thirty-three categories. About one third of the categories were related to external causes of death, and many of the other were what we today would call symptoms or unspecified causes. The list was not intended to be all-inclusive, and there were concerns because the clergy lacked necessary medical knowledge to classify the deaths. Nevertheless, the clergy often had some basic medical training and significant experience in meeting illness and death among their parishioners.

In 1859, the National Central Bureau of Statistics (Statistiska Centralbyrån/Statistics Sweden) was created. Cause of death statistics from the cities were to be based on death certificates from a physician; in the countryside, the registrations were made by the clergy, as before. The classification in use from 1861 was influenced by the systems of Farr and d'Espine (see section 8.6 below). From 1931 the inter-Scandinavian list was in use, and from 1949 the international classification from the World Health Organization (ICD-6) (20).

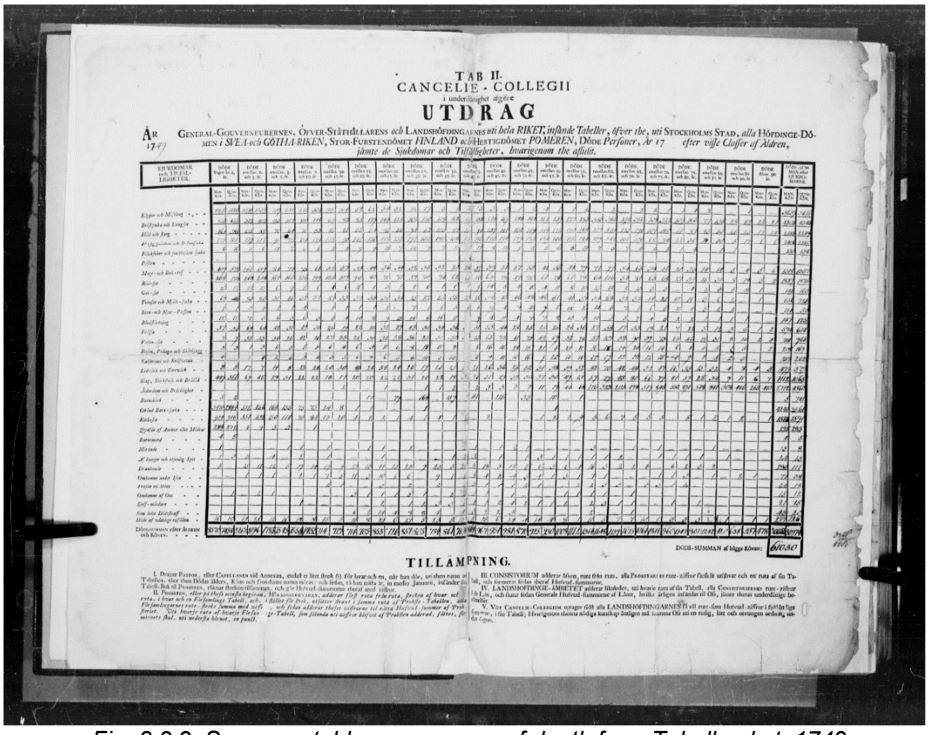

TAB II.
CANCELIE · COLLEGII
UTDRAG
TILLÄMPNING.

Fig. 8.2.2. Summary table over causes of death from Tabellverket, 1749. (Reprinted with permission from Arkivverket Sweden.)

In England, William Farr (1807-1883), physician and epidemiologist/statistician, worked at the Office of the Registrar General from the start in 1837. As the Compiler of Abstracts, he created the first national vital statistics system, including analyses of the causes of death (21).

8.3 History of the Norwegian Cause of Death Registry

As mentioned above, from 1685, the parsons were obliged to register burials (along baptisms and marriages) in the parish records (13). From the first part of the 18th century, the parsons had to send reports to the authorities, but the official statistics over the number of deaths did not start until 1801 (22). Until 1866, these reports were only summary lists, thereafter individual records. From 1839, the parsons also had to report the number of violent deaths (accidents, suicides, and homicides). Apart from

this, there was no registration of the causes of death. From 1853, there are yearly publications on the health conditions in Norway ("Sundhedstilstanden og Medicinalforholdene i Norge"), based on reports from the physicians to the ministry of the interior (the medicinal directorate). In the first years, these reports covered only a proportion of the deaths, mainly in the cities, estimated to 60% in 1860, 81% by the turn of the century and 90% in 1920 (22). In the table in the report from 1853 (23), there are 5406 deaths, of these 2484 from cholera.

In 1925, the responsibility for medical statistics was transferred to Statistics Norway (SN). From 1928, the production was centralized, based on individual reports from the chief municipal officers, supplemented by information from the parsons and bailiffs ("lensmann") (22, 24). From 1939, there was a standardized form for the death certificate, and the classification of the causes of death was made at SN. This lead to better consistency in the statistics, but still many of the causes of death, mainly in the rural districts, were recorded by the bailiffs (22). This system was formally abandoned as late as in 2015 (25). The Norwegian Institute of Public Health has been formally responsible for the Norwegian Cause of Death Registry (NCoDR) since 2001, and took over the operation of the registry from Statistics Norway in 2014 (26).

For classification of the causes of death, an inter-Scandinavian list was used from 1927-40, from 1941 an international list (ICD-5). Norway has been a member of the World Health Organization (WHO) since the organization was established in 1948, and from 1951 the WHO principles for classification of causes of death has been in use (22). From 1951-57: ICD-6, 1958-68: ICD-7, 1969-85: ICD-8, 1986-96: ICD-9, and from 1996 ICD-10 (27). Until 1956, only one diagnosis was registered, 1956-68: up to 3 diagnoses, 1969-95: up to 4, 1996-2005: up to 7, and from 2005 up to 86 diagnoses (for all practical purposes no limitations) (27).

Until 2005, the coding and selection of the underlying cause of death was a fully manual task, performed by the medical coders. From 2005, NCoDR used the computer program ACME (Automated Classification of Medical Entities) from the

National Center for Health Statistics in USA (27, 28). The paper forms were scanned, and the information was manually entered into the data system. From there, the rest of the coding and data processing was electronic. ACME was supposed to closely follow the coding and selection rules in ICD-10 (29), disregarding local practises and guidelines. This led to some minor shifts in the distribution of underlying causes of death (27). There were still a substantial number of deaths requiring manual supervision of the coding, among these were deaths with an external cause of death and deaths with multiple sources of information, such as autopsy reports (26, 28). From 2011, ACME was incorporated in the larger program suite Iris (30). In version 5 of Iris, ACME was substituted by the MUSE engine (Multi-causal and Uni-causal Selection Engine) (30). NCoDR now has electronic data from 1951 and onwards.

Until 2017, all deaths were certified manually, on paper. The last version of the paper form was from 1993. From 2017, Norway has gradually introduced a system for electronic certification of death, from 2020 available for all physicians. From 2022, electronic certification is compulsory (8, 31).

The current legal basis for the NCoDR is (mainly) the law concerning health registries (32) and the regulation concerning the Norwegian Cause of Death Registry (8).

8.4 International publications of cause of death statistics

With the advent of international organizations, notably the World Health Organization, there are incentives to present mortality statistics on an international level. A prerequisite for this is that the statistics are produced and presented in ways that allow aggregation and comparison. A few examples can be mentioned. See also section 8.6.1.

The international classification of diseases by the World Health Organization, currently ICD-10, in addition to describing the classification itself and the rules for selecting the underlying cause of death, also has guidelines for aggregation

(tabulation) of detailed causes into larger groups and statistical presentation of the results (29). WHO also has a mortality data base with cause of death data gathered from as many of the member states as possible (33).

Eurostat, the statistical organ for the European Union (EU), publishes cause of death statistics for the EU and collaborating non-EU states within the European Statistical System (34). Eurostat also produces mandatory guidelines for the production and presentation of statistics, such as the code of practice (35), a tabulation list for causes of death (COD-SL-2012) (34), and a standard for age adjustment (36). NCoDR publishes cause of death statistics according to Eurostat guidelines.

There are also other international bodies publishing cause of death statistics, such as OECD (the Organisation for Economic Co-operation and Development) and the World Bank. These will not be discussed further.

Of special interest to the studies in this thesis is the Global Burden of Disease project, described in more detail below.

8.5 The Global Burden of Disease (GBD)

In this thesis, the object of study is mainly cause of death statistics, but the GBD Study has a wider scope, and produces estimates both on fatal and non-fatal health loss. To cite from the GBD website (37):

> *"[W]e need a comprehensive picture of what disables and kills people across countries, time, age, and sex. The Global Burden of Disease (GBD) provides a tool to quantify health loss from hundreds of diseases, injuries, and risk factors, so that health systems can be improved and disparities can be eliminated."*

Among the many estimates are life expectancy and all-cause mortality, as well as mortality, years of life lost (YLL), years lived with disability (YLD), and disability-adjusted life years (DALY) by cause. The full list of key products and a description of the process can be found in the main protocol (38) and the methods appendix of

the main study reports (39). A clear goal is to make the results available and usable not only to scientists, but also to policymakers.

A GBD dogma is:

> *"An uncertain estimate, even when data are sparse and not available, is preferable to no estimate because no estimate is often taken to mean no health loss from that condition." (38)*

GBD gathers health related data from all over the world and processes them to make comprehensive estimates. Complete and good quality data are used to develop models to make estimates for locations where data are sparse or missing ("borrowing strength"). The results are presented in a way that makes comparisons (across time and place) possible. For each new iteration ("round") of the study, the most up-to-date methods and models are applied on *all* data, making new estimates back to 1990 (38).

The GBD includes a Scientific Council, a Management Team, and a Core Analytic Team, presently based at the Institute of Health Metrics and Evaluation (IHME) at the University of Washington in Seattle. In addition, there are more than 7000 collaborators around the world (37, 38).

8.5.1 History

The history of the GBD goes back to the 1990s. The first GBD study was led by physician and health economist Christopher Murray and medical demographer Alan Lopez and published by the World Bank in the World Development Report in 1993 (40). The further studies were affiliated to the WHO, mainly with researchers from WHO and Harvard University. WHO created a Disease Burden Unit in 1998, and the results were published in the World Health Reports (41, 42). The Institute of Health Metrics and Evaluation at the University of Washington, Seattle, was founded in 2007 with funding from the Bill & Melinda Gates Foundation and conducted the work leading up to the GBD 2010 Study. The WHO withdrew prior to publication, presumably because of lack of transparency (42). Apparently, there has also been

pressure from some member states that WHO should not publish GBD estimates if they differed from the national or WHO results in a non-favourable way (42). Starting in 2013, WHO has regularly published Global Health Estimates, while IHME has been the centre for publishing GBD Study results. The iterations (rounds) has been GBD 2013, GBD 2015, GBD 2016, GBD 2017, and most recent GBD 2019, published in The Lancet in October 2020 (39). There has been some cooperation between WHO and IHME/GBD, for example resulting in the GATHER standards for reporting health estimates (43). In 2015 and 2018, the two organizations signed memoranda of understanding, with a goal of over time moving to a single common GBD study (42).

8.5.2 Criticism

The GBD Study has been criticized, along several lines: Especially in the start, the methods were not fully transparent, and the validity of the results could not be independently ascertained. This has been problematic in cases where the GBD estimates differed significantly from national or WHO results, and the reason for the discrepancy was not easily explained (42, 44). Second, in locations with sparse data, GBD relies extensively on modelling and imputations. Third, the concept of YLD (Years Lived with Disability) and subsequently DALY (Disability-adjusted Life Years) has been questioned. YLD estimates years of equivalent health loss for a given condition by multiplying the years lived with a disability weight, ranging from 0 (no health loss) to 1 (maximum health loss) (39, 42). The apparent severity of a non-fatal condition is heavily influenced by the disability weight, which by itself is a value-based entity. YLL (Years of Life Lost) for a condition estimates the potential remaining life years lost to a given condition. (For example, if a person dies from condition A at age 20, but could have expected to live until 83 years, then this person has lost 63 years. This implies that if two conditions have the same number of deaths in a population, but the mean age of death is lower for one of the causes, then the YLL from this condition will be higher.) The DALY for a condition is the sum of YLL and YLD. This means that conditions mainly affecting elderly people may

appear with a lower disease burden than conditions in young people. There has also been concern that the focus on the GBD enterprise might delay or hamper the development of reliable national data and also transfers the definition power from national actors and international organizations (such as the WHO) to institutions in high-income countries (44).

8.6 Classification systems – International Classification of Diseases

What is the ontological status of a disease or a cause of death? Do they have some independent existence, or are they processes or dysfunctions? How can they be delineated from each other and collected into categories (45)? Which characteristics should be used: the aetiology, the anatomic site, or the symptoms? Through the ages there have been a number of different attempts to classify the various causes of death, reflecting both the current medical knowledge and the needs of the classifier.

In the first modern attempts to registrations, such as the Bills of Mortality, there seems to be no systematic classification of the causes of death (18). This is contrast to Tabellverket in Sweden, where the parsons could choose from a predefined list, in the beginning thirty-three causes. This list was a compromise between the current concept of medical entities, which conditions the authorities were interested in, and the diagnostic abilities of the clergy. The list was not necessarily exhaustive (20). Still, it was a step towards standardization.

In England 1839, William Farr noted the following:

> *The advantages of a uniform statistical nomenclature, however imperfect, are so obvious, that it is surprising no attention has been paid to its enforcement in Bills of Mortality. Each disease has, in many instances, been denoted by three or four terms, and each term has been applied to as many different diseases: vague, inconvenient names have been employed, or complications have been registered instead of primary diseases. The nomenclature is of as much importance in this department of inquiry as weights and measures in the physical sciences, and should be settled without delay.*

And:

> *Classification is a method of generalization. Several classifications may, therefore, be used with advantage; and the physician, the pathologist, or the jurist, each from his own point of view, may legitimately classify the diseases and the causes of death in the way that he thinks best adapted to facilitate his inquiries, and to yield general results (29).*

Farr developed a classification system for the General Registrar Office with three main classes: 1. Infectious diseases, 2. Sporadic diseases, and 3. Accidents or external violence (17, 45). At the first International Statistical Congress in Brussels in 1853, Farr and Marc d'Espine (1806-1865) from Geneva were requested to prepare an internationally applicable classification of causes of death. They could not agree, and presented two different lists for the next congress, in Paris in 1855. The congress adopted a compromise list that underwent a number of revisions (17, 29). In the 1891 meeting of the International Statistical Institute (the successor to the Statistical Congress) in Vienna, Jacques Bertillon (1851-1922) of Paris was appointed chair of a committee to prepare a classification of causes of death. This list with 161 items in 14 sections was presented in Chicago in 1893, and is the origin of the *International List of Causes of Death* (17, 29, 45). The main headings in this classification were:

I	General diseases
II	Diseases of nerve system and sense organs
III	Diseases of circulatory system
IV	Diseases of respiratory system
V	Diseases of digestive system
VI	Diseases of genitourinary system
VII	Puerperal diseases
VIII	Diseases of skin and annexes
IX	Diseases of locomotor organs
X	Malformations
XI	Diseases of early infancy
XII	Diseases of old age
XIII	Effects of external causes
XIV	Ill-defined diseases

Fig. 8.6.1. Headings in the first International List of Causes of Death.

Broadly, this pattern can be identified also in recent classification systems, with sections for infectious/epidemic diseases, constitutional or general diseases, local diseases arranged by site, developmental diseases, and injuries (29).

In the following years, this classification was adopted in several countries, and underwent a revision around once every ten years. The Scandinavian countries used a local list, in Norway used from 1927-40 (22). The sixth revision, in 1948, was major, both in terms of content and range of application. The work was led by the newly established World Health Organization (WHO). This classification, now called the International Classification of Diseases (ICD-6), as all the following revisions, applied to morbidity as well as mortality. The purpose of the ICD is no longer restricted to classifying causes of death and producing cause of death statistics. It is used for a variety of functions, such as payment systems, service planning and health service research (46). The tenth revision (ICD-10) stems from 1989, and has been in use in Norway from 1996 (27). It has 22 chapters; the exact number of codes/entities varies between countries, due to local adaptations and variants used for special purposes, but is more than 8000 (17). The full name of the classification is now

International Statistical Classification of Diseases and Related Health Problems. The latest revision, ICD-11 (47), was endorsed by the World Health Assembly in 2019, and officially came into effect in January 2022, but as to the best of knowledge, no country has implemented the revision yet (October 2022). WHO expects a transition phase for mortality coding of around five years. ICD-11 has been regarded as the most substantial revision since ICD-6, not only updating the list of entities, but also affecting the fundamental structure of classification. For example, ICD-11 is designed with more flexibility in the hierarchy and allows for clustering of related diagnoses (46).

8.6.1 Tabulation lists

The complete ICD-10, with several thousand entities, is not suited for comprehensive presentation of cause of death statistics. Statistical and public health bodies usually present results according to one of a number of tabulation lists, aggregating the ICD-codes into larger groups. For example has WHO in ICD-10 four such lists, two for general mortality (103 and 80 causes) and two for infant and child mortality (67 and 51 causes) (48). The Norwegian Cause of Death Registry presents statistics according to Eurostat's European Shortlist of Causes of Death (COD-SL-2012) with 86 headings in three hierarchical levels (34, 49). The Global Burden of Disease cause list is also a form of tabulation, with four levels. In the current version at the time of writing there are 279 headings for causes of death (included four categories of garbage codes) (39), but not all causes are specified on level 4.

Besides making the statistics more comprehensible, tabulation lists may also be used to follow statistics across changes in the underlying classification scheme. For example, Eurostat's shortlist includes mapping from ICD-8, -9, and -10 (34).

Confusions may arise if different classifications share names for cause groups, but with different definitions. If one uses tabulations to rank causes of death, the type of list and hierarchical structure will influence the ranking. (For example, if one groups all malignant tumours together, this will be the leading cause of death (in number of

deaths) in Norway 2020. If ranking on the next level of Eurostat's shortlist, ischaemic heart disease is a larger group than any of the specific cancers (49).)

8.6.2 Classification systems beside ICD

There are several other classification systems, both inside and outside the WHO system. Some are for general use, others for specific purposes. It is outside the scope to present all types of classifications in use, but two might be worth mentioning.

ICPC (International Classification of Primary Care), currently version 2 (ICPC-2) is a classification system originally from the World Organization of National Colleges, Academies and Academic Associations of General Practitioners/Family Physicians (WONCA), adopted by WHO for encounter classification in primary care, and is the main classification system in use by Norwegian general practitioners (50). The current version has 707 codes. Even if the physicians are encouraged to use codes for specific disease/injury entities, a large proportion of the codes are symptom-related. We have found no studies indicating that general practitioners, accustomed to ICPC-2, might be more inclined than hospital-based doctors to use symptom-related terms for certifying causes of death.

NORPAT (Norsk patologikodeverk) is the coding system in use by Norwegian pathologists/forensic pathologists (51). It is based on SNOMED, developed in the 1970s by the College of American Pathologists (CAP), based on the earlier SNOP (Systematized Nomenclature of Pathology) (45, 52). (SNOMED is not the same as SNOMED CT, which will not be considered here.) NORPAT is a multiaxial system, with axes for *topography* (T), *morphology* (M), *disease entities* (S), *aetiology* (E), *function* (F), and *procedures* (P). A valid NORPAT coding consists of (at least) one T code combined with one or more codes from one or more of the other axes. Traditionally, emphasis has been on morphological coding. NORPAT coding will be found on autopsy reports submitted to the Norwegian Cause of Death Registry. If the wording of the autopsy diagnoses are insufficient for cause of death coding, the

nosologist may try to “translate” the NORPAT codes to the most equivalent ICD codes.

An example:

NORPAT	**ICD-10**
T 00020 (Multiple topography)	X80 (Intentional self-harm by jumping from a high place) (underlying cause of death) T07 (Unspecified multiple injuries) (nature of injury)
M 10080 (Multiple serious injuries)	
F Y1170 (Fall from building)	
F Y3300 (Suicide)	
P 30160 (Forensic autopsy)	

9. The cause of death

"Felix qui potuit rerum cognoscere causas.
(Fortunate is the man who has been able
to discover the causes of things.)"
(Virgil (70 – 19 BC), Georgica)

9.1 Causality in relation to the cause of death

Consider this constructed case history (partly adapted from Rothman (53)):

Mrs H is an **85-year old** widow, living **alone** in a small semi-detached house. Ten years ago, she was diagnosed with **polymyalgia rheumatica**, and has been treated with **prednisolone**. She is **osteoporotic**, possibly due to (or at least exacerbated by) steroid treatment. One winter morning, she **trips** outside the house when collecting the newspaper. It has **snowed**, and the **caretaker** has not had time yet to clear away the snow. In addition, the **handrail** at the steps is broken. Mrs H **fractures her right femoral neck** and is brought to hospital. Due to **many patients** admitted at the same time, she has to **wait** until the next day before she is **operated**. The operation is uneventful, and after five days Mrs H is transferred to a short-term rehabilitation centre. At the same day, the treatment with s.c. lmw **heparin** is discontinued. She is discharged on a Friday, and there are **few nurses and no physiotherapist** present in the **week-end**, so Mrs H spends most of the time **in bed** or in a recliner. On Tuesday, she suddenly becomes short of breath and unresponsive, with no effect of resuscitation efforts. A subsequent autopsy shows **venous thrombosis** in her right leg and massive **pulmonary embolism**. In addition, the pathologist finds a **pancreatic carcinoma with liver metastases**, not previously diagnosed.

What is the cause of death? Are there more than one cause? Are there different valid causes of death, suitable for different purposes?

9.2 Cause

Most people probably have some form of commonsensical notion of *cause.* If an event *C* occur, this will in some way influence whether another event *E* also occurs – *C* leads to *E.* We also feel that causality implies something more than just correlation. Still the concept of causality has troubled philosophers since antiquity (54). What is really causality? Is there only one kind of causality, or many? There are profound differences between the fundamental question "What is causation?" and the more operational "Given that we have a theory of causation, how can we judge if *C* is a cause of *E*?" Our notion of causality is important for understanding what a cause of death is, how various causes or conditions relate to each other, and which criteria we can use to establish a causal sequence.

There is a difference between general and particular (or singular) causation (54). General causation considers whether a condition of type *C* always or in general or in some instances leads to conditions of type *E*. Epidemiological studies often tries to assess *general causation*, such as whether smoking causes lung cancer. This can be reformulated as to whether smoking in general increases the risk of developing lung cancer. *Singular causation*, on the other hand, considers the cause-effect relation in one particular instance. What was the cause of death for this individual? Whether lung cancer may cause death is not the same question as whether lung cancer caused death in this specific person.

Of course, the concepts of general and singular causation interacts. To be able to say something about general causation, one must study (many) individual cases, and to judge in an individual case, one must have general knowledge. (Incidentally, this may lead to circular argumentation and perhaps erroneous conclusions. E.g. If a person dies suddenly, the certifying physician might conclude that the cause of death probably was coronary heart disease, as this is a common cause of sudden death. If a large number of physicians make the same judgment in similar cases, this will

"strengthen" the body of knowledge that coronary heart disease is a common cause of sudden death.)

There is also a distinction between necessary and sufficient causes (55). A *necessary* cause is a condition without which the effect *cannot* occur. A *sufficient* cause is a condition with which the effect *must* occur. From this one can derive four different constellations:

	Examples
Necessary and sufficient	Some genetic disorders with 100% penetrance. A person must have the mutation to develop the disease, and all persons with the mutation eventually will develop symptoms.
Unnecessary, but sufficient	A ruptured myocardial infarct with massive hemopericardium as cause of death.
Necessary, but insufficient	SARS-CoV-2 as the cause of Covid-19 disease. (Not all persons exposed to the virus will develop disease.)
Unnecessary and insufficient	Smoking as the cause of lung cancer.

Fig. 9.2.1. Necessary and sufficient causes.

9.3 Views on causality through history

Through history, there has been numerous views on causality. A few contrasting views, not supposed to be an encyclopaedic account, are presented here.

Aristotle (384-322 BC) operated with four different types of causes or explanations (56), each being an answer to the question "Why?": the material cause (matter), the formal cause (design), the efficient cause (who or what made something to happen), and the final cause (the purpose). These are not mutually exclusive. Of these, only the efficient cause approaches what we today would call a cause (but in the history of Mrs H, Aristotle might have called the slippery snow a material cause). Aristotle's view was further elaborated by the mediaeval scholastic philosophers.

The Scottish philosopher **David Hume** (1711-1776) was an empiricist, rejecting inductive science (57). He stated that an event *C* was a cause of another event *E* if and only if: *C* and *E* were related in space and time, *E* followed *C*, and any event of type *C* was followed by *E* (56). Based on our previous experience, we expect that *C* will be followed by *E*, but there is no logical necessity in that, as we cannot observe that crucial causal link between the two events. Certain knowledge on causality therefore is not possible, and our notion of cause and effect is close to a habit (the theory of regularity). Hume probably did not hold a completely nihilistic view of science. Some hypotheses were better corroborated than others, but none could be logically *proved.* Hume also offers a counterfactual interpretation: *C* causes *E* if and only if, without *C*, *E* would not occur (56). Hume's view correspond to a certain extent to a notion of monocausal sufficient and necessary causes.

Immanuel Kant (1724-1804) agreed with Hume that we depend on experience to ascertain if two events are regularly connected, but opposed to Hume, he holds it is not contingent that there are regularities in our world of experiences. Our mind is constructed in such a way that we by *necessity* must understand the world in terms of cause and effect (56).

John Stuart Mill (1806-1873) had a more holistic view on causality (58, 59). What we ordinarily call *the* cause often is only *one of a set* of conditions, the sum of which leads to the effect. Each of the conditions in the set is necessary, no one is sufficient alone. If the set is complete, the effect will follow unconditionally. Mill says that what we tend to call *the* cause often is either the last condition to be fulfilled before the effect to take place or "the most conspicuous condition" (58). Some of Mill's notions can be tracked to Rothman's causal pie theory (below).

Robert Koch (1843-1910), a German microbiologist, put forward four postulates for establishing the relation between a microorganism and a disease manifestation (60). Parts of this was based on work by Jakob Henle and Friedrich Löffler. The four postulates can be stated as follows:

1. The microorganisms must be shown to be present in all cases of the disease.
2. The presence of microorganisms must be in such numbers and distribution that all the symptoms of the disease can be explained.
3. The microorganisms must be isolated and grown in pure culture.
4. It must be possible to reproduce the disease by introducing this pure culture into animals.

These postulates concern infectious diseases, but they spurred a stringent view of causation in medicine. Conceptually, they are related to Hume's view of a monocausal notion of sufficient and necessary causes.

In the 20th century, probably the best known criteria for causality in epidemiology are linked to Sir **Austin Bradford Hill** (1987-1991), English epidemiologist and statistician, perhaps most known for studying the relation between cigarette smoking and lung cancer (53). Bradford Hill himself used the terms "viewpoints" or "perspectives" instead of "criteria". His nine standards can be stated as follows:

Criterium	**Explanation**
Strength	Effect size. The larger the association, the more likely it is causal.
Consistency	Can the findings be reproduced in several studies?
Specificity	One-to-one cause-effect relation.
Temporality	The cause must precede the effect.
Biologic gradient	Is there a dose-response relation?
Plausibility	Is the cause-effect relation plausible from what we know about biology?
Coherence	Is there coherence between different types of evidence (e.g. laboratory and clinical studies)?
Experimental evidence	Is there evidence from experiments?
Analogy	Are there other cause-effect relationships that mimic the one in question?

Fig. 9.3.1. Sir Bradford Hill's viewpoints of causality.

All of the standards (except temporality) can and has been challenged. To discuss the weaknesses and strengths of the criteria is outside the scope of this presentation.

Rothman et al. concludes the chapter on causality in their textbook with: “[U]niversal and objective causal criteria, if they exist, have yet to be identified.”(53).

9.4 The causal pie model

A theory for understanding causation in epidemiology that has gained popularity is the sufficient cause (or causal pie) model (53, 61), introduced in epidemiology by Kenneth J. Rothman. A “causal pie” is made up of individual component causes (C1, C2, … Cn), and when the pie is complete, the cause (sum of causes) is sufficient for the event to occur (in this manner at this time). If some component is missing, the pie is not complete, and the event will not occur. To prevent the effect, one therefore does not have to eliminate *all* the component causes. If one specific component is needed in any instance of a complete pie/sufficient cause, this is a necessary cause (N). Often, there will be one or more unknown component causes needed (U1). All components of the sufficient cause need not necessarily be present at the same time. Most causes of interest in medicine are components of sufficient causes, but are not sufficient in themselves (61).

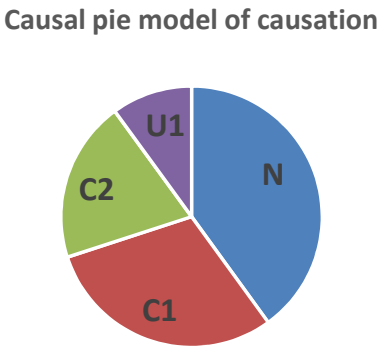


Fig. 9.4.1. The causal pie model of causation

This sufficient-cause definition of causality (which by itself is deterministic) can be amended to allow for a probabilistic interpretation. One way is to say that the product (a complete pie) contributes together to the *probability* of an effect, rather than being

unconditionally sufficient (55). Another interpretation is to state that what we might experience as a stochastic component in reality are the unaccounted parts of a sufficient cause (U1 in the diagram above.)

In a unidimensional model, where one event has only one cause, the sum of causes for all events of the same type must add up to 100%. This is implicit when we present cause of death statistics by (a single) underlying cause of death. The sum of deaths due to all different causes equals the number of deaths in total. As is often stated: "Mutually exclusive, collectively exhaustive" (38).

In a multidimensional model, such as the causal pie model, the sum of causes will often exceed 100%. If a report states that condition A is the cause of X% of the deaths, it is important to know whether this refers to unidimensional or multidimensional statistics. (See also section 9.9 on multiple causes of death below.)

We sometimes see the notion "web of causation". By itself, this is not a theory of causality, merely a metaphor for the multiplicity and complex interaction of causes (55).

9.5 Causal diagrams and directed acyclic graphs (DAGs)

Graphs or diagrams are effective aids to study the path of causality. A diagram with the relevant conditions and diagnoses, connected with arrows, is a simple yet powerful way of structuring the sequence of causes of death (62). See also section 9.7.

The more extensive and rigorous theory based on directed acyclic graphs (DAGs) has become a popular way of visualising causal patterns or networks in epidemiological research, especially for identifying various types of bias caused by confounders as well as "colliders" (a condition affected by both the cause and effect studied) (63, 64). DAGs will not be discussed further here.

9.6 Some special notions regarding the cause(s) of death

As mentioned above, certification of death concerns singular causation – what the cause of death was in a specific person. In medicine, we accept the postulate that the death always has a cause, a pre-existing condition (disorder, injury) (or set of conditions) that is sufficient and necessary for the cessation of life (65). If a cause of death cannot be stated, this means that the cause is unknown, not that it is non-existent.

Since the outcome (effect) is the same (death), the arguments concerning a specific (one-to-one) cause-effect relation are not valid. Rather, we must accept a many-to-one relationship.

Regarding the contrafactual view of causation; in the strict sense, death cannot be prevented, only postponed. The contrafactual notion must be amended: If the cause had not been present, death would not have occurred *in this way at this time.*

9.7 The World Health Organization, International Classification of Diseases, and the underlying cause of death

Without further explanation and clarification, it is not always evident what is meant by "the cause of death". Is it the terminal event - the condition "pushing the patient over the edge", the first recognized condition or what the certifying doctor believes is the most significant condition (17, 66)? If one decides to use the start of a chain of events, how far back is it meaningful to go – what constitutes a *medical* cause of death? Even after the first adoption of an international list of causes of death in 1893, there was not necessarily instructions to the certifying doctors on the desired logic of cause of death certification (17). Gradually, standardized death certificates and guidelines were published (17, 66, 67). In Norway, the first guidelines are stated to stem from 1896 (22). In the revised guidelines from 1927 (68), the "main cause" is

the “probable originating disease or injury”. Complications to this condition are “contributory causes”. (Note the difference from the WHO definitions below.)

The most important condition has variably been named the “main cause”, “principal cause”, “originating cause”, and so on. In WHO/ICD, the term is “underlying cause of death”. If only one condition is mentioned by the certifying doctor, this will (almost always) be selected as the most important condition. If more than one condition is mentioned, there must be some rules or guidelines for selecting the main cause. The first set of rules were developed by Bertillon (17). They were adopted and refined in various countries (68, 69).

With the establishment of the World Health Organization (WHO) in 1948 and the 6th revision of the International Classification of Diseases (ICD-6), an international template for death certificate was introduced, as well as a framework for structuring causes of death that has remained largely unchanged up to now (17, 29), even if the details and the classification system (list of conditions) has been revised.

All quotes in the section below are from volume 2 of the ICD-10 (the instruction manual) (29).

The underlying cause of death (UCOD) is defined by the WHO:

> *“(a) the disease or injury which initiated the train of morbid events leading directly to death, or (b) the circumstances of the accident or violence which produced the fatal injury”*

The reason for this is from the purpose of prevention:

> *From the standpoint of prevention of death, it is necessary to break the chain of events or to effect a cure at some point. The most effective public health objective is to prevent the precipitating cause from operating.*

In cause of death statistics, usually only one condition is tabulated, and this is the underlying cause of death.

The instruction manual is not especially helpful for deciding what constitutes a valid cause:

> *A causal relationship exists if a condition mentioned on the certificate can be caused by another condition also mentioned on the certificate. However, whether a causal relationship is considered acceptable or not for mortality coding is founded not only on a medical assessment but also on epidemiological and public health considerations.*

And:

> *Stated relationships that are not listed as rejected in Section 4.2.3 should be accepted as far as possible. They reflect the certifier's opinion about the causes leading to death and should not be disregarded lightly.*

It seems that WHO has a pragmatic (atheoretical) view on causality regarding causes of death. Something that the certifying physician regards as a cause, can be accepted as a cause, unless the agent responsible for production of statistics deems it highly improbable. Nevertheless, in order to improve comparability across time and space, ICD has a large number of detailed instructions on how to interpret diagnoses and sequences on the death certificate.

According to the ICD guidelines and the structure of the international form of medical certificate of cause of death (29), there is one main sequence (part 1 A-D) and any number of contributory causes (part 2). The condition that starts the main sequence will normally be identified as the underlying cause of death. Modes of dying, such as cardiac arrest, respiratory failure, or heart failure, should not be recorded. The contributory causes should be separate entities, not part of or complications to a condition in the main sequence. See fig. 9.7.1.

> *It is the responsibility of the medical practitioner or other qualified certifier signing the death certificate to indicate which morbid conditions led directly to death and to state any antecedent conditions giving rise to this cause. The certifier should use his or her clinical judgment in completing the medical certificate of cause of death.*

And:

> *Start at line 1(a), with the immediate (direct) cause, then go back in time to preceding conditions until you get to the one that started the sequence of events. You will get very close to the time the patient was healthy.*

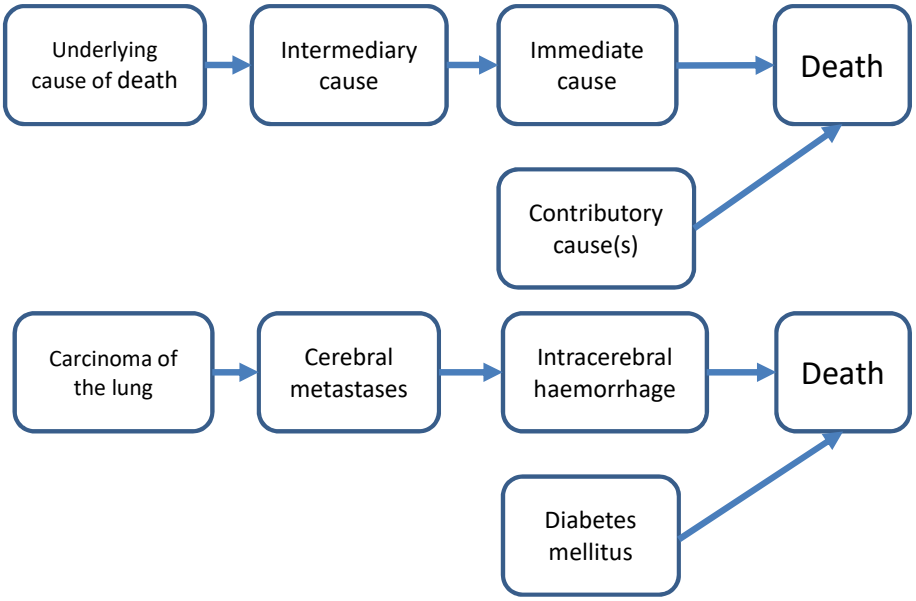


Fig. 9.7.1. Valid cause of death sequence according to ICD, with example.

9.8 Criticism of the WHO (ICD) concept

The WHO framework for understanding causes of death (as demonstrated in the instructions to ICD-10) is a *deliberate choice*, not some form of natural law. There has been criticism of the concept, claiming that it is not suited for epidemiological needs, at least not with the present epidemiological situation. It must be stressed that criticism of the principles of the framework itself is more fundamental than discussing both the actual entities in the classification and whether the registered diagnoses are correct or not.

There has been dissatisfaction with the single underlying cause concept (66, 70, 71). One aspect is that often only an intermediate or immediate cause of death is reported, so that the (real) underlying cause of death is missing. A related issue is to decide how long back in the causal chain it is reasonable to go. For example, the ICD-10 coding rules states that if the certifying doctor has given the cause of death as liver cirrhosis due to alcohol dependency, the underlying cause of death is to be coded as alcoholic liver cirrhosis (ICD-10 code K70.3), and not as alcohol dependence (F10.2) (29). Still, the cause of death can be seen to be alcohol-related. If the certifying doctor states that the cause of death was hepatocellular carcinoma due to chronic viral hepatitis, the underlying cause of death will be liver cancer (C22.0), and the information on viral hepatitis will be lost (29). On the other hand, where the starting condition is very remote, the clinician might feel that it is impropriate to register this as the underlying cause of death instead of a more recent (and perhaps amenable) condition. Johansson uses as an example a woman that was successfully treated for an ovarian carcinoma many years ago, but has peritoneal adhesions and subsequently dies from a mechanical ileus (72). According to the ICD guidelines, ovarian carcinoma is the underlying cause of death, even if there is no residual malignant deposits.

One of the main objections is that many deaths are caused by the interaction of several conditions, and choosing only one cause of death for tabulation omits important information (70). Attributing death to a single cause may be appropriate when the death is caused by a well-defined entity or overwhelming acute condition, such as a serious infection or major injury (71). Especially with an aging population, many persons live with chronic conditions, such as diabetes, chronic pulmonary disease and chronic ischaemic heart disease, which may contribute to death (72, 73). According to the instructions for completing a death certificate, the physician is obliged to report in part II “other significant conditions contributing to death” (29). This means that the information regarding these contributory causes may be present, but not included in the reported statistics (based on the underlying cause of death).

For example, for the deaths registered with Covid-19 as underlying cause of death in Norway in 2020, 56% also had mentioned cardiovascular disease and 36% chronic pulmonary disease on the death certificate (74).

Another scenario where information may be lost is when there has been a medical misadventure or therapeutic complication (75). According to the coding rules, the underlying cause of death is the reason for treatment (disease or injury), unless this is a trivial condition (29). Any mention of therapeutic complication etc will be omitted from the single-cause statistics.

The definition of contributory cause may also be problematic. Part II on the death certificate is intended for conditions that contributed to death, but was *not part* of the sequence in part I (71). That means that if two conditions both contributed to the immediate cause of death, one of them could and should be regarded as the underlying cause of death. The other could not be given as a contributory cause, if one strictly follows the certification rules. The example given by Lindahl et al (71) is a person with bile stones, chronic alcoholism, and acute pancreatitis, developing into sepsis. Both bile stones and alcoholism predisposes to pancreatitis and could thus qualify as the underlying cause of death. It would not be in accordance with the ICD coding rules to put the other condition, *which also can lead to pancreatitis* and in that way be part of the main sequence (part I), as a contributory cause (part II), see fig. 9.8.1. (It is probably very dubious whether this is evident for most certifying doctors.)

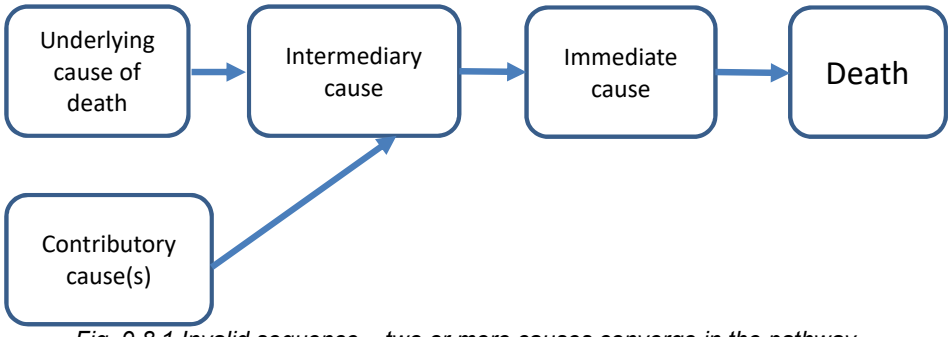


Fig. 9.8.1 Invalid sequence – two or more causes converge in the pathway.

A related problem is when one underlying cause "branches" into two or more different sequences. An example: A person admitted to hospital after an accidental heroin overdose may have *both* hypoxic brain damage *and* rhabdomyolysis. The certifying doctor may choose only one of these paths to be in the main sequence. The other condition must be omitted if the doctor follows the rules. As it is not a condition unrelated to the main sequence, it is not appropriate to put it in part II of the death certificate. See fig. 9.8.2.

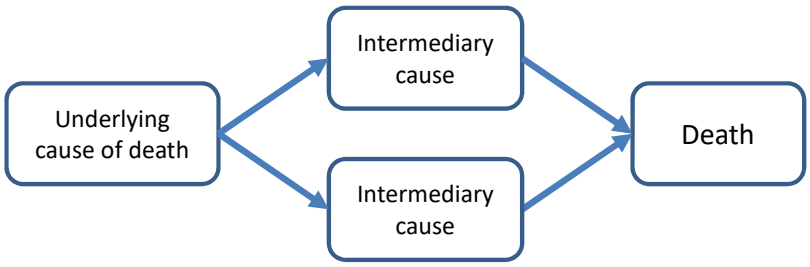


Fig. 9.8.2. Invalid sequence – branching of the pathway.

9.9 Multiple causes of death (MCOD)

An obvious way to amend some of the stated shortcomings above is to register and report more than one condition for each death.

In contrast to presenting only the underlying cause of death, to present multiple cause of death data in a meaningful way is not a trivial task (76). One approach is to expand the current standard table to show two frequencies for each entity – one for the number of deaths where the entity was selected as the underlying cause of death (the current presentation) and one for the number of deaths where the condition was mentioned, but not selected as the underlying cause (75). Obviously, the sum of cases in the second entry will be much higher than the number of deaths, as each death can be assigned a number of causes; this can lead to ambiguity concerning the use of "caused by". Some examples: Dorn and Moriyama found in data from the United States in 1955 that diabetes mellitus was mentioned in 61,909 deaths, but selected as the underlying cause of death in 25,217 (41%). In Canada 2004-2011, Park found that

Alzheimer's disease was mentioned in 80,868 deaths, as underlying cause in 48,525 (60%). Moreover, where Alzheimer's disease was the underlying cause, cardiovascular diseases were most often listed as contributory cause, and where Alzheimer's disease was contributory cause, cardiovascular disease was most often underlying cause (77).

Analysing multiple causes of death could be useful to study whether an observed trend is real or could be the result of changing certification and coding practices (73). For example, Lindahl and Johansson found that even if the registered mortality rate for Parkinson's disease had declined in Sweden in the 1970s and 1980s, the multiple-cause mortality rate had not (78), and the observed trend did probably not reflect real epidemiological changes.

A more sophisticated analysis could be to identify and present "clusters" of diagnosis, e.g. the number of deaths that are registered with both ischaemic heart disease and diabetes. One may calculate the ratio of observed pairs (or triplets, quadruplets) to the expected number of pairs under the assumption of independence (73). A ratio higher than 1.0 would indicate an association. As always, an association does not necessarily imply causation.

A special instance of MCOD is to record the main injury (nature of injury) in external causes of death. As mentioned before, in external causes of death, the underlying cause of death are the circumstances around the fatal injury (chapter XX in ICD-10). The coding rules explicitly states that the type of injury (chapter XIX) also must be recorded (29).

Of course, using the MCOD approach cannot improve the cause of death analysis in cases where the diagnoses are wrong or missing from the death certificate.

To register and report multiple cause of deaths is not the same as recording all the conditions present at the time of death. Cause of death statistics were never intended to give a comprehensive presentation of the morbidity present at the time of death,

just the conditions that contributed to the death (70). A person might have a serious disease (such as a cancer), but die from a completely different cause (such as a ruptured aortic aneurysm). A corollary of this means that a list of discharge diagnoses from a hospital stay could not fully substitute a death certificate.

Until 1956 only one diagnosis, the underlying cause of death, was registered in NCoDR. From 1956-1968, the limit was three diagnoses, 1969-1994 four, 1996-2005 seven, and thereafter the upper limit was 86 diagnoses (27). In Norway in 2019, a mean of 3.1 conditions were registered in each death (own analysis, unpublished). Even if all diagnoses on the death certificate are registered and available for analysis, only the underlying cause of death is reported in the usual presentation of cause of death statistics.

9.10 Manner, mode, and cause

A related set of concepts, but definitely not identical to the WHO framework, are the *manner, mode and cause of death.* (29, 79, 80). The terminology is linked to the medicolegal certification of death, especially in countries with a coroner or medical examiner system, such as the United Kingdom and USA. It is probable that some confusion arises from having similar terms for different concepts. In Norwegian, the term “dødsmåte” is used in several ways, something that may be confusing.

Modes of death, or more exact **modes or mechanisms of dying**, refers to the pathophysiological states and processes around the moment of death, such as asphyxia, exsanguination, cardiac arrest, heart failure, hyperkalaemia, and so on. These are terms that may answer “how”, but do not answer a “why” question in any meaningful way. Guidelines for completing death certificates explicitly states that modes of dying should not be used as causes of death, and should not be entered alone on the death certificate (29, 65). In the former Norwegian certificate of death (form IS-1025 B) mode of death is translated to “dødsmåte”. From an epidemiological point of view, the mode of death usually has little interest, but one

can imagine that some clinical doctors might be preoccupied with the events immediately connected to the moment of death.

Modes of dying are typical garbage codes (see later), many of these comes from chapter XVIII (R codes) in ICD-10. In the earlier framework, they might be class 3 garbage codes, the final steps in a disease pathway leading to death (81). In the present classification, they are major garbage codes, as they can represent a wide variety of underlying causes of death (82).

Cause of death (in this setting) has partly the same meaning as the WHO definition ("(a) the disease or injury which initiated the train of morbid events leading directly to death"). For natural deaths, the meaning is identical. For non-natural deaths, cause of death (again, within this framework) is sometimes used to describe the nature of injury (such as laceration of the liver) without mentioning how the injury came about. This corresponds to the ICD-10 chapter XIX (range S00-T98). Codes for the nature of injury are garbage codes, as they do not convey information on the circumstances. In other cases, the circumstances (such as a fall) is included, but without mentioning the intention of the event. The intention (accident, suicide, homicide) would be the manner of death.

Manner of death is the medicolegal classification of the death. The number of categories and their definition varies between jurisdictions, but they usually include natural death, accident, suicide, homicide, and undetermined (79). In ICD-10 terminology, the manner of death is not a single code, but can be translated to broad categories, chapters or sections. As an example, "accidents" encompass the ICD-10 range V01-X59 and Y85-Y86. Some jurisdictions might have further categories for medical misadventure, acts of war, and so on. In many jurisdictions, a coroner or medicolegal investigator decides the manner of death (except in cases of natural death). In other places, this ruling lies with the certifying physician. In Norwegian and Danish forensic terminology, manner of death is sometimes translated to "dødsmåte" (83).

Even when the cause of death (in this meaning) is clear, it is sometimes difficult to ascertain the manner. A typical example is poisoning with substances of abuse, where the distinction between accident and suicide might be impossible. That the manner of death is undetermined is not the same that it is missing. To state the manner of death as undetermined is a deliberate ruling, saying that from the best of the certifier's knowledge, it is not possible to ascertain the manner of death. ICD-10 has a range of codes (Y10-Y34) to be used in such cases. When the cause of death is non-natural and the manner of death is missing on the death certificate or autopsy report, the tradition at the Norwegian Cause of Death Registry is not to classify these deaths within the group of "undetermined intent". Rather, they are classified as accidents. The exception is hanging, which is classified as suicide unless specified otherwise. This coding tradition seems to be poorly documented (Pedersen AG, NIPH, personal communication). The result might be that there is a risk that some deaths (mainly suicides) might be wrongly registered as accidents. See section 10.8.

Within the WHO (ICD-10) classification scheme, the underlying cause of death is a combination of the manner and cause of death. E.g. an accidental fall will in ICD-10 be coded in the range W00-W19, a suicidal fall/jump as X80, homicidal pushing form a high place as Y01, and where the intent is undetermined as Y30 (48). If multiple causes of death are registered, the type of injury (ICD-10 chapter XIX) is coded as "the nature of injury". In the Norwegian suicide statistics, the term "dødsmåte" is used for the method of suicide, such as hanging, poisoning, drowning etc. (49).

Example 1 A person suffers a large myocardial infarction and dies with fulminant heart failure. According to ICD-10, the underlying cause of death is I21 (acute myocardial infarction). According to the manner-mode-cause framework, the cause of death is acute myocardial infarction, the mode of death is heart failure, and the manner of death is natural.

Example 2 A person falls from a building by accident and sustains a fatal head injury with crushing of the skull and laceration of the brain. According to ICD-10, the

underlying cause of death is W13 (accidental fall from building), and the nature of injury S07.1 (crushing injury of skull). According to the manner-mode-cause framework, the cause of death is crushing injury of the skull due to fall from building, the mode of death might be total destruction of the brain, and the manner of death accident.

Example 3 A person jumps from a building in order to commit suicide and sustains a fatal head injury with crushing of the skull and laceration of the brain. According to ICD-10, the underlying cause of death is X80 (intentional self-harm from jumping from a high place), and the nature of injury S07.1 (crushing injury of skull). According to the manner-mode-cause framework, the cause of death is crushing injury of the skull due to fall from building, the mode of death might be total destruction of the brain, and the manner of death suicide.

10. The concept of garbage codes

10.1 The underlying cause of death

The underlying cause of death, as defined by the World Health Organization (WHO), has been discussed in the previous chapter. It is the underlying cause of death that gives most information on the aetiology and possible targets for prevention, and thus has highest value for *public health purposes*.

Unfortunately, many death certificates are not completed according to the guidelines, and the WHO has developed rules for selecting the most probable underlying cause of death from the diagnoses given on the certificate. These rules are published in the instruction manual (volume 2) of ICD-10 (29). In spite of this, the information on the death certificate is sometimes so insufficient that the selected underlying cause of death has limited value. Some examples: The physician may state only the intermediate conditions or terminal events (immediate cause of death), such as sudden death, heart failure or unspecified sepsis, but not the condition that initiated the chain of events. Sometimes the condition is insufficiently specified, such as cancer of unknown site. If a large proportion of the deaths are insufficiently certified or coded, this means that the real underlying mortality pattern is masked (84, 85).

From the 6th revision, the International Classification of Diseases (ICD-6), now the International Classification of Diseases and Related Health Problems, has included not only disorders that may be a cause of death, but also non-fatal conditions, symptoms, signs, and in the last revisions also causes for contact with the health services (17, 48, 81). This means that even if a condition is listed in the current official classification system of diseases, this does not necessarily imply that it is a suitable cause of death.

On the other hand, there may be other uses of cause of death information, besides the public health perspective, where other registrations of “causes of death”, or more

correctly, conditions present at death, might be of more use. One might imagine, for example, that for trauma registries the type of injuries sustained (such as head, thoracic or abdominal), might be of more interest than whether then fatal event was a fall or a traffic accident.

10.2 Various terms for insufficiently informative codes

Several terms have been used for diagnostic codes that do not convey sufficient information on the real underlying cause of death, such as “ill-defined causes of death”, “unusable or uninformative codes” or just “R codes”, as many of these codes are gathered in chapter XVIII (R chapter) of ICD-10. There is no fixed list of uninformative codes. It depends on the intended use of the data and the agency or author behind the analyses. The various terms include different sets of codes, and even within the same agency, such as the Global Burden of Disease, the specific content of the list have evolved over time. It is not possible to make comparisons over space and time unless the same definition is used. There is nothing inherent in the concept of insufficiently informative codes that connects it to the International Classification of Diseases and Related Health Problems (ICD), but all countries that are member of the World Health Organization are obliged to use the WHO classification and rules for registering causes of death. It follows then that garbage codes usually are defined by ICD codes. Most publications relate to ICD-10, but GBD also has mapping lists from ICD-9 (39).

“Ill-defined conditions” or “ill-defined causes” are the terms used by WHO in the manual for ICD-10 (29). In Eurostat’s tabulation list (European Shortlist of Causes of Death), one group is called “Symptoms, signs, and ill-defined causes” (34). The National Center for Health Statistics (NCHS) in USA uses the term “Unsuitable Underlying Causes of Death” (86).

The term **“garbage code”** was introduced in 1996 by Murray and Lopez (81) and is probably now the most commonly used term, even if it might be considered

pejorative. In the strict sense, the term garbage codes is linked to the Global Burden of Disease studies. The definition includes ill-defined causes as well as a much larger spectrum of codes with suboptimal information value (see below). “A garbage code refers to anything that is marked as a cause of death on a death certificate that cannot officially kill you. “ (87) For convenience, in this thesis the term garbage code comprises any set of insufficiently informative codes, not only the GBD set, unless otherwise stated.

10.3 The deleterious effects of garbage codes

If a death is assigned a garbage code for the cause of death, it has at least two implications: First, on group level: The number of deaths in the group where this case (really) belongs is reduced. When the number of garbage coded deaths is large enough, the cause of death statistics will be misleading. “Out of sight, out of mind.” If the probability of misclassification is unequal across the different causes of death, this will introduce bias in the statistics. E.g. if there are equally many deaths in the population from cause A and cause B, but 20% of the deaths in the B group are assigned a garbage code, then the registered mortality rate from cause B will be 20% lower than from cause A. This might misguide the allocation of preventive or health care resources. Some researchers argue that use of garbage codes partly can explain differences between regions in the registered mortality from suicides and drug overdoses (88, 89).

Second, on individual level: A garbage coded death has often limited value for cause of deaths investigation, quality assurance, and research.

The positive part, if any, is when a death is assigned a garbage code, one knows that it is not well certified and can act accordingly. If a death (e.g. a suicide) is misclassified using a *non-garbage* code (e.g. myocardial infarction), it is much harder to detect the flaw.

10.4 World Health Organization and ICD

Independently from the GBD, WHO has published lists of undesirable codes in the guidelines and coding rules to ICD-10 (29). There are two lists, one with “ill-defined conditions” (annex 7.3), and one with “conditions unlikely to cause death” (annex 7.4). The list with ill-defined conditions includes most of the codes in chapter XVIII (Symptoms, signs, and ill-defined conditions), in addition to a few others. The second list consists of conditions that may cause morbidity or reasons to contact with health services, but are unlikely to cause death. In essence, the coding rules states that if there is another, not ill-defined or trivial condition on the death certificate, the ill-defined or trivial condition should be disregarded (rules SP7 and SP8). Similar instructions, albeit with different wording, existed in earlier versions. Nevertheless, in many cases an ill-defined code will be selected as the underlying cause of death, as it is the only diagnosis on the death certificate.

In the 2014 technical report for the Global Health Estimates, the World Health Organization has an expanded definition of garbage codes (90).

10.5 Global Burden of Disease Study

Through the years of the Global Burden of Disease project, there has been development in the concept and typology of garbage codes, as well as the definition of the list of codes.

In 2010, Naghavi et al. classified garbage codes by their origin or place in the certification process (81):

Class of garbage code		Examples
1.	Causes that cannot or should not be considered as underlying causes of death	Symptoms, signs, reasons for contact with health service
2.	Intermediate causes of death	E.g. heart failure, sepsis, pulmonary embolism Defined clinical entities, but not the initiation of the chain of events leading to death
3.	Immediate causes of death that are the final steps in a disease pathway leading to death	E.g. cardiac arrest, respiratory failure
4.	Unspecified causes within a larger cause grouping	E.g. cancer with unknown site, unspecified accident

Fig. 10.5.1 "Early" classification of garbage codes, adapted from (81).

In 2014, Phillips et al divided garbage codes in two groups, those which did not contain any information about the underlying cause of death (type 1), and those that had *some* information (type 2) (91).

From GBD 2016 (published 2017), there has been a change in view (92). The garbage codes are now classified by how deleterious they are for public health analysis (82, 85). More specifically, how wide is the spectrum of disorders that are masked by each garbage code? For the garbage codes with most serious implications, the real underlying cause of death might be in all three main groups of causes of death: *communicable or non-communicable diseases, or injuries.* For the least serious garbage codes, the real underlying cause is restricted to a single disease or injury category.

Class of garbage codes		Explanation
Level 1 (very high)	Codes with serious policy implications	The true UCOD might belong to any of the three broad groups of causes of death. E.g. sepsis
Level 2 (high)	Codes with substantial policy implications	The true UCOD might belong to one (or at most two) of the three broad groups of causes of death. E.g. unspecified injury
Level 3 (medium)	Codes with important policy implications	The true UCOD is likely to be within the same ICD chapter. E.g. cancer of unknown site
Level 4 (low)	Codes with limited policy implications	The true UCOD is likely to be within a single disease or injury category. E.g. unspecified stroke

Fig. 10.5.2. "Late" classification of garbage codes, adapted from (82).

Level 1 and 2 are called major garbage codes, level 3 and 4 minor (39, 85). The importance of category 4 in the first typology and level 3 and 4 in the last version is a function of the detail needed for statistics or analysis. If the desired group is "all malignant neoplasms", then "cancer of unknown site" is good enough.

The lists of undesired/unacceptable/garbage codes from these sources are supplied in the appendix to the thesis, section 22.1.

10.6 The use of garbage codes

The frequency and distribution of garbage codes obviously depends on the set of codes used as well as the coding practises. There is a large variation in the prevalence of garbage codes in cause of death statistics from different countries and time periods (81). In the GBD 2019 publication, the proportion of major garbage codes in different country-years varies from 3 to >80%. There is a tendency that developing countries have poorer vital registration, but even within high-income countries, there is a large

variation in the use of garbage codes. In the same study, for the year 2015, the prevalence of major garbage codes was 20% in France, in contrast to 6% in Finland.

Different countries or regions may also have peculiar patterns in the use of garbage codes, possibly reflecting traditions in death certification. An example is the coding of death due to unspecified external cause. First, the proportion of deaths assigned one of the codes for unspecified external cause varies from country to country. Second, there are also geographical variation in which of the codes that are used (93). See also section 16.2.4.

In Korea in 2010-2012, 24.6-25.2% of the deaths were assigned a garbage code (94). The authors used an earlier garbage code list from GBD, from the 2010 GBD study. The most prevalent garbage codes were senility (5% of all deaths), pneumonitis, heart failure, renal failure, and disseminated intravascular coagulation, cardiac arrest, acute respiratory failure, and coma (in a single group).

Iburg, Mikkelsen, and Richards analysed the deaths in Greenland 2006-2015, using the ANACONDA framework (95). A total of 32% of the deaths were coded with an unusable (24%) or insufficiently specified (8%) cause of death. About half (47%) of these deaths were a level 1 garbage code, the group with most severe implication for public health analysis (96).

In Italy in 2017, using the current GBD garbage code list, 25.8% of all deaths were assigned a garbage code, major or minor (97). The five most prevalent garbage codes were unspecified stroke (5.1%), unspecified diabetes (2.3%), unspecified heart disease (1.7%), unspecified lower respiratory tract infection (1.7%), and exposure to unspecified (external) factor, 1.3%.

In Brasil, França et al analysed the pattern of garbage codes for the period 1996-2016, using the recent GBD typology (98). There was a reduction in the total proportion of garbage codes from 52.5/45.3% (females/males) in 1996 to 42.2/36.0% in 2006. The largest reduction was in level 1 (the most serious) garbage codes. In 2016, the most

important garbage code groups were unspecified pneumonia (level 4), unspecified stroke (level 4), ill-defined causes (gathered) (level 1), unspecified diabetes (level 4), and heart failure (level 1).

In the United States 2018, using the set of garbage codes published by Flagg and Anderson (86), 34.7% of the deaths were coded by an unsuitable cause of death. The five most prevalent garbage codes were atherosclerotic heart disease (ICD-10 code I25.1), 5.8%; unspecified dementia (F03), 3.5%; heart failure (I50), 2.9%; atherosclerotic cardiovascular disease (I25.1), 2.3%; and renal failure (N17-N19), 1.8%. The garbage code list used in this study is different from the GBD list. For comparison, using the garbage code list from GBD, 14% of the deaths in the US in 2015 (the latest year available) were assigned a major garbage code (39).

Iburg, Mikkelsen, Adair, and Lopez analysed data from 20 countries at different socio-economic levels (84). They found that the level of garbage coding varied from 7 to 66%, generally with a lower proportion in countries at higher socio-economic level. They noted, however, that even if the specific pattern or ranking of garbage codes varied, many of the codes were the same across the countries. Ill-defined/unspecified causes of death, senility, heart failure, unspecified neoplasm, and sepsis were common.

10.7 The selection of garbage codes

Every classification is the result of deliberate choices, reflecting both the current understanding of the subject matter, the parameters (or “axes”) used for classification, and the needs of the classifier. The same subject may be classified according to a number of different systems, equally valid, but reflecting varying needs.

The structure of ICD is the result of more than a centennium of development. To cite from the ICD-10 manual (29):

> *The categories have to be chosen to facilitate the statistical study of disease phenomena. A specific disease entity that is of particular public health importance, or that occurs frequently, should have its own category.*

And

> *The ICD has developed as a practical, rather than a purely theoretical classification, in which there are a number of compromises between classification based on aetiology, anatomical site, circumstances of onset, etc. There have also been adjustments to meet the variety of statistical applications for which the ICD is designed, such as mortality, morbidity, social security and other types of health statistics and surveys.*

One of the consequences is that not all entities in the ICD are usable for describing causes of death. The selection of which codes that are deemed appropriate and inappropriate, is again a choice. The structure of the GBD cause list (including the categories of garbage codes) is a result of the work of the GBD team, developed over years, reflecting what is considered to have the best public health utility. The ultimate decision about the GBD process and methods lies with the GBD Scientific Council (38).

The change of garbage code typology is described in the papers by Iburg et al (84), Mikkelsen et al (96), Naghavi et al (82), and Johnson et al (85). In short, less focus is placed on their origin in the certification process, and more on the impact on public health analysis. I.e. the wider the range of causes that can be masked by a specific garbage code, the less is the information value. Some information on the selection on garbage codes can be found in the methods appendix to the GBD capstone papers on mortality (39).

The wider the garbage code list, the larger the proportion of the deaths that have a useless or suboptimal cause of death, and this will influence the perceived quality of a cause of death register. More important, the composition of a garbage code list will influence the process of redistribution and the "corrected" cause of death statistics. If a code is considered a non-garbage code, it will remain in the statistics. If it is a

garbage code, it will be removed and replaced by a valid cause. If it is a major garbage code, the range of target codes is wide, compared to a minor garbage code. Another aspect is that the concept of garbage codes can be used in guidelines and training of certifying physicians (99). Whether a specific code is in the garbage code list or not may influence the certification habits.

For many, perhaps most, codes, it is easy to agree whether they are suitable or not. For some, it is not always clear why they are classified as a garbage code or placed in a valid cause group. A few examples are presented.

Unspecified (broncho)pneumonia

In Naghavi's classification from 2010 (81), unspecified pneumonia (J18.X) was not a garbage code. In GBD 2015 (100), it was counted as a garbage code, type not specified. In GBD 2016 (92) and beyond, it was classified as a level 4 garbage code (least problematic). The argument is that unspecified pneumonia represents other, more specific, lower respiratory infections, that is, a narrow cause group. In the redistribution, it seems that these deaths are placed among the more specific lower respiratory infections.

The possibility that pneumonia might be the terminal complication of a number of other conditions, such as dementia, drug overdose, or malignancy, seems not to be commented on. In the manual for ICD-10, there are numerous examples of this kind, such as bronchopneumonia *due to* cerebral infarction (29). In correspondence with this, unspecified pneumonia is listed among "immediate and intermediate" in the report from NCHS (86). If translated into the GBD framework, unspecified pneumonia probably should be a major garbage code, with a much wider range of target codes.

Poisonings with drugs or alcohol

In GBD 2016 and beyond, the codes for accidental poisonings to drugs and substances of abuse (X40-X44) are considered level 1 (major) garbage codes (92). In Naghavi's classification from 2010 they were not garbage codes. In GBD 2015 (100), they were counted as garbage codes, type not specified. The reason for classifying these as major garbage codes can be found in the description of the redistribution processes of GBD (39). From other studies, one has found that the majority of these deaths are poisonings by drugs of abuse in adults. GBD has chosen to regard these deaths as *drug use disorders* (within non-communicable diseases), and not as external causes of death. This is in contrast to the current coding guidelines from WHO (ICD), which explicitly states that the external cause should be coded as the underlying cause of death (39). Therefore, the codes for mental and behavioural disorders due to psychoactive substance use (F10-F19) will be used as the underlying cause of death only in instances where there is no mention of poisoning. This coding recommendation was put to use in Norway in 2003 (27)

The reason from WHO seems to be that deaths due to external causes should not be "hidden" among diseases. The same principle has as consequence that depression cannot be coded as the underlying cause of death in cases of suicide. This means that a drug overdose that is correctly coded according to the WHO guidelines is regarded by GBD as not well certified, and vice versa.

There are some other quirks regarding deaths due to drug and alcohol use, not all involving garbage codes. Accidental poisonings with alcohol (X45) are directly classified in the GBD cause list within substance use disorders, and not via garbage code redistribution. Suicides due to alcohol ingestion (X65) are also classified with substance use disorders, and not as suicides. On the other hand, suicides with drugs and substances of abuse (X60-X64) are classified as suicides (39).

Some somatic complications of alcohol abuse (e.g. G31.2 alcoholic encephalopathy) are classified with substance use, while others are not. For instance: Some codes for alcoholic liver disease (K70.0-K70.3) are classified as digestive disorders, while others (K70.4-K70.9) are level 3 garbage codes. Alcoholic cardiomyopathy (I42.6) is classified with cardiovascular disorders (39). I have not found compelling explanations for these apparent paradoxes.

10.8 The X59 problem

Part II of this study concerns the use of the ICD-10 garbage code X59 (X59.0-X59.9, (accidental) exposure to unspecified factor) in Norway. This warrants a more detailed discussion of the code.

When there is an external cause of death, the underlying cause of death is defined as "the circumstances of the accident or violence which produced the fatal injury" (29). These codes can be found in chapter XX of ICD-10. The details of the injury (or poisoning or other adverse effect) should be coded as the nature of injury. These codes are in chapter XIX. Knowledge of both the circumstances leading to the injury and the nature of injury is necessary to fully understand the condition. The same circumstances (e.g. a pedestrian struck by a car) might lead to a number of different injuries, and the same injury (e.g. a traumatic rupture of the spleen) might arise in a number of different settings. To understand the aetiology of an injury and ascertain the potential of prevention, it is more important to know the circumstances (e.g. if the injury was caused by a traffic accident or a work-place fall).

If the information on the circumstances is lacking on the death certificate, the underlying cause of death will be given an unspecified code. For unspecified *accidents*, this is X59 (exposure to unspecified factor). In an ICD-10 update in effect from 2006, X59 was further divided into X59.0 (exposure to unspecified factor causing fracture) and X59.9 (exposure to unspecified factor causing other and unspecified injury) (101). If not only the circumstances around the injury, but also the

intent is unknown, a code in the range Y10-Y34 (event of undetermined intent), in particular Y34 (unspecified event, undetermined intent) should be used.

At the Norwegian Cause of Death Registry there is a poorly documented tradition to classify external cause death lacking information as “accidents”, and code them with X59 (X59.0-X59.9). The exception is hanging, which is classified as suicide unless specified otherwise. (Pedersen AG, NIPH, personal communication). This can explain a very low use of codes in the Y10-Y34 range in Norway. In the years 1996-2020, between 0 and 19 deaths each year were assigned a code in this range (49, 102).

In ICD-9, there was an E887 (fracture unspecified) code, with more or less the same function as the ICD-10 code X59.0 (exposure to unspecified factor causing fracture). The difference was that E887 was included in the ICD-9 section for accidental falls (E880-E888) and thus usually was counted along with falls (103). The transition from ICD-9 to ICD-10 could then lead to an apparent reduction of the number of deaths registered as accidental falls and a concordant rise in the number of unspecified accidents (104). In Norway, in the first years after the introduction of ICD-10 (1996-2004), there was a local guideline stating that if a death certificate stated fracture of the femur as the main injury, but without mentioning of the circumstances, the cause of death should be coded as W19 (unspecified fall). This meant that there was not a reduction in the number of registered deaths from falls after introduction of ICD-10 (49). In 2005, concomitant with introduction of ACME, this guideline was removed, and these deaths subsequently were coded with X59.0 (27), which lead to a large reduction in the registered deaths from falls (49). A similar approach is described from Australia by Kreisfeld and Harrison (105).

Worldwide, there is a large variation in the proportion of deaths coded with X59. In a study by Lu et al. from 2007, the proportion of unintentional injury deaths coded with X59 ranged from 7% to 33% in four high-income countries (106). Bhalla et al. found in a study from 2010 that in 15 out of 83 countries, the proportion was higher than

20%, with 45% as the highest recorded proportion (93). In the United States in 2019, the proportion of unintentional injury deaths coded with X59 varied from 0.77% to 8.28% between states (107).

11. The quality of a cause of death register

Information from health registries, including cause of death registries, is used for a variety of purposes. Among these are production of official statistics, research, analysis of the performance of health care systems and planning of resource allocation (8). For a health register to be useful, the data quality must be as good as possible. If the data are incomplete, inconsistent, incommensurable or inaccurate, the results from analysing them will not be much better. Therefore, we need ways to evaluate the quality of the register to assess how trustworthy the results are and to identify targets for improvement. To find differences between countries or changes in register quality over time, one must be able to do some kind of benchmarking. Various studies have utilized different parameters for evaluating the quality. Some have used only one parameter, other have relied on a combination of different features, sometimes put together in a scoring system (10, 91, 96, 108, 109). The exact composition varies, but most include at least some of the aspects listed below. In 2006, Johansson, Westerling and Rosenberg (110) examined a number of different studies and found that many of these had substandard methodology in various ways, such as not specifying what constituted a "difference" or error or whether the method for identifying the cause of death was congruent with the ICD rules.

11.1 Legal and organizational foundation

The registry should be part of a permanent official civil registration and vital statistics system (CVRS) with a proper legal foundation, adequate staffing and funding and efficient system for data acquisition, storage and processing. The deaths should be certified by registered medical practitioners and not by laypersons, police or other non-medical personnel. The registry should use a recognized and up-to-date international system for registration and classification of causes of death. For all practical reasons, by the time of writing this means ICD-10 from the World Health

Organization (29), to be replaced with ICD-11 (probably within a couple of years) (11, 91, 108, 109).

11.2 Timeliness

Is the registry able to publish results within "reasonable" time? Ideally, the system should be able to identify changes in the number of deaths and distribution of causes of death in near real time. With a system like that, it would be possible to identify emerging epidemics. Many European countries, including Norway, have systems to detect changes in all-cause mortality early, such as NorMOMO (111). This has been of great value during the Covid-19 pandemic. Few, if any, countries are able to produce similar rapid information on the causes of death. After introduction of electronic certification of death, the current time lag at the NCoDR is about 6 months from the end of the registration year to the publication of results.

11.3 Coverage and completeness

Coverage can be defined as the proportion of the population that is supposed to be in a registry and **completeness** as the part of the target population that is actually registered (112). Used in this way, the coverage of the NCoDR is all Norwegian residents dying in Norway or abroad, and, from 2012, non-residents dying in Norway (albeit registered in a slightly different way) (8). Note that *resident* is not the same as *citizen*, as there are Norwegian citizens that permanently live abroad and non-citizens with a permanent residency in Norway.

In most high-income countries, the intended coverage is for all practical purposes the entire population.

The **completeness** of the NCoDR is assessed by crosschecking with the Norwegian Population Registry (Folkeregisteret), run by the Norwegian Tax Administration (113). The ambition of the NCoDR is to keep the completeness for all residents >98%

and >99% for residents dying in Norway. It is not possible to assess the completeness for non-residents, as there is no complete and central registration over non-residents present in Norway (e.g. on holiday).

To describe the proportion of records that has information on a given variable, some use completeness (for the variable in question) while other include this in the **validity** (see below).

In low-resource settings, lacking a well-functioning population register, the completeness can be coarsely and indirectly estimated by demographic methods (114).

11.3.1 Consequences of missing data

The impact of reduced coverage or completeness depends on several factors. One of them is the type of analyses we want to perform. If using register data on individual level, for example for linkage studies, it is important to have information on as many as possible of the study subjects. If we use the register data to produce population-level statistics, the results may still be valid even if a proportion of the records is missing. It depends on whether the remaining data are representative for the total population, i.e. if the observations or registrations are missing at random or not (115).

Missing completely at random (MCAR): The missing observations are a random subset of the population. The distribution of the missing observations does not depend on other variables. This will not introduce bias in the analyses, but may affect statistical strength. Unfortunately, data are seldom MCAR.

Missing at random (MAR): The distribution of the missing observations depend on other, observed data. This may or may not introduce bias, depending on the situation. An example can be if there are more missing records among young people, but that this has nothing to do with the cause of death. The completeness is so low in some municipalities in Norway that the estimates in these places might be misleading.

Missing not at random (MNAR): The distribution of the missing observations depend on other, unobserved data. In other words, the propensity for data to be missing is dependent on the variable in question. An example might be if a number of suicide deaths are missing *because* they are suicides, perhaps because stigmatization.

It is possible to discern between MCAR and MAR by studying the data set, but one cannot discern between MAR and MNAR just by analysing the data. To get an idea of the nature and magnitude of the problem, one must be familiar with the data acquisition and registration process.

If information on the cause of death is missing in a large proportion of the cases, we will underestimate e.g. the mortality rates unless we compensate for the loss. With a completeness above 98%, one would expect that the estimates for the population as a whole are reasonable valid. There are various methods to deal with missing data, but the details are outside the scope of this presentation.

11.4 Are the data correct?

To many people, this is probably their main concern regarding data quality. This is not as straightforward a question as it seems. What does it mean for a registration to be “true” or “false” for a given variable, and how can status be determined? In principle, this may concern all kinds of information in a registry, but the question is probably most often related to the underlying cause of death.

Fault in diagnosis: Sometimes the certifying physician must make an educated guess based on what is believed to be the most probable correct information; this might be right or wrong. In other cases the physician clearly states the uncertainty, which then can be carried forward into the registry.

Data may be wrong or sometimes better regarded as incomplete if it is not possible to produce the relevant information. Typical examples can be if the cause of death is unknown and no autopsy has been performed, or if the death is caused by poisoning,

but it is not possible to determine the manner of death (whether it was a suicide or an accident).

Fault in certification: If the physician certifying the death is unaware of the guidelines for completing the death certificate, important information may be omitted. An example is if the physician enters only the terminal complication (immediate cause of death) and not the initial condition (the underlying cause of death).

Errors may be introduced during the stages of data entering and processing. There is always the possibility of clerical errors and illegible handwriting. Even if there are detailed guidelines for interpreting the chain of diagnoses and selecting the underlying cause of death (29), the nosologists' task can be difficult.

11.4.1 External validation

In this setting, **external validation** means comparing the data in the register with some other, independent, source. An example is comparing the death certificate with information in autopsy reports, hospital records or other, independent registries. If a discrepancy is found, it is necessary to have procedures for determining which source that is believed to be most accurate.

Already in the process of selecting the underlying cause of death in the registry there may be some element of external validation. There may be more than one source of information, such as more than one death certificate, an autopsy report or an answer to a query letter. The medical coders (nosologists) in the registry must then manually extract and synthesise the relevant information.

According to the current Norwegian regulations, the departments performing autopsies are obliged to report all autopsy results, both forensic and non-forensic, to NCoDR. The NCoDR may also cross-check information with other national health registries, such as the Cancer Registry of Norway, the Norwegian Patient Registry and the Medical Birth Registry of Norway (8).

Traditionally, comparing the diagnoses on the death certificate with autopsy results has been considered the “gold standard” for quality control. There are several problems in using autopsy results in this way. The most obvious is that the proportion of deaths undergoing autopsy is low in most countries. In the decade 2010-19, the NCoDR received an autopsy report (forensic or non-forensic) in 8.1% of the deaths (49). If the selection for autopsy is not random, the autopsied cases will not be a representative sample of all deaths, and we cannot generalize the findings. One might suspect that the propensity for requesting an autopsy is higher in unclear cases, and thus the proportion of cases with important new findings at autopsy would be high. The overall proportion of deaths undergoing autopsy is low in Norway, but the proportion is higher in persons dying outside health care institutions, 24.9% in the decade 2010-2019 (own, unpublished data). In the same group, one might suspect that the certifying doctor often lack information on the cause of death, and the autopsy can give important insight. Another problem is that the autopsy results themselves may be misleading. The performance or reporting of the autopsy might be substandard, the pathologist’s diagnosis can be wrong, and some causes of death, such as death from epilepsy or hypoglycaemia in diabetes, may have few or no specific findings at autopsy. In a study from Norway, Eng et al. found errors relating to the reporting of the cause of death in 69 of 389 (18%) reviewed medical autopsy reports (116).

Probably a better quality control is a 360 degrees evaluation by an independent investigator or expert panel, taking all relevant information into account. This information can be used to fill out a new death certificate, the information of which can be compared to the original certificate (or the registered cause of death).

The Finnish death certificate includes a blank item where the certifying physician is obliged to give supplemental clinical information, such as a short case history. Lahti and Penttilä published a study on validation of 3478 death certificates from the year 1995 (117) where they used this extra information to improve the certificates. This was a highly selected sample of 7.1% of the deaths, comprising the most

inconsistently filled-in certificates. Of these certificates, 80.9% could be amended from the clinical information alone. The authors found a significant decline in deaths due to symptoms, signs and ill-defined conditions and “other external causes”, non-malignant neoplasms, mental disorders, and respiratory diseases. There was a significant gain in the groups of endocrine disorders, malignant neoplasms and unnatural causes due to (specified) injury.

In several countries, there have been studies comparing the registered cause of death with discharge diagnoses or similar information, such as national patient registers (118-120). In general, they find a relatively high concordance between the ailment for which the patient was treated and the registered cause of death, at least for some cause of death groups and if the last hospital admission was a short time before death. For cancer, this concordance is especially high, often around 90%. A lack of concordance, on the other hand, does not necessarily indicate that the registered cause of death is wrong. A person may die from a completely different cause than the reason for the latest admittance to hospital.

11.4.2 Internal validation

Another approach is to detect inconsistencies in the data. Ovarian cancer in a man or Alzheimer’s disease in a 4-year-old are obvious impossibilities. Iris, the data program in use by many cause of death registries (30), including NCoDR, has many built-in checks of this type. Other tests could be to look for abrupt changes in secular trends. In 2016, Denissov found a sharp decrease in the registered mortality from cerebrovascular diseases in Estonia. This was paralleled by a rise in the use of hypertension as underlying cause of death, indicating that much of the apparent reduction in cerebrovascular mortality really was a change in certification and coding practise (121).

A related method is to take a closer look on the codes used for underlying cause of death. In a way, this might be considered an evaluation of *usefulness* as much as *correctness*. What is the proportion of deaths coded with garbage codes? A large

proportion of such codes indicates a low quality of the input to the registry (the death certificates) and makes the information in the registry less useful in the same way as a low completeness. On the other hand, if a death is assigned a non-garbage code does not necessarily mean that the diagnosis is *correct.* The Global Burden of Disease project publishes in their capstone papers on causes of death the proportion of deaths that are coded with garbage codes in each country and year. As is explained later, the definition of garbage codes has changed over time, so earlier results are not automatically comparable with the latest. For each iteration of the GBD study, new methods are applied to older data, and the results from different years can be compared *within each iteration*. In the GBD 2019 publication, the proportion of major garbage codes in different country-years varies from 3 to >80% (39). Garbage codes are discussed in detail in chapter 10 and 12.

11.4.3 A note on the term "validity"

Especially when it comes to the performance of diagnostic tests or measuring instruments, the term "validity" can be used with different meanings. One interpretation is that a test is valid if it measures what it is intended to measure (122). In this setting, this might mean if the WHO/ICD rules for understanding and registration the cause of death gives a correct picture of the "reality" (see section 9.7 and 9.8). Another, more narrow interpretation, is that a test is valid if it does not have a systematic error (bias) (123). This comes closer to the use of "validation" above.

11.5 Compound scoring systems

There have been a number of efforts to make compound scoring systems that take several of these factors into account. In 2005, Mathers et al. published an evaluation of the global status of cause of death data (108), where they used completeness, timeliness and the percentage of deaths assigned an ill-defined cause of death. The criteria for "high quality" were: completeness over 90%, under 10% garbage codes and use of ICD-9 or ICD-10 for coding. Only 115 countries had supplied data to the

WHO, 23 of these were judged to have high quality of cause of death data, 55 medium quality and 28 had low quality. Among the Nordic countries, Finland and Iceland had “high” quality, and Denmark, Sweden, and Norway “medium”. This study was criticized, both because of the cut-offs of the criteria, the selection of garbage codes, and lack of age adjustment (124).

In 2007, Mahapatra et al. published a review of civil registration and vital statistics (CRVS) systems where the main areas of concern were: accuracy, relevance, comparability, timeliness, and accessibility (109). The criteria used for evaluation were whether the register used an updated classification with a high level of granularity (ICD 3- or 4-character code), completeness, and the proportion of garbage codes. Of the 192 countries evaluated, 31 had “high” quality, 24 “medium-high”, 26 “medium-low”, and 111 “low”/”limited use”/”no report”. Among the Nordic countries, Finland, Sweden, and Iceland had “high” quality, and Denmark and Norway “medium-high”.

In 2014, Phillips et al. created a “vital statistics performance index (VSPI)” with six dimensions: quality of cause-of-death reporting (garbage coding), quality of age and sex reporting, internal consistency, completeness, level of cause-of-death detail (number of codes used) and timeliness (10, 91), with a possible total score between 0 and 1 (100%). One hundred and forty-eight countries were evaluated, with a mean score of 61.4%. Hungary received the highest score, 95.7%. The scores for the Nordic countries were: Finland 95.6%, Iceland 91.2, Sweden 89.4, Denmark 87.8, and Norway 87.6%.

In the GBD 2016 study, the authors implemented a five-star ranking system with three elements: 1) completeness of death registration, 2) fraction of deaths not assigned to (major) garbage codes, and 3) fraction of deaths assigned to detailed GBD causes (92).

At the time of writing, ANACONDA (Analysis of Causes of National Deaths for Action), developed by the University of Melbourne/Bloomberg Data for Health Initiative is the most recent tool, with ten steps and several substeps (84, 96, 99). In many aspects, ANACONDA is an extension of the VSPI, but with more detail and identifiable targets for improvement. For instance is the reported distribution of age, sex, and the main causes of death compared to estimates from GBD to assess their plausibility. By the time of writing, ANACONDA score has not been calculated for Norway. The ten parts of ANACONDA are (114):

1	Data input checks; basic tabulations of deaths by age, sex, and cause of death
2	Crude death rates; completeness of death reporting
3	Age and sex-specific mortality rates
4	Age and sex distribution of deaths
5	Child mortality rates
6	Classification of deaths into broad GBD cause groups
7	Quality of cause of death data; “unusable” causes of death
8	Age pattern of mortality for broad disease groups
9	Leading causes of disease
10	Vital Statistics Performance Index for Quality (VSPI(Q))

Fig. 11.5.1. The parts of ANACONDA, from (114).

11.6 Previous studies on the quality of NCoDR

11.6.1 Completeness

Missing death certificates are identified by crosschecking with data from the National Population Register. In the online data bank for NCoDR, the number of missing death certificates are given for the ICD-10 period, 1996 and onwards. There is a rising trend, from 144 missing records in 1996 (0.3%) to 1360 (3.4%) in 2020 (49). From 2018, part of this is probably due to (temporarily) diminished potential for sending reminders, related to the implementation of electronic certification of death. Before introduction of electronic certification of death, NCoDR could send reminders about missing certificates to the Chief Municipal Medical Officers. With electronic certification, the information is relayed directly from the certifying physician to

NCoDR and the Population Registry, and the Chief Municipal Medical Officers have no longer this function. In the transition phase, NCoDR cannot send reminders about missing paper certificates. When the transition to electronic certification is completed, one expects very good completeness (Pedersen AG, NIPH, personal communication).

For the first part of this period, the numbers are not fully reliable: There was a local adaptation at NCoDR with a fourth character to the ICD-10 code R99 (Unknown cause of mortality). R99.0 was used in cases where the cause of death was unascertained on the death certificate, R99.8 where there was a document without a statement about the cause of death (e.g. a document from abroad), and R99.9 where there was no document at all concerning the death (27). This distinction was lost when NCoDR data was migrated from Statistics Norway to Norwegian Institute of Public Health in 2013-14. This can lead to that some cases with missing death certificates may appear in the data with an apparent, albeit unknown, cause of death (Pedersen AG, NIPH, personal communication).

As part of the internal quality assurance process, NCoDR produces yearly (internal) reports on the completeness. As an example, for the year 2018, the completeness for all Norwegian residents was 97.8%, for residents dying in Norway 99.1% and for residents dying abroad 4.6%. Even if the total completeness was good, there was some geographical variation, with six (mostly small) municipalities with a completeness below 80% (Slungård GF, NIPH, personal communication).

11.6.2 Validity

Glattre and Blix performed a study on all death certificates for the second part of 1976 (24). They found one or more errors (all categories) in 5349 certificates (27.4%). This includes both errors and omissions regarding the cause of death (7.6%), as well as more formal or clerical errors. This was an entirely internal validation, so we do not know in how many cases the errors lead to registration of an incorrect underlying cause of death. The authors noted, however, that 17.1% of the death

certificates concerning external causes of death had errors concerning the cause of death, and a large proportion of these lacked information on the circumstances of the event.

Alfsen and Mæhlen (125) reviewed all medical (non-forensic) autopsy reports received at the NCoDR for the year 2005 (N = 1773) and found that the autopsy findings lead to change in the underlying cause of death from the initial diagnoses on the death certificate in 61% of cases, in 32% this was a major change (from one ICD-10 chapter to another). As the proportion of deaths undergoing autopsy was low (4.3%), and the selection of cases undergoing autopsy is non-random, one cannot generalize from their findings to all death certificates.

Alfsen, Lyckander, Lindboe and Svaar reviewed death certificates and patient records for a total of 630 deceased from one hospital in Norway in 2007-2008 (126). They found serious mistakes or omissions in 134 (21%) of the death certificates. In this study did the authors not investigate in how many cases these deficiencies would lead to an incorrect registration of the underlying cause of death. Alfsen and Lyckander performed a similar study on 1,001 deaths in 2008-2009 (127). In this study, they corrected significant deficiencies in 223 death certificates (22.3%). In 176 cases (17.6%), this lead to a change in the underlying cause of death, in 121 of these (12.1%) a change in ICD-10 chapter. There was a reduction in unspecified diagnoses and an increase primarily in cancer and accidents. Interestingly, many of the changes tended to cancel each other out, so the overall effect on the cause of death statistics *on group level* was less pronounced.

Tøllefsen et al re-evaluated a sample of 1,800 deaths from the three Scandinavian countries in 2008 (128). From each country, there were 200 deaths registered as suicides, 200 accidents or undetermined manner of death, and 200 natural deaths. The reclassification was based on information on death certificates and autopsy reports, where available. No further information was collected. For the Norwegian cases, there was 88% agreement with the initial classification of suicides. In 11%, suicides

were reclassified as events of undetermined intent, 1% as accidents, and 0.1% as natural deaths. In total, 2% of accidental deaths and 0.5% of natural deaths were reclassified as suicides. The authors concluded that the reclassification did not increase the official suicide statistics. An obvious weakness in this study was that the reclassification was based on the information already available at NCoDR, and not by new, additional information, such as patient records or police reports.

Löffeler et al. compared information from NCoDR, the Cancer Registry of Norway and patient records regarding death from prostate cancer in the Norwegian county of Vestfold for the years 2009-2014 (129). They found evidence for both over- and underreporting of deaths due to prostate cancer, but with a net overreporting, highest in the oldest (> 75 years). The agreement, measured with Cohen's kappa, between data from NCoDR and the expert panel, was 0.81.

Vangen et al. found by register linkage that only half (14/26) of the maternal deaths in Norway in 2005-2009 could be identified as such in NCoDR (130).

Bakken et al. compared data from the Norwegian Patient Register (NPR) and NCoDR for the years 2009-2011 (120). They found that 80.9% of the deceased had been admitted to a somatic hospital or attended an outpatient clinic during the last year of life. This study is not per se a validation of NCoDR, but the authors suggest that NPR-data can be of value in cases where the information on death certificates are insufficient.

11.6.3 Garbage coding

Using the definition of garbage codes from the WHO Global Health Estimates technical paper from 2014 (90), for the years 1998-2012, the garbage code proportion in Norway was 11-12%.

In the most recent capstone paper on mortality and causes of death from the GBD (39) (Appendix 1 to the referenced article, figure S4), the fraction of deaths in Norway in 1980-2017 assigned a major garbage code varied between 8 and 16%,

with a clear tendency to a higher proportion in the latest decade. This analysis was made using the latest version of the garbage code list (the same as used in **paper I**). In the 2016 version of the GBD Study, using the same underlying data, but with a different specification of garbage codes, for the years 1980-2014, the fraction of deaths assigned a garbage code varied between 11 and 22%, with the highest numbers in the first years (131).

11.6.4 Compound scoring systems

In the study from 2005, conducted by Mathers et al (108), NCoDR had high coverage and completeness, but received a "medium" quality because of 12% of the deaths were assigned an ill-defined cause. For the other studies mentioned below, the detailed sub-scores for each criterium are not published.

Year	Reference	Criteria for quality	NCoDR evaluation
2005	Mathers et al (108)	Coverage and completeness Percentage garbage codes	Medium
2007	Mahapatra (109)	Updated classification with high granularity Completeness Proportion garbage codes	Medium-high
2014	Phillips et al (91)	Garbage coding Age or sex unspecified Medically impossible diagnoses Completeness Length of cause list Timeliness	87.6% (Average world: 61.4% Average high-income countries: 81.4%)
2015	Mikkelsen et al (10)	Same as Phillips et al	78.4-87.6% (1980-2012)
2017	GBD 2016 (92)	Completeness Major garbage codes Detailed cause	5 stars, 78.6-85.4% well certified

Fig. 11.6.1. Comparison of compund scoring systems for the quality of cause of death data

12. Redistribution of garbage codes

All models are approximations. Essentially, all models are wrong, but some are useful. However, the approximate nature of the model must always be borne in mind.

(George E.P. Box (1919-2013), British statistician)

12.1 Redistribution methods

The prevalence of garbage codes has been used as one of the parameters for evaluating the quality of a cause of death register (chapter 11). The information value of the cause of death statistics is reduced if a large proportion of the deaths is assigned a garbage code instead of a more informative code for the underlying cause of death. Obviously, the best way to remedy this is to make the statistics as good as possible from the outset, putting effort into diagnosis, certification, and coding. No country has been able to eliminate the use of garbage codes completely; the lowest reported proportions of major garbage codes, using the latest version of the GBD list, is 3-4% (New Zealand, Singapore, Moldova) (39). For example, even after optimal investigation, the cause of death will sometimes remain unclear (132).

The next logical step is to try to ascertain which codes are hidden behind the garbage codes, in order to rebuild (more) correct cause of death statistics. This process is called *redistribution* (81). Both the concepts of garbage codes and redistribution are closely linked to the Global Burden of Disease (GBD) study.

Redistribution is fundamentally a form of *prediction*, using what we know to say something about what we do not know. A variety of approaches can be and has been used. The most sophisticated solution would be if one could find the most probable underlying cause of death for each person, i.e. *individual-level redistribution***.** This would allow to use the corrected data for individual-level analyses. Almost all efforts have been on *group-level* redistribution, which is to find the most probable number/fraction/rate of deaths due to a given cause in a group, without considering

exact which individuals in the group that died from this cause. A group of this kind could be defined by location, year, sex, and age. Group-level redistribution gives estimates that look like ordinary cause of death statistics, and can be used in the same way to inform public health decisions.

The cause of death groups that a certain set of garbage codes can be redistributed to are called *target groups.* In the present definition of garbage codes from GBD, they are classified into four levels of severity on the basis of the breadth of target groups. The most deleterious garbage codes, such as R09.2 (respiratory arrest) can represent almost any cause of death, and so the spectrum of target groups is very wide. In the other end, V89.2 (unspecified road traffic accident) can only represent the various specified road traffic accidents (39, 85).

Conceptually, the simplest method would be to proportionally *(pro rata)* reallocate the garbage coded deaths to the non-garbage codes. If X% of the non-garbage coded deaths were from cause *C*, then X% of the garbage coded deaths would be reallocated to *C*. This is more or less equivalent to consider the garbage coded deaths as randomly missing death certificates. For example, this approach was used for unspecified accidents (ICD-10 code X59) in early GBD rounds (81), but probably lead to overestimating the number of road traffic deaths in high-income countries (133). Still, proportional redistribution is used for some of the most ill-defined garbage codes, but then separately for each location, year, sex, and age group (85).

Probably the most powerful method is to utilize individual-level data with multiple causes of death (MCOD), especially for garbage codes that represents an intermediate or immediate cause of death (85), for example pulmonary embolism. From well-certified cases, one can extract the underlying cause of death in sequences that ends with the garbage code in question, and thus identify the most relevant target groups. One can then construct a predictive model with sex, age group, and other covariates and use this model to determine the fraction of garbage coded deaths that should be ascribed to each target group (85). A MCOD approach was also used for unspecified

injuries (X59 and Y34) in GBD 2019 (39, 85). Individual-level information on well-certified injury deaths that included information both on the underlying cause of death and the nature of injury was used to build models linking the nature of injury and demographic variables to the underlying cause of death. Next, these models could be applied to injury deaths lacking information on the real underlying cause of death to find the proportion to be redistributed to each relevant target group. Finally, these proportions could be used for redistribution where only group-level data were available.

The MCOD approach is not possible in the least deleterious group of garbage codes, the unspecified causes within a larger group (such as unspecified road traffic accident). A valid death certificate would never include a sequence where a specified cause was given as the underlying cause of death and an unspecified version of the same cause as the immediate cause.

Where individual-level data are unavailable or cannot be used for the reason mentioned above, GBD may use negative correlation (85). There is an inverse relationship between the number of garbage-coded deaths and the number of death assigned to their specific target codes. As the number of garbage-coded deaths increases, the number of deaths due to the probable real underlying causes decreases. This can be utilized to identify the proportion of garbage codes that should be redistributed to each target group.

GBD uses an ensemble model (CODEm), incorporating different methods, each suited to different garbage code challenges (39, 85, 134). The overarching principles for the process are (134):

1. Identify all the available data
2. Maximize the comparability and quality of the data set
3. Develop a diverse set of plausible models

4. Assess the predictive value of each plausible individual model and of ensemble models
5. Choose the model or ensemble model with the best performance in the out-of-sample predictive validity tests

The estimates are reported with uncertainty intervals, based upon replications of the estimates by taking 1000 draws of the parameters, reflecting the distribution of the coefficients (39, 134). The uncertainty interval is defined by the central 95% of the set of estimates.

12.2 Validation of redistribution models

All predictive models must be validated (134, 135). Testing the performance of a predictive model is described in chapter 15. A fundamental problem with redistribution models is that one cannot exactly know the real underlying cause of death. If we knew that, it would no longer be estimates of the distribution of causes of death, but reports of observations. The common approach is to split the available (well-certified) data into training and test sets and perform out-of-sample validation on the test set. The crucial problem is whether one can suppose that the predictions will behave in the same way on unknown data or in other locations. If the models are developed and tested on well-characterized data sets from locations with good data quality (e.g. high-income countries), how can we know if they are valid e.g. on another continent? One would suppose that using models for estimating health data is most important where the data are scarce or of poor quality, and this is exactly the same settings where it is hardest to procure data for out-of-sample validation.

12.3 Default “redistribution” without garbage code?

As a rule, conditions that normally do not cause death are classified as level 1 garbage codes, since they say very little about the real cause of death. An example is viral warts (B07). In the GBD cause list, there are quite a few instances where a non-

lethal condition is directly mapped to a valid cause of death, and not via garbage code redistribution. Examples are some lesser congenital malformations, such as Q70 (syndactyly) that are directly mapped to deaths due to congenital malformation, as well as some benign tumours such as D22 (melanocytic nevus), which is directly coded to death due to malignant melanoma (39). The reason might be that one considers these cases to be markers or miscodings for more serious conditions (for example malignant melanoma instead of benign nevus) in a way that all these cases represent the more lethal counterpart. Nevertheless, there seems to be some inconsistencies.

Where the immediate cause of death is sequelae or complications from medical treatment, ICD-10 regards the underlying cause of death to be the condition that was the reason for treatment (unless it is a trivial condition) (29). In the GBD cause list, there are some instances where treatment complications are placed in the section of endocrine and metabolic disorders. Examples are postprocedural respiratory disorders (J95) and postprocedural gastrointestinal disorders (K91), including postoperative intestinal obstruction (K91.3) (39). Without being aware of the possible explanation for this choice, one would think that the consistent way of handling these codes would be to classify them as garbage codes and then redistribute them to their probable origin (the condition that was the reason for treatment).

13. Autopsies and cause of death statistics

13.1 Medical and forensic autopsies

An autopsy is a thorough external and internal examination of the dead body to demonstrate pathological conditions present at the time of death, analyse these and identify the cause (and often also the manner) of death (see section 9.10).

There are two main types of autopsies, medical (academic, clinical, non-forensic) and forensic (medicolegal) (79). A medical autopsy is part of the medical diagnostic workup, usually performed by a clinical pathologist on request of a physician. A forensic autopsy is part of the investigation by the police or other legal body in cases of possible unnatural deaths, usually carried out by a forensic pathologist. Different states and jurisdictions have different death investigation systems and rules for which death that should be reported to the legal authorities. They all include homicides and deaths that might be disguised criminal cases. The may also include cases where there is a public interest in investigating the death, even if the suspicion of homicide is low. Examples are suicides, drug overdoses, traffic accidents or medical misadventures (136).

13.2 The golden standard?

Autopsies have often been regarded as the golden standard for establishing the cause of death (79). For various reasons, some diagnoses go undetected before death. It is evident that after an autopsy, there is more information available for cause of death analysis than before. After autopsy, there are fewer cases with an ill-defined cause of death (132, 137). There are numerous studies over the theme: “In what proportion of autopsies do we find significant new diagnoses?” (125, 138, 139). The interpretation of the results from this kind of studies is not always straightforward. One subject is that it is not always clearly defined what constitutes an “error” or “substantial new finding”, another is that as the proportion of deaths undergoing autopsy is low in

many populations, the studies are prone to selection bias. If the selection of cases for autopsy is non-random, one would expect that it is the most unclear or least investigated deaths that are sent for autopsy. The “discrepancy proportion” probably would not be representative for the diagnostic accuracy in the entire population (140). In Norway, as in many other countries, the proportion of deaths undergoing autopsy is low and/or decreasing. For 2021, the Norwegian Cause of Death Registry received autopsy reports in 8.0% of the deaths, 3.5% medical and 4.6% forensic (49). Even if the total autopsy proportion is low, it is higher in some parts of the population, and the value would be higher for correcting the aggregated cause of death statistics (and not only the individual’s cause of death) in these groups.

Another issue is the quality of the autopsy itself. It the performance is substandard, there is a risk that important findings will go unnoticed or a wrong cause of death might be identified (116, 141). In addition, the autopsy was traditionally a purely morphological procedure. Some causes of death have few or none morphological findings (e.g. diabetic ketoacidosis, most poisonings) and would therefore escape diagnosis unless ancillary tests are performed. At least earlier, this could mean a bias towards diagnosing causes of death with morphological findings. For example, toxicological analyses might be underutilized in medical autopsies in Norway, and this might lead to some poisonings being undetected (116). In “modern” autopsies, more and more additional investigations are used to get as complete a picture as possible. Among these are toxicology, clinical chemistry, microbiology, genetics and radiology (142).

To discuss in depth the value of autopsy for teaching and pathological/pathophysiological research is outside the scope of this thesis.

13.3 Sources for autopsy data in Norway

There are three accessible sources for the number of autopsies in Norway, none of them perfect. The Norwegian Cause of Death Registry (NCoDR) is supposed to

receive notification of the results from the laboratories performing autopsies (8). The Norwegian Society for Pathology (Den Norske Patologforening, DNP) receives summary production data from the laboratories and publishes these in the yearly reports (143). The Norwegian Board of Forensic Medicine (Den rettsmedisinske kommisjon, DRK) is supposed to receive and review all medicolegal reports and publishes an overview in the yearly reports (144, 145). There are some differences in the scope and type of data collected. The NCoDR data are the only ones that are directly linked to other individual data. They are supposed to cover both forensic and non-forensic autopsies, but only for Norwegian residents (in the standard data registration). In some cases, there has been confusion whether a given autopsy has been a medical or forensic one. The DNP data are aggregated, consists of all autopsies (both residents and non-residents), and are linked to the place where the autopsy is performed (and not the place where the death took place or the residency of the deceased). In addition, they include foetal autopsies which must be subtracted before the numbers can be compared. The DRK data consist only of forensic autopsies, but includes deaths both in residents and non-residents. They are presented according to the place of death (either the county or the police district). Thus, one would expect some discrepancies in the numbers just from these differences. In addition, all these sources rely on the completeness in the reporting from the pathologists/laboratories.

13.4 The frequency of forensic autopsies

As mentioned above, a forensic (medicolegal) autopsy is part of the investigation of a death by the police or other legal body. The organization of the death investigation systems as well as the type of deaths that must be reported differ between jurisdictions (136, 146). The number of deaths that are (or should be) reported depends both on the number of deaths from a given cause (e.g. traffic accidents) as well as the criteria for which deaths that must be reported and to which extent the doctors adhere to these rules. In the next line there may be variation between districts

in the proportion of notifiable deaths that actually undergo forensic autopsy. It is therefore difficult to compare the forensic autopsy proportion. In addition, for many countries, it is surprisingly difficult to find publicly available data, and almost impossible to find reports stating regional figures.

There are also several ways of presenting the frequency of (forensic) autopsies. We can relate the number of autopsies either to the size of the population at risk (as number of autopsies per 100.000) or to the number of deaths occurring in the population (as proportion/per cent). Either way we must ensure that both the nominator and denominator stem from the *same* population. The number of autopsies as supplied from both the Norwegian Board of Forensic Medicine (145) and the Norwegian Society of Pathology (143) concerns *all* autopsies, both in residents and non-residents, but population data includes only residents. Standard data from the NCoDR includes only Norwegian residents. When analysing data from subnational locations, we would usually base these on the place of residence. If we would like to compare the proportions in different police districts, we must use the place of death, as it is the police at the place where the event that lead to the death took place (or the body was discovered) that has the responsibility for investigating the case. As some people die outside their residential area, we cannot at the same time use the number of autopsies in a district as nominator and the number of residents as denominator. To make the figures comparable, we calculated the forensic autopsy proportion in a police district as percentage of the number of deaths in Norwegian residents where the death took place in said district. To allow for differences in the composition of circumstances, one should ideally look at the percentage of forensic autopsies in deaths notifiable to the police (or at least notified to the police), but this number cannot be procured.

In Norway, with national regulations concerning death investigation (147, 148) and relatively low geographical variation in the distribution of causes of death (49), there still is a considerable variation between counties or police districts in the proportion of deaths undergoing forensic autopsy, both in total and for specific causes of deaths.

In a government report from 2001, the variation in total forensic autopsy proportion between counties is reported to be from 1.5-7.8% (a factor of 5.2), and this could be a cause of concern (149). In the yearly report for 2021 from the Norwegian Board of Forensic Medicine, the variation between counties is given as 16.2-71.5 forensic autopsies per 100.000 citizens (a factor of 4.4), and the cost of transportation of the body has been discussed as a possible cause (145). Igeltjørn and Nordrum (150) found that the proportion of forensic autopsies after road traffic accidents in 1996-2005 varied from 49-70% between two neighbouring counties. Frost et al. (151) found for 2007-2009 a variation from 11-91% in autopsies after suicides in the same two counties.

Winkel et al. found geographical variations in Denmark in the forensic autopsy proportion in sudden death in young persons (152). Even if Finland has a very high forensic autopsy proportion, 23.8% in 2004, there still was some geographical variation (153).

14. Aims

14.1 The main purpose with the thesis

The main purpose of the thesis was to study selected quality aspects of Norwegian cause of death statistics, with special emphasis on 1) the use of garbage codes for the cause of death, and 2) the utilization of forensic autopsies.

14.2 Aims of the specific parts of the study

14.2.1 Paper I – The use of garbage codes in Norway

Garbage codes in the Norwegian Cause of Death Registry 1996-2019 (1)

The aim of this part of the study was to investigate the magnitude and pattern of use of garbage codes in the Norwegian Cause of Death Registry.

1. Study changes over time as well as demographic and other factors that might correlate with use of garbage codes.
2. Describe the most commonly used garbage codes overall and in certain groups of the deceased.
3. In the deaths coded with a garbage code as the underlying cause of death, are there other, more informative diagnoses ("non-garbage codes") elsewhere on the death certificate?

14.2.2 Paper II – The garbage code X59 ("Exposure to unspecified factor")

Injury death certificates without specification of the circumstances leading to the fatal injury – the Norwegian Cause of Death Registry 2005-2014 (2)

The aim of this part of the study was to explore the use of the ICD-10 code X59 for injury deaths lacking information on external cause in Norway during 2005–2014.

1. Find characteristics for the use of X59 as underlying cause of death in Norway.
2. Using deaths with known external cause of death, to develop a classification (redistribution) algorithm in order to place the X59 deaths in the most appropriate external cause groups (target groups).
3. Compare the results of the redistribution with a query to the certifying doctors in Norway regarding the X59-coded deaths for the calendar year 2015.

14.2.3 Paper III – The utilization of forensic autopsies in Norway

Forensic autopsies in Norway 1996-2017: A retrospective study of factors associated with deaths undergoing forensic autopsy (3)

The aim of this part of the study was to examine the use of forensic autopsies in Norway for the years 1996–2017.

1. Describe variations in the autopsy proportions in different geographical locations and causes of death.
2. Explore demographic and other possible explanatory factors that might correlate with the utilization of forensic autopsies.

15. Materials and methods

15.1 The data material

15.1.1 The Norwegian Cause of Death Registry (NCoDR)

The main data source for all three papers in this thesis is the Norwegian Cause of Death Registry (NCoDR). Until 2014, NCoDR was managed by Statistics Norway, thereafter by the Norwegian Institute of Public Health. The NCoDR is supposed to have information on all deaths in Norwegian residents, occurring in Norway and abroad, and from 2012 also information on non-residents dying in Norway (8). The main input to NCoDR consists of death certificates issued by the physicians viewing the dead body, and autopsy reports from the departments of pathology and the forensic centres. In addition, there is supplementary information from queries to the certifying physicians and Chief Municipal Medical Officers, and from other health registries, mainly the Cancer Registry of Norway and the Medical Birth Registry of Norway (26).

Completeness is ensured by cross-linking with the National Population Register. The completeness has generally been viewed as sufficient, with information on more than 98% of all Norwegian residents dying in Norway. Each year, the death certificates have been missing for 500-700 deaths, even after multiple reminders have been sent. About half of these have been from Norwegian residents dying abroad (26). From 2018, there are more missing certificates, up to 1360 (3.4 % of all deaths) in 2020, probably related to (temporarily) diminished potential for sending reminders, related to the implementation of electronic certification of death (Pedersen AG, NIPH, personal communication).

From 2005, NCoDR used the computer program ACME (Automated Classification of Medical Entities) from the National Center for Health Statistics in USA for selecting the underlying cause of death according to the rules from the World Health Organization (ICD-10) (27-29). In earlier years, this was a fully manual task,

performed by the nosologists (medical coders). There is still a substantial number of deaths requiring manual supervision of the coding, among these are deaths with an external cause of death and deaths with multiple sources of information, such as autopsy reports (26, 28). From 2011, ACME was incorporated in the larger program suite Iris (30). In version 5 of Iris, ACME was substituted by the MUSE engine (Multi-causal and Uni-causal Selection Engine) (30).

Until 2017, all deaths were certified manually, on paper. From 2017, Norway has gradually introduced a system for electronic certification of death, from 2020 available for all physicians. From 2022, electronic certification is compulsory (8, 31). In 2019, 1231 deaths (3.0%) were electronically certified, in 2020 14912 (36.8%), and 32981 (79.2%) in 2021 (Pedersen AG, NIPH, personal communication). NCoDR still receives the autopsy reports on paper.

In **paper I** (1), we used data on all deaths among Norwegian residents in the years 1996-2019 (N = 1,013,802). After data cleaning, 1,000,128 deaths remained for analysis.

In **paper II** (2), we used data on all deaths among Norwegian residents in the years 2005-2014, registered with an external cause of death (N = 24,963).

In **paper III** (3), we used data on all deaths among Norwegian residents in the years 1996-2017 (N = 930,589). After data cleaning, 920,232 deaths remained for analysis.

The details regarding the variables used in each study are described in the individual papers and in the appendix (chapter 22).

The reason for using 1996 as starting point in **paper I** and **paper III** was that ICD-10 was introduced in Norway this year. The analyses would then not be influenced by possible drifts in the coding arising in the transition from ICD-9 to ICD-10. In addition, information on autopsies was incomplete in the years before 1996. The reason for using 2005 as the starting point in **paper II** was a substantial shift in the

national coding guidelines for injury deaths lacking specification of the circumstances leading to the fatal injury from 2004 to 2005 (2, 27). See also section 10.8. The end points for the various studies were the most recent year available at the time of performing the analyses.

15.1.2 Statistics Norway

In **paper III** information from the online data bank at Statistics Norway (154) on the population in the municipalities of Norway was used. As the population changed during the study period, we used the 2007 population (close to the midpoint of the study period) as reference, classified the municipalities according to a 6-level population scale used by Statistics Norway, and used this index for the entire period. We also used a 7-level urbanity/rurality index from Statistics Norway. This is a compound scale based on the distance to population centres and the size of these centres, with 0B as the most rural and 3A most urban.

15.1.3 The National Police Directorate

In **paper III** information from the National Police Directorate (155) about which municipalities that was included in each police district was used. During the study period, there were some adjustments in the municipalities (especially after 2014) and police districts; we therefore recoded the geographical data to the structure as it was in 2012. In 2016, there was a major reorganization of the police district structure in Norway, with a reduction from 27 to 12 districts (156). Being aware of possible consequences of this reorganization for the utilization of forensic autopsies, we still decided to use the district structure as it was in 2012. To evaluate an effect of the reorganization was outside the scope of the study. This could more effectively be investigated in a later study, with data available from a longer period after the reorganization.

15.1.4 Geographical data

In **paper III** map data from the Norwegian Mapping Authority (157) was used, and we calculated the distance from the centre of the municipality where the death had

occurred to the autopsy facility by using an online service at the Norwegian Public Roads Authority (158). During the study period, there were some changes in which forensic centre that served each police district. As a default, the distance to the facility performing the most autopsies from each municipality for the entire period was used.

15.1.5 ICD-10

There was no easy way to download a complete list of ICD-10 codes and descriptions from the WHO. To build a complete list over all possible ICD-10 codes in use in Norway, we started out with data from the Norwegian Directorate of eHealth (159). For external causes (chapter XX), the ICD-10 version in use in the Norwegian health care system is not congruent with the international version (48), which is used at the NCoDR. For this chapter, the Norwegian version of ICD-10 was enriched by other sources, partly from an old version accessible online (160), and partly by manual comparison with the online version at WHO (48). Before starting the analyses, we also performed a thorough assessment to ensure that all the ICD-10 codes used in the data from the NCoDR also were present in the mapping lists. There were a few missing codes, mainly from earlier years, and for these cases, the list was enriched manually from the international version.

15.1.6 The Global Burden of Disease Project (GBD)

From GBD, the mapping list from ICD-10 codes to GBD cause list, including the list of garbage codes (39), was used. The list was published as Table S5 in the Supplementary appendix 1 to the referenced study.

Before starting the analyses, we ensured that all ICD-10 codes used in the data from NCoDR could be mapped to a GBD cause. For some codes, the mapping list had to be supplemented manually.

15.1.7 Other, minor data sources

Additional data on the number of forensic autopsied performed were collected from the yearly reports from the Norwegian Board of Forensic Medicine (145) and the Norwegian Society of Pathology (143). These data were not used for actual analyses, but as a quality check of the data from NCoDR, used in **paper III**.

From the WHO Mortality Data Base (33) (note that the current URL has changed from the reference in the published paper), we retrieved tabular cause of death data on unspecified external causes of death for the years 2005-2015 as background information for **paper II** and for producing the figures in section 16.2.4.

15.2 Ethical and data privacy considerations

All parts of the study were endorsed by the relevant authorities.

During the period of the work with the thesis, the regulations concerning data privacy changed in terms, but not necessarily in essence, by introduction of GDPR (EU's General Data Protection Regulation). GDPR does not apply to information regarding deceased persons (articles 72, 158, and 160), but has nevertheless had influence on regulations concerning research data (161).

15.2.1 Paper I

The project was approved by the Regional Committee for Medical and Health Research Ethics (ref. 177346) and in consultation with the Data Protection Officer at Stavanger University Hospital.

15.2.2 Paper II

The part of the study using registry data from 2005 to 2014 was approved by the Regional Committee for Medical Research Ethics (2013/2311/REK sør-øst D). The query on data from 2015 was performed as part of the quality assurance of the Norwegian Cause of Death Registry and as such did not require further approval.

15.2.3 Paper III

The project was approved by the Regional Committee for Medical and Health Research Ethics (ref 2018/125/REK Sør-øst) and in consultation with the Data Protection Officer at Stavanger University Hospital.

The data were securely stored at designated research data servers at either Stavanger University Hospital (**Paper I** and **III**) or the Norwegian Institute of Public Health (**Paper II**), in accordance with the procedures at each institution.

15.3 Methods

General statistical methods used in each study are described in the individual papers. Some aspects concerning prediction and redistribution warrant a more detailed description here. Some details regarding grouping of variables are also mentioned, as the descriptions in the papers are short, due to space constraints.

15.3.1 Explain or predict?

There is a fundamental difference between explaining and prediction when it comes to statistical modelling. Some authors also view descriptive modelling as a third, separate process. The description below is mainly based on Schmueli (135) and Sainani (162).

Descriptive modelling tries to describe the relationship between one or more input (independent) values and an outcome, being agnostic about possible causal explanations. The relationship does not necessarily need to be a causation; it can be merely a correlation. An important aspect is that both the input and output values are known. An example: Since 1970, there has been a reduction in total mortality in Norway with an almost perfect linear relationship between year and mortality rate. Clearly this cannot be a causal effect.

Explanatory modelling goes further and tries to describe or test a causal theory. The scientist may start out from one or more hypotheses about a cause-effect relation.

From the theoretical construct, the scientist makes operationalisations, bridging the gap between the theory and observable measurements. Models are built and refined, effect sizes are estimated and statistical significance can be tested. Based on the testing of the models, the underlying hypothesis can be rejected or substantiated (or at least not rejected).

Evaluating descriptive and explanatory models usually involves formal description and testing of the model fit such as investigating whether the size of an effect differs significantly from the null hypothesis, visualizing residuals, performing likelihood tests and so on.

Predictive modelling is applying a statistical model or algorithm to predict new, or at least unknown, observations, based on one or more input values. Important aspects are that the outcome value is unknown, and that the "inner workings" of the model (the causal mechanisms by which the input variables are connected to the outcome) in principle are irrelevant, as long as the prediction is accurate. A familiar example of prediction is forecasting tomorrow's weather based on today's observations. When evaluating a predictive model, the paramount property is *how well the model predicts the outcome.*

In this thesis, there are elements of both descriptive, explanatory, and predictive modelling, where the redistribution of X59 coded deaths in **paper II** is a predictive process.

15.3.2 Redistribution

The concept of redistribution is described elsewhere (chapter 12). Very briefly, it is the process of by statistical models estimate the real underlying cause of death (remove the garbage codes). As mentioned above, redistribution is a predictive process: Even if it does not concern a prediction of an event in the future, the outcome (the real underlying cause of death) is not known. In some forms of predictive processes, such as a weather forecast, one can wait until the relevant time

in the future, and then evaluate the accuracy of the prediction. For redistribution of garbage codes, the possibility to find the true underlying cause is much smaller, and one has to rely on other ways to evaluate the performance of the predictive model. (In **paper II**, we try to use a query to the certifying physicians to find the real underlying cause of death.)

A usual way to make a predictive model is to start out with a data set with known predictors and outcome (supervised learning) (163). The data is then divided into two (sometimes three) parts: a training set and a test set, sometimes also a separate validation set. The model is developed on the training set. If the model is tested on the same data that we used to develop the model only (the training set), there is a risk that the model is perfectly suited to the characteristics of this particular data set, but less robust for other data (overfitting). That would lead to overestimation of the performance. The test set therefore contains data that the algorithm has not been exposed to before, and thus gives a more realistic view on the performance.

There are various ways to do this split-model-test process. One way is to divide the data set only once, for example in 0.67/0.33 or 0.8/0.2 fractions. An alternative is to do a K-fold cross validation: Split the data set in K subsets, train the model on K-1 subsets, and test the model on the remaining subset. This is repeated until all subsets are used once for testing, and the error or performance measures are averaged.

We used a variation of the first approach: We split the data in 0.67/0.33 fractions, trained the model on the training set, tested the performance on the test set, and applied the model on the new data where the outcome (the real underlying cause of death) was unknown. This process was repeated 1000 times, each time with a new randomization into training and test sets. We could then average both the performance measures and the outcome of the redistribution. The range of the results of the redistribution process indicates how robust the process is to variations in the composition of the training set.

15.3.3 Testing the performance of a predictive model

For categorical outcomes, such as redistribution, this usually involves some kind of classification matrix, sometimes called a confusion matrix (163). In its simplest form it looks like the table below, but can be extended with more than two outcome classes. For more than two classes, results are calculated by comparing each level to the remaining levels.

		Predicted condition		
		Positive	Negative	Total
Actual condition	Positive	True positive (TP)	False negative (FN)	TP + FN
	Negative	False positive (FP)	True negative (TN)	FP + TN
	Total	TP + FP	FN + TN	N

Fig. 15.3.1. Classification matrix, 2 x 2 table.

From this table, it is possible to calculate a variety of performance measures, used in various settings. In **paper II**, we used the following:

- Accuracy: (TP + TN)/N (Correct predictions/total number of cases)
- Sensitivity: TP/(TP + FN) (Percent of positives correctly predicted)
- Specificity: TN/(TN + FP) (Percent of negatives correctly predicted)

Especially in imbalanced classification, where a large proportion of the cases are in the same group, simple accuracy can produce an overly optimistic result. For instance, if 80% of the cases belong in one group, simply predicting all cases belonging to this group will give an accuracy of 80%. Kappa (also called Cohen's kappa) measures the relationship between observed accuracy and expected accuracy (accuracy by chance). The definition of kappa is as follows:

$$\kappa \equiv \frac{p_o - p_e}{1 - p_e}$$

where p_o is the observed agreement and p_e is the probability of agreement by chance. A kappa value of 1 means perfect agreement, while the agreement is poor with kappa below 0.20 (163).

15.3.4 Multinomial logistic regression

Multinomial logistic regression (polytomous logistic regression, multinomial logit model) is a *multiclass classification method*, a form for supervised learning. *Supervised learning* are classification methods where the models are trained on data sets with known outcome or label. In contrast, *unsupervised learning* are methods where the outcome or labels are unavailable, and the purpose of the methods often is to detect patterns or clusters in the data material (163).

Multinomial logistic regression can be viewed as an extension of ordinary logistic regression (163, 164). Ordinary logistic regression can be expressed schematically as:

$$ln\left(\frac{\Pr(Y = 1|X)}{\Pr(Y = 0|X)}\right) = \beta_0 + \beta_1 X$$

Where the first part is the log odds for the outcome (Y = 1) relative to the reference (Y = 0), β_0 is a constant, β_1 the regression coefficient and X the predictor variable. In a multipredictor model, there are more than one predictor variable (X is a vector of predictors), each with its own regression coefficient. When presenting the results, the coefficients are usually exponentiated into odds ratios.

While ordinary (binary) logistic regression has a dichotomous outcome (0/1, yes/no, alive/dead), multinomial logistic regression has more than two possible (unordered categorical) outcomes, where one of the outcomes serves as the baseline. If there are *K* different outcomes, it can be viewed as a combination of *K-1* binary logistic regression models. (Ordinary logistic regression can be viewed as a special case of multinomial regression, where $K = 2$.)

$$ln\left(\frac{\Pr(Y = A|X)}{\Pr(Y = S|X)}\right) = \beta_0^A + \beta_1^A X$$

$$ln\left(\frac{\Pr(Y = B|X)}{\Pr(Y = S|X)}\right) = \beta_0^B + \beta_1^B X$$

Where A…S are the possible outcomes, S acting as the reference (baseline). For K possible outcomes, there are *K-1* sets of coefficients. If there are *J* predictors, each set of coefficients have *J* + 1 items (the constant + one coefficient for each explanatory variable). The explanatory (independent) variables of the model can be specified as in an ordinary logistic regression, with continuous or categorical predictors. The estimated coefficients are the log odds (or exponentiated into odds ratio) for being classified into the outcome category in question compared to the reference category, given the level of the explanatory variable. For practical classification purposes, this can be translated into the predicted probability for each case (with the specified combination of independent variables) to be classified into each outcome category. In the joint expression, the sum of all probabilities must be 1. The mathematical process of estimating the coefficients is very complex. We used the **multinom()** function in the **nnet** package, part of the standard installation of R, to perform the estimation. The model can be evaluated with the same measures as an ordinary logistic regression. We chose to evaluate the model based on the performance of classification (prediction) on a test set of the data.

Details regarding the present study: The deaths which contained information on the circumstances regarding the injury, were split into a training (67%) and a test dataset (33%). A multinomial regression model was developed on the training set and evaluated on the test set. The outcome variable (target groups) of the model was external cause of death in six groups (road traffic accidents, accidental falls, accidental poisonings, other accidents and events of undetermined intent, suicide, and homicide). The explanatory variables were: age, gender, the nature of injury, place of

death, whether there was information on the scene of injury (yes/no), whether an autopsy was performed (yes/no), and calendar year of death in two groups. For each death, we chose as the target code the external cause group with the highest estimated probability, regardless of level. As the complete results from the multinomial regression analysis are very complex and the interest was not so much in the individual parameters as in the classification ability of the model, the complete set of parameters are not presented.

The performance of the model on the test set was evaluated by comparing the registered underlying cause of death with the prediction of the model. We calculated overall and groupwise accuracy and Cohen's kappa, and also calculated the performance of reduced models, where one explanatory variable was left out. This was done to ascertain which factor that had highest predictive value. We then applied the model to the X59 deaths. This procedure was repeated 1000 times, with new separation into training and test sets, and the mean and SD of the results were calculated. (The median and IQR were also calculated, but not presented in the study, as the mean and SD were considered sufficient.)

There are also other multiclass classification methods, probably more used in dedicated machine learning settings than in medical research. Examples are support vector machine and naïve Bayes classification. None of these will be discussed here.

15.3.5 Grouping of continous variables

Some variables used in the analyses were registered as continuous variables (calendar year of death, age at death, the population of each municipality, and distance from municipality of death to autopsy facility). (In the very strict sense, these are discrete data. For example, we record age at death in one-year intervals.) In the analyses, these were grouped and analysed as unordered categorical variables. The reason for this was that for many of the investigated outcomes, the predictor-outcome relationship was neither linear nor monotonous, and could not easily be transformed to achieve this. This violates one of the fundamental assumptions of regression,

(more-or less) linearity between the predictor and the outcome (log odds of the response in case of logistic regression) (164).

The population of the municipalities varied during the study period. To accommodate for this, we used a 6-level grouping based on a classification from Statistics Norway, as described in section 15.1.2.

The grouping definitions are given in the individual papers.

15.3.6 Grouping of categorical variables

A number of the variables were by nature categorical, but with so many levels that they had to be aggregated into fewer categories. The definitions are given in the individual papers as well as the appendix to the thesis.

For presentation of the most common **garbage codes** in **paper I** we chose to use ICD-10 codes on three-character level. E.g. codes in the range C80-C80.9 were presented as C80 (malignant neoplasm, without specification of site). It is possible to aggregate garbage codes into more functional oriented clusters or "packages". At the time of analyses, the only publicly available specification of this kind could be found in the appendix to the study by Johnson et al. (85). Regrettably, this list (as published) had a number of errors, making it less suitable. Clustering of garbage codes is also used in the ANACONDA framework for quality assessment of cause of death statistics (96, 165), but the definition has not been publicly available.

The grouping of the **nature of injury** in **paper II** follows to a large extent the subsections of chapter XIX in ICD-10 (48).

The grouping of **external underlying causes of death** in **paper II** follows Eurostat's shortlist of causes of death (34), with few exceptions. Road traffic accidents is a separate category, and the rest of transport accidents are placed with other and unspecified accidents. The reason was that we wanted to evaluate our redistribution

results specifically for road traffic accidents. Exposure to unspecified factor (X59) is a separate category, as this is the object of interest in the study.

The grouping of **underlying causes of death** in **paper III** in general also follows Eurostat's list, but with some more exceptions. Codes related to drug abuse in chapter V of ICD-10 (F11-F12, F14-F16, F19) are grouped with accidental poisonings, as we believe these to a large extent represent the same category of deaths. Based on our results from **paper II**, as well as other sources (105), there is good reason to believe that deaths with fracture of the femur are accidental falls, if not otherwise specified (the combination of the ICD-10 code X59 (X59, X59.0, X59.9) for underlying cause of death with S72 (S72.0-S72.9, fracture of femur) as the nature of injury).

15.3.7 Statistical program

For all analyses, we used the program/language R (166), with the integrated development environment (IDE) Rstudio (167), and the additional packages in the Tidyverse collection (168). For the specific parts of the study, we used various other packages, as described in the individual papers.

15.4 Planning the analytical process

The term "data science" is sometimes used for a set of skills encompassing elements from computer science, statistics, information science, mathematics, and information visualization (169). Some would say that it is just a part of statistics, while others see it as a separate field of knowledge.

In the book "Data Science with R", Wickham & Grolemund has visualized the workflow in data analysis in this way (170):

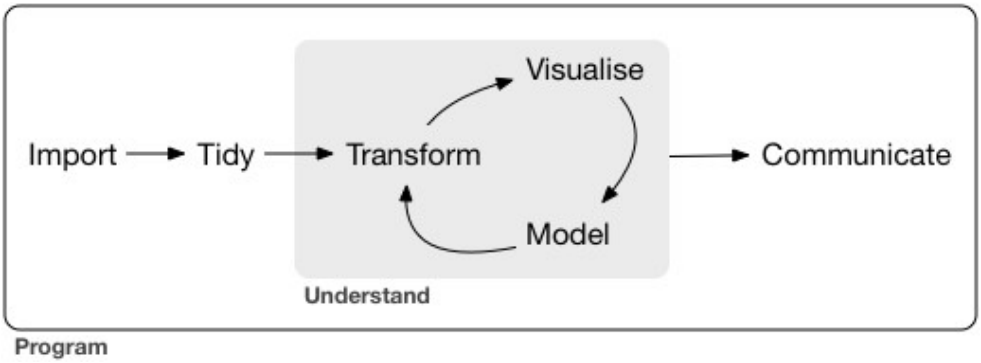


Fig. 15.4.1. The analytical process. Reproduced from (170).
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Most, if not all, courses in medical statistics and basic research methodology focus only on a small part of this: developing models and performing formal tests. Sometimes, more effort is required in data housekeeping and tidying than in the actual analyses. Large-scale research programs may have dedicated professionals responsible for data base administration and related tasks, while in smaller projects, the researcher(s) must be a jack-of-all-trades, taking care of all steps in the workflow in addition to developing the scientific concepts.

15.4.1 A tidy and reproducible work flow

It was necessary to implement a tidy and reproducible workflow. I tried to strike a balance between doing it well enough without making it more complicated than necessary.

I imply two different meanings of “tidy”. One is keeping a tidy data folder structure for the project, with the raw data in one folder, the scripts in another, the outputs (tables and graphs) in a third, and so on. I basically used the same setup for each study. The second meaning of “tidy” is to keep the data themselves tidy. This means to strive to keep the data in a rectangular data frame with one row for each observation (person) and one column for each variable, using meaningful and consistent variable names etc (171).

Apart from the absolutely simplest calculations, all data handling, statistical calculations and visualizations were made by scripts. All large processes were broken down in a number of mostly shorter scripts, where each script performed one or a handful procedures. The output from one script in the line was the input of the next. A generic example could be:

1. Reading in raw data, cleaning and restructuring
2. Merging with data from other sources
3. Exploratory data analysis
4. Statistical modelling and testing
5. Making tables, diagrams, and maps

Each script, in turn, was structured in a predictable manner: First loading the required packages and setting preferences, then reading in data. The next step was to make the data ready for analysing by computing intermediary variables, doing aggregation, and so on. Only then actual calculations could be made before adjusting the output, making figures and saving the results. It is very useful to have comments and explanations ***within*** the scripts, close to the actual program lines. It was crucial to view the script, and not the tables and graphs, as the permanent record, together with the original data. If one has the data and the scripts, it is always possible to recreate the output. Without the scripts, the transparency and reproducibility is lost, and it is extremely difficult to detect possible flaws and errors in the analytical process. If one detects an error or otherwise need for change, the script on the relevant stage of the process must be amended, and all subsequent scripts rerun.

I spent considerable time doing *exploratory data analysis*, or "getting to know the data". I started with simple univariate counts, both to get an overview of the distribution of the variables in the data set and to identify possible missing entries and errors. I then proceeded to simple bivariate tabulations and graphs. These could reveal interesting patters in the data as well as detect possible errors or inaccuracies. One example from the latter category was the relation between the name and register

number of the municipality of death. In the data from NCoDR, I found a number of deaths with a mismatch between municipality name and number. Using a master file from Statistics Norway with the correct matching and information on the changes in municipality structure during the study period, I recreated corrected municipality numbers that subsequently could be used when merging data. This kind of data cleaning process obviously must be documented.

15.4.2 R, RStudio, and the Tidyverse

R (166), with the integrated development environment (IDE) Rstudio (167), can be considered both a program for statistical computing and graphics, and a programming language by itself. R consists of a core or base component with the possibility to utilize a vast array of different accessory libraries or packages. For the work presented in this thesis, R has been versatile and powerful. Compared to many other statistical programs, R has good tools to handle also the parts of the analytical process coming before and after the statistical models and tests. R is an open source program, and the packages are supplied by a large number of volunteers. This has some very important implications: First, there is almost always more than one way to handle a task, and it can be a challenge to find the most suitable package for the job. Second, it can be challenging to find relevant documentation and tutorials, as there is no single authoritative source. (The officially published documentation for a package can be rather terse.) There are a number of excellent introductory resources, but more unsystematic when it comes to more specialized analyses. Different books and web sites may focus on different “flavours” or philosophies in approaching a problem. Third, there is always a risk that there might be an error or flaw in the package, and the user must take care to ensure both that the correct package is implemented and that the functions in the package give the expected results.

The Tidyverse is an opinionated and curated collection of packages designed to work together in an efficient work flow, sharing the same underlying design philosophy, grammar, and data structures (168). The packages in the Tidyverse collection are well developed and documented and can thus be considered “safe”.

RMarkdown (172) is a very useful addition to R, making it possible to weave calculations, output and comments together in the same document. Due to unknown reasons, RMarkdown did unfortunately not work well within the secure data storage system at Stavanger University Hospital.

15.4.3 Testing and validation of the code

It was not necessary to program any of the specific statistical function in detail, as it was possible to find them in various R packages. The programming related to the analytical process, with preparing the data for analysis, doing the actual modelling and testing, and processing the output, either as numbers, tables or graphs. Various approaches were used to be sure that the data wrangling was correct. As described above, the process was broken down to smaller steps that were easier to grasp and test, and many of these "sub-processes" could subsequently be reused without much new programming. When programming a routine, usually a smaller data set was used for testing to keep it simple. It was often possible to find some data that I knew how they were supposed to behave, e.g. from published statistics from the Cause of Death Registry or from various courses in medical statistics. If the scripts produced the expected results on a known data set, the calculations on unknown data could also be trusted. Often it was possible to conduct the analyses in two or more different ways. If they gave comparable results, the programming was probably sound. A good example is the redistribution of deaths coded with the garbage code X59. In the formal study, we used multinomial logistic regression, but during the programming, I tried other machine learning methods, which gave almost the same estimates. It was also very useful to visualize the data and the results of the analyses to spot errors and anomalies.

For some of the analyses, the calculations were repeated many times (often 100 or 1000 iterations) on randomly selected subsets of the data. This can give an impression on the stability of the estimates. In other instances, the analyses could be repeated after deliberately omitting some of the data, e.g. from a single year or geographical

region. This could serve as a sensitivity check, especially if we feared that incomplete data would introduce spurious shifts in the results.

Some of this kind of work is presented in the published papers, such as repetitions in the redistribution process in the X59 paper (**paper II**), but most of this work remain an unpublished part of the research process.

16. Results

Detailed results are presented in **papers I-III**. Only the main findings from the publications are recapitulated in this chapter. In addition there are some supplemental results that were omitted from the original publications because of space constraints.

16.1 Garbage codes in the Norwegian Cause of Death Registry 1996-2019 (paper I)

We investigated the use of garbage codes in the Norwegian Cause of Death Registry (NCoDR) for the years 1996-2019 (1).

Using the definition of garbage codes from the latest iteration of the GBD study (as described in chapter 10 and appendix 22.1.7), we found that a total of 29.0% of the deaths were coded with a garbage code; 14.1% with a major and 15.0% with a minor garbage code. For major garbage codes, there were fluctuations over time, with an increasing tendency overall and a peak in 2013. There was a reduction in the proportion of deaths coded with minor garbage codes. Looking at age adjusted proportions, the sex difference was small, and there was no significant sex difference at the end of the study period.

The proportion of deaths with a garbage code rose with age at death above circa 60 years. Major garbage codes were also used in a high proportion of deaths in young adults, although the absolute number of deaths were fewer.

Fewer of the deaths in hospitals were coded with major garbage codes compared to deaths in other locations, unadjusted 9.1%, compared to 15.8-21.7%. For minor garbage codes, the proportion was highest in deaths in nursing homes, 20.5%, compared to 6.5-11.2%.

Detailed results on age, sex, period, and place of death can be found in **paper I** (1), tables 2, 3, and 4.

The figures below, previously unpublished, illustrate some details in the temporal changes in the use of garbage codes.

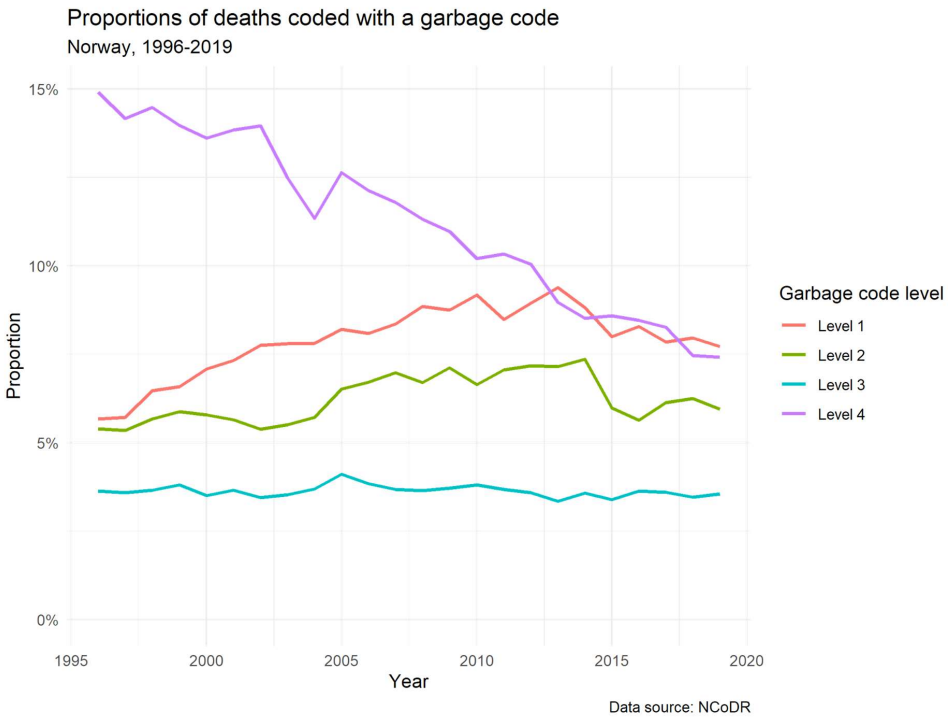

Figure 16.1.1 The proportion of deaths in Norway 1996-2019 assigned a garbage code (Level 1-4)

The temporal changes are dominated by a clear reduction in the use of Level 4 garbage codes (the least deleterious group) and an increase, followed by a reduction in the last years of the study period in the use of Level 1 codes (the most serious group). The changes in Level 2 and Level 3 codes were less pronounced.

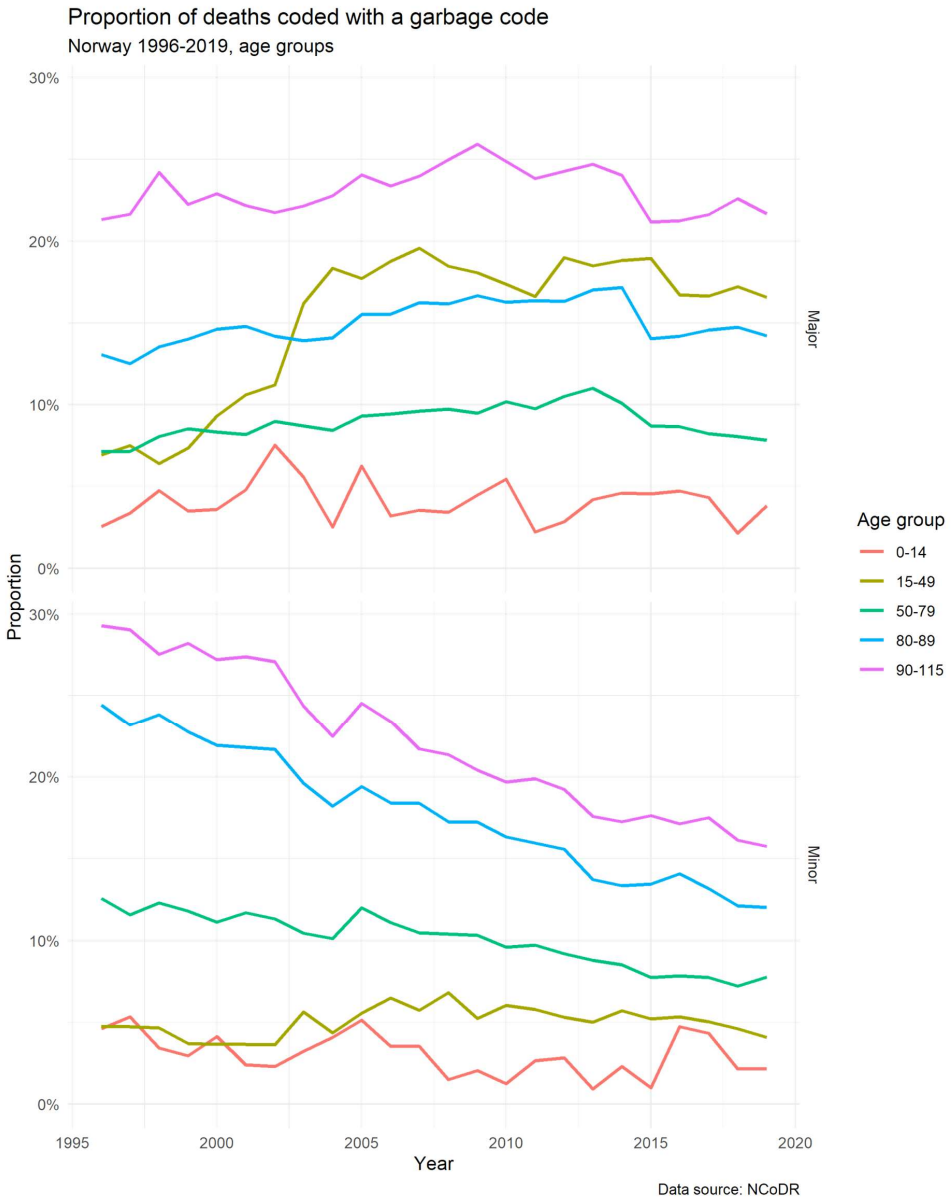

Figure 16.1.2. The proportion of deaths in Norway 1996-2019 assigned a major and minor garbage code, according to age group

The proportion of deaths in the 15-49 years age group coded with a major garbage code increased steeply around 2000-2005. This coincided with a change in the coding

rules regarding overdose deaths (see **paper I** (1) and discussion section 17.2.1). For minor garbage codes, the reduction was most pronounced in the elderly.

16.1.1 The most common garbage codes

The three most common major garbage codes were heart failure, sudden death, and senility, together 43.4% of all major garbage codes and occurring in 6.1% of all deaths. The most common minor garbage codes were unspecified stroke, unspecified pneumonia, and cancer with unknown primary site, together 9.7% of all deaths and 64.6% of all minor garbage codes.

There were different patterns of garbage codes in some population segments. Detailed tables are presented in the supplemental material to **paper I** (1). However, one must have in mind that the majority of deaths are among people >80 years, dying in hospitals and nursing homes. By consequence, this will dominate the overall pattern of garbage code use.

16.1.2 Changes in the pattern of garbage codes

The change in the proportion of deaths with a major garbage code was the sum of multiple smaller changes, both increases and declines. The most important of these were an increase and subsequent decline in the use of X59 (exposure to unspecified factor), increase in unspecified infectious disease (B99), unspecified sepsis (A41), and unknown cause of death (R99), and a decrease in heart failure (I50), see **paper I** (1). The reduction of minor garbage codes was dominated by a decline in I64 (unspecified stroke), and J18 (unspecified pneumonia). The changes in these two codes alone explained 80% of the reduction.

16.1.3 Factors correlating with the use of a garbage code – logistic regression analysis

We performed logistic regression analyses to investigate the determinants of use of a garbage code as the underlying cause of death, both for major and minor garbage codes separately and together. The decedent's age and place of death were the most important explanatory factors. In minor garbage codes, the year of death was also

important, reflecting the substantial decrease in minor garbage codes over time (**paper I** (1), table 6 and supplemental material).

16.1.4 Other registered (non-garbage) codes in deaths coded with a garbage code

Of all deaths coded with a garbage code as the underlying cause of death, 36.0% had one or more non-garbage codes among the registered diagnoses. The highest proportion was in hospital deaths (44.4%), and lowest in deaths in other specified locations (outside health care institutions and the decedent's home) (15.5%).

The most prevalent non-garbage codes were Alzheimer disease and other dementias (24.1% of the cases with at least one non-garbage code), ischemic heart disease (17.8%), atrial fibrillation and flutter (11.2%), chronic obstructive pulmonary disease (COPD) (8.1%), and urinary tract infection (6.0%).

16.2 The use of X59 ("Exposure to unspecified factor") in the Norwegian Cause of Death Registry 2005-2014 (paper II)

We studied in more detail the use of the garbage code X59 (X59, X59.0-X59.9), exposure to unspecified factor. The ICD-10 (WHO) defines the underlying cause of death in cases of external cause of death as "the circumstances of the accident or violence which produced the fatal injury" (29). In an accident where the circumstances are unknown, the underlying cause of death is coded with X59. See section 10.8 for further explanation.

We used data on all deaths with external cause of death registered in the Norwegian Cause of Death Registry in the years 2005-2014, as well as results from querying the certifying doctors in 2015.

16.2.1 External causes of death and deaths coded with X59 as underlying cause of death

Of the total number of deaths among Norwegian residents registered at the NCoDR in the study period (413,838), 24,963 (6.0%) were registered with an external cause of death. Of these, 6,440 deaths (1.6% of all deaths and 25.8% of all deaths with an external cause) lacked information on the circumstances leading to the injury, and thus were coded with X59. According to the grouping used in the study, exposure to unspecified factor was the largest group of external causes.

Compared to other external causes of death, the deceased in X59 deaths were older (median age 88 years) and with a larger proportion of females (61.6%). A larger proportion (93.1%) died in health care institutions (and not at the scene of the injury), and nearly 80% had an injury in the hip or thigh region (such as a fracture of the proximal femur). In short, the typical X59 death was an elderly woman with a hip or thigh injury, dying in a nursing home.

To further study the correlation with the characteristics or predictors, we performed a logistic regression analysis. The results are presented in table 3 in **paper II** (2). The strongest predictor (based on ranking of the LR stat) was the nature of injury (odds ratio 12.1 for injury in hip/thigh and 4.05 in abdomen/pelvis compared to head injuries), followed by lack of knowledge about the scene of the injury.

16.2.2 Redistribution of X59 coded deaths with multinomial logistic regression

We used multinomial logistic regression to try to redistribute X59 deaths to the most likely non-garbage code group. The overall accuracy when applying the model on the test set was 0.71, kappa 0.64. For the distinction fall/not fall, the sensitivity was 0.85, specificity 0.96. The most important predictive factors were the nature of injury, followed by the place of death and the age of the deceased. According to our model, 6,272 of 6,440 (97.4%) of the X59 deaths could be redistributed to accidental falls. The number of deaths in this group increased by 149%. If these results were to be applied on the Norwegian cause of death statistics, the mean age-standardized death

rate from accidental falls for the years 2005–2014 would increase from 10.3 per 100,000 to 25.9 per 100,000.

16.2.3 Query to the certifying doctors

For the year 2015, we sent a query letter to the certifying doctors regarding deaths (initially) coded with X59. In total, we could reclassify 298 of the 591 X59 cases (50.4%). In the majority of these (88.3%) the new underlying cause of death was an accidental fall (**paper II** (2), table 7 and figure 3).

16.2.4 Coding pattern in other countries

In **paper II** (2) we used data from the WHO Mortality Database for 2014 to investigate the use of the ICD-10 codes X59 and Y34 (unspecified event, unspecified intent) in different countries, as we suspected that these might include the same type of deaths, see section 10.8. We found that no countries simultaneously had a large proportion of *both* X59 and Y34 (both some had a small proportion of both); the pattern of use was almost mutually exclusive. See figure below (previously unpublished).

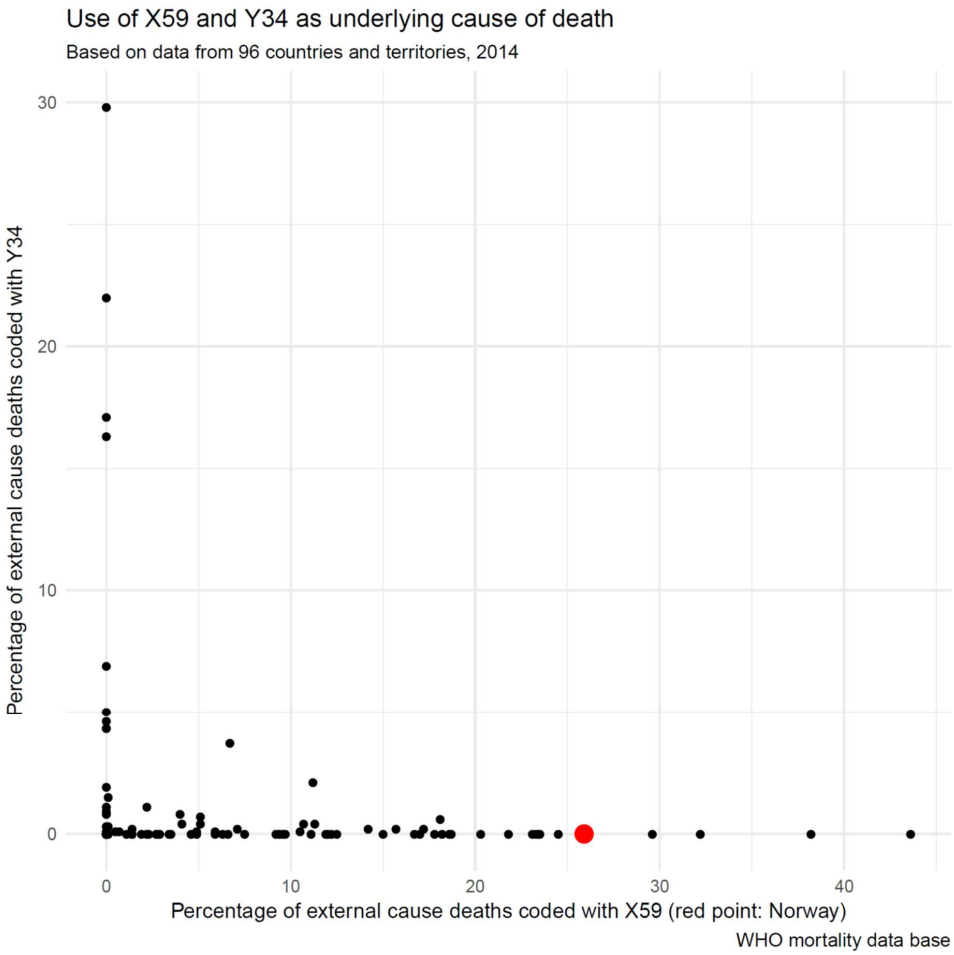

Figure 16.2.1. Comparison of the use of the ICD-10 code X59 and Y34 in 96 countries, 2014.

We also did a similar comparison of the use of X59 and the percentage of external cause deaths that were registered as accidental falls (ICD-10 code W00-W19.9). Based on visual interpretation only, there seems to be a tendency towards a negative correlation (a high proportion of accidental falls coincides with a low proportion of X59 coded deaths and vice versa.) See figure below (previously unpublished).

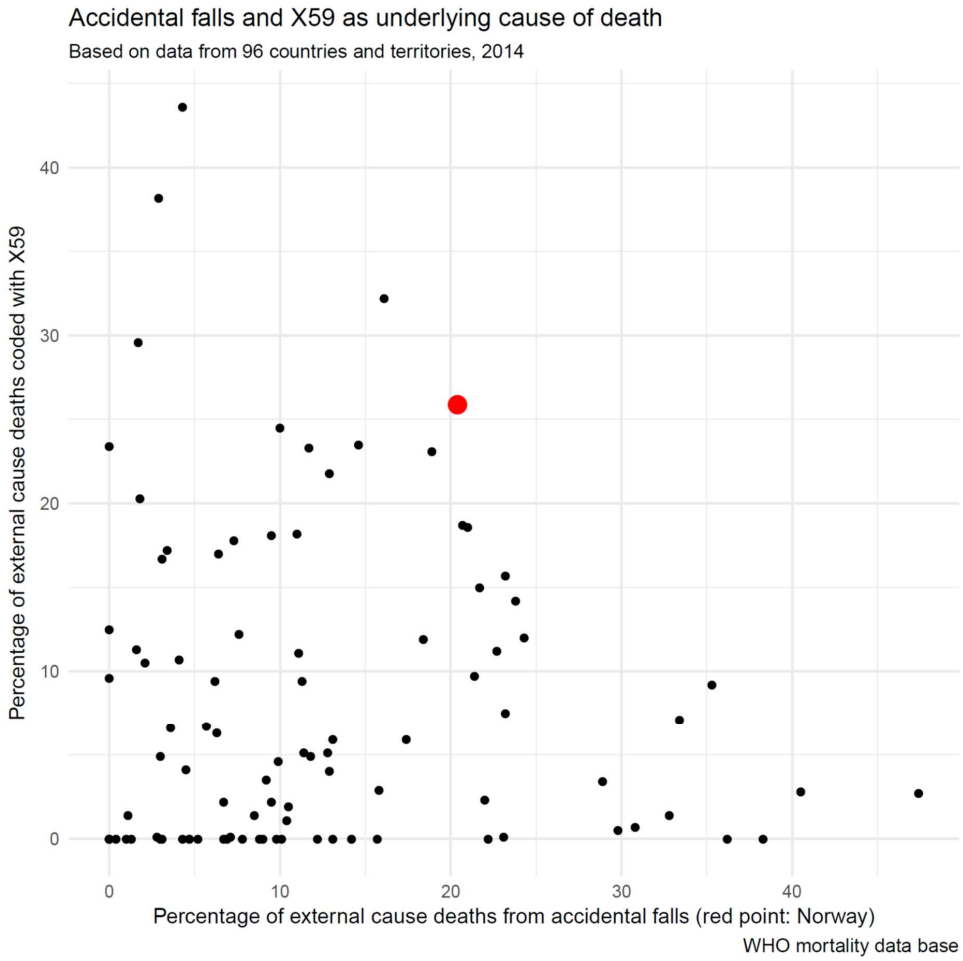

Figure 16.2.2. Comparison of the use of the ICD-10 code X59 and deaths from accidental fall in 96 countries, 2014.

16.3 Forensic autopsies in Norway 1996-2017 (paper III and partly paper I)

We investigated the use of forensic autopsies in Norway in the years 1996-2017, with special emphasis on the association with demographic and geographic factors. We also calculated the proportion of the deceased that had been autopsied according to the registered cause of death.

The overall proportion of deaths undergoing forensic autopsy varied between 3.7% (2012) and 4.5% (1998 and 2015), without any obvious trend. There was a clear sex difference, where 2.3% of the females and 6.0% of the males underwent a forensic autopsy. There was also an age gradient, where the highest proportion was in the 20-29 years group (59.5%), followed by the 10-19 and 30-39 years groups, but the highest absolute number was in the 50-59 years group.

There was also a large variation according to the place of death, with very few forensic autopsies in deaths occurring in health care institutions.

We also calculated the autopsy proportion according to the registered cause of death groups, as well as the registered cause of death in the deaths that had undergone forensic autopsy. It must be stressed that "the *registered* cause of death" is not the same as "the cause of death", as the registered cause may be missing, wrong or incomplete. We found that the proportion of deaths that had undergone forensic autopsy in the cause of death groups varied from 1.7% in the deaths with a registered natural cause of death to 96.6% in the homicides. If we change the point of view and look at the distribution of causes of death in the cases that had undergone forensic autopsy (reflecting the case-load of forensic pathology practice), the results are opposite: 38.3% of the forensic autopsies are assigned a natural cause of death, whereas only 2.3% are homicides.

Complete results can be found in **paper III** (3), table I and supplemental material.

16.3.1 Geographical factors

Generally, we found a larger forensic autopsy proportion in the municipalities with the largest population, the highest urbanity index and a short distance from the place of death to the autopsy facility. (To some extent, these are the same municipalities.) Interestingly, there was no clear gradient *within* the smaller/more rural/more distant municipalities (**paper III** (3), supplemental material and table 16.3.1. below).

16.3.2 Police districts

During the study period, there was some adjustment of the structure of police districts in Norway. The most important chance was the reduction from 27 to 12 districts in 2016. To ensure comparability, we used the 2012 structure for the entire study period.

We found that the forensic autopsy proportion ranged from 0.9% (Gudbrandsdal) to 7.8% (Hordaland), a factor of almost nine (**paper III** (3), table II and figure 1). The variation between the districts did not become smaller during the study period. There was some change in ranking from the first to the second part of the study, but no district shifted from the highest to the lowest third, or vice versa.

In general, in all districts the autopsy proportion was high in cases where the registered cause of death was homicide, and the proportion was low in accidental falls, ill-defined causes, and natural deaths. For accidental poisonings, suicides, traffic accidents, and other external causes, the variation between police districts was much higher. The largest variation was observed in traffic accidents, from 5.6% to 87.2% and in suicides, from 15.9% to 94.4% (**paper III** (3), figure 2 and supplemental material.

16.3.3 Factors correlating with use of forensic autopsy

For each of the groups of *registered* cause of death, we performed a logistic regression analysis to evaluate factors that could correlate with the use of forensic autopsy. The complete results are presented in the supplemental material to **paper III** (3). Within each group, we ascertained the importance of each explanatory factor by the relative size of the likelihood ratio statistic (how much the model was weakened by leaving out the variable), see table 3 in **paper III** (3).

For deaths due to natural causes, accidental poisonings and other external causes, the (type of) place of death was the most important factor influencing autopsy, with a low proportion in deaths occurring in health-care institutions. For ill-defined causes of death and accidental falls, age was the most important factor. For deaths due to traffic

accidents and suicides, the police district was the most important explanatory factor. For homicides, almost all deaths underwent autopsy, and none of the explanatory factors were associated with the use of forensic autopsy. The exception was (type of) place of death, with fewer autopsies of deaths in nursing homes. However, the numbers are very small (only four deaths classified as homicides). It is noteworthy that the police district was among the top three explanatory factors in all cause-of-death groups (homicides excluded), whereas variables related to population size, the rurality of the municipality and distance to the autopsy facility seemed to have only a minor influence.

We also performed analyses trying to circumvent the methodological problem of including the registered cause of death as an explanatory factor, by only including the geographical explanatory variables. (See discussion section 17.1.6.) The results were not included in the publication, but are presented below. Also in these analyses, the police district was the most important explanatory factor.

Table 16.3.1. Geographical factors associated with deaths undergoing forensic autopsy in Norway 1996-2017. Logistic regression analysis.

Variable	Level	Per cent	OR (univariate)	95% CI	LRT (univariate)	p value	OR (multi predictor)	95% CI	LRT (multi predictor)	p value
Police	Agder	1.7	1.00	Ref.	10946	< 0.001	1.00	Ref.	4954	< 0.001
district	Asker og Bærum	4.6	2.75	(2.51-3.01)			2.64	(2.28-3.06)		
	Follo	4.2	2.53	(2.29-2.79)			2.30	(1.97-2.68)		
	Gudbrandsdal	0.9	0.52	(0.44-0.61)			0.53	(0.43-0.65)		
	Haugaland og Sunnhordland	5.4	3.26	(3.00-3.56)			3.94	(3.45-4.51)		
	Hedmark	1.6	0.92	(0.84-1.01)			1.07	(0.93-1.23)		
	Helgeland	3.1	1.80	(1.61-2.01)			2.22	(1.86-2.64)		
	Hordaland	7.9	4.86	(4.53-5.22)			4.75	(4.15-5.43)		
	Midtre Hålogaland	2.2	1.26	(1.13-1.40)			1.38	(1.21-1.58)		
	Nord-Trøndelag	2.1	1.20	(1.08-1.34)			1.31	(1.14-1.52)		
	Nordmøre og Romsdal	1.8	1.06	(0.94-1.19)			1.08	(0.93-1.26)		
	Nordre Buskerud	3.2	1.86	(1.67-2.06)			1.93	(1.65-2.24)		
	Oslo	7.4	4.52	(4.22-4.85)			4.35	(3.81-4.98)		
	Rogaland	6.0	3.62	(3.35-3.91)			3.44	(3.00-3.95)		
	Romerike	2.3	1.37	(1.25-1.50)			1.30	(1.12-1.51)		
	Salten	4.4	2.60	(2.35-2.87)			2.87	(2.40-3.43)		
	Sogn og Fjordane	2.7	1.59	(1.43-1.76)			1.65	(1.44-1.90)		
	Sunnmøre	1.0	0.59	(0.51-0.68)			0.58	(0.49-0.69)		
	Søndre Buskerud	4.4	2.59	(2.39-2.82)			2.54	(2.21-2.91)		
	Sør-Trøndelag	4.2	2.50	(2.32-2.71)			2.38	(2.07-2.73)		
	Telemark	4.3	2.57	(2.37-2.79)			3.03	(2.67-3.45)		
	Troms	3.7	2.19	(1.99-2.41)			2.19	(1.89-2.54)		
	Vestfinnmark	2.7	1.57	(1.34-1.83)			1.97	(1.62-2.40)		
	Vestfold	2.9	1.69	(1.55-1.85)			2.26	(1.96-2.60)		
	Vestoppland	1.6	0.92	(0.82-1.04)			1.10	(0.94-1.28)		
	Østfinnmark	3.9	2.32	(2.01-2.68)			4.18	(3.02-5.82)		
	Østfold	4.0	2.35	(2.17-2.54)			2.91	(2.53-3.36)		

Continued

Variable	Level	Per cent	OR (univariate)	95% CI	LRT (univariate)	p value	OR (multi predictor)	95 % CI	LRT (multi predictor)	p value
Municipality	< 2000	3.5	1.00	Ref.	4007	< 0.001	1.00	Ref.	184	< 0.001
population	2000-4999	3.6	1.03	(0.95-1.11)			0.92	(0.85-1.00)		
	5000-9999	3.1	0.88	(0.81-0.95)			0.93	(0.86-1.02)		
	10000-19999	3.2	0.89	(0.83-0.96)			0.75	(0.69-0.82)		
	20000-49000	2.7	0.77	(0.72-0.83)			0.70	(0.64-0.76)		
	> 50000	5.7	1.67	(1.56-1.79)			0.69	(0.63-0.75)		
Urbanity	0B (Most rural)	3.1	1.00	Ref.	3656	< 0.001	1.00	Ref.	64.8	< 0.001
index	0A	3.7	1.21	(1.12-1.30)			0.92	(0.84-1.01)		
	1B	2.7	0.88	(0.82-0.95)			0.92	(0.84-1.00)		
	1A	2.9	0.95	(0.89-1.03)			1.12	(1.01-1.23)		
	2B	2.4	0.78	(0.74-0.83)			1.08	(0.99-1.18)		
	2A	2.8	0.92	(0.88-0.96)			1.11	(1.02-1.21)		
	3A (Most urban)	5.3	1.76	(1.70-1.84)			1.26	(1.15-1.38)		
Distance	0-49	5.7	1.00	Ref.	5299	< 0.001	1.00	Ref.	181	< 0.001
to autopsy	50-99	3.6	0.61	(0.59-0.62)			0.83	(0.79-0.88)		
facility (km)	100-149	2.8	0.48	(0.46-0.49)			0.75	(0.70-0.81)		
	150-199	3.5	0.60	(0.57-0.63)			1.01	(0.92-1.12)		
	200-249	2.8	0.47	(0.44-0.50)			0.94	(0.84-1.06)		
	250-299	1.8	0.30	(0.27-0.32)			0.79	(0.68-0.92)		
	300-349	2.0	0.33	(0.31-0.36)			0.99	(0.86-1.14)		
	350-399	1.8	0.29	(0.27-0.32)			1.04	(0.87-1.24)		
	400-449	2.1	0.35	(0.31-0.38)			0.74	(0.61-0.9)		
	450-499	2.5	0.43	(0.38-0.48)			0.76	(0.62-0.93)		
	> 500	3.5	0.59	(0.52-0.67)			0.48	(0.34-0.66)		

16.3.4 Garbage codes in relation to forensic autopsies

As shown in **paper I** (1), a garbage code (GC) was registered as underlying cause of death in 29.0% of the deaths in Norway in 1996-2019, 14.1% major and 15.0% minor. (Note that the study period in **paper I** was 1996-2019, in **paper III** 1996-2017). In deaths undergoing forensic autopsy, the proportion was 20.6%, 16.5% major GC, 4.1% minor GC. The unadjusted proportion of major GC was thus slightly *higher* in the deceased undergoing forensic autopsy than in the not autopsied. For minor GC the proportion was *lower* (**paper I** (1), supplemental table S2d). Adjusting for the differences in age composition, the proportion of major GC was somewhat lower than in the unautopsied, but still much higher than in the deceased undergoing non-forensic autopsy. Of the five most commonly occurring major garbage codes in forensic autopsies, four were related to drug abuse. The three codes for accidental poisonings X42, X44, and X41 together occurred in 10.4% of the deaths, 62.3% of the major GC.

17. Discussion

17.1 Strengths and limitations

17.1.1 The data material

For all three parts of the study, we used data from the Norwegian Cause of Death Registry. The major strength is that the study is population-based, using individual-level data, and the data material is large and comprehensive. The completeness and quality of demographic data in NCoDR is very good, with a completeness of generally >98% and with demographic data supplied by the National Population Register.

ICD-10 has been used as classification system throughout the study period, and data processing and coding in the registry has been performed by skilled personnel in Statistics Norway up to 2013 and at The Norwegian Institute of Public Health from 2014. From 2005, the coding is semiautomatic, using the ACME and Iris software, as described in section 15.1.1, helping to make the coding more consistent. During the study period, there has been some changes in the coding rules, notably for external causes of death (drug-related deaths and injury deaths without specification of the circumstances) (27). This has probably had some influence on the changes in the proportion of deaths assigned a garbage code, see discussion of results below.

17.1.2 Selection of garbage codes

In **paper I** (1), we analysed the use of garbage codes in Norway. We used the list of garbage codes from the GBD Study, as we believe that much of the current research on the quality of cause of death statistics is linked to the GBD. There has been a gradual development over the iterations of the GBD analyses (39, 81). The results of this study would be different if we had used another definition of garbage codes. Use of the GBD list makes it possible to compare our results with other studies that uses the GBD framework. Studying the occurrence of garbage codes does not include any assumptions whether the (non-garbage) codes are correct. A death may be coded with

an informative, but wrong code. This study was not designed to ascertain the magnitude of incorrect diagnoses.

To describe the distribution of garbage codes, we tabulated them by ICD-10 3-character level. Johnson et al (85) and the ANACONDA tool use functional grouping of garbage codes into "packages" (not the same as the level 1-4 of severity) (165), e.g. "Shock & Cardiac arrest". We found some obvious errors and omissions in the published definition of these groups in the appendix to the Johnson study, so we have not been able to use this grouping in our analyses, and the ANACONDA definitions has not been publicly available.

17.1.3 Selection of target groups for redistribution

In **paper II** (2), we tried to redistribute the deaths coded with X59 to the most probable informative (non-garbage) underlying cause of death. For target groups, we used all external cause groups in six categories (road traffic accidents, accidental falls, accidental poisonings, other accidents and events of undetermined intent, suicides, and homicides). Even if X59 in strict sense is a code for *accidents* (accidental exposure to unspecified factor), we chose to include all external causes (included suicides and homicides) as potential targets. The reason for this was twofold: First, in the GBD system, X59 is redistributed to all injuries, not only accidents (131). Second, the ICD-10 section for events of undetermined intent (Y10-Y34) is very seldom used in Norway, 0-11 deaths/year in the study period. The tradition in NCoDR has been to code external cause death with unknown manner of death to accidents as default (the exception is hangings, which by default are coded as suicides), see sections 9.10 and 10.8. The number and definition (ICD-10 codes) for the target groups is a balance between having many enough groups to make the results relevant and few enough to make the calculations manageable and the estimates robust. We did not include non-injury deaths as target groups. When querying the certifying doctors, we realized that some of the injury deaths could be reclassified or re-certified in a way that moved the injury to a contributory cause of death (part II of the death certificate) and placed a disease as the underlying cause of

death. This occurred in 17 out of 298 deaths (5.7%) where we could assign a new underlying cause of death. It is not always possible to decide whether a medical condition such as a myocardial infarction is a complication to the injury or a completely separate condition.

17.1.4 Class imbalance in redistribution

The multinomial logistic regression approach to redistribution is described in section 15.3.4. As target, we used the external cause group with the highest probability, regardless of level of probability. This technique may suffer from class imbalance problem. Class imbalance occurs when prior distribution of high probability class(es) influences the predicted probability so that the low proportion classes (almost) never is assigned a case (163). In our case, a very large proportion (97.4%) of the X59 cases were reclassified as accidental falls. However, in the training sets, the imbalance was much less pronounced. The training sets were drawn from the external cause deaths with known underlying cause of death, and here accidental falls had a share of 22.8% (4,218/18,523). The frequency of the various cause groups can be found in table 2 in **paper II** (2).

If the data are dominated by one group, overall accuracy may be artificially high. Cohen's kappa is a better way of estimating model performance. In this case, overall accuracy when testing the model was 0.71, kappa 0.64. There is no universally agreed interpretation of kappa scores, other than higher is better, but a score in the range 0.60-0.80 has been judged as "good" (163).

17.1.5 Autopsy data

In all three parts of the study we used data on whether an autopsy (forensic or non-forensic) was performed. This information was based on autopsy reports received at the NCoDR. As described in sections 13.3 and 13.4, there is no authoritative source on the number of autopsies in Norway. If the institution performing autopsies forgets to send copy of the report to NCoDR, the number of autopsies will be underestimated. In addition, it is not always evident whether an autopsy report stems

from a forensic or non-forensic autopsy. We tried to estimate the magnitude of missing forensic autopsy reports from the homicide deaths, the group with highest autopsy proportion. Where the registered cause of death was homicide, NCoDR had received an autopsy report in 96.6% of the cases (**paper II** (2)). As the maximum autopsy proportion cannot be more than 100%, this means that at least *for this cause of death group*, a maximum of 3.4% of the autopsy reports might be missing. From this, we estimated that probably not more than 5% of the forensic autopsy reports were missing, contributing to a slight underestimation of the autopsy proportion. If the reports are not missing at random (e.g. if there are more missing reports from one geographical region), this could introduce bias in the results.

17.1.6 Relation between the registered cause of death and the forensic autopsy proportion

In **paper III** (3), we investigated variation in the autopsy proportion according to the registered cause of death. The perceived cause of death and the circumstances around the discovery of the body should be the major determinant for whether the physician viewing the body should notify the police, and whether the police decides to request a forensic autopsy (147, 148). To date, neither the Police Directorate nor the NCoDR have reliable figures for how many deaths that are reported to the police. If a notifiable death is not sent for autopsy, we do not know if this is because the doctor has not notified the police or if the police have been notified, but subsequently declined an autopsy.

There is a two-way relationship between the cause of death and whether a forensic autopsy has been requested and performed. On one hand, the initial assessment of the perceived cause of death (e.g. whether it might be a natural death or a suicide) influences whether a death is reported to the police and an autopsy is requested. On the other hand, the registered cause of death might be influenced by the autopsy results (or lack thereof). For example, a suicide by poisoning, but not undergoing autopsy, might wrongly be registered with a natural or ill-defined cause of death. Using the registered cause of death as an explanatory factor in a regression analysis is

therefore methodologically unsound. In an analysis of factors that may be correlated with or even influencing the decision of requesting an autopsy, one would like to know the information available *before* the decision of autopsy (the perceived cause of death or the circumstances around the discovery of the body), but this information is not available in any systematic way. A major limitation of this part of the study is that the registered cause might be wrong, especially when no autopsy has been performed. Indeed, classification of cause of death to the ill-defined group might be the *result* of a lack of autopsy, as claimed by Ylijoki-Sørensen et al. (132). On the other hand, completely leaving out the cause of death in the analyses would introduce confounding regarding age, sex, and (type of) place of death estimates, as the proportion of deaths due to many external causes is higher in men and young people, as well in deaths occurring outside health care institutions (49). We therefore chose to investigate the impact of other explanatory factors in different scenarios, dividing the data according to the *registered* underlying cause of death, even if the assignment of underlying cause of death might be wrong in a number of cases. Our study was not designed to ascertain misclassification due to a lack of autopsy. In addition, we performed analyses with only the geography-related variables (previously unpublished, table 16.3.1). Also in these analyses, the police district was much more important than the other geography-related factors.

17.2 Discussion of results

17.2.1 The use of garbage codes in Norway

The main findings are presented in section 16.1, and the complete results in **paper I** (1).

We found that in the years 1996-2019 a total of 29.0% of the deaths in Norway were assigned a garbage code, 14.1% major and 15.0% minor, according to the definitions used by the Global Burden of Disease study. This is in accordance with the results presented by the GBD (39). It is the use of major garbage codes that are considered

most deleterious for public health analyses, as they convey least information. Worldwide, the proportion of major garbage codes in cause of death registries ranges from 4% to more than 80% in the latest available year (39). Johnson et al (85) found that for the countries where data were available for 2015, the proportion of major garbage codes ranged from 3.7% to 67.3%, minor garbage codes from 2.4% to 34.6%. There was a tendency toward higher proportions in lower resource countries (low socio-demographic index). The proportion in Norway is similar to several comparable countries, such as Sweden (13% in 2017), Denmark (16% in 2015), Germany (15% in 2016), and the Netherlands (16% in 2016), but higher than e.g. Finland (6% in 2016), UK (9% in 2017), and New Zealand (4% in 2015). This would suggest that even if Norway is in the lower (better) end, there is still potential for improvement.

The proportion of deaths assigned a garbage code increased with the age of the deceased. As mentioned in **paper I** (1), other studies have divergent observations regarding age and garbage coding. Iburg et al. (84) found no large age gradient in major garbage codes in most of countries studied, while Johnson et al. (85) stated that the garbage code proportion often is higher in locations with an elderly population, and suggested using age standardization to improve comparability. An age gradient has been described in Greenland (95), Brazil (98), and Korea (94). Flagg and Anderson (86) found an age gradient in the Unites States, but they used another definition of unsuitable causes of death. Older people often have several diseases, and it can probably be difficult to identify a single cause of death. Still, one might argue that this not necessarily would lead to more garbage coding, only to difficulties in choosing between several non-garbage codes. In the oldest population segment, a large proportion of the deaths occur in nursing homes, perhaps with more focus on symptom relief than on exact diagnosis. Nevertheless, there was a highly significant age gradient even after adjusting for the place of death (in the multiple predictor regression analyses).

The garbage code proportion was larger in women than in men. This can in a large part be explained by the age effect. The median age of death was 6 years higher in women than in men in Norway in the study period, and the difference in age-adjusted proportions were smaller than the crude differences, almost non-existent in the last years of the study period. If we compare the garbage code proportion in men and women in different age groups, the differences are very small, except for major garbage codes in young adults. Adair et al. (173) found a slightly higher age-adjusted garbage code proportion in women in a study on data from 42 countries.

There was a large proportion of deaths with a major garbage code in the 15-49 year group. This can to a large extent be explained by coding of accidental poisonings. The three accidental poisonings codes X41, X42, and X44 together accounted for 53.2% of all major garbage codes in this age group. Before 2003, an accidental drug poisoning in a person with addiction was coded as a substance use disorder (ICD-10 section F11-16, F19). In 2003, there was a change in the rules from the WHO, and accidental poisonings were to be coded as external causes of death (ICD-10 section X40-X49). Most codes in this section are regarded as garbage codes by the GBD, whereas many of the corresponding codes in the section of the F chapter are not. Coding correct according to the WHO guidelines thus leads to an underlying cause of death regarded as a garbage code by the GBD. The change in coding rules in 2003 must have led to changes in the prevalence of major garbage codes, at least in young adults and in the persons undergoing forensic autopsy. See figure 17.2.1 below for a visualization of the effect of change in coding rules.

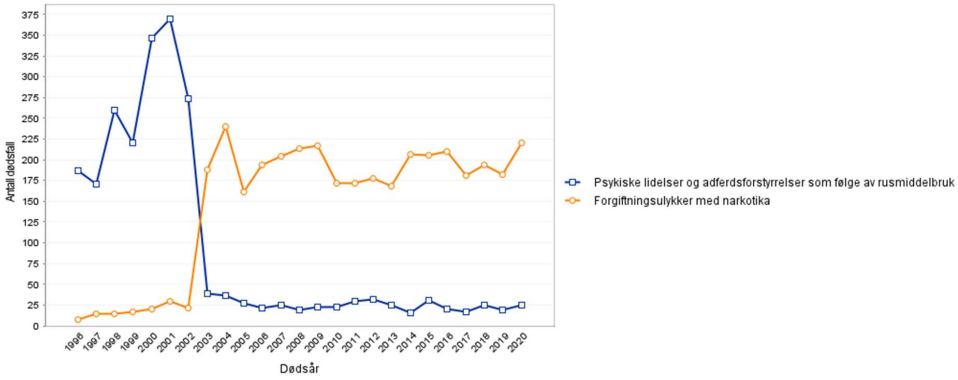

Fig.17.2.1. Temporal change in coding of drug-related deaths in Norway. From the databank of NCoDR (49)
(Blue line F11-F12, F14-F16, F19, Orange line X42, X44, Y12, Y14 with T40.X)

As shown in **paper I** (1), the proportion of deaths assigned a garbage code was lowest in hospitals. This can probably be explained partly by better diagnostic resources in hospitals. There are also more sudden, unexpected or unattended deaths outside health care institutions. This is reflected in the spectrum of major garbage codes for deaths outside health care institutions, with R96 (sudden death), R99 (unknown cause of death), and I46 (cardiac arrest) among the most prevalent.

We found that the most prevalent major garbage codes were heart failure, sudden death, and senility, with unspecified stroke, unspecified pneumonia, and malignant neoplasm with unknown primary site the most common minor garbage code. Johnson et al (85) used another grouping of garbage codes (as explained in section 17.1.2) and investigated only a single year (2015), but found that the five most prevalent garbage code groups in Norway were: all ill-defined causes of death, heart failure, unspecified site cancer, senility, and unspecified infectious diseases.

17.2.2 Effect of redistribution of garbage codes

Johnson et al (85) presented results on the occurrence of the most common non-garbage codes in Norway 2015 before and after redistribution according to the GBD methods (39). The 10 most prevalent groups before and after redistribution are presented in the table below. This indirectly shows the deleterious effects of garbage

codes in the underestimation of the number of deaths in some diagnostic groups. Not only increases the number of death in some groups, the ranking is also adjusted. (Of course, this ranking is subject to the quality of the redistribution methods.)

Diagnostic group	**Before redistribution**			**After redistribution**	
	Deaths	Rank		Deaths	Rank
Ischemic heart disease	4213	1		5688	1
Alzheimer and other dementia	3291	2		3081	2
Lung/tracheal/bronchial cancer	2197	3		2472	4 ↓
COPD	2109	4		2587	3 ↑
Colorectal cancer	1606	5		1979	6 ↓
Prostate cancer	1046	6		1234	8 ↓
Falls	815	7		1261	7 ↑
Pancreatic cancer	761	8		893	10 ↓
Atrial fibrillation and flutter	719	9		760	12 ↓
Breast cancer	592	10		701	14 ↓
Ischemic stroke	503	13		2093	5 ↑
Other lower respiratory infections	Not presented	101		983	9 ↑

Table 17.2.1. The effect of redistribution of garbage codes in Norway 2015. Adapted from (85).

17.2.3 The garbage code X59 (exposure to unspecified factor)

As described in **paper II** (2), we found that in the study period (2005-2014), 25.8% of all external cause deaths in Norway lacked information on the circumstances around the injury. The denominator here includes all external cause deaths, not only the unintentional deaths. By analysing data from the WHO Mortality Database, we found that the proportion of external cause deaths coded with X59 varied from 0 to 42.1% between countries. Bhalla et al (93), in a study published in 2010, calculated the proportion in Norway to be 32% of the unintentional injury deaths. With 45% as

the highest recorded proportion, this means that Norway is among the countries with the most prevalent use of X59. Hua et al. investigated the coding quality of fall mortality data in the elderly worldwide, and placed Norway in the group with the lowest quality (174). This was partly because of the prevalence of X59 coding and frequent use of the code W19 (unspecified fall). In addition, the authors evaluated the use of a fourth digit (the place of occurrence) in the ICD-10 coding. In NCoDR, the place of occurrence is stored in a separate variable, and not included in the ICD-10 codes, a feature that in this setting gave an artificially low score.

We also calculated the proportion of deaths coded with Y34 (unspecified event, undetermined intent), see section 10.8. The proportion worldwide varied between 0 and 82.6% of all external cause deaths. The proportion in Norway was 0%. No countries had both a high X59 proportion and a high Y34 proportion (but some had low proportions of both). This might point to that these two codes in reality serve much of the same function, even if their precise ICD-10 definition differs. See figure 16.2.1 in section 16.2.4 in this thesis.

We found that most (85%) of the X59 coded deaths in Norway were in deceased 80 years and older, and the most frequent injury was a fracture in the hip region. Kreisfeld and Harrison found the same pattern in Australia (105).

Both from the attempt of redistribution with multinomial logistic regression (97%) and the query to the certifying physicians (88% of the informative responses), a very large proportion of the X59 coded deaths could be reclassified as accidental falls. Even if the response proportion in the query was rather low, the replies support the results from the regression model. (The study period for the redistribution attempt was 2005-2014, and the query was in 2015, but we have no reason to believe that the conditions differed.) As discussed in **paper II** (2), this is in line with studies from various high-income countries (United States, Canada, Sweden, and Australia). In a study by Johnson et al with data from the year 2015 (85), the authors compared the GBD X59 redistribution results by age and geographical super-region. They found

that even if there was some variation, the proportion of X59 redistributed to falls increased with advancing age, generally to 80-90% in deceased over 80 years. From figure 16.2.2 in this thesis, one might get the impression of a negative correlation between the fractions of external cause deaths coded with X59 and accidental falls. Since we have not made a formal analysis of this, we cannot draw any decisive conclusions.

Not unlike the case for coding of deaths due to drug overdoses (section 16.1.5 and 17.2.1) there was a change in coding practice with importance for the X59 garbage code, as described in section 10.8. In short, in the first years after the introduction of ICD-10 in Norway, injury deaths with fracture of the femur would regularly be coded as accidental falls (W19), even when the information on the circumstances were lacking. This was changed in 2005, and the number of deaths registered as accidental falls declined. In 2015 and 2015, the number increased due to quality efforts (querying) at the NCoDR. These quality measures were discontinued in 2017 (Pedersen AG, NIPH, personal communication), and the registered mortality due to falls declined again. See figure 17.2.2 below, note that “other accidents” includes more than just X59.

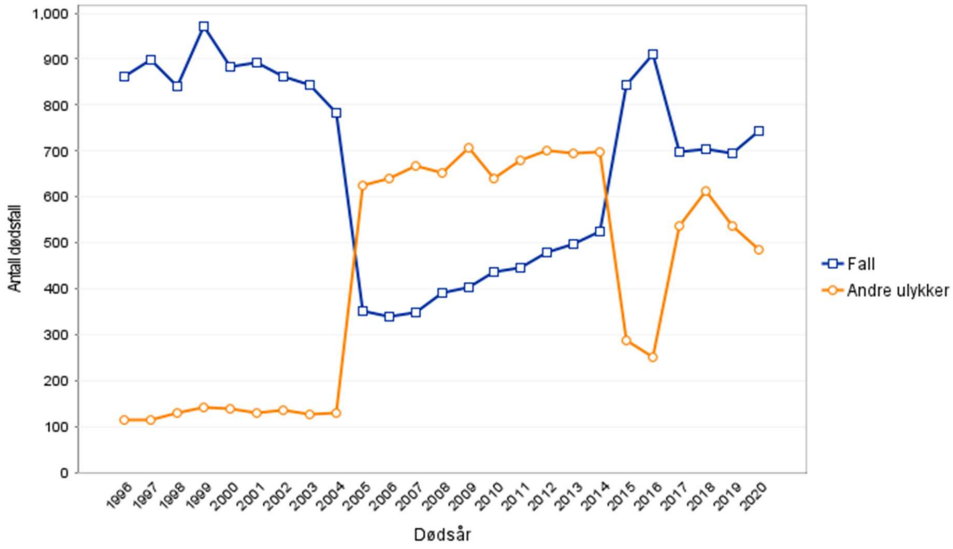

Fig. 17.2.2. Temporal change in coding of selected accidental deaths in Norway. From the databank of NCoDR (49)
(Blue line W00-W19, Orange line W20-W64, W75-X39, X50-X59, V98-V99)

It thus seems that the assumption underlying the 1996-2004 practise of coding the deaths with femoral fracture as accidental fall was correct. Nevertheless, such "automated redistribution" probably is methodologically unsound, disguising missing information and – in the cases where there are other circumstances – introducing outright errors.

17.2.4 Forensic autopsies in Norway

As described in **paper III** (3), we found that in the study period (1996-2017), 4.1% of the deaths in Norwegian citizens underwent forensic autopsy, with no significant increasing or decreasing trend.

There was a large variation between police districts (0.9-7.8%). The variation in forensic autopsy proportion between police districts was not equal across the various cause of death groups. The largest span was for traffic accidents, with a range from 6.5% to 87.2%.

In 1992, there was a change in the reimbursement system for forensic autopsies in Norway. Earlier, the costs both for the transport and the autopsy itself were covered directly by the Ministry of Justice (now the Ministry of Justice and Public Security), but from 1992 the responsibility was transferred to the individual police districts (149). The "external" cost for a forensic autopsy consists of the fee for the autopsy itself and for the transportation. With long distances, the cost for the transportation might easily supersede the cost for the autopsy itself. (In addition comes the "internal" cost in the police for investigating the case.) The autopsy fee is more or less decided by the Ministry, but the transportation cost varies by the distance from the place of death to the autopsy facility. It is believed that this system change was the cause of a decline in the number of forensic autopsies. In 1991, 2762 forensic autopsies were performed in Norway, compared to 1849 in 1993 (175). As far as we know, there are no published reports on whether this also lead to larger differences between the police districts. We found that the distance from the place of death to the autopsy facility was among the least important explanatory factors, measured by the relative magnitude of the likelihood ratio (LR) statistic. Even after adjusting for the various geography-related factors (size of the population of the municipality, urbanity index and distance to the autopsy facility), the police district had an important effect, and were in all cause of death groups among the top three factors (**paper III** (3), table III and supplementary material). In the analyses including all cause of deaths, but where only police district and the geography-related variables were used (table 16.3.1 in this thesis), the police district was by far the most important predictor, judged by the LR statistic. This might indicate that there are influencing factors related to the operation of the various police districts, not identified in the present study, e.g. local attitudes, habits, procedures, economic priorities etc. After the study was completed, we have been made aware that in some districts in northern Norway, the police applies to the local court for requesting an autopsy, and in these cases, it is the court and not the police that pays for the autopsy (175). This takes the economic burden away from the police, and might thus influence the propensity for requesting an autopsy. It has not been possible to find out if this applies to all or only some police

districts in northern Norway and all or only a proportion of the autopsies (Uhlin-Hansen L, University of Tromsø, personal communication). Most of the police districts in northern Norway have an autopsy proportion in the middle third in the ranking (**paper III** (3), table II).

In most cause of death groups, the place of death and age of the deceased were the dominating explanatory factors. Very few deaths in health care institutions are sent for forensic autopsy, even in case of external cause of death (such as suspected accidents or suicides). A possible explanation might be that in these cases there is more information available regarding the injuries and circumstances, with a perceived less need for the autopsy results. One might also suspect (substantiated from personal experience), that if there is a long interval from the accident (or similar) to the death, perhaps with "medical" complications to the injury, such as septicaemia or multi organ failure, there is a risk that the treating physician does not report the death to the police. A special case is accidental falls. A very large proportion of the deaths due to accidental falls is in elderly people (median age 85 years) and about 80% occurs in health care institutions (**paper II** (2)), and in this group, the forensic autopsy proportion is much lower (5.2%) than in other external causes of death (**paper III** (3), table 1). A Swedish study by Pettersson and Eriksson found that almost half of the external cause deaths were not reported to the police (176). Of these, 69% were accidental falls on the same level, mostly in elderly persons. Nevertheless, the authors regarded 14% of the unreported deaths as "obviously unnatural".

The proportion of forensic autopsies is highest in young adults (nearly 60% in the 20-29 years old) and declines with advancing age. A large part of this can be explained by a low proportion of natural death (and thus a larger proportion of external cause deaths) in the young. However, there is an age gradient also *within* several of the cause of death groups, such as suicides, and this might be more problematic. A suspicious death in an elderly person should be investigated as thoroughly as in the young.

17.2.5 The consequences of a low autopsy proportion

The purpose of a forensic autopsy is first and foremost to be a part of the police investigation in a suspicious death (148, 175). Ideally, the decision about starting an investigation should not be influenced by age, sex and geographical factors, only by the circumstances around the death or discovery of the body. An insufficient investigation may in the worst case scenario mean that a criminal case goes undetected. In a Swedish study based on 29,000 forensic autopsies performed 1975-2000, the authors found that 7.5% of the homicides were not detected until autopsy (177). The responsibility of the police extends also to the investigation of deaths where the suspicion of homicide is low, but where the death might be caused by recklessness or negligence, such as traffic accidents or medical misadventure (136, 148). If an autopsy is not carried out, important findings about the injuries, co-existing disease and influence of drugs might go unnoticed. It must be stressed that a forensic autopsy is only a (small) part of the police investigation, and in some cases the police may be satisfied with the other investigative efforts, such as witness statements and reports from the scene of crime officers/forensic scientists.

In a broader view, (forensic) autopsy reports are important adjuncts to the death certificates for the production of cause of death statistics. This is especially important where the certifying physician has insufficient information from the patient records. Typical examples are sudden, unexpected or unwitnessed deaths outside health care institutions. Ylijoki-Sørensen et al. found in a Danish/Finnish study that the coding of ill-defined and unknown cause of death was 13 times more frequent in Denmark than in Finland and related this to differences in the forensic autopsy proportion, which was 6 times higher in Finland (132). Even if the total forensic autopsy proportion in the study period was about 4% in Norway (currently about 5% (49)), the proportion of deaths outside health care institutions undergoing forensic autopsy is higher, around 18% (**paper III** (3), supplemental material). When it comes to garbage codes, 20.6% of the deaths undergoing forensic autopsy are assigned a major or minor garbage code, compared to 30.2% of the non-autopsied (**paper I** (1), table 5). In

addition, around 60% of the major garbage codes in the persons undergoing forensic autopsy relates to accidental poisonings (X41, X42, X44), and thus are considered by the WHO to be sufficiently informative (see sections 10.7 and 16.3.5). A low forensic autopsy proportion might lead to deficiencies in the cause of death statistics, especially in persons dying outside health care institutions. In addition, variation in the autopsy frequency might introduce spurious shifts in the statistics, e.g. between geographical regions. In a project thesis in 2018, Siri Jensen found geographical variation both in the choice of suicide methods and autopsy frequency between Norwegian counties and suggested that some suicides by poisoning might go undetected because of lack of autopsies (178).

Based on numbers from the NCoDR data bank, in 2020 the total forensic autopsy proportion was 5.1%, with a range 2.7-8.0% (CV 38%) between counties (not police districts) (49). This variation is lower than we found between police districts in our study (CV 53%), which ended in 2017. As the methods differs somewhat from those used in this thesis, the results are not fully compatible. It will be important to analyse whether the police reform in 2016 (156) have had any influence on the utilization of forensic autopsies.

An important issue here is what is conceived the responsibility of the police. Is it restricted only to investigate possibly criminal cases? Does the task include assisting the society with information on public health issues, such as suicides and drug-related deaths, the relatives' needs and data for cause of death statistics and research? One could argue that these are important issues for the society and the police is the relevant body for requesting an autopsy, but that the police should be exempted from the economic burden.

18. Conclusion

In this thesis, I have presented some quality aspects of the Norwegian cause of death statistics. A relatively large proportion of the deaths (29%) are assigned a garbage code for the underlying cause of death, according to the definition from the Global Burden of Disease Study (GBD). The proportion of the least informative (major) garbage codes was 14.1%, and this proportion did not improve during the study period. The proportion of minor garbage codes improved, though (1). It is important to know which garbage codes that are most prevalent, and in which population segments they occur. This can guide the users of cause of death data about the quality in certain population groups (elderly, deaths outside hospitals) as well as give targets for quality improvement efforts. Nevertheless, it is important to have in mind that a non-garbage code is not necessarily *correct* – it might be informative, but *wrong*. The prevalence of garbage codes is probably the most important adverse quality aspect of the data from the Norwegian Cause of Death Registry. The proportion is similar to our closest neighbouring countries, Sweden and Denmark, but higher than in some other high-income countries, such as Finland, New Zealand, and the United Kingdom. This means that there is potential for improvement. Use of queries to the certifying doctors in unclear cases, as well as utilizing autopsy results, can improve the quality. In 36% of the deaths coded with a garbage code, there were also other, non-garbage codes, elsewhere on the death certificate. Even if these diagnoses not necessarily represent the true underlying cause of death, they signalize that there might be more information available.

We investigated more closely the use of a single garbage code concerning external cause deaths lacking information on the circumstances around the injury (ICD-10 code X59). For the years 2005-2014 25.8% of all external cause deaths were assigned this code. The typical X59 coded death was in an elderly woman, dying in a health care institution with a fracture in the proximal femur. We developed a redistribution method for trying to estimate the missing information, and validated the methods

with a query to the certifying doctors (2). The query showed that the lacking information is often accessible, but the certifying doctors were not aware that it was important. Both the redistribution and the query indicated that the absolute majority of these deaths were accidental falls; this means that the official statistics severely underestimates the mortality from falls in the elderly in Norway. The age-adjusted mortality rate from accidental falls probably is around 25 per 100.000 instead of the registered 10 per 100.000.

Autopsies give valuable information for the cause of death statistics. Forensic autopsies are often conducted in deaths where the available information from patient records is scarce, such as unexpected deaths or trauma deaths outside hospitals. We have shown a large variation in the autopsy proportions between different types of deaths and police districts (3), from 0.9-7.8% in 1996-2017, and the variation apparently did not decrease during the study period. The variation was most pronounced for road traffic accidents and suicides. Unjustified geographical differences in the use of forensic autopsies might in the worst case (on individual level) lead to insufficient investigation of possible unnatural deaths and (on group level) introduce bias in the cause of death statistics. Contrary to earlier belief, the distance from the place of death to the autopsy facility was not among the most important predictors for a deceased undergoing forensic autopsy.

19. Further perpectives and directions for future research

The quality of a cause of death registry can be evaluated along different axes, and several compound scoring systems have been used. At the time of writing, the most updated framework for comprehensive quality assessment of cause of death data is probably ANACONDA. Such assessment has not yet been performed in Norway. This is an important benchmarking that should be done at the Norwegian Institute of Public Health, the body responsible for the Norwegian Cause of Death Registry. The results of such study could highlight areas for quality improvement, as well as providing an objective measure for comparing across time and geography.

Electronic certification of death has been gradually introduced in Norway during the last years, and is mandatory from 2022. An important task in the next years is to evaluate the system; will there be improvement in the data quality? In my opinion, the potential for real-time quality assessment and feedback to the certifying doctors has not been exhausted. It is always better to do things right from the start instead of trying to repair the flaws in retrospect.

The newest version of the ICD (ICD-11) has not been implemented in Norway. This is expected to imply some changes in the classification and registration of causes of death (if not, there would be no need for a revision). By itself it would probably not eliminate the use of garbage codes, but it is supposed to make better use of online coding tools (46), something that might improve the quality of cause of death coding in general.

The concept of garbage codes is closely linked with the Global Burden of Disease Study. The members of the WHO (almost all countries) are obliged to follow the WHO guidelines when producing cause of death statistics. In some aspects, this might be in conflict with the methods of the GBD, e.g. regarding deaths due to drug overdoses. This means that the national cause of death registries, such as NCoDR,

cannot indiscriminately used the GBD methods and definitions in their daily routine. It would be of value with a closer cooperation and understanding between the Global Burden of Disease Study and the World Health Organization (WHO).

In 2016, there was a reduction in the number of police districts in Norway, from 27 to 12. It will be of interest to see if this had an impact on the utilization of forensic autopsies, with more homogenous practise. In 2011, there was a regulation change, requesting more thorough investigation in childhood deaths (148). In 2020, there was a law amendment, requesting autopsies in all road traffic deaths (179). The impact of these regulatory changes has not been evaluated. In 2020, the government launched a plan for prevention of suicides. One item in this plan was to gain better knowledge of suicides, including “hidden” or undetected suicides (180). More autopsies could be of value here. The Directorate of Health has initiated efforts to strengthen forensic medicine in Norway, planning to establish a medical speciality and giving the regional health authorities a defined responsibility for the forensic medical services (181). This might also lead to better harmonization of the services.

20. References

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21. Abbreviations

ACME	Automated Classification of Medical Entities. Part of MMDS. Formerly used in Iris, superseded by MUSE.
ANACONDA	Analysis of National causes of Death for Action: A data tool for evaluation of the quality of mortality and cause of death data
CI	Confidence interval, 95% if not otherwise stated
COD-SL-2012	Eurostat's tabulation list for causes of death
CODEm	Cause of Death Ensemble model: A set of models used by the GBD for estimating the causes of death
CRVS	Civil Registration and Vital Statistics
Eurostat	The statistical organ for the European Union and collaborating states
GBD	The Global Burden of Disease Project
GC	Garbage code
ICD	International Statistical Classification of Diseases and Related Health Problems (ICD-10: 10th revision)
IHME	Institute for Health Metrics and Evaluation, University of Washington, Seattle
IQR	Interquartile range
Iris	Software for coding causes of death
-2LL	-2 log likelihood, deviance, likelihood ratio statistic
MCOD	Multiple causes of death
MMDS	Mortality Medical Data System: System for coding causes of death, developed by the National Center for Health Statistics, USA
MUSE	Multi-causal and Uni-causal Selection Engine. A part of Iris.
NCoDR	The Norwegian Cause of Death Registry

NIPH	The Norwegian Institute of Public Health (Folkehelseinstituttet, FHI)
R	The program/language used for statistical calculations
RStudio	An integrated development environment for R
SD	Standard deviation
SN	Statistics Norway (Statistisk sentralbyrå, SSB)
Tidyverse	A set of additional packages for R
UCOD	Underlying cause of death
VSPI	Vital statistics performance index: A scoring system for evaluating the quality of cause of death data
WHO	The World Health Organization
X59 (X59.0/X59.9)	ICD-10 code: (Accidental) exposure to unspecified factor

22. Appendix

22.1 Definitions of garbage codes

Lists over ICD-10 codes with suboptimal information on the cause of death ("garbage codes") from various sources illustrates different notions of what is "good enough" information value.

22.1.1 WHO/ICD-10

From ICD-10 Instruction manual (29).

Appendix table 7.3 List of ill-defined conditions
I46.1, I46.9, (I50.-)*, I95.9, I99, J96.0, J96.9, P28.5, R00-R57.1, R57.8-R59.9, R65.2-R65.3, R68.0-R94, R96-R99
* *Acute heart failure in I50.-* The terms in I50.- in ICD-10 do not specify "acute" or "chronic".
Appendix table 7.4 List of conditions unlikely to cause death
A31.1, A42.8, A60.0, A71.0-A71.9, A74.0, B00.2, B00.5, B00.8, B07, B08.1, B08.8, B30.0-B30.9, B35.0-B35.9, B36.0-B36.9, B85.0-B85.4, F45.3-F45.9, F50.1, F50.3-F50.9, F51.0-F51.9, F52.0-F52.9, F60.0-F60.9, F61, F62.0-F62.9, F63.0-F63.9, F64.0-F64.9, F65.0-F65.9, F66.0-F66.9, F68.0-F68.9, F69, F80-F89, F95.0-F95.9, F98.0-F98.9, G43.0-G43.2, G43.8-G43.9, F44.0-F44.2, G45.0-G45.9, G50.0-G50.9, G51.0-G51.9, G54.0-G54.9, G56.0-G56.9, G57.0-G57.9, G58.7, H00.0-H00.1, H01.0-H01.9, H02.0-H02.9, H04.0-H04.9, H10.0-H10.9, H11.0-H11.9, H15.0-H15.9, H16.0-H16.9, H17.0-H17.9, H18.0-H18.9, H20.0-H20.9, H21.0-H21.9, H25.0-H25.9, H26.0-H26.9, H27.0-H27.9, H30.0-H30.9, H31.0-H31.9, H33.0-H33.5, H34.0-H34.9, H35.0-H35.9, H40.0-H40.9, H43.0-H43.9, H46, H47.0-H47.7, H49.0-H49.9, H50.0-H50.9, H51.0-H51.9, H52.0-H52.7, H53.0-H53.9, H54.0-H54.9, H55, H57.0-H57.9, H60.0-H60.9, H61.0-H61.9, H80.0-H80.9, H83.3-H83.9, H90.0-H90.8, H91.0-H91.9, H92.0-H92.2, H93.0-H93.9, J00, J06.0-J06.9, J30.0-J30.4, J33.0-J33.9, J34.2, J35.0-J35.9, K00.0-K00.9, K01.0-K01.1, K02.0-K02.9, K03.0-K03.9, K04.0-K04.9, K05.0-K05.6, K06.0-K06.9, K07.0-K07.9, K08.0-K08.9, K09.0-K09.9, K10.0-K10.9, K11.0-K11.9, K14.0-K14.9,

L01.0-L01.1, L03.0, L04.0-L04.9, L05.0-L05.9, L08.0-L08.8, L20.0-L20.9, L21.0-L21.9, L22, L23.0-L23.9, L24.0-L24.9, L25.0-L25.9, L28.0-L28.2, L29.0-L29.9, L30.0-L30.9, L41.0-L41.9, L42, L43.0-L43.9, L44.0-L44.9, L55.0-L55.1, L55.8-L55.9, L56.0-L56.9, L57.0-L57.9, L58.0-L58.9, L59.0-L59.9, L60-L60.9, L63.0-L63.9, L64.0-L64.9, L65.0-L65.9, L66.0-L66.9, L67.0-L67.9, L68.0-L68.9, L70.0-L70.9, L72.0-L72.9, L73.0-L73.9, L74.0-L74.9, L75.0-L75.9, L80, L81.0-L81.9, L83, L84, L85.0-L85.9, L87.0-L87.9, L90.0-L90.9, L91.0-L91.9, L92.0-L92.9, L94.0-L94.9, L98.0-L98.3, L98.5-L98.9, M20.0-M20.6, M21.0-M21.9, M22.0-M22.9, M23.0-M23.9, M24.0-M24.9, M25.0-M25.9, M35.3, M40.0-M40.5, M43.6, M43.8-M43.9, M48.0, M53.0-M53.9, M54.0-M54.9, M60.0-M60.9, M65.0-M65.9, M66.0-M66.5, M67.0-M67.9, M70.0-M70.9, M71.0-M71.9, M75.0-M75.9, M76.0-M76.9, M77.0-M77.9, M79.0-M79.9, M95.0-M95.9, M99.9-M99.9, N39.3, N46, N47, N60.0-N60.9, N84.0-N84.9, N85.0-N85.9, N86, N87.0-N87.9, N88.0-N88.9, N89.0-N89.9, N90.0-N90.9, N91.0-N91.5, N92.0-N92.6, N93.0-N93.9, N94.0-N94.9, N96, N97.0-N97.9, Q10.0-Q10.7, Q11.0-Q11.3, Q12.0-Q12.9, Q13.0-Q13.9, Q14.0-Q14.9, Q15.0-Q15.9, Q16.0-Q16.9, Q17.0-Q17.9, Q18.0-Q18.9, Q38.1, Q65.0-Q65.9, Q66.0-Q66.9, Q67.0-Q67.8, Q68.0-Q68.8, Q69.0-Q69.9, Q70.0-Q70.9, Q71.0-Q71.9, Q72.0-Q72.9, Q73.0-Q73.8, Q74.0-Q74.9, Q80.0-Q80.3, Q80.0-Q80.9, Q81.0, Q81.2-Q81.9, Q82.0-Q82.9, Q83.0-Q83.9,Q84.0-Q84.9, S00.0-S00.9, S05.0, S05.1, S05.8, S10.0-S10.9, S20.0-S20.8, S30.0-S30.9, S40.0-S40.9, S50.0-S50.9, S60.0-S60.9, S70.0-S70.9, S80.0-S80.9, S90.0-S90.9, T09.0, T11.0, T13.0, T14.0, T20.1, T21.1, T22.1, T23.1, T24.1, T25.1,

22.1.2 Eurostat's tabulation list

European Shortlist of Causes of Death (COD-SL-2012) (34).

16. Symptoms, signs, and ill-defined causes
R00-R99

22.1.3 National Center of Health Statistics (USA)

From National Vital Statistics Report (2021): Unsuitable Underlying Causes of Death for Assessing the Quality of Cause-of-Death Reporting (86) (table A).

Unknown and ill-defined causes
I46, J96, P28.5, R00-R94, R96-R99
Immediate and intermediate causes
A41.9, A48.0, A48.3, C77, C78, C79, D50.0, D62, D64.1, D64.9, D65, D69.5, D69.9, D75.1, E03.3, E16.1-E16.2, E21.1, E26.1, E73.1, E85.3, E86, E87, F07.1-F07.2, G91.1, G91.3, G91.8-G91.9, G92, G93.1, G93.3-G93.6, I15, I26, I27.1, I42.9, I47, I48, I49, I50, I80-I82, I95.8-I95.9, J18, J80-J81, J86, J90, J93.8-J94, J98.1, J98.3, K52.9, K65-K66, K72, K74.4, K75.0, K76.0-K76.2, K82.2, K92.0-K92.1, K92.2, L02-L03, L89, M02, M10.4, M15.3, M16.4-M16.7, M17.2-M17.5, M18.2-M18.5, M19.1-M19.2, M41.5, M80.1, M80.3, M81.1, M81.3, M86, M87.3, N17-N19, N35.0-N35.1, N39.0, O10.4, O62.1, P22, P50.9, P54.9, P90
Nonspecific underlying causes of death
A09, A49.9, A64, B34.9, B49, B64, B88.9-B89, B94.9, C26.9, C39.0, C39.9, C57.9, C63.9, C68.9, C72.9, C75.9-C76, C80, C96,9, D01.9, D02.4, D09.9, D13.9, D14.4, D15.9, D28.9, D29.9, D30.9, D33.9, D35.9, D36.9, D37.9, D38.6, D39.9, D40.9, D41.9, D43.9, D44.9, D47.9, D48.9, D68.9, D72.9, D73.9, D75.9, D84.9, D89,9

E07.9, E14, E21.5, E23.7, E27.9, E28.9, E29.9, E31.9, E32.9, E34.9, E88.9, F03, F06.9, F07.9, F09, F99, G31.9, G62.9, G72.9, G90.9, G93.9, G95.9, G96.9, H05.9, H44.9, H69.9, H73.9, H74.9, I25.0, I25.1, I25.9, I28.9, I45.9, I51.6, I51.8, I51.9, I64, I67.9, I69.4, I72.9, I77.9, I78.9, I87.9, I89.9, J22, J39.9, J70.9, J98.9, K22.9, K31.9, K38.9, K62.9, K63.9, K75.9, K76.9, K82.9, K83.9, K86.9, K92.9, L27.9, M50.9, M51.9, M62.9, M72.9, M89.9, M94.9, N05, N28.9, N32.9, N36.9, N39.9, N42.9, N48.9, N50.9, N63, N64.9, N75.9, N83.9, O06,024.9, O26.9, O41.9, O43.9, O71.9, O75.9, O90.9, O95, O96.9, O97.9, O98.9, P00.9, P01.9, P02.9, P03.9, P04.9, P28.9, P29.9, P35.9, P36.9, P37.9, P39.9, P61.9, P72.9, P74.9, P78.9, P83.9, P91.9, P94.9, P96.9, Q28.9, Q34.9, Q45.9, Q64.9, Q79.9, Q89.9, Q97.9, Q98.9, Q99.9, U01.9, V99, W19, W74, W84, X29, X57, X59, X84, X90, Y09, Y34, Y35.7, Y36.9, Y57.9, Y59.9, Y69, Y83.9, Y84.9, Y89.9

As the reports states that the National Center of Health Statistics codes causes of death according to the WHO guidelines, this would imply that these codes comes in addition to the list(s) in the ICD-10 Instruction manual.

22.1.4 Naghavi et al, 2010

From the paper: Algorithms for enhancing public health utility of national causes-of-death data (81) (table 2).

Type 1. Causes that cannot or should not be considered as underlying causes of death.
A31.1, A59, A60.0, A71-A74, A63.0, B00.0, B07, B08.1, B08.8, B30, B35-B36, B94.8, B949.9, F32-F33.9, F40-F42.9, F45-F48.9, F51-F53.9, F60-F98.9, G43-G45.9, G47-G52.9, G54-G54.9, G56-G58.9, G80-G83, H00-H04.9, H05.2-H69.9, H71-H80.9, H83-H93, I10, I15, I70, J30, J33, J34.2, J35, K00-K11.9, K14, L04-L08.9, L20-L25.9, L28-L87.9, L90-L92, L94, L98.0-L98.3, L98.5-L98.9, M03, M07, M09-M12, M14-M25, M35.3, M40, M43.6-M43.9, M45.9, M47-M60, M63-M71, M73-M79, M95-M99,

N39.3, N40, N46, N60, N84-N93, N97, Q10-Q18, Q36, Q38.1, Q54, Q65-Q74, Q82-Q84, R00-R99, Y86, Y87.2, Y89
Type 2. Intermediate causes of death such as heart failure, septicaemia, peritonitis, osteomyelitis, or pulmonary embolism.
A40-A41, A48.0, A48.3, E85.3-E85.9, E86-E87, G91.1, G91.3-G91.8, G92, G93.1-G93.6, I26, I27.1, I44-I45, I49-I50, I74, I81, J69, J80-J81, J86, J90, J93, J93.8-J93.9, J94, J98.1-J98.3, K65-K66, K71-K72 (except K71.7), K75, K76.0-K76.4, K92.0-K92.2, M86, N14, N17-N19
Type 3. Immediate causes of death that are the final steps in a disease pathway leading to death.
D65, I45-I46, J96
Type 4. Unspecified causes within a larger cause grouping.
A49.9, B83.9, B99, C80, C26, C39, C57.9, C64.9, C76, D00-D13, D16-D18, D20-D24, D28-D48, E88.9, I51, I99, X59, Y10-Y34

22.1.5 Phillips et al, 2014

From the paper: A composite metric for assessing data on mortality and causes of death: the vital statistics performance index (91) (Appendix table S2).

Type 1. No inherent information about the underlying cause of death.
A59, A71, A74*, B07, B08, B09, B30, B35, B36, B85, B87, B88, E50, E64*,

F09, F17, F30, F31, F32, F33, F34, F35, F36, F37, F38, F39, F40, F41, F42, F43, F44, F45, F46, F47, F48, F49, F51, F52, F53, F54, F55, F56, F57, F58, F59, F60, F61, F62, F63, F64, F65, F66, F67, F68, F69, F70, F71, F72, F73, F74, F75, F76, F77, F78, F79, F80, F81, F82, F83, F84, F85, F86, F87, F88, F89, F90, F91, F92, F93, F94, F95, F96, F97, F98, F99,
G15, G16, G17, G18, G19, G27, G28, G29, G32, G33, G34, G38, G39, G42, G43, G44, G47*, G48, G49, G50, G51, G52, G53, G54, G55, G56, G57, G58, G59, G60, G62, G63, G64, G65, G66, G67, G68, G69, G74, G75, G76, G77, G78, G79, G84, G85, G86, G87, G88, G89,
H00, H01, H02, H03, H04, H05*, H06, H07, H08, H09, H10, H11, H12, H13, H14, H15, H16, H17, H18, H19, H20, H21, H22, H23, H24, H25, H27, H28, H29, H30, H31, H32, H33, H34, H35, H36, H37, H38, H39, H40, H41, H42, H43, H44, H45, H46, H47, H48, H49, H50, H51, H52, H53, H54, H55, H56, H57, H58, H59, H60, H61, H62, H65, H66, H67, H68, H69, H71, H72, H73, H74, H75, H76, H77, H78, H79, H80, H81, H82, H83, H84, H85, H86, H87, H88, H89, H90, H91, H92, H93, H94, H95, H96, H97, H98, H99,
K00, K01, K02, K03, K04, K05, K06, K07, K08, K09, K10, K11, K12, K13, K14, K15, K16, K17, K18, K19, K30, K31*,
L20, L21, L22, L23, L24, L25, L26, L27, L28, L29, L30, L40, L41, L42, L43, L44, L45, L49, L50, L52, L53, L54, L55, L56, L57, L58, L59, L60, L62, L63, L64, L65, L66, L67, L68, L70, L71, L72, L73, L74, L75, L76, L77, L78, L79, L80, L81, L82, L83, L84, L85, L86, L87, L90, L91, L92, L94, L95, L98*, L99,
M04, M10, M11, M13, M14, M15, M16, M17, M18, M22, M23, M24, M25, M26, M27, M28, M29, M37, M38, M39, M43*, M44, M45, M46, M47, M48, M49*, M50, M51, M52, M53, M54, M55, M56, M57, M58, M59, M60, M61, M62, M63, M64, M65*, M66, M67, M68, M69, M70, M71*, M72, M73*, M74, M75, M76, M77, M78, M79, M80, M81, M82, M83, M84, M85, M89*, M90, M91, M92, M93, M94, M95, M96, M97, M98, M99, N09,
N24, N32*, N33, N35, N37, N38, N40, N42, N43, N46, N47, N48, N52, N53, N54, N55, N56, N57, N58, N59, N60, N61, N62, N63, N64, N66, N67, N68, N69, N78, N79, N85, N86, N88, N89, N90, N91, N95, N97,
Q08, Q09, Q10*, Q19, Q29, Q36, Q46, Q47, Q48, Q49, Q88, Q94,
R07, R08, R09, R12, R14, R15, R19*, R20, R21, R22, R23, R24, R25, R26, R27, R28, R29, R30, R32, R33, R34, R35, R36, R37, R38, R39, R41, R42, R43, R44, R45, R46, R47, R48, R49, R51, R52, R53, R55, R57, R58, R59, R60, R61, R62, R63, R64, R65, R66, R67, R68, R69, R70, R71, R72, R74, R75, R76, R77, R78*, R79, R80, R81, R82, R83, R84, R85, R86, R87, R88, R89, R90, R91, R92, R93, R94, R95, R96, R97, R98, R99,
U04,
Z00, Z01, Z02, Z03, Z04, Z05, Z06, Z07, Z08, Z09, Z10, Z11, Z12, Z13, Z14, Z15, Z16, Z17, Z18, Z19, Z20, Z21, Z22, Z23, Z24, Z25, Z26, Z27, Z28, Z29, Z30, Z31, Z32, Z33, Z34, Z35, Z36, Z37, Z38, Z39, Z40, Z41, Z42, Z43, Z44, Z45, Z46, Z47, Z48, Z49, Z50, Z51, Z52, Z53, Z54, Z55, Z56, Z57, Z58, Z59, Z60, Z61, Z62, Z63, Z64, Z65, Z66, Z67, Z68, Z69, Z70, Z71, Z72, Z73, Z74, Z75, Z76, Z77, Z78, Z79,

Z80, Z81, Z82, Z83, Z84, Z85, Z86, Z87, Z88, Z89, Z90, Z91, Z92, Z93, Z94, Z95, Z96, Z97, Z98, Z99
Type 2. Informative about the underlying cause of death but sub-optimal.
A14, A29, A40, A41, A45, A47, A48*, A49*, A61, A62, A64, A72, A73, A76, A97, A99, B11, B12, B13, B14, B17*, B19*, B28, B31, B32, B34, B55*, B61, B62, B64, B82, B83*, B84, B89, B93, B94*, B95*, B96, B97, B98, B99, C14, C26, C27, C28, C29, C35, C36, C39, C42, C46, C55, C57*, C59, C63*, C68*, C75*, C76, C77, C78, C79, C80, C87, C98, C99, D00*, D01*, D02*, D07*, D08, D09*, D10*, D13*, D14*, D17, D18, D19, D20, D21, D26*, D28*, D29*, D30*, D36*, D37*, D38*, D39*, D40*, D41*, D44*, D48*, D49*, D54, D59*, D75*, D79, D84*, D85, D87, D88, D89*, D90, D91, D92, D93, D94, D95, D96, D97, D98, D99, E07*, E08, E17, E18, E19, E34*, E35, E37, E38, E39, E47, E48, E49, E62, E69, E90, E91, E92, E93, E94, E95, E96, E97, E98, E99, F06*, F07*, F08, F50*, G00*, G01, G02, G03*, G09, G91, G93*, G94, G96, G98, G99, H26, I00, I03, I04, I14, I16, I17, I18, I19, I29, I32, I43, I50, I51*, I52, I53, I54, I55, I56, I57, I58, I59, I62*, I64, I67*, I68, I69*, I79, I90, I92, I93, I94, I98*, I99, J07, J08, J15*, J17, J18, J19, J22, J23, J24, J25, J26, J27, J28, J29, J48, J49, J50, J51, J52, J53, J54, J55, J56, J57, J58, J59, J64, J71, J72, J73, J74, J75, J76, J77, J78, J79, J81, J83, J85, J87, J88, J89, J90, J93, J97, J98, J99, K23, K24, K32, K33, K34, K39, K47, K48, K49, K53, K54, K63*, K69, K75*, K78, K79, K84, K87, K88, K89, K92*, K93*, K96, K97, K98, K99, L06, L07, L09, L15, L16, L17, L18, L19, L31, L32, L33, L34, L35, L36, L37, L38, L39, L46, L47, L48, L61, L69, L96, M12*, M19, M20, M21, M87*, N39*, N84*, O08, O17, O18, O19, O27, O37, O38, O39, O49, O50, O51, O52, O53, O54, O55, O56, O57, O58, O59, O78, O79, O93, O94, O95, P06, P16, P17, P18, P30, P31, P32, P33, P34, P40, P41, P42, P43, P44, P45, P46, P47, P48, P49, P62, P63, P64, P65, P66, P67, P68, P69, P73, P79, P82, P85, P86, P87, P88, P89, P96*, P97, P98, P99, Q89*, Q99*, R54, S00, S01, S02, S03, S04, S05, S06, S07, S08, S09, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20, S21, S22, S23, S24, S25, S26, S27, S28, S29, S30, S31, S32, S33, S34, S35, S36, S37, S38, S39, S40, S41, S42, S43, S44, S45, S46, S47, S48, S49, S50, S51, S52, S53, S54, S55, S56, S57, S58, S59, S60, S61, S62, S63, S64, S65, S66, S67, S68, S69, S70, S71, S72, S73, S74, S75, S76, S77, S78, S79, S80, S81, S82, S83, S84, S85, S86, S87, S88, S89, S90, S91, S92, S93, S94, S95, S96, S97, S98, S99,

T00, T01, T02, T03, T04, T05, T06, T07, T08, T09, T10, T11, T12, T13, T14, T15, T16, T17, T18, T19, T20, T21, T22, T23, T24, T25, T26, T27, T28, T29, T30, T31, T32, T33, T34, T35, T36, T37, T38, T39, T40, T41, T42, T43, T44, T45, T46, T47, T48, T49, T50, T51, T52, T53, T54, T55, T56, T57, T58, T59, T60, T61, T62, T63, T64, T65, T66, T67, T68, T69, T70, T71, T73, T74, T75, T76, T78, T79, T80, T81, T82, T83, T84, T85, T86, T87, T88, T90, T91, T92, T93, T94, T95, T96, T97, T98, V87*, V88*, V89, V90*, V99, W47, W48, W63, W71, W72, W82, W95, W96, W98, X07, X41, X42, X44, X55, X56, X59, Y09, Y10, Y11, Y12, Y13, Y14, Y15, Y16, Y17, Y18, Y19, Y20, Y21, Y22, Y23, Y24, Y25, Y26, Y27, Y28, Y29, Y30, Y31, Y32, Y33, Y34, Y85, Y86, Y87*, Y89*, Y90, Y91, Y92, Y93, Y94, Y95, Y96, Y97, Y98, Y99
* At least one corresponding 4-digit code not classified as garbage code

22.1.6 "Early" GBD

As exemplified from GBD 2015: Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015 (100) (Appendix table 7).

Garbage Code (not further specified)
A01, A14.9, A29, A31-A31.9, A40-A45.9, A47-A48.0, A48.3, A48.8-A49.02, A49.2-A49.9, A59-A59.9, A61-A62, A64-A64.0, A71-A73, A74.0, A76, A97, A99-A99.0, B07-B09, B11-B14, B28-B29, B30-B32.4, B34-B46.9, B49-B49.9, B54-B55, B55.1-B55.9, B58-B59.9, B61-B62, B64, B68-B68.9, B73-B74.2, B76-B76.9, B78-B82.9, B83.9-B85.4, B87-B89, B93-B94.0, B94.8-B94.9, B95.6-B99.9, C14-C14.9, C26-C29, C35-C36, C39-C39.9, C42, C46-C46.9, C55-C55.9, C57.9, C59-C6, C63.9, C68, C68.9, C75.9-C80.9, C87, C97 D00.0, D01, D01.4-D02, D02.4-D02.9, D07, D07.3-D07.39, D07.6-D09, D09.1-D09.19, D09.7, D09.9-D10, D10.9, D13, D13.9-D14, D14.4, D17-D21.9, D28, D28.9-D29, D29.9-D30, D30.9, D36.0, D36.9-D37.0, D37.6-D38, D38.6-D39.0, D39.7, D39.9-D40, D40.9-D41, D41.9, D44, D44.9, D46-D46.9, D47.1, D48, D48.7-D49.1, D49.5, D49.7-D49.8, D49.89-D50.0, D50.9, D54, D59, D59.4, D59.8-D59.9, D62-D63.0, D63.8-D64, D64.1-D64.2, D64.8-D65.9, D68, D69.9, D75.9, D79-D85, D87-D88, D89.8-D99, E07.8-E08.9, E15, E16, E17-E19, E34.9-E35.8, E37-E39, E47-E50.9, E62, E64.1, E69, E85.3-E87.70, E87.79-E87.99, E90-E998, F04-F06.1, F06.3-F07.0, F07.2-F09.9, F17-F17.9, F30-F50, F50.8-F99, G00, G00.9-G02.8, G03.9, G06-G09.9, G15-G19, G27-G29, G32-G34, G38-G39, G42-G44.89, G47-G47.29, G47.4-G60.9, G62-G69, G74-G89.4, G91-G93.6, G93.8-G94.8, G96-G96.9, G98-G99.8

H00-H05, H05.12-H69.93, H71-H99, I00.0, I03-I04, I10-I10.9, I14-I19, I26-I27.0, I27.2-I27.9, I28.9-I29.9, I31.2-I31.4, I44-I46.9, I49-I51, I51.6-I59, I62, I62.1-I62.9, I64-I64.9, I67, I67.4, I67.8-I68, I68.8-I69, I69.4-I70.1, I70.8-I70.92, I74-I76, I90, I92-I95.1, I95.8-I96.9, I98.4-I98.8, I99 J00.0, J02, J02.8-J03, J03.8-J04, J04.1-J04.31, J05.1-J05.10, J06-J08, J15.9, J17-J19.6, J22-J29, J48-J59, J64-J64.9, J69-J69.9, J71-J81.9, J83, J85-J90.9, J93-J94.9, J96-J99.8, K00-K19, K30, K31.9-K34, K39, K47-K49, K53-K54, K63-K63.4, K63.8-K63.9, K65-K66.1, K66.9, K69, K71-K71.2, K71.6, K71.8-K72.01, K75-K75.1, K78-K79, K84, K87-K89, K92-K92.2, K92.9-K93, K93.1-K93.8, K96-K99, L06-L07, L09, L15-L50.9, L52-L87.9, L90-L92.9, L94-L96, L98.5-L99.8, M04, M10-M12.09, M12.2-M29, M37-M39, M43.2-M49, M49.2-M64, M65.1-M71, M71.2-M73, M73.8-M79.9, M83-M86.29, M86.5-M86.9, M87.2-M87.9, M89.1-M89.49, M90-M99.9, N09, N13-N13.9, N17-N17.9, N19-N19.9, N24, N32.1-N32.2, N32.8-N33.8, N35-N35.9, N37-N38, N39.3-N40.9, N42-N43.42, N44.1-N44.8, N46-N48.9, N50-N59, N61-N64.9, N66-N69, N78-N79, N82-N82.9, N84, N84.2-N86, N88-N95.9, N97-N97.9, O08-O08.9, O17-O19, O27, O37-O39, O49-O59, O78-O79, O93-O95.9, P06, P16-P18, P23, P23.5-P23.9, P30-P34.2, P37.3-P37.4, P40-P49, P62-P69, P73, P79, P82, P85-P89, P96.9-P99.9, Q08-Q10.3, Q19, Q29, Q36.0-Q36.9, Q46-Q49, Q88, Q89.9, Q94, Q99.9 R00-R19.6, R19.8-R50.1, R50.8-R50.81, R50.84-R72.9, R74-R78, R78.6-R94.8, R95.0-R99, T00-T71.161, T71.163-T98.3, U00-U03, U05-U99, V87-V87.1, V87.4-V88.1, V88.4-V89.9, V99-V99.0, W47-W48, W63, W71-W72, W76-W76.9, W82, W95-W97, W98, X07, X40-X44.9, X47.0, X47.9, X49-X49.9, X55-X56, X59-X59.9, Y09-Y34.9, Y85-Y87, Y87.2, Y89, Y89.9

22.1.7 “Late” GBD

As exemplified from GBD 2019: Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019 (39) (Appendix table S5).

This is the definition used in the present study.

Garbage Code (GBD Level 1)
A40-A41.9, A48.0, A48.3, A49.0-A49.1, A59-A59.9, A71-A71.9, A74.0,

B07-B07.9, B30-B30.9, B35-B36.9, B85-B85.4, B87-B88.9, B94.0, D50-D50.0, D50.9, D62-D63.0, D63.8-D64, D64.1-D65.9, D68, D69.9, E15, E16, E50-E50.9, E64.1, E85.3-E87.6, E87.8-E87.9, F06.2-F06.4, F07.2, F09-F09.9, F19-F23.9, F25-F49, F51-F99.0, G06-G08.0, G32-G32.8, G43-G44.2, G44.4-G44.8, G47-G47.2, G47.4-G47.9, G50-G60.9, G62-G62.0, G62.2-G65.2, G80-G83.9, G89-G89.4, G91-G91.2, G91.4-G93, G93.1-G93.2, G93.4-G93.6, G94.0-G94.8, G99-G99.8, H00-H05, H05.2-H69.9, H71-H99, I26-I26.9, I31.2-I31.4, I46-I46.9, I50.0-I50.4, I76, I95-I95.1, I95.8-I95.9, J69-J69.9, J80-J80.9, J81.0, J85-J85.3, J86-J86.9, J93-J93.1, J93.8-J93.9, J94.2, J96-J96.9, J98.1-J98.3, K00-K19, K30, K65-K66.1, K66.9, K68.1-K68.9, K71-K71.6, K71.8-K72.9, K75.0, L20-L30.9, L40-L50.9, L52-L54.8, L56-L56.2, L56.4-L56.5, L57-L57.9, L59- L68.9, L70-L76.8, L80-L87.9, L90-L92.9, L94-L96, L98.5-L99.8, M04, M10-M12.0, M12.2-M29, M37-M39, M43.2-M49, M49.2-M64, M65.1-M71, M71.2-M72.4, M72.8-M73, M73.8-M79.9, M83-M86.2, M86.5-M86.9, M87.2- M87.9, M89.1-M89.4, M90-M99.9, N17-N17.9, N19-N19.9, N32.1-N32.2, N32.8-N33.8, N35-N35.9, N37-N37.8, N39.3-N39.8, N42-N43.4, N44.1-N44.8, N46-N48.9, N50-N53.9, N61-N64.9, N82-N82.9, N91-N91.5, N95, N95.1-N95.9, N97-N97.9, R02-R02.9, R03.1, R07.0, R08-R09, R09.3, R11-R12.0, R14-R19.6, R19.8-R23, R23.1-R30.9, R32-R50.1, R50.8-R57.9, R58.0-R72.9, R74-R78, R78.6-R94.8, R96-R99.9, U05, U07-U81, U89.9-U99, X40-X44.9, X46-X46.9, X49-X49.9, Y10-Y14.9, Y16-Y19.9, Z00-Z15.8, Z17-unsp.
Garbage Code (GBD Level 2)
A14.9, A29-A30.9, A45-A45.9, A47-A48, A48.8-A49, A49.3-A49.9, A61-A62, A72-A73, A76, A97, B08-B09, B11-B14, B28-B29, B31-B32.4, B34-B34.9, B61-B62, B68-B68.9, B73- B74.2, B76-B76.9, B78-B81.8, B84, B92-B94, B94.8-B94.9, B95.6, B97.3, B97.7- B99.9, D59, D59.4, D59.8-D59.9, F17-F17.9, G44.3, G91.3, G93.0, G93.3, I10-I10.9, I15-I15.9, I27, I27.8-I27.9, I50, I50.8-I50.9, I67.4, I70-I70.1, I70.9, I74- I75.8, J81, J81.1, J90-J90.0, J94-J94.1, J94.8-J94.9, K92.0-K92.2, N70-N71.9, N73-N74.0, N74.2-N74.8, R03-R03.0, R04-R06.9, R09.0-R09.2, R09.8-R10.9, R13-R13.9, R23.0, R58,

S00-T98.3, W47-W48, W63, W71-W72, W76-W76.9, W82, W95-W97, W98, X07, X55-X56, X59-X59.9, Y20-Y34.9, Y86-Y87, Y87.2, Y89, Y89.9-Y99.9
Garbage Code (GBD Level 3)
A01, A31-A31.9, A42-A44.9, A49.2, A64-A64.0, A99-A99.0, B17, B17.1, B17.8-B17.9, B19-B19.0, B19.2-B19.9, B37-B46.9, B49-B49.9, B55, B55.1-B55.9, B58-B59.9, B89, B94.2, C14-C14.9, C22.9, C26-C29, C35-C36, C39-C39.9, C42, C46-C46.9, C55-C55.9, C57.9, C59, C63.9, C68, C68.9, C74-C74.9, C75.9-C80.9, C87, C97, D00.0, D01, D01.4-D02, D02.4-D02.9, D07, D07.3, D07.6-D09, D09.1, D09.7, D09.9-D10, D10.9, D13, D13.9-D14, D14.4, D17-D21.9, D28, D28.9-D29, D29.9-D30, D30.9, D36.0, D36.9-D37.0, D37.6-D38, D38.6-D39.0, D39.7, D39.9-D40, D40.9-D41, D41.9, D44, D44.9, D48, D48.7-D49.1, D49.5, D49.7-D49.9, D54, D75.9, D79-D85, D87-D88, D89.8-D99, E07.8-E08.9, E17-E19, E34.0, E34.9-E35.8, E37-E39, E47-E49., E62, E69, E87.7, E90-E998, F04-F06.1, F06.5-F07.0, F07.8-F08, F50, F50.8-F50.9, G09-G09.9, G15-G19, G21, G21.2, G21.4-G22.0, G27-G29, G33-G34, G38-G39., G42, G48-G49, G66-G69, G74-G79, G84-G88, G93.8-G94, G96-G96.9, G98-G98.9, I00.0, I03-I04., I14-I14., I16-I19, I29-I29.9, I44-I45.9, I49-I49.9, I51, I51.6-I59, I90-I94, I96-I96.9, I98.4-I98.8, I99-ID5.9, J02.9, J03.9, J04.3, J06, J06.9, J40-J40.9, J47-J59, J71-J79, J81.9, J83, J85.9, J87-J89, J90.9, J93.6, J97-J98.0, J98.4-J99.8, K21-K21.9, K22.7, K31.9-K34, K39, K47-K49, K53-K54, K63-K63.4, K63.8-K63.9, K69, K70.4-K70.9, K78-K79, K84, K87-K89, K92, K92.9-K93, K96-K99, L06-L07, L09, L15-L19, L31-L39, L69, L77-L79, N09, N13-N13.5, N13.7-N13.9, N24, N28.8-N28.9, N38, N39.9-N40.9, N54-N59, N66-N69, N78-N79, N84, N84.2-N86, N88-N90.9, N92-N94.9, N95.0, O08-O08.9, O17-O19, O27, O37-O39, O49-O59, O78-O79, O93-O95.9, P06, P16-P18, P30-P34.2, P40-P49, P62-P69, P73, P79, P82, P85-P89, P96.9-P99.9, Q08-Q10.3, Q19, Q29-Q29., Q36.0-Q36.9, Q46-Q49, Q88, Q89.9, Q94, Q99.9 R00-R01.2, R07, R07.1-R07.9, R31-R31.9
Garbage Code (GBD Level 4)
B16.9, B64, B82-B82.9, B83.9, C69, C69.9, C91.1, C91.4-C91.5, C91.7-C91.9, C92.7-C92.9, C93.2, C93.5-C93.7, C93.9, E12-E14.9, G00, G00.9-G02.8, G03.9, I37.9, I42-I42.0, I42.9, I51.5, I64-I64.9, I67, I67.8-I68, I68.8-I69, I69.4-I69.9, J07-J08, J15.9, J17-J19.6, J22-J29, J64-J64.9,

P23, P23.5-P23.9, P37.3-P37.4, R73-R73.9, V87-V87.1, V87.4-V88.1, V88.4-V89.9, V99-V99.0, X84-X84.9, Y09-Y09.9, Y85-Y85.9

22.2 Regulations concerning non-natural deaths and forensic autopsies in Norway

Author's translations

22.2.1 The criminal procedure act ("straffeprosessloven") (144)

§228. An expert autopsy shall be carried out when there is reason to suspect that any person's death has been caused by a criminal act. The prosecuting authority may also otherwise decide that an expert autopsy shall be carried out when the cause of death is uncertain and special circumstances require such an examination. The King will prescribe further regulations relating to expert autopsy, including the cases in which such an examination should be carried out.

22.2.2 The prosecution instructions ("påtaleinstruksen") (148)

§13-1. The police shall demand an expert autopsy when there is reason to suspect that any person's death has been caused by a criminal act. The same is the case when a dead person is discovered and the identity is not immediately clear.

§13-2. The police shall normally demand an expert autopsy when the cause of death is uncertain and may be caused by:

a) Suicide or self-inflicted injury
b) Accident
c) Work-related injury or disease
d) Medical misadventure

The same is the case when the cause of death is uncertain and the death is sudden and unexpected, in particular if there is reason to believe that the deceased has been alone at the time of death.

The police shall demand an expert autopsy when a child under 18 years of age dies outside health care institution and the cause of death is uncertain, unless obvious reasons make this unneccesary.

The police shall normally demand an expert autopsy when the cause of death is uncertain and ad the death has occurred in prison or police arrest.

These regulations is not a hindrance for demanding an expert autopsy in other cases, as long as the qualifications of the law are fulfilled.

22.2.3 Law concerning autopsies ("obduksjonslova") (179)

§7a. All casualties in road traffic accidents shall be autopsied. If the prosecution authorities does not demand an autopsy according to §228 in the criminal procedure act, the police shall authorize an autopsy according to this law. The purpose of the autopsy is to ascertain the cause of death, signs of disease and injury, ingestion of medicines and poisonous substances, and relate the findings to the circumstances regarding the death. […]

22.2.4 Regulation concerning notification to the police in case of non-natural deaths (147)

§1. If there is reason to believe that a death is non-natural, doctors have a duty to notify the police as soon as possible, cf. §36 in the health personnel act. […]

§2. A death is considered non-natural if the cause might be:

- Homicide or other inflicted violence
- Suicide or self-inflicted injury
- Accident such as shipwreck, fire, landslide, lightning, drowning, fall, traffic accident etc.

- Work-related accident or injury
- Medical misadventure
- Drug abuse
- Sudden and unexpected death of uncertain cause
- Death in prison or police or military arrest
- Unidentified bodies

22.3 Classification of categorical factors in the papers

22.3.1 Nature of injury

As used in paper II.

Categories used in the study	**ICD-10 codes**
1. Head and neck injuries	S00-S19.9
2. Thoracic injuries	S20-S29.9
3. Injuries to abdomen and pelvis	S30-S39.9
4. Injuries to hip and thigh	S70-S79.9
5. Other mechanical injuries, multitrauma	S40-S69.9, S80-T14.9
6. Poisoning	T36-T65.9
7. Suffocation/drowning	T17-T17.9, T71, T75.1
8. Other injuries, sequelae	T15-T16, T18-T35.7, T66-T70.9, T73-T75.0, T75.2-T98.3

22.3.2 External underlying cause of death

As used in paper II.

Categories used in the study	ICD-10 codes
1. Road traffic accidents	V00-V89.9, Y85.0
2. Accidental falls	W00-W19.9
3. Accidental poisonings	X40-X49.9
4. Other accidents and events of undetermined intent	V90-V99, W20-X39.9, X50-X58, Y10-Y84, Y85.9-Y86, Y87.2-Y89.9
5. Exposure to unspecified factor (X59)	X59, X59.0, X59.9
6. Intentional self-harm (Suicide)	X60-X84, Y87.0
7. Assault (Homicide)	X85-Y09, Y87.1

22.3.3 Causes of death

As used in paper III.

Categories used in the study	ICD-10 codes
1. Natural	A00-Q99 (except F11-F12, F14-F16, F19), R95
2. Ill-defined	R00-R99 (except R95)
3. Traffic accidents	V00-V89, Y85.0
4. Accidental falls	W00-W19, X59 in combination with S72
5. Accidental poisonings	X40-X49, F11-F12, F14-F16, F19
6. Other accidents and events of undetermined intent	V90-V99, W20-X39.9, X50-X59, Y10-Y84, Y85.9-Y86, Y87.2-Y89.9
7. Intentional self-harm (suicide)	X60-X84, Y87.0
8. Assault (homicide)	X85-Y09, Y87.1

22.3.4 Place of death

Categories used in the study	Categories from NCoDR data
At home	5: At home (“Hjemme”)
Hospital	1: Somatic hospital (“Somatisk sykehus”) 2: Psychiatric hospital (“Psykiatrisk sykehus”)
Nursing home	3: Nursing home (“Pleie- og omsorgsinstitusjon») 4: Other health care institution (“Other health care institutions”)
Other known	6: Under transport to hospital (“Under transport til sykehus”)

	8: Other known (“Annet oppgitt”)
Unknown	0: Abroad (“I utlandet”) 9: Unknown (“Uoppgitt”)

23. Papers I-III

Paper I

BMC Public Health

RESEARCH

Open Access

Garbage codes in the Norwegian Cause of Death Registry 1996–2019

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Abstract

Background: Reliable statistics on the underlying cause of death are essential for monitoring the health in a population. When there is insufficient information to identify the true underlying cause of death, the death will be classified using less informative codes, garbage codes. If many deaths are assigned a garbage code, the information value of the cause-of-death statistics is reduced. The aim of this study was to analyse the use of garbage codes in the Norwegian Cause of Death Registry (NCoDR).

Methods: Data from NCoDR on all deaths among Norwegian residents in the years 1996–2019 were used to describe the occurrence of garbage codes. We used logistic regression analyses to identify determinants for the use of garbage codes. Possible explanatory factors were year of death, sex, age of death, place of death and whether an autopsy was performed.

Results: A total of 29.0% (290,469/1,000,128) of the deaths were coded with a garbage code; 14.1% (140,804/1,000,128) with a major and 15.0% (149,665/1,000,128) with a minor garbage code. The five most common major garbage codes overall were ICD-10 codes I50 (heart failure), R96 (sudden death), R54 (senility), X59 (exposure to unspecified factor), and A41 (other sepsis). The most prevalent minor garbage codes were I64 (unspecified stroke), J18 (unspecified pneumonia), C80 (malignant neoplasm with unknown primary site), E14 (unspecified diabetes mellitus), and I69 (sequelae of cerebrovascular disease).

The most important determinants for the use of garbage codes were the age of the deceased (OR 17.4 for age $\geq$ 90 vs age < 1) and death outside hospital (OR 2.08 for unknown place of death vs hospital).

Conclusion: Over a 24-year period, garbage codes were used in 29.0% of all deaths. The most important determinants of a death to be assigned a garbage code were advanced age and place of death outside hospital. Knowledge of the national epidemiological situation, as well as the rules and guidelines for mortality coding, is essential for understanding the prevalence and distribution of garbage codes, in order to rely on vital statistics.

Keywords: Cause of death, Death certificate, Cause of death register, Garbage code, Non-informative code

Background

Reliable vital statistics on the numbers of births and deaths – including causes of death – are essential for monitoring the health in a population [1], but not all cause of death data are fit for purpose [2]. The World Health Organization (WHO) defines the underlying cause of death as: "(a) the disease or injury which initiated the train of morbid events leading directly to death,

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or (b) the circumstances of the accident or violence which produced the fatal injury" [3]. It is the underlying cause of death that gives most information on the aetiology and thus possible targets for prevention. The International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10) [4], does not only provide entities suitable for stating the (underlying) cause of death, but also for non-fatal diseases, for symptoms and signs or for conditions that could be an intermediate or terminal complication.

When there is insufficient information on the death certificate to identify the true underlying cause of death, the death will be classified using less informative codes. In the instruction manual for ICD-10, there are lists of ill-defined conditions and conditions unlikely to cause death [3], and these should be avoided, if possible. The term "garbage codes" was introduced by Murray and Lopez in 1996 as part of the Global Burden of Disease (GBD) framework to describe codes that are not useful for public health analysis [5, 6]. If many deaths are assigned a garbage code as the underlying cause of death, the true mortality pattern may be biased. In studies assessing the quality of cause of death data, the proportion of deaths assigned an ill-defined or garbage code has been one of the parameters used.

The list of garbage codes has been developed during the iterations of the GBD analyses, reflecting changes in the view of the origin and public health relevance [5, 7, 8]. In the current definition of garbage codes according to the GBD, there are 4 levels of garbage codes, reflecting the severity of public health implications. For level 1, the true underlying cause of death might belong to any of the three broad groups of causes of death (communicable, maternal, neonatal and nutritional disease; non-communicable diseases; injuries), and the information value of the garbage code is thus very limited. For level 2, the true underlying cause of death might belong to one (or at most two) of the three broad groups of causes of death. For level 3, the true underlying cause of death is likely to be within the same ICD chapter, and for level 4 the true underlying cause of death is likely to be within a single disease or injury category [6, 8]. For level 3 and 4, the spectrum of possible true underlying cause of death is narrower, and the garbage code has at least some information value.

Level 1 and 2 are major garbage codes, while level 3 and 4 are minor garbage codes. Examples of major garbage codes are sudden death, heart failure and unspecified sepsis, and of minor garbage codes unspecified stroke and cancer of unknown primary site.

The quality of the data in the Norwegian Cause of Death Registry (NCoDR) has been ranked as "medium" to "high" [9–12]. In 1980–2017, between 8 and 16% of the cases in NCoDR has been assigned a major garbage code, with the highest proportions in the more recent years. The closest neighbouring countries, Denmark and Sweden, have similar figures. Finland, Hungary and New Zealand are among countries with lowest proportion, 4–6% major garbage codes [7] (The numbers can be found in the supplementary appendix to the referenced article.)

Aim

Our aim was to provide an in depth study of garbage codes in Norwegian cause of death data from 1996 to 2019.

1. Investigate the magnitude and pattern of use of garbage codes in the Norwegian Cause of Death Registry.
2. In the deaths coded with a garbage code as the underlying cause of death, are there other, more informative diagnoses ("non-garbage codes") elsewhere on the death certificate?

Materials and methods

Materials

We used data from the Norwegian Cause of Death Registry (NCoDR) [13], on all deaths among Norwegian residents in the years 1996–2019 ($N = 1{,}013{,}802$). We chose 1996, when ICD-10 was introduced in the registry, as the start of the study period. We used the following variables: calendar year of death, sex, age at death, underlying cause of death (ICD-10 code) as well as all diagnoses entered on the death certificate (ICD-10), the (type of) place of death, and whether an autopsy (forensic or medical) was performed. The NCoDR selects the underlying cause of death according to the rules and guidelines provided by the WHO (ICD-10) [3], using the IRIS software [14]. A brief description of the processing at NCoDR has been published earlier [13]. Until 2017, all deaths were certified manually, on paper. Electronic certification of death was gradually introduced with a pilot in 2017, in the beginning available to only some hospitals and municipalities. It was not compulsory until January 2022. In 2017, 1 death was electronically certified, 75 in 2018, and in 2019 (the last year of the study period), 1231, 3% of the deaths were electronically certified. (The proportion increased to 37% in 2020 and 79% in 2021 (the last year with a dual system) (AG Pedersen, NCoDR, personal communication).)

Data from both manual and electronic certification was used, but the dataset does not contain information on which deaths that were certified electronically or on paper.

From the Global Burden of Disease Study (GBD), we used the mapping list from ICD-10 codes to the GBD cause list, including the list of garbage codes [7] (Table S4 in the supplemental material).

Methods

Garbage codes in GBD class 1 and 2 were defined as major garbage codes, class 3 and 4 as minor. For tabulation of non-garbage codes, we used level 3 of the GBD cause list. For descriptive purposes, we grouped garbage codes that only differed in the fourth character of the ICD-10 code. In cases where both garbage and non-garbage codes were defined within the same 3-digit ICD-10 level, only the garbage codes were counted.

We used logistic regression analyses to identify determinants for the use of garbage codes. The outcome variables were whether the death was assigned a garbage code (any garbage code, major or minor) as the underlying cause of death. Possible explanatory factors were calendar year of death in 5 groups (4 or 5 year), sex, age of death in 7 groups, the (type of) place of death in five groups (hospital, nursing home, at home, other known, unknown), and whether an autopsy (either medical or forensic) was performed.

We used direct age standardization with the distribution of age of death in Norway 2015 as the age standard.

For all statistical analyses, we used R (version 4.0.4) and RStudio (version 1.4.1103) with additional packages from epitools and the Tidyverse collection [15–17]. We used Wilson's method for calculating confidence intervals for proportions. For logistic regression, we calculated odds ratios with 95% confidence interval, likelihood ratio statistics (−2LogLikelihood) and two-sided p values. A two-sided p value <0.05 was considered statistically significant.

Results

Overview over the data material

During 1996–2019, NCoDR had registered 1,013,802 deaths in Norwegian residents. After removal of deaths with missing death certificates, 1,000,128 (98.7%) remained, 513,851 women (51.4%) and 486,277 men (48.6%). The number of deaths each year varied between 39,110 (2019) and 44,825 (1999). During the study period, the median age of death rose from 82 to 85 year in women, and from 76 to 79 years in men. 50% of the deaths (Q1-Q3) in women occurred in the age interval 76–90 years, in men 68–85 years. The proportion of deaths occurring in hospitals declined from 40.9% (1996) to 29.5% (2019), whereas the proportion occurring in nursing homes rose from 36.8 to 52.6%.

For the entire study period, 29.0% (290,469/1,000,128) of the deaths were coded with a garbage code; 140,804 (14.1%) with a major and 149,665 (15.0%) with a minor garbage code.

The most common garbage codes

Table 1 shows the most used major and minor garbage codes. The three most common major garbage codes were I50 (heart failure), R96 (sudden death), and R54 (senility), together accounting for 43.4% of the major garbage codes. The most common minor garbage codes were I64 (unspecified stroke), J18 (unspecified pneumonia), and C80 (malignant neoplasm with unknown primary site), together 64.6% of minor garbage codes. We found no considerable sex differences in the overall ranking.

We found another spectrum of garbage codes in the young. For deaths in the 15–49 years age group, three groups of accidental poisonings (X42, X44, and X41) accounted for 53.2% of the major garbage codes, and F19 (unspecified drug abuse) for another 8.1%.

There were also differences according to the place of death, especially for major garbage codes. In hospitals, the most common major garbage codes were I50 (heart failure) and A41 (other sepsis), in nursing homes I50 (heart failure) and R54 (senility). In deaths outside health care institutions, R99 (unknown cause of death), R96 (sudden death), I46 (cardiac arrest), I50 (heart failure) and X42 (accidental poisoning with narcotic or psychodysleptics) were common. The most common minor garbage codes were I64 (unspecified stroke) and J18 (unspecified pneumonia) in deaths at hospitals and nursing homes, whereas I51 (ill-defined heart disease), and I64 (unspecified stroke) were commonly used in deaths occurring outside health care facilities.

Detailed tables are presented in the supplemental material, Tables S2a-d.

Garbage codes over time

For major garbage codes, there were fluctuations over time, with an increasing tendency overall and a peak in 2013. In the first four years of the study period (1996–1999), the proportions of deaths coded with a major garbage code were 13.5% in women, 9.9% in men. In the last five years (2015–2019), the proportions were 15.3% in women, 12.5% in men.

A reduction in the proportion of deaths coded with minor garbage codes was found for both sexes. In the first four years of the study period, the proportions were 20.9% in women, 15.2% in men. In the last five years, the proportions were 12.3% in women, 10.8% in men (Fig. 1, Table 2).

Change in pattern of garbage codes

No single pattern explained the change in the proportion of deaths with a major garbage code. The slow

Table 1 The most common garbage codes in Norway 1996–2019

Diagnostic code	*N*	*Percent of all deaths (95% CI)*	*Percent of GC in group*
ALL DEATHS, *N* = 1,000,128			
Major GC	*140,804*	*14.1 (14.0–14.1)*	
I50 Heart failure	36,683	3.7 (3.6–3.7)	26.1
R96 Sudden death	14,127	1.4 (1.4–1.4)	10.0
R54 Senility	10,298	1.0 (1.1–1.1)	7.3
X59 Exposure to unspecified factor	9415	0.9 (0.9–1.0)	6.7
A41 Other sepsis	6574	0.7 (0.6–0.7)	4.7
N19 Unspecified kidney failure	6173	0.6 (0.6–0.6)	4.4
R99 Unknown cause of death	5966	0.6 (0.6–0.6)	4.2
I10 Essential hypertension	5409	0.5 (0.5–0.6)	3.8
B99 Unspecified infectious diseases	4188	0.4 (0.4–0.4)	3.0
I70 Atherosclerosis	3731	0.4 (0.4–0.4)	2.6
Minor GC	*149,665*	*15.0 (14.9–15.0)*	
I64 Unspecified stroke	43,814	4.4 (4.3–4.4)	29.3
J18 Unspecified pneumonia	41,753	4.2 (4.1–4.2)	27.9
C80 Malignant neoplasm, unknown primary site	11,013	1.1 (1.1–1.1)	7.4
E14 Unspecified diabetes mellitus	10,425	1.0 (1.0–1.1)	7.0
I69 Sequelae of cerebrovascular disease	10,124	1.0 (1.0–1.1)	6.8
I51 Ill-defined heart disease	8673	0.9 (0.8–0.9)	5.8
I49 Unspecified cardiac arrythmia	1981	0.2 (0.2–0.2)	1.3
C91 Lymphoid leukemia (unspecified)	1919	0.2 (0.2–0.2)	1.3
I42 Unspecified cardiomyopathy	1906	0.2 (0.2–0.1)	1.3
C26 Malignant neoplasm of ill-defined digestive organs	1544	0.2 (0.1–0.2)	1.0

Data source: NCoDR

increase to 2013 and the subsequent decline was the sum of multiple smaller changes, both increases and declines. There was an increase of X59 deaths (exposure to unspecified factor) from 0.2% in the first four years to 1.6% in 2010–2014, and a decline to 1.0% in 2015–2019. The B99 deaths (unspecified infectious diseases) increased from 0.1 to 0.9% during the study period. There were also increases in A41 (other sepsis) and R99 (unknown cause of death). The proportion of deaths coded with I50 (heart failure) declined from 4.2% in the first four years to 3.0% in the last five year.

The reduction of minor garbage codes was almost fully accounted for by decline in I64 (unspecified stroke), 6.5% in the first four years, 2.4% in the last five years, and J18 (unspecified pneumonia), decline from 4.6 to 3.6%. The changes in these two codes alone explained 80% of the reduction.

I50 (heart failure), X59 (exposure to unspecified factor), X42 (accidental poisoning by narcotics and psychodysleptics) and I64 (unspecified stroke) are discussed more thoroughly below. Some of the observed changes (notably in X59 and accidental poisonings) can be explained by changes in the coding rules.

Sex and age

A larger proportion of all deaths in women were coded with a garbage code, both major and minor. For major garbage codes the proportions were 15.6% in women, 12.5% in men. For minor garbage codes: 16.7% in women, 13.1% in men. The sex difference decreased towards the end of the study period (Fig. 1). When comparing age-adjusted proportions, there was hardly any difference between sexes in the last 5-year period. Major garbage codes: 14.0% in women, 13.5% in men; minor garbage codes: 11.5% in women, 11.8% in men (supplemental Fig. S1).

The proportion of deaths with a garbage code rose with age at death above circa 60 years. In the group with age at death ≥90 years, 24.1% of women and 20.6% of men had a major garbage code and 21.5% of women and 21.1% of men a minor garbage code. Major garbage codes were also used in a high proportion of deaths in

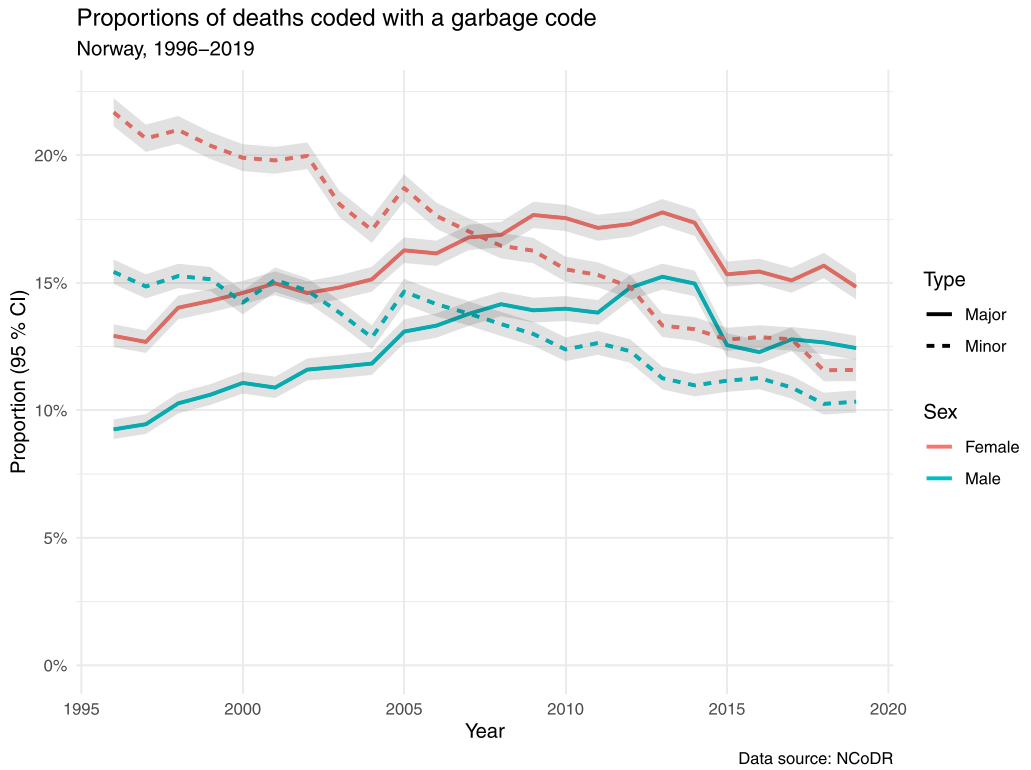

Fig. 1 Proportions of deaths coded with a garbage code

young adults. Within each age segment, there are relatively small differences between men and women, except for major garbage codes in young adults (Fig. 2, Table 3).

Place of death

The age-adjusted proportion of deaths coded with a major garbage code was lowest for deaths in hospitals and in nursing homes and other health care institutions, and highest in deaths occurring outside health care facilities: at home, in other known locations, and where the place of death was unregistered. For minor garbage codes, the age-adjusted proportion was highest in nursing homes (Table 4).

Autopsy

During the study period, 4.2% of the deceased underwent a forensic autopsy, 4.7% a non-forensic one. The median age of death was 51 years in the forensic autopsy group, 72 years in the non-forensic autopsy group and 82 years in the not autopsied. More deceased men than women underwent an autopsy, both forensic and non-forensic (6.2% vs 2.4% and 5.6% vs 3.8%).

The relationship between garbage codes and autopsy showed a mixed pattern. In deceased undergoing a non-forensic autopsy, the age-adjusted proportion of deaths coded with a major garbage code (7.3%) was lower than in the non-autopsied (14.6%). In deceased undergoing a forensic autopsy, the age-adjusted proportion of major garbage codes was almost the same as in the non-autopsied, (12.8%). In both types of autopsy, the age-adjusted proportions of minor garbage codes were lower than in the non-autopsied (forensic 5.8%, non-forensic 6.8%, non-autopsied 15.8%) (Table 5).

Factors correlating with use of a garbage code

We performed logistic regression analyses to investigate the determinants of use of a garbage code as the underlying cause of death. All the investigated factors had a significant explanatory effect, both in single-predictor and multiple-predictor models. When comparing the odds

Table 2 Garbage codes in Norway 1996–2019, according to sex and time period

Women					
Year	**All deaths**	**Major garbage codes**		**Minor garbage codes**	
	N	N	Percent (95% CI)	N	Percent (95% CI)
1996–1999	88,601	11,947	13.5 (13.3–13.7)	18,538	20.9 (20.7–21.2)
2000–2004	109,982	16,302	14.8 (14.6–15.0)	20,889	19.0 (18.8–19.2)
2005–2009	106,496	17,836	16.7 (16.5–17.0)	18,329	17.2 (17.0–17.4)
2010–2014	105,564	18,391	17.4 (17.2–17.7)	15,251	14.4 (14.2–14.7)
2015–2019	103,208	15,769	15.3 (15.1–15.5)	12,719	12.3 (12.1–12.5)
Total	*513,851*	*80,245*	*15.6 (15.5–15.7)*	*85,725*	*16.7 (16.6–16.8)*
Men					
Year	**All deaths**	**Major garbage codes**		**Minor garbage codes**	
	N	N	Percent (95% CI)	N	Percent (95% CI)
1996–1999	88,442	8755	9.9 (9.7–10.1)	13,418	15.2 (14.9–15.4)
2000–2004	104,420	11,915	11.4 (11.2–11.6)	14,794	14.2 (14.0–14.4)
2005–2009	98,682	13,476	13.7 (13.4–13.9)	13,616	13.8 (13.6–14.0)
2010–2014	98,083	14,288	14.6 (14.3–14.8)	11,688	11.9 (11.7–12.1)
2015–2019	96,650	12,125	12.5 (12.3–12.8)	10,423	10.8 (10.6–11.0)
Total	*486,277*	*60,557*	*12,5 (12.4–12.5)*	*63,939*	*13.1 (13.1–13.2)*

Data source: NCoDR

ratios for deaths coded with a garbage code, we noticed that the sex difference was less pronounced, and that the odds ratio for deaths in nursing homes was lower in the multiple-predictor model than in the single-predictor model. For deaths occurring in other known places, the odds ratio was higher in the multiple-predictor than in the single-predictor models. For deceased that underwent autopsy, the odds ratios were also higher in the multiple-predictor model compared to the single-predictor model. In the multi-predictor model, the most important explanatory factors (evaluated by ranking of the LR statistic) were age and place of death (Table 6).

Results from separate analyses for major and minor garbage codes are presented in the supplemental material, Tables S1a-b. For major garbage codes, the most important explanatory factors were age and place of death, whereas for minor garbage codes, also the year of death was one of the most important factors.

Other registered diagnoses in deaths coded with a garbage code

Of the deaths coded with a major or minor garbage code as the underlying cause of death, 104,680 of 290,469 (36.0, 95% CI 35.9–36.2%) had one or more non-garbage codes among the registered diagnoses. The proportion varied considerably between different places of death: hospital 44.4% (44.1–44.8%), nursing home 37.0% (36.8–37.3%), at home 23.8% (23.8–24.2%), other known place 15.5% (14.8–16.3%), and 25.5% (24.3–26.7%) where the place of death was unknown.

Grouped according to the GBD cause list (level 3), the most prevalent non-garbage codes were Alzheimer disease and other dementias (24.1% of the cases with at least one non-garbage code), ischaemic heart disease (17.8%), atrial fibrillation and flutter (11.2%), chronic obstructive pulmonary disease (COPD) (8.1%), and urinary tract infection (6.0%). There were only small differences in rank between the groups with major and minor garbage codes, but different garbage codes had very different patterns of non-garbage codes. (Supplementary Tables S3a and b show the most common non-garbage codes for each of the most prevalent major and minor garbage codes).

More on the most prevalent garbage codes

I50 heart failure

I50 (heart failure) is the most prevalent major garbage code in Norway, 3.7% of all deaths in the study period. The proportion of deaths coded with I50 declined from 4.2% (95% CI 4.1–4.3%) in the first 4 years to 3.0% (2.9–3.1%) in the last five years. In the same years, the proportion of deaths coded to cardiovascular causes except cerebrovascular disease, declined from 32.6 to 20.6%.

Of the deaths coded with I50 as the underlying cause of death, 12,844 of 36,683 (35.0, 95% CI 34.5–35.5%) had one or more non-garbage codes among the registered diagnoses. The most prevalent were: Alzheimer disease and other dementias, chronic obstructive pulmonary disease, atrial fibrillation and flutter, urinary diseases and stroke.

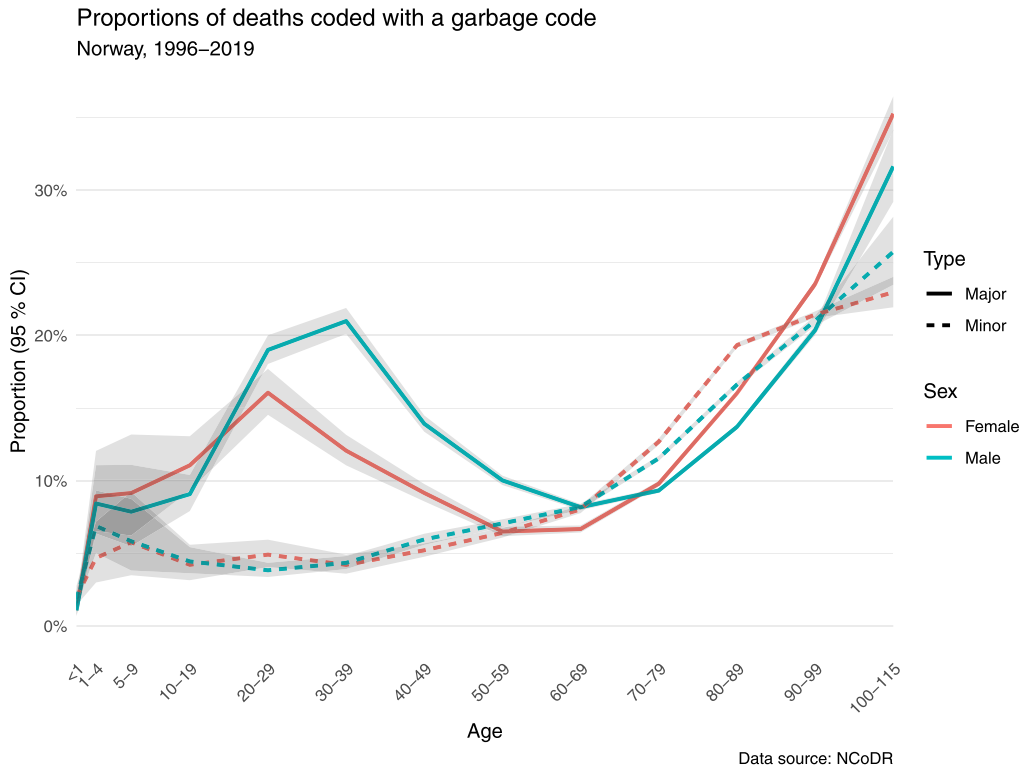

Fig. 2 Proportions of deaths coded with a garbage code, according to age and sex

I64 unspecified stroke

I64 (unspecified stroke) is the most prevalent minor garbage code, found in 4.4% of all deaths, and there has been a decline in the proportion of cases from 6.7% (95% CI 6.6–6.9%) of all deaths in the first four years to 2.4% (2.3–2.5%) in the last five years. At the same time, there has been a decline in the proportion of deaths due to all cerebrovascular diseases (I60-I69) from 11.3 to 5.9%. The proportion of all cerebrovascular diseases coded to unspecified stroke declined from 59.5 to 40.7% during the study period.

Of the deaths coded with I64 as the underlying cause of death, 18,156 of 43,814, (41.4, 95% CI 40.0–41.9%) had one or more non-garbage codes among the registered diagnoses. The five most prevalent non-garbage codes were Alzheimer disease and other dementias, ischaemic heart disease, atrial fibrillation and flutter, (specified) stroke, and chronic obstructive pulmonary disease.

X42 accidental poisoning by narcotics and psychodysleptics

X42 (accidental poisoning by narcotics and psychodysleptics) is the most prevalent garbage code in the NCoDR for the age group 15–49 years, found in 5.0% (95% CI 4.8–5.2%) of all deaths and constituting 34.3% of all major garbage codes in this age group. The three accidental poisonings codes X41, X42, and X44 together account for 53.2% of all major garbage codes in this age group (Supplemental Table S2b). There is a striking time trend, with a mean number of 16 yearly cases in the years 1996–2002, and a mean number of 165 yearly cases in the years 2003–2019. The same codes explain the high proportion of major garbage codes in forensic autopsies (supplementary Table S2d). Before 2003, an accidental drug poisoning in a person with addiction was coded as a disorder due to substance use (ICD-10 section F11–16, F19). In 2003, there was a change in the rules from the WHO, and accidental poisonings were to be coded as external causes of

Table 3 Garbage codes in Norway 1996–2019, according to sex and age

	All deaths	Major garbage codes		Minor garbage codes	
	N	N	Percent (95% CI)	N	Percent (95% CI)
Women					
Under 1 year	1852	20	1.1 (0.7–1.7)	37	2.0 (1.4–2.8)
1–4 years	448	40	8.9 (6.5–12.1)	21	4.7 (3.0–7.2)
5–14 years	628	70	11.1 (8.9–13.9)	29	4.6 (3.2–6.7)
15–49 years	15,893	1723	10.8 (10.4–11.3)	778	4.9 (4.6–5.2)
50–79 years	157,436	13,401	8.5 (8.4–8.7)	16,662	10.6 (10.4–10.7)
80–89 years	202,338	32,419	16.0 (15.9–16.2)	39,113	19.3 (19.2–19.5)
90 years and above	135,256	32,572	24.1 (23.9–24.3)	29,086	21.5 (21.3–21.7)
Total	*513,851*	*80,245*	*15.6 (15.5–15.7)*	*85,726*	*16.7 (16.6–16.8)*
Men					
Under 1 year	2412	26	1.1 (0.7–1.6)	44	1.8 (1.3–2.5)
1–4 years	581	49	8.4 (6.4–11.1)	40	6.9 (5.0–9.3)
5–14 years	825	72	8.7 (6.9–10.9)	43	5.2 (3.8–7.0)
15–49 years	31,017	5125	16.5 (16.1–16.9)	1559	5.0 (4.8–5.3)
50–79 years	227,868	20,713	9.1 (9.0–9.2)	22,544	9.9 (9.8–10.0)
80–89 years	166,886	22,875	13.7 (13.5–13.9)	27,731	16.6 (16.4–16.8)
90 years and above	56,688	11,699	20.6 (20.3–21.0)	11,978	21.1 (20.8–21.5)
Total	*486,277*	*60,559*	*12.5 (12.4–12.5)*	*63,939*	*13.1 (13.1–13.2)*

Data source: NCoDR

death (ICD-10 section X40-X49). Most codes in this section are regarded as garbage codes by the GBD, whereas many of the corresponding codes in the section of the F chapter are not.

X59 exposure to unspecified factor

X59 (exposure to unspecified factor) is the most prevalent garbage code in the external cause of death section, found in 0.9% of all deaths. Also here, there is a striking time trend, with a mean of 95 yearly cases in 1996–2004, a mean of 644 yearly cases 2005–2014, a drop to 264 and 232 cases in 2015 and 2016, and then again a rise to a mean of 540 cases 2017–2019. Before 2005, a local guideline in NCoDR stated that deaths from fractures of the femur without information on the circumstances were to be coded as W19 (accidental fall), which is not regarded as a garbage code by the GBD. From 2005 and onward, NCoDR adhered to the WHO rules, coding these cases as X59. In the years 2015 and 2016, a quality improvement project in the NCoDR caused a temporary fall in the number of X59 cases [18].

Of the deaths coded with X59 as the underlying cause of death, 6442 of 9415, (68.4, 95% CI 67.5–69.3%) had one or more non-garbage codes among the registered diagnoses. The most prevalent were: Effects of medical treatment, Alzheimer disease and other dementias, ischaemic heart disease, atrial fibrillation and flutter, and chronic obstructive pulmonary disease. The coding of "effects of medical treatment" does not necessarily indicate a complication, only that some kind of medical or surgical procedure was mentioned on the death certificate. The nature of injury (S- and T-codes in ICD-10), is by definition a garbage code and therefore not counted among the non-garbage codes. In 69.8% of the X59 deaths, fracture of femur (S72.X) was registered as the nature of injury.

Discussion

In this population-based study, we used data from the Norwegian Cause of Death Registry for the years 1996–2019 to investigate the use of garbage codes for the underlying cause of death. We found that the proportion of deaths coded with major garbage codes increased slightly during the study period, whereas the proportion of minor garbage codes declined. The two most important determinants of use of garbage codes in the registry were the age of the deceased and the place of death.

Strengths and limitations

The data material is large and comprehensive, and consists of all deaths in Norway with a registered cause of death (98.7% of all deaths) over a 24-year period. ICD-10 has been used as classification system throughout the period, and data processing and coding in the registry

Table 4 Garbage codes in Norway 1996–2019, according to place of death

Place of death	All deaths		All garbage codes			Major garbage codes			Minor garbage codes		
	N	Median age at death (years)	N	Unadjusted (%)	Age adjusted (%) (95% CI)	N	Unadjusted (%)	Age adjusted (%) (95% CI)	N	Unadjusted (%)	Adjusted (%) (95% CI)
Hospital	366,855	78	74,666	20.4	23.7 (23.5–23.9)	33,531	9.1	11.0 (10.9–11.2)	41,135	11.2	12.7 (12.6–12.9)
Nursing home	434,271	86	157,632	36.3	31.6 (31.4–31.8)	68,638	15.8	13.6 (13.4–13.7)	88,994	20.5	18.0 (17.9–18.2)
At home	149,203	75	44,238	29.6	34.3 (34.0–34.7)	28,545	19.1	22.0 (21.7–22.3)	15,693	10.5	12.3 (12.1–12.6)
Other known	34,620	61	9037	26.1	34.3 (33.2–35.5)	6796	19.6	24.0 (23.0–24.9)	2241	6.5	10.3 (9.7–11.0)
Not known	15,179	73	4896	32.3	36.3 (35.2–37.5)	3294	21.7	23.1 (22.2–24.1)	1602	10.6	13.2 (12.5–13.9)
Total	*1,000,128*	*81*	*290,469*	*29.0*	*30.0 (29.9–30.2)*	*140,804*	*14.1*	*14.7 (14.6–14.8)*	*149,665*	*15.0*	*15.4 (15.3–15.4)*

Data source: NCoDR

Table 5 Garbage codes in Norway 1996–2019, according to autopsy type

Autopsy type	All deaths			Major garbage codes			Minor garbage codes		
	N	Percent (95% CI)	Median age at death (years)	N	Unadjusted (%)	Age adjusted (%) (95% CI)	N	Unadjusted (%)	Age adjusted (%) (95% CI)
Forensic autopsy	42,074	4.2 (4.2–4.2)	51	6953	16.5	12.8 (11.6–14.2)	1732	4.1	5.8 (4.9–6.8)
Non-forensic autopsy	46,862	4.7 (4.6–4.7)	72	3118	6.7	7.3 (6.9–7.8)	2634	5.6	6.8 (6.4–7.3)
No autopsy	911,192	91.1 (91.1–91.2)	82	130,733	14.3	14.6 (14.5–14.7)	145,299	15.9	15.8 (15.7–15.9)
Total	*1,000,128*		*81*	*140,804*	*14.1*	*14.7 (14.6–14.8)*	*149,665*	*15.0*	*15.4 (15.3–15.4)*

Data source: NCoDR

Table 6 Logistic regression analysis of determinants for use of garbage codes in Norway 1996–2019

Explanatory variable	All GC (%) $N = 290,469$	All deaths $N = 1,000,128$	Single predictor models				Multiple predictor model			
			OR	(95% CI)	LR stat*	*p* value	OR	(95% CI)	LR stat*	*p* value
Year of death					**1645**	**< 0.001**			**3644**	**< 0.001**
1996–1999	52,658 (29.7)	177,043	1 (ref.)				1 (ref.)			
2000–2004	63,900 (29.8)	214,402	1.00	(0.99–1.02)			0.96	(0.95–0.98)		
2005–2009	63,257 (30.8)	205,178	1.05	(1.04–1.07)			0.96	(0.95–0.98)		
2010–2014	59,618 (29.3)	203,647	0.98	(0.96–0.99)			0.85	(0.84–0.86)		
2015–2019	51,036 (25.5)	199,858	0.81	(0.81–0.82)			0.68	(0.67–0.69)		
Sex					**5454**	**< 0.001**			**482**	**< 0.001**
Female	165,971 (32.3)	513,851	1 (ref.)				1 (ref.)			
Male	124,498 (25.6)	486,277	0.72	(0.72–0.73)			0.90	(0.89–0.91)		
Age at death					**48,158**	**< 0.001**			**30,379**	**< 0.001**
Under 1	127 (2.98)	4264	1 (ref.)				1 (ref.)			
1–4	150 (14.6)	1029	5.56	(4.34–7.13)			4.57	(3.56–5.86)		
5–14	214 (14.7)	1453	5.63	(4.48–7.09)			4.44	(3.54–5.60)		
15–49	9185 (19.6)	46,910	7.93	(6.67–9.52)			5.87	(4.93–7.05)		
50–79	73,320 (19.0)	385,304	7.66	(6.45–9.18)			5.81	(4.89–6.97)		
80–89	122,138 (33.1)	369,224	16.1	(13.6–19.3)			11.3	(9.49–13.5)		
90–115	85,335 (44.5)	191,944	26.1	(22.0–31.3)			17.4	(14.6–20.9)		
Place of death					**25,291**	**< 0.001**			**10,369**	**< 0.001**
Hospital	74,666 (20.4)	366,855	1 (ref.)				1 (ref.)			
Nursing home	157,632 (36.3)	434,271	2.23	(2.21–2.25)			1.62	(1.60–1.64)		
At home	44,238 (29.6)	149,203	1.65	(1.63–1.67)			1.76	(1.73–1.78)		
Other known	9037 (26.1)	34,620	1.38	(1.35–1.42)			1.84	(1.79–1.89)		
Unknown	4896 (32.3)	15,179	1.86	(1.80–1.93)			2.08	(2.00–2.15)		
Autopsy					**9761**	**< 0.001**			**1828**	**< 0.001**
No autopsy	276,032 (30.3)	911,192	1 (ref.)				1 (ref.)			
Non-forensic	5752 (12.3)	46,862	0.32	(0.31–0.33)			0.56	(0.55–0.58)		
Forensic	8685 (20.6)	42,074	0.60	(0.58–0.61)			0.83	(0.81–0.85)		

Data source: NCoDR

LR stat: Likelihood ratio statistic (−2LogL)

has been performed by skilled personnel in Statistics Norway up to 2013 and at The Norwegian Institute of Public Health from 2014.

During the study period, there has been some changes in the coding rules, notably for external causes of death. This is reflected in some of the time trends, for example

for the major garbage codes X42 (accidental poisoning by narcotics and psychodysleptics) and X59 (exposure to unspecified factor).

We have used the list of garbage codes from the GBD Study, as we believe that much of the current research on the quality of cause of death statistics is linked to the GBD. The composition of this list is based upon choices made by the GBD research team, and there has been a gradual development over the iterations of the GBD analyses [5, 7].

The list of garbage codes from the GBD is much longer than the list of ill-defined causes of death from the WHO [3]. The results of this study would be different if we had used another definition of garbage codes. Use of the GBD list is both a strength and a weakness. It makes it possible to compare our results with other studies that use the GBD framework, but makes it difficult to compare with studies using another definition.

A garbage code may arise on several stages in the diagnostic, certification, and coding process of deaths, and knowing the contribution of each stage could guide quality improvement efforts. A weakness in our study is that we cannot discern the importance of each stage.

We have investigated the correlation of a number of putative explanatory factors with the use of garbage codes, but there are likely also other important factors, not included in our analyses.

If a death is coded with a non-garbage code as the underlying cause of death, it does not imply that the cause of death is correct. An example: the symptoms of a perforated peptic ulcer (a valid diagnosis) might be misinterpreted as a myocardial infarction (another valid diagnosis). This study was not designed to ascertain the magnitude of incorrect diagnoses.

The study is from a single country, and from the ICD-10 period only. Therefore, we cannot claim that the results can be generalized to other countries.

Discussion of results

General considerations

We found that 29.0% of the deaths in Norway in the study period were coded with a garbage code as the underlying cause of death, 14.1% major and 15.0% minor. It is the use of major garbage codes that are considered most deleterious for public health analyses, as they convey least information. Worldwide, the proportion of major garbage codes in cause of death registries ranges from 4% to more than 80% in the latest available year [7]. The proportion in Norway is similar to several comparable countries, such as Sweden (13% in 2017), Denmark (16% in 2015), Germany (15% in 2016), and the Netherlands (16% in 2016), but higher than e.g. Finland (6% in 2016), UK (9% in 2017), and New Zealand (4% in 2015). This would suggest that even if Norway is in the lower end, there is still potential for improvement.

Age and sex

We found that the proportion of deaths assigned a garbage code increased with the age of the deceased, and hence were larger in women than in men, as median age of death was 6 years higher in women. Other studies have divergent observations. Iburg et al. [2] found that in most of the 20 studied countries, there were no large age gradient in major garbage codes. Johnson et al. [6] stated that the garbage code proportion often is higher in locations with an elderly population, and suggest using age standardization to improve comparability. An age gradient has been described in Greenland [19], Brazil [20], and Korea [21]. Flagg and Anderson [22] found an age gradient in the Unites States, but they used another definition of unsuitable causes of death. Adair et al. [23] found a slightly higher age-adjusted garbage code proportion in women in a study on data from 42 countries.

Older people often have several diseases, and it can be challenging to identify a single cause of death. One could also speculate that as the end of life comes closer, the focus of the health care can be more on symptom relief than on identifying and treating the exact cause. There was a large proportion of deaths with a major garbage code in the 15–49 year group. This can almost fully be explained by coding of accidental poisonings, discussed more closely below.

The place of death

The proportion of deaths assigned a garbage code was lowest in hospitals, this can probably be explained by on one hand better diagnostic resources in hospitals and on the other hand more sudden, unexpected or unattended deaths outside health care institutions. The risk of dying before reaching hospital is higher in sudden catastrophic illness. This is reflected in the spectrum of major garbage codes for deaths outside health care institutions, with R96 (sudden death), R99 (unknown cause of death), and I46 (cardiac arrest) among the most prevalent. The unadjusted proportion was highest in nursing homes, but the age-adjusted proportions were lower than deaths in other places, except in hospitals, reflecting the high median age of death in nursing homes.

The origin of garbage codes

We believe that a garbage code for the cause of death can arise in two fundamentally different ways: either by insufficient diagnosis, or by faults in the certification and coding process. An insufficient diagnosis is when the certifying doctor does not have enough information on the real underlying cause of death. A typical example is

if a person is found dead and no autopsy is performed. Even if the medical doctor is confident in the principles regarding certification of death, it is not possible to give an informative diagnosis.

A fault in certification is when the certifying doctor possesses enough information to give a sufficient cause of death, but because of lack of training or otherwise fails to give a proper statement on the cause of death. The second instance, but not the first, has a potential of improvement by better training and information on how to certify a death. From our study, we cannot distinguish between these two origins. However, the presence of non-garbage codes on the death certificate in a case could perhaps be an indication that there is more information available. We found that the proportion of garbage code deaths with non-garbage codes in the records was considerably lower in deaths outside health care institutions. One cannot claim, however, that the true underlying cause of death is among these non-garbage codes.

The central coding in the registry can also influence the prevalence of garbage codes in the cause-of-death statistics, for instance by asking for additional information in unclear cases.

The frequency and type of garbage codes can be influenced by several factors beside the certifying doctor's abilities.

The epidemiological situation

If there is a rise or decline in diseases that might give origin to a certain garbage code on the death certificate, this might lead to a corresponding rise or decline in the number of deaths coded with this code. The mortality of cardiovascular diseases have declined in Norway [24], and in parallel with this the proportion of all deaths coded with garbage codes related to these causes of death, such as I50 (heart failure) and I64 (unspecified stroke).

The diagnostic efforts: pre- and postmortem

If the diagnostic process before the death of a patient has been comprehensive, there is more information in the records that can be used to give a specific cause of death. Stroke is a good example. The reduction in the number of deaths coded with I64 (unspecified stroke) is larger than can be explained by the changing epidemiological situation alone. The fraction of all cerebrovascular deaths coded with I64 has declined from almost 60 to 40% during the study period. The more widespread use of diagnostic procedures to distinguish between thrombotic and haemorrhagic stroke [25] can probably explain more specific causes of death.

The age-adjusted proportion of deaths assigned a garbage code is generally lower in the autopsied than in the non-autopsied. The relatively high proportion of major garbage codes in the persons undergoing forensic autopsy can be explained by accidental poisonings (see below).

The WHO coding rules and local guidelines

In 2003, there was a change in the coding rules from WHO; accidental poisonings with drugs of abuse should be coded with external causes of death (ICD-10 X41, X42 and X44) instead of deaths due to drug abuse (F11–16, F19) [26]. GBD views most of the codes in X40-X49 as garbage codes and most codes in F10-F19 as non-garbage codes. Following the WHO guidelines thus leads to more use of garbage codes. The reason that the codes for accidental poisonings are regarded as garbage codes are mainly that GBD considers drug overdoses as dependency disorder-related deaths and also that some of these deaths in reality are suicides and thus should be redistributed (M. Naghavi, IHME, personal communication).

Before 2005, fractures of the femur without information on the circumstances around the injury were by default coded as W19 (accidental falls). From 2005, these deaths were coded with X59 (exposure to unidentified factor), a major garbage code [26]. More diligently following the WHO coding rules lead to a rise in the number of garbage codes. We have earlier analysed these deaths in detail [18]. Most of these cases really are accidental falls, but many of the deaths occur a long time after the incident, and the certifying doctor may not know anything about the circumstances or is unfamiliar with the rules for coding of external cause deaths. The official Norwegian online coding tool [27], used by the certifying medical doctors, is not fully congruent with the international version of ICD-10 for external causes, placing more emphasis on the nature of injury and less on the circumstances.

Other diagnoses present on the death certificate

We found that 36% of the garbage coded deaths had other, non-garbage codes mentioned on the death certificate. Could these diagnoses have been used in a multiple cause of death approach to identify a more informative underlying cause of death? There are at least two objections to this: First, the NCoDR, as other cause of death registries, must conform to the rules and guidelines from the WHO. "Garbage code" is not an ICD-10 concept. The closest is the lists of ill-defined conditions and conditions unlikely to cause death, mentioned in the introduction (Annex 7.3 and 7.4 in the instruction manual of ICD-10 [3]). They are to be avoided, if possible (Step SP7 and SP8 in the ICD-10 coding rules). If a more specific code is present somewhere on the death certificate, it should be selected as the underlying cause of death. This can be seen in that a non-garbage code is mentioned in only 2.3% of

the deaths coded with R96 (sudden death) as underlying cause of death (Supplemental Table S3a). The list of garbage codes from the GBD is much more extensive than the list of ill-defined codes from WHO. As the NCoDR must follow the WHO rules and guidelines, codes that are accepted by WHO, but classified as garbage codes by the GBD, cannot be disregarded. Second, presence of a non-garbage code can give valuable information on co-morbidity, but not necessarily on the real underlying cause of death. For example, for the minor garbage code C80 (malignant neoplasm, site unknown), the most commonly occurring non-garbage code is ischaemic heart disease, which does not point to a specific origin of cancer (Supplemental Table S3b). In other instances, one may find a candidate for the underlying cause of death among the non-garbage codes. For example, the most common non-garbage code for J18 (unspecified pneumonia) is Alzheimer disease and other dementias (Supplemental Table S3b), and this could in some instances be the condition leading to an airway infection.

Implications of the study

If a large proportion of the deaths in a population is assigned a garbage code for the underlying cause of death, the cause of death data would be less useful for public health purposes such as health surveillance, analyses and research. We have found that the most important determinants of use of garbage codes as underlying cause of death is advanced age at death and place of death outside hospital. Knowledge of the national epidemiological situation as well as the rules and guidelines for mortality coding is essential for understanding the prevalence and distribution of garbage codes.

Better training of the certifying medical doctors could probably eliminate some of the garbage codes that are caused by certification errors [28], but not those that are caused by lack of information. The Norwegian Medical Association already provides an online tutorial on death certification [29], and this could be made compulsory, at least for doctors who regularly completes death certificates. Alfsen and Lyckander [30] found that the cause of death could be changed in 18% of the deaths in a Norwegian hospital just from better use of the information in the patient records and adherence to the certification guideline, but this study was not directed against garbage codes. Many of the deaths outside hospitals are certified by doctors on call who not necessarily have access to the medical records of the deceased. Better access to relevant information, for example via the summary care record [31] would probably be useful, as well as more use of autopsy [32]. In Norway, the majority of deaths occur in health care institutions, and almost all are certified by a medical doctor. Verbal autopsy (in the original sense with interview of the relatives of the deceased or other lay persons) seems less relevant for Norwegian and similar high-income countries, but might be of value in low-resource settings.

Directed quality assurance efforts at the cause of death registries with queries to the certifying doctors can improve the data quality [18].

From the year 2022, electronic certification of deaths is compulsory in Norway [33]. In our study, only 0.13% of the total number of deaths were electronically certified. From 2022, all deaths will be certified by this system. Time will show whether this has influence on the data quality. In an electronic system, there is a potential for decision support or real-time feedback for the certifying medical doctors, for instance discouraging the use of garbage codes. The present-day system for electronic certification of deaths in Norway has only limited decision support and does not give feedback to the physician on use of garbage codes [33].

Issuing death certificates is a professional duty for the individual medical doctor. To ensure conformity in practice among different practitioners, there thus should be some kind of collegial or institutional mechanisms for quality assurance of this work. The proportion of garbage codes in an otherwise well working system of death certification, as in Norway, may indicate that there still is a considerable room for further improvement.

Abbreviations

WHO: World Health Organization; ICD-10: International Statistical Classification of Diseases and Related Health Problems, 10th Revision; GBD: The Global Burden of Disease; GC: Garbage code (as defined by the Global Burden of Disease); NCoDR: The Norwegian Cause of Death Registry at the Norwegian Institute of Public Health; Q1-Q3: The range from the 25th to the 75th percentile; CI: Confidence interval.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-022-13693-w.

Additional file 1.

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Authors' contributions

CLE and SEV conceived the study. CLE conducted the analyses. CLE and GSB drafted the manuscript. AGP supplied important information on coding practices. All authors gave input to the interpretation of the results and the discussion and critically revised the manuscript. The author(s) read and approved the final manuscript.

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Availability of data and materials
According to Norwegian data privacy regulations, it is not possible to make the data publicly available. Researchers wishing to replicate or expand the study may seek approval by the Committee for Medical Research Ethics and request data from the Norwegian Institute of Public Health.

Declarations

Ethics approval and consent to participate
The project was approved by the Regional Committee for Medical and Health Research Ethics (ref. 177346) and in consultation with the Data Protection Officer at Stavanger University Hospital. Due to the nature of the study, consent to participate was not possible to obtain, and the study was exempted from requiring individual consent from next-of kin of the deceased. The study met the requirements in accordance with the General Data Protection Regulation (GDPR) and conforms to the Declaration of Helsinki. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication
Not applicable, as no identifiable information is revealed in the publication.

Competing interests
The authors declare that there are no conflict of interest.

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Publisher's Note

Non-informative codes in the Norwegian Cause of Death Registry – supplemental material

Figure S1 – Age adjusted proportions of deaths coded with a garbage code

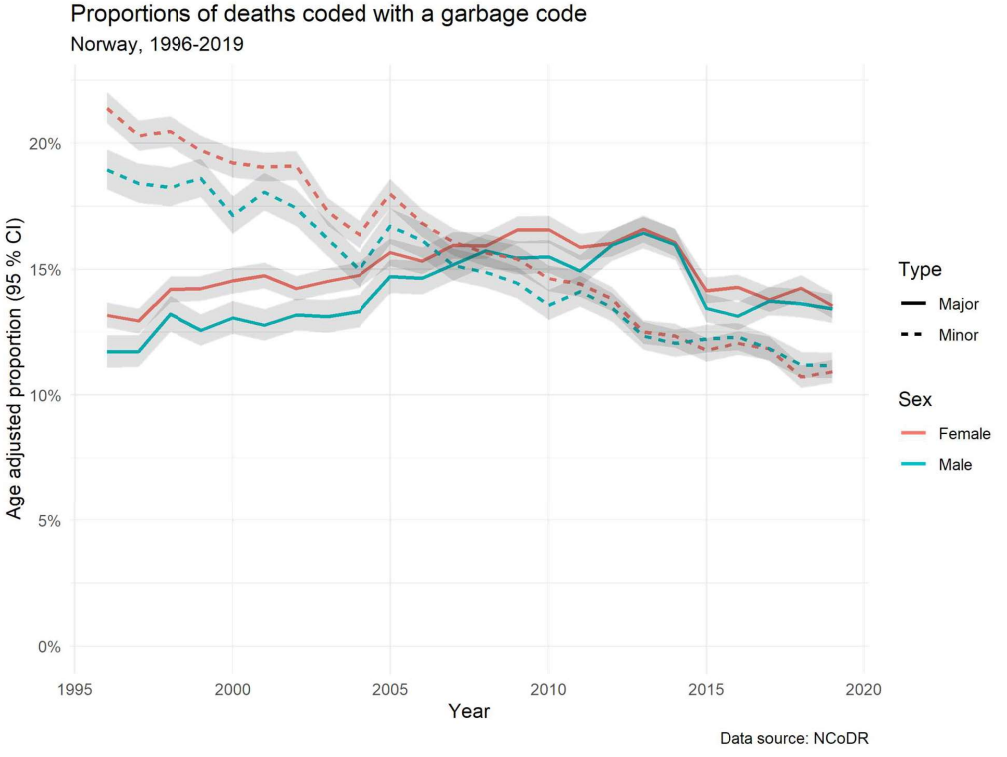

Table S1a – Logistic regression, factors correlated with major garbage codes

Explanatory variable	Major GC (%) N = 153,426	All deaths N = 1,000,128	Single predictor models				Multiple predictor model			
			OR	95 % CI	LR stat*	p	OR	95 % CI	LR stat*	p
Year of death					**1,891**	**< 0.001**			**1,158**	**< 0.001**
1996-1999	20,702 (11.7)	177,043	1 (ref.)				1 (ref.)			
2000-2004	28,217 (13.2)	214,402	1.14	(1.12-1.17)			1.12	(1.09-1.14)		
2005-2009	31,312 (15.3)	205,178	1.36	(1.33-1.39)			1.28	(1.26-1.31)		
2010-2014	32,679 (16.0)	203,647	1.44	(1.44-1.42)			1.32	(1.29-1.34)		
2015-2019	27,894 (14.0)	199,858	1.22	(1.20-1.25)			1.10	(1.08-1.12)		
Sex					**2,073**	**< 0.001**			**409**	**< 0.001**
Female	80,245 (15.6)	513,851	1 (ref.)				1 (ref.)			
Male	60,559 (12.5)	486,277	0.77	(0.76-0.78)			0.88	(0.87-0.89)		
Age at death					**22,157**	**< 0.001**			**19,019**	**< 0.001**
Under 1	46 (1.1)	4,264	1(ref.)				1 (ref.)			
1-4	89 (8.7)	1,029	8.68	(6.07-12.6)			6.35	(4.44-9.22)		
5-14	142 (9.8)	1,453	9.93	(7.14-14.1)			6.96	(5.00-9.88)		
15-49	6848 (14.6)	46,910	15.7	(11.9-21.3)			9.42	(7.12-12.8)		
50-79	34,114 (8.9)	385,304	8.91	(6.75-12.1)			7.17	(5.42-9.73)		
80-89	55,294 (15.0)	369,224	16.2	(12.2-21.9)			13.8	(10.4-18.7)		
90-115	44,271 (23.1)	191,944	27.5	(20.8-37.3)			22.8	(17.3-31.0)		
Place of death					**13,649**	**< 0.001**			**11,757**	**< 0.001**
Hospital	33,531 (9.1)	366,855	1 (ref.)				1 (ref.)			
Nursing home	68,638 (15.8)	434,271	1.87	(1.84-1.89)			1.31	(1.30-1.33)		
At home	28,545 (19.1)	149,203	2.35	(2.31-2.39)			2.45	(2.40-2.49)		
Other known	6796 (19.6)	34,620	2.43	(2.36-2.50)			2.90	(2.81-3.00)		
Unknown	3294 (21.7)	15,179	2.76	(2.65-2.87)			2.77	(2.65-2.88)		
Autopsy					**2,831**	**< 0.001**			**343**	**< 0.001**
No	130,733 (14.3)	911,192	1 (ref.				1 (ref.)			
Non-forensic	46,862 (6.7)	46,862	0.43	(0.41-0.44)			0.72	(0.69-0.74)		
Forensic	42,074 (16.5)	42,074	1.18	(1.15-1.21)			1.06	(1.03-1.09)		

Logistic regression model, data from Norwegian Cause of Death Registry, 1996-2019
LR stat = Likelihood ratio statistic (-2LogL)

Table S1b – Logistic regression, factors correlated with minor garbage codes

Explanatory variable	Minor GC (%) N = 133,044	All deaths N = 1,000,128	Single predictor models				Multiple predictor model			
			OR	95 % CI	LR stat*	p	OR	95 % CI	LR stat*	p
Year of death					**4,202**	**< 0.001**			**6,862**	**< 0.001**
1996-1999	31,956 (18.0)	177,043	1 (ref.)				1 (ref.)			
2000-2004	35,683 (16.6)	214,402	0.91	(0.89-0.91)			0.87	(0.85-0.88)		
2005-2009	31,945 (15.6)	205,178	0.84	(0.82-0.85)			0.77	(0.75-0.78)		
2010-2014	26,939 (13.2)	203,647	0.69	(0.68-0.70)			0.60	(0.59-0.62)		
2015-2019	23,142 (11.6)	199,858	0.59	(0.58-0.61)			0.51	(0.50-0.52)		
Sex					**2,462**	**< 0.001**			**55**	**< 0.001**
Female	85,726 (16.7)	513,851	1 (ref.)				1 (ref.)			
Male	63,939 (13.1)	486,277	0.76	(0.75-0.76)			0.96	(0.95-0.97)		
Age at death					**21,869**	**< 0.001**			**8,424**	**< 0.001**
Under 1	81 (1.9)	4,264	1 (ref.)				1 (ref.)			
1-4	61 (5.9)	1,029	3.25	(2.31-4.56)			3.35	(2.37-4.70)		
5-14	72 (5.0)	1,453	2.69	(1.95-3.72)			2.66	(1.92-3.67)		
15-49	2337 (5.0)	46,910	2.71	(2.18-3.41)			2.90	(2.34-3.66)		
50-79	39,206 (10.2)	385,304	5.85	(4.73-7.35)			4.41	(3.57-5.55)		
80-89	66,844 (18.1)	369,224	11.4	(9.23-14.3)			7.16	(5.78-9.00)		
90-115	41,064 (21.4)	191,944	14.1	(11.4-17.7)			8.40	(6.79-10.6)		
Place of death					**19,123**	**< 0.001**			**6,820**	**< 0.001**
Hospital	41,135 (11.2)	366,855	1 (ref.)				1 (ref.)			
Nursing home	88,994 (20.5)	434,271	2.04	(2.02-2.07)			1.65	(1.63-1.68)		
At home	15,693 (10.5)	149,203	0.93	(0.91-0.95)			0.99	(0.97-1.01)		
Other known	2241 (6.5)	34,620	0.55	(0.52-0,57)			0.79	(0.75-0.83)		
Unknown	1602 (10.6)	15,179	0.93	(0.89-8.98)			1.12	(1.06-1.18)		
Autopsy					**9,958**	**< 0.001**			**2,097**	**< 0.001**
No	145,299 (15.9)	911,192	1 (ref.)				1 (ref.)			
Non-forensic	2634 (5.6)	46,862	0.31	(0.30-0.33)			0.49	(0.47-0.51)		
Forensic	1732 (4.1)	42,074	0.23	(0.22-0.24)			0.51	(0.48-0.54)		

Logistic regression model, data from Norwegian Cause of Death Registry, 1996-2019
LR stat = Likelihood ratio statistic (-2LogL)

Table S2a – The most prevalent garbage codes by sex

The most prevalent garbage codes in Norway 1996-2019			
Diagnostic code	*N*	*% of all deaths in group*	*% of GC in group*
BY SEX			
Females, N = 513,851			
Major GC	*80,245*	*15.6*	
I50 Heart failure	22,694	4.4	28.3
R54 Senility	7,871	1.5	9.8
R96 Sudden death	7,510	1.5	9.4
X59 Exposure to unspecified factor	5,719	1.1	7.1
A41 Other sepsis	3,359	0.7	4.2
Minor GC	*85,726*	*16.7*	
I64 Unspecified stroke	27,835	5.4	32.5
J18 Unspecified pneumonia	23,930	4.7	27.9
C80 Malignant neoplasm, unknown primary site	6,062	1.2	7.1
I69 Sequelae of cerebrovascular disease	5,533	1.1	6.5
E14 Unspecified diabetes mellitus	5,471	1.1	6.4
Males, N = 486,277			
Major GC	*60,559*	*12.5*	
I50 Heart failure	13,989	2.9	23.1
R96 Sudden death	6,617	1.4	10.9
X59 Exposure to unspecified factor	3,696	0.8	6.1
R99 Unknown cause of death	3,282	0.7	5.4
A41 Other sepsis	3,215	0.7	5.3
Minor GC	*63,939*	*13.1*	
J18 Unspecified pneumonia	17,823	3.7	27.9
I64 Unspecified stroke	15,979	3.3	25.0
E14 Unspecified diabetes mellitus	4,954	1.0	7.7
C80 Malignant neoplasm, unknown primary site	4,951	1.0	7.7
I69 Sequelae of cerebrovascular disease	4,591	0.9	7.2

Data source: NCoDR

Table S2b – The most prevalent garbage codes by age group

The most prevalent garbage codes in Norway 1996-2019

Diagnostic code	*N*	*% of all deaths in group*	*% of GC in group*
BY AGE AT DEATH			
Under 1 year, N = 4,264			
Major GC	*46*	*1.1*	
R99 Unknown cause of death	16	0.4	34.8
A41 Other sepsis	8	0.2	17.4
A40 Streptococcal sepsis	4	0.1	8.7
W76 Other accidental hanging and strangulation	4	0.1	8.7
B34 Viral infection, unspecified	2	0.05	4.3
G93 Unspecified disorder of brain	2	0.05	4.3
Minor GC	*81*	*1.9*	
J18 Unspecified pneumonia	13	0.3	16.0
Q89 Other congenital malformations	12	0.3	14.8
P23 Congenital pneumonia	8	0.2	9.9
D82 Immunodeficiency with other major defects	6	0.1	7.4
Q99 Other chromosomal abnormalities	6	0.1	7.4
1-4 years, N = 1,029			
Major GC	*89*	*8.6*	
G80 Cerebral palsy	13	1.3	14.6
R99 Unknown cause of death	12	1.2	13.5
W76 Other accidental hanging and strangulation	11	1.1	12.4
A40 Streptococcal sepsis	10	1.0	11.2
A41 Other sepsis	9	0.9	10.1
Minor GC	*61*	*5.9*	
J18 Unspecified pneumonia	8	0.8	13.1
C74 Malignant neoplasm of adrenal gland	6	0.6	9.8
G03 Meningitis, unspecified	5	0.5	8.2
V89 Unspecified traffic accident	4	0.4	6.6
C76 Malignant neoplasm, ill-defined site	3	0.3	4.9

D81 Combined immunodeficiency, unspecified	3	0.3	4.9
G00 Bacterial meningitis, unspecified	3	0.3	4.9
J22 Unspecified lower respiratory infection	3	0.3	4.9
Q89 Other congenital malformations	3	0.3	4.9
5-14 years, N = 1,453			
Major GC	*142*	*9.8*	
G80 Cerebral palsy	61	4.2	43.0
R99 Unknown cause of death	14	1.0	9.9
W76 Other accidental hanging and strangulation	14	1.0	9.9
F84 Pervasive developmental disorders	8	0.6	5.6
G93 Unspecified disorder of brain	7	0.5	4.9
Minor GC	*72*	*5.0*	
C74 Malignant neoplasm of adrenal gland	15	1.0	20.8
I42 Cardiomyopathy, unspecified	10	0.7	13.9
I49 Cardiac arrhythmia, unspecified	6	0.4	8.3
C91 Lymphoid leukemia, unspecified	5	0.3	6.9
I45 Other cardiac conduction disorders	5	0.3	6.9
V89 Unspecified traffic accident	5	0.3	6.9
15-49 years, N = 46,910			
Major GC	*6,848*	*14.6*	
X42 Accidental poisoning by narcotics and psychodysleptics	2,352	5.0	34.3
X44 Accidental poisoning by unspecified drugs	799	1.7	11.7
R99 Unknown cause of death	608	1.3	8.9
F19 Mental and behavioural disorders due to multiple drug use	552	1.2	8.1
X41 Accidental poisoning by sedatives	496	1.1	7.2
Minor GC	*2,337*	*5.0*	
C80 Malignant neoplasm, unknown primary site	289	0.6	12.4
E14 Unspecified diabetes mellitus	273	0.6	11.7
V89 Unspecified traffic accident	224	0.5	9.6

I51 Ill-defined heart disease	182	0.4	7.8
X84 Intentional self-harm by unspecified means	167	0.4	7.1
50-79 years, N = 385,304			
Major GC	*34,114*	*8.9*	
I50 Heart failure	5,675	1.5	16.6
R96 Sudden death	4,863	1.3	14.3
R99 Unknown cause of death	2,659	0.7	7.8
I10 Essential hypertension	2,112	0.5	6.2
A41 Other sepsis	2,056	0.5	6.0
Minor GC	*39,206*	*10.2*	
I64 Unspecified stroke	9,590	2.5	24.5
J18 Unspecified pneumonia	5,856	1.5	14.9
C80 Malignant neoplasm, unknown primary site	5,333	1.4	13.6
E14 Unspecified diabetes mellitus	3,901	1.0	10.0
I51 Ill-defined heart disease	2,559	0.5	6.5
80-89 years, N = 369,224			
Major GC	*55,294*	*15.0*	
I50 Heart failure	16,751	4.5	30.3
R96 Sudden death	5,366	1.5	9.7
X59 Exposure to unspecified factor	4,333	1.2	7.8
R54 Senility	3,332	0.9	6.0
N19 Unspecified kidney failure	3,075	0.8	5.6
Minor GC	*66,844*	*18.1*	
I64 Unspecified stroke	22,216	6.0	33.2
J18 Unspecified pneumonia	19,208	5.2	28.7
I69 Sequelae of cerebrovascular disease	5,095	1.4	7.6
E14 Unspecified diabetes mellitus	4,338	1.2	6.5
C80 Malignant neoplasm, unknown primary site	4,057	1.1	6.1
90 years and above, N = 191,944			
Major GC	*44,271*	*23.1*	

I50 Heart failure	14,183	7.4	32.0
R54 Senility	6,660	3.5	15.0
X59 Exposure to unspecified factor	3,628	1.9	8.2
R96 Sudden death	3,540	1.8	8.0
N19 Unspecified kidney failure	1,912	1.0	4.2
Minor GC	*41,064*	*21.4*	
J18 Unspecified pneumonia	16,510	8.6	40.2
I64 Unspecified stroke	11,963	6.2	29.1
I69 Sequelae of cerebrovascular disease	2,544	1.3	6.2
I51 Ill-defined heart disease	2,350	1.2	5.7
E14 Unspecified diabetes mellitus	1,912	1.0	4.7

Data source: NCoDR

Table S2c – The most prevalent garbage codes by place of death

The most prevalent garbage codes in Norway 1996-2019

Diagnostic code	*N*	*% of all deaths in group*	*% of GC in group*
BY PLACE OF DEATH			
Hospital, N = 366,855			
Major GC	*33,531*	*9.1*	
I50 Heart failure	7,837	2.1	23.4
A41 Other sepsis	4,750	1.3	14.2
X59 Exposure to unspecified factor	3,441	0.9	10.3
N19 Unspecified kidney failure	2,058	0.6	6.1
I26 Pulmonary embolism	1,785	0.5	5.3
Minor GC	*41,135*	*11.2*	
J18 Unspecified pneumonia	11,819	3.2	28.7
I64 Unspecified stroke	10,971	3.0	26.7
C80 Malignant neoplasm, unknown primary site	5,091	1.4	12.4
E14 Unspecified diabetes mellitus	2,054	0.6	5.0
I69 Sequelae of cerebrovascular disease	1,132	0.3	2.8
Nursing home, N = 434,271			
Major GC	*68,638*	*15.8*	
I50 Heart failure	23,301	5.4	33.9
R54 Senility	8,923	2.1	13.0
X59 Exposure to unspecified factor	5,236	1.2	7.6
R96 Sudden death	4,742	1.1	6.9
N19 Unspecified kidney failure	3,509	0.8	5.1
Minor GC	*88,994*	*20.5*	
I64 Unspecified stroke	28,921	6.7	32.5
J18 Unspecified pneumonia	27,211	6.3	30.6
I69 Sequelae of cerebrovascular disease	7,963	1.8	8.9
E14 Unspecified diabetes mellitus	5,530	1.3	6.2
C80 Malignant neoplasm, unknown primary site	4,637	1.1	5.2

At home, N = 149,203			
Major GC	*28,545*	*19.1*	
R96 Sudden death	7,140	4.8	25.0
I50 Heart failure	4,671	3.1	16.4
I10 Essential hypertension	2,556	1.7	9.0
R99 Unknown cause of death	2,138	1.4	7.5
I46 Cardiac arrest	1,439	1.0	5.0
Minor GC	*15,693*	*10.5*	
I64 Unspecified stroke	3,231	2.2	20.6
I51 Ill-defined heart disease	2,677	1.8	17.1
E14 Unspecified diabetes mellitus	2,382	1.6	15.2
J18 Unspecified pneumonia	2,142	1.4	13.6
C80 Malignant neoplasm, unknown primary site	1,115	0.7	7.1
Other known place, N = 34,620			
Major GC	6,796	19.6	
R99 Unknown cause of death	1,817	5.2	26.7
R96 Sudden death	1,319	3.8	19.4
X42 Accidental poisoning by narcotics and psychodysleptics	766	2.2	11.3
I46 Cardiac arrest	471	1.4	6.9
I50 Heart failure	432	1.2	6.4
Minor GC	2,241	6.5	
I51 Ill-defined heart disease	432	1.2	19.3
I64 Unspecified stroke	348	1.0	15.5
E14 Unspecified diabetes mellitus	264	0.8	11.8
V89 Unspecified traffic accident	251	0.7	11.2
J18 Unspecified pneumonia	223	0.6	10.0
Unknown place of death, N = 15,179			
Major GC	3,294	21.7	
R99 Unknown cause of death	626	4.1	19.0
R96 Sudden death	466	3.1	14.1

I50 Heart failure	442	2.9	13.4
X42 Accidental poisoning by narcotics and psychodysleptics	418	2.8	12.7
R54 Senility	151	1.0	4.6
Minor GC	1,602	10.6	
J18 Unspecified pneumonia	358	2.4	22.3
I64 Unspecified stroke	343	2.3	21.4
E14 Unspecified diabetes mellitus	195	1.3	12.2
I51 Ill-defined heart disease	189	1.2	11.8
I69 Sequelae of cerebrovascular disease	100	0.7	6.2

Data source: NCoDR

Table S2d - The most prevalent garbage codes by autopsy type

The most prevalent garbage codes in Norway 1996-2019			
Diagnostic code	*N*	*% of all deaths in group*	*% of GC in group*
BY AUTOPSY TYPE			
No autopsy, N = 911,192			
Major GC	*130,733*	*14.3*	
I50 Heart failure	36,496	4.0	27.9
R96 Sudden death	13,904	1.5	10.6
R54 Senility	10,297	1.1	7.9
X59 Exposure to unspecified factor	9,011	1.0	6.0
A41 Other sepsis	6,280	0.7	4.8
Minor GC	*145,299*	*15.9*	
I64 Unspecified stroke	43,722	4.8	30.1
J18 Unspecified pneumonia	40,614	4.5	28.0
C80 Malignant neoplasm, unknown primary site	10,723	1.2	7.4
I69 Sequelae of cerebrovascular disease	10,087	1.1	6.9
E14 Unspecified diabetes mellitus	10,058	1.1	6.9
Non-forensic autopsy, N = 46,862			
Major GC	*3,118*	*6.7*	
I26 Pulmonary embolism	493	1.1	15.8
A41 Other sepsis	256	0.5	8.2
X59 Exposure to unspecified factor	221	0.5	7.1
E85 Amyloidosis	204	0.4	6.5
J85 Abscess of lung and mediastinum	122	0.3	3.9
Minor GC	*2,634*	*5.6*	
J18 Unspecified pneumonia	780	1.7	29.6
C80 Malignant neoplasm, unknown primary site	274	0.6	10.4
I51 Ill-defined heart disease	252	0.5	9.6
I42 Cardiomyopathy (unspecified)	169	0.4	6.4
E14 Unspecified diabetes mellitus	133	0.3	5.0

Forensic autopsy, N = 42,074			
Major GC	*6,953*	*16.5*	
X42 Accidental poisoning by narcotics and psychodysleptics	2,639	6.3	38.0
X44 Accidental poisoning by unspecified drugs	947	2.3	13.6
X41 Accidental poisoning by sedatives	746	1.8	10.7
R99 Unknown cause of death	570	1.4	8.2
F19 Mental and behavioural disorders due to multiple drug use	356	0.8	5.1
Minor GC	*1,732*	*4.1*	
I51 Ill-defined heart disease	504	1.2	29.1
J18 Unspecified pneumonia	359	0.9	20.7
E14 Unspecified diabetes mellitus	234	0.6	13.5
I42 Cardiomyopathy (unspecified)	111	0.3	6.4
V89 Unspecified traffic accident	78	0.2	4.5

Data source: NCoDR

Table S3a - The most prevalent non-garbage codes by major garbage code

Non-garbage codes according to GBD Cause List, detail level 3
(Note that there may be more than one non-garbage code in each death.)

Diagnostic code	*N*	% of all deaths in group
All Major GC, N = 140,804	*46,287*	*32.9*
Alzheimer disease and other dementias	10,348	7.4
Ischaemic heart disease	6,563	4.7
Atrial fibrillation and flutter	5,183	3.6
Chronic obstructive pulmonary disease	4,866	3.4
Effects of medical treatment	4,186	2.9
I50 Heart failure, N = 36,683	*12,844*	*35.0*
Alzheimer disease and other dementias	3,342	9.1
Chronic obstructive pulmonary disease	1,869	5.1
Atrial fibrillation and flutter	1,520	4.1
Urinary diseases	765	2.1
Cerebrovascular diseases	548	1.5
R96 Sudden death, N = 14,127	*328*	*2.3*
Prostate cancer	54	0.4
Colorectal cancer	48	0.3
Skin cancer	44	0.3
Bladder cancer	35	0.3
Breast cancer	28	0.3
R54 Senility, N = 10,298	*279*	*2.7*
Skin cancer	64	0.6
Breast cancer	46	0.4
Prostate cancer	29	0.3
Colorectal cancer	26	0.3
Bladder cancer	16	0.2
X59 Exposure to unspecified factor, N = 9,415	*6,442*	*68.4*
Effects of medical treatment	2,543	27.0

Alzheimer disease and other dementias	1,966	20.9
Ischaemic heart disease	1,274	13.5
Atrial fibrillation and flutter	774	8.2
Chronic obstructive pulmonary disease	492	5.2
A41 Other sepsis, N = 6,574	*3,444*	*52.3*
Ischaemic heart disease	919	14.0
Alzheimer disease and other dementias	564	8.6
Atrial fibrillation and flutter	353	5.4
Chronic obstructive pulmonary disease	328	5.0
Urinary diseases	221	3.4

Table S3b - The most prevalent non-garbage codes by minor garbage code

Non-garbage codes according to GBD Cause List, detail level 3
(Note that there may be more than one non-garbage code in each death.)

Diagnostic code	*N*	% of all deaths in group
All Minor GC, N = 149,665	*58,393*	*39.0*
Alzheimer disease and other dementias	14,920	10.0
Ischaemic heart disease	12,040	8.0
Atrial fibrillation and flutter	6,505	4.4
Urinary diseases	3,728	2.5
Chronic obstructive pulmonary disease	3,621	2.4
I64 Unspecified stroke, N = 43,814	*18,156*	*41.4*
Alzheimer disease and other dementias	6,204	14.2
Ischaemic heart disease	2,972	6.8
Atrial fibrillation and flutter	2,287	5.2
Cerebrovascular diseases	1,138	2.6
Chronic obstructive pulmonary disease	1,108	2.5
J18 Unspecified pneumonia, N = 41,753	*12,226*	*29.3*
Alzheimer disease and other dementias	3,249	7.8
Ischaemic heart disease	2,992	7.2
Atrial fibrillation and flutter	1,471	3.5
Urinary diseases	666	2.6
Diabetes mellitus	577	1.4
C80 Malignant neoplasm, site unknown, N = 11,013	*2,956*	*26.8*
Ischaemic heart disease	549	5.0
Chronic obstructive pulmonary disease	432	3.9
Alzheimer disease and other dementias	406	3.7
Atrial fibrillation and flutter	267	2.4
Endocrine, metabolic, blood, and immune disorders	139	1.3
E14 Unspecified diabetes mellitus, N = 10,425	*6189*	*59.4*
Ischaemic heart disease	3,045	29.2

Alzheimer disease and other dementias	1,050	10.1
Atrial fibrillation and flutter	623	6.0
Chronic kidney disease	501	4.8
Cerebrovascular diseases	453	4.4
I69 Sequelae of cerebrovascular disease, N = 10,124	*4,538*	*44.8*
Alzheimer disease and other dementias	1,267	12.5
Ischaemic heart disease	728	7.2
Urinary diseases	511	5.1
Atrial fibrillation and flutter	503	5.0
Cerebrovascular diseases	235	2.3

Table S4 - Definition of garbage codes

The definition is copied from Table S5 in the methods appendix to GBD 2019 Diseases and Injuries Collaborators. GBD 2019: Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 2020;396(10258):1204-22. (Corrected for some obvious typographic errors.)

Level 1 (very high)	Codes with serious policy implications	The true UCD might belong to any of the three broad groups of causes of death (communicable, maternal, neonatal and nutritional disease; non-communicable diseases; injuries). E.g. sepsis
Level 2 (high)	Codes with substantial policy implications	The true UCD might belong to one (or at most two) of the three broad groups of causes of death. E.g. unspecified injury
Level 3 (medium)	Codes with important policy implications	The true UCD is likely to be within the same ICD chapter. E.g. cancer of unknown site
Level 4 (low)	Codes with limited policy implications	The true UCD is likely to be within a single disease or injury category. E.g. unspecified stroke

Level 1 and 2 are major garbage codes, level 3 and 4 minor.

Garbage Code (GBD Level 1)
A40-A41.9, A48.0, A48.3, A49.0-A49.1, A59-A59.9, A71-A71.9, A74.0, B07-B07.9, B30-B30.9, B35-B36.9, B85-B85.4, B87-B88.9, B94.0, D50-D50.0, D50.9, D62-D63.0, D63.8-D64, D64.1-D65.9, D68, D69.9, E15, E16, E50-E50.9, E64.1, E85.3-E87.6, E87.8-E87.9, F06.2-F06.4, F07.2, F09-F09.9, F19-F23.9, F25-F49, F51-F99.0, G06-G08.0, G32-G32.8, G43-G44.2, G44.4-G44.8, G47-G47.2, G47.4-G47.9, G50-G60.9, G62-G62.0, G62.2-G65.2, G80-G83.9, G89-G89.4, G91-G91.2, G91.4-G93, G93.1-G93.2, G93.4-G93.6, G94.0-G94.8, G99-G99.8, H00-H05, H05.2-H69.9, H71-H99, I26-I26.9, I31.2-I31.4, I46-I46.9, I50.0-I50.4, I76, I95-I95.1, I95.8-I95.9,

J69-J69.9, J80-J80.9, J81.0, J85-J85.3, J86-J86.9, J93-J93.1, J93.8-J93.9, J94.2, J96-J96.9, J98.1-J98.3, K00-K19, K30, K65-K66.1, K66.9, K68.1-K68.9, K71-K71.6, K71.8-K72.9, K75.0, L20-L30.9, L40-L50.9, L52-L54.8, L56-L56.2, L56.4-L56.5, L57-L57.9, L59-L68.9, L70-L76.8, L80-L87.9, L90-L92.9, L94-L96, L98.5-L99.8, M04, M10-M12.0, M12.2-M29, M37-M39, M43.2-M49, M49.2-M64, M65.1-M71, M71.2-M72.4, M72.8-M73, M73.8-M79.9, M83-M86.2, M86.5-M86.9, M87.2-M87.9, M89.1-M89.4, M90-M99.9, N17-N17.9, N19-N19.9, N32.1-N32.2, N32.8-N33.8, N35-N35.9, N37-N37.8, N39.3-N39.8, N42-N43.4, N44.1-N44.8, N46-N48.9, N50-N53.9, N61-N64.9, N82-N82.9, N91-N91.5, N95, N95.1-N95.9, N97-N97.9, R02-R02.9, R03.1, R07.0, R08-R09, R09.3, R11-R12.0, R14-R19.6, R19.8-R23, R23.1-R30.9, R32-R50.1, R50.8-R57.9, R58.0-R72.9, R74-R78, R78.6-R94.8, R96-R99.9, U05, U07-U81, U89.9-U99, X40-X44.9, X46-X46.9, X49-X49.9, Y10-Y14.9, Y16-Y19.9, Z00-Z15.8, Z17-unsp.
Garbage Code (GBD Level 2)
A14.9, A29-A30.9, A45-A45.9, A47-A48, A48.8-A49, A49.3-A49.9, A61-A62, A72-A73, A76, A97, B08-B09, B11-B14, B28-B29, B31-B32.4, B34-B34.9, B61-B62, B68-B68.9, B73-B74.2, B76-B76.9, B78-B81.8, B84, B92-B94, B94.8-B94.9, B95.6, B97.3, B97.7-B99.9, D59, D59.4, D59.8-D59.9, F17-F17.9, G44.3, G91.3, G93.0, G93.3, I10-I10.9, I15-I15.9, I27, I27.8-I27.9, I50, I50.8-I50.9, I67.4, I70-I70.1, I70.9, I74-I75.8, J81, J81.1, J90-J90.0, J94-J94.1, J94.8-J94.9, K92.0-K92.2, N70-N71.9, N73-N74.0, N74.2-N74.8, R03-R03.0, R04-R06.9, R09.0-R09.2, R09.8-R10.9, R13-R13.9, R23.0, R58, S00-T98.3, W47-W48, W63, W71-W72, W76-W76.9, W82, W95-W97, W98, X07, X55-X56, X59-X59.9, Y20-Y34.9, Y86-Y87, Y87.2, Y89, Y89.9-Y99.9

Garbage Code (GBD Level 3)
A01, A31-A31.9, A42-A44.9, A49.2, A64-A64.0, A99-A99.0, B17, B17.1, B17.8-B17.9, B19-B19.0, B19.2-B19.9, B37-B46.9, B49-B49.9, B55, B55.1-B55.9, B58-B59.9, B89, B94.2, C14-C14.9, C22.9, C26-C29, C35-C36, C39-C39.9, C42, C46-C46.9, C55-C55.9, C57.9, C59, C63.9, C68, C68.9, C74-C74.9, C75.9-C80.9, C87, C97, D00.0, D01, D01.4-D02, D02.4-D02.9, D07, D07.3, D07.6-D09, D09.1, D09.7, D09.9-D10, D10.9, D13, D13.9-D14, D14.4, D17-D21.9, D28, D28.9-D29, D29.9-D30, D30.9, D36.0, D36.9-D37.0, D37.6-D38, D38.6-D39.0, D39.7, D39.9-D40, D40.9-D41, D41.9, D44, D44.9, D48, D48.7-D49.1, D49.5, D49.7-D49.9, D54, D75.9, D79-D85, D87-D88, D89.8-D99, E07.8-E08.9, E17-E19, E34.0, E34.9-E35.8, E37-E39, E47-E49, E62, E69, E87.7, E90-E998, F04-F06.1, F06.5-F07.0, F07.8-F08, F50, F50.8-F50.9, G09-G09.9, G15-G19, G21, G21.2, G21.4-G22.0, G27-G29, G33-G34, G38-G39, G42, G48-G49, G66-G69, G74-G79, G84-G88, G93.8-G94, G96-G96.9, G98-G98.9, I00.0, I03-I04, I14-I14, I16-I19, I29-I29.9, I44-I45.9, I49-I49.9, I51, I51.6-I59, I90-I94, I96-I96.9, I98.4-I98.8, I99-ID5.9, J02.9, J03.9, J04.3, J06, J06.9, J40-J40.9, J47-J59, J71-J79, J81.9, J83, J85.9, J87-J89, J90.9, J93.6, J97-J98.0, J98.4-J99.8, K21-K21.9, K22.7, K31.9-K34, K39, K47-K49, K53-K54, K63-K63.4, K63.8-K63.9, K69, K70.4-K70.9, K78-K79, K84, K87-K89, K92, K92.9-K93, K96-K99, L06-L07, L09, L15-L19, L31-L39, L69, L77-L79, N09, N13-N13.5, N13.7-N13.9, N24, N28.8-N28.9, N38, N39.9-N40.9, N54-N59, N66-N69, N78-N79, N84, N84.2-N86, N88-N90.9, N92-N94.9, N95.0, O08-O08.9, O17-O19, O27, O37-O39, O49-O59, O78-O79, O93-O95.9, P06, P16-P18, P30-P34.2, P40-P49, P62-P69, P73, P79, P82, P85-P89, P96.9-P99.9, Q08-Q10.3, Q19, Q29-Q29, Q36.0-Q36.9, Q46-Q49, Q88, Q89.9, Q94, Q99.9 R00-R01.2, R07, R07.1-R07.9, R31-R31.9
Garbage Code (GBD Level 4)
B16.9, B64, B82-B82.9, B83.9, C69, C69.9, C91.1, C91.4-C91.5, C91.7-C91.9, C92.7-C92.9, C93.2, C93.5-C93.7, C93.9, E12-E14.9, G00, G00.9-G02.8, G03.9, I37.9, I42-I42.0, I42.9, I51.5, I64-I64.9, I67, I67.8-I68, I68.8-I69, I69.4-I69.9,

J07-J08, J15.9, J17-J19.6, J22-J29, J64-J64.9, P23, P23.5-P23.9, P37.3-P37.4, R73-R73.9, V87-V87.1, V87.4-V88.1, V88.4-V89.9, V99-V99.0, X84-X84.9, Y09-Y09.9, Y85-Y85.9

Paper II

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Injury death certificates without specification of the circumstances leading to the fatal injury – the Norwegian Cause of Death Registry 2005–2014

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Abstract

Background: For injury deaths, the underlying cause of death is defined as the circumstances leading to the injury. When this information is missing, the ICD-10 code X59 (Exposure to unspecified factor) is used. Lack of knowledge of factors causing injuries reduces the value of the cause of death statistics. The aim of this study was to identify predictors of X59-coded deaths in Norway, and to assess methods to identify the true underlying cause of injury deaths.

Methods: We used data from the Norwegian Cause of Death Registry from 2005 to 2014. We used logistic regression to identify determinants of X59-coded deaths. For redistribution of the X59 deaths, we used a multinomial logistic regression model based on the cases where injury circumstances were known. The data were divided into training and test sets. The model was developed on the training set and assessed on the test set before it was applied to the X59 deaths. The models used death certificate information on the nature of injury and demographic characteristics as predictor variables. Furthermore, we mailed a query to the certifying physicians of X59 deaths reported in the year 2015, where we asked for additional information on the circumstances leading to the fatal injury.

Results: There were 24,963 injury deaths reported to the Cause of Death Registry of Norway 2005–2014. Of these, 6440 (25.8%) lacked information on the circumstances leading to the death. The strongest predictor for a X59 death was the nature of injury (hip fracture), followed by lack of information on the scene of injury. Applying our redistribution algorithm, we estimated that 97% of the X59-coded deaths were accidental falls. The strongest covariate was the nature of injury, followed by place of death and age at death. In 2015, there were 591 X59-coded deaths. Queries were sent to the certifying doctors in 559 cases. Among the informative replies to the query, 88% of the deaths were reclassified to accidental falls.

Conclusions: A large proportion of injury deaths in Norway lack information on the circumstances leading to the fatal injury. Typically, these deaths represent accidental falls causing hip fracture in elderly individuals.

Keywords: Cause of death, Accidental falls, Hip fractures, Garbage code, Redistribution, X59

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Background

According to the Global Burden of Disease Project, about 4.7 million (8%) deaths worldwide are caused by injuries [1]. In Norway, this represents about 2500 deaths (6% of all deaths) [1]. One of the main purposes of the classification of causes of death is to give information relevant to prevention programs and planning of health care services [2]. According to the instructions from the World Health Organization (WHO), when the cause of death is an injury or other effect of an external cause, the circumstances that gave rise to that condition should be selected as the underlying cause of death [3]. The reason for this is clear: the same anatomical injury (e.g., a skull fracture) can arise in numerous situations (for example traffic accidents, falls, and interpersonal violence), each with their own risk factors and targets for prevention. When there is insufficient information on the death certificate about the circumstances for an injury, "Exposure to unspecified factor" (ICD-10 code X59) is used as the underlying cause of death. In an ICD-10 update in effect since 2006, X59 was subdivided into X59.0 ("Exposure to unspecified factor causing fracture") and X59.9 ("Exposure to unspecified factor causing other and unspecified injury").

In general, when the information on the death certificate is insufficient to identify the true underlying cause of death, the death will be classified using uninformative codes. The term "garbage codes" was introduced by Murray and Lopez in 1996 to describe such codes [4]. In order to get a better epidemiological overview and be able to compare cause of death statistics in different countries and over different periods, there have been attempts to identify which informative causes of death (target groups) the garbage code deaths statistically represent [5]. The most comprehensive work has been carried out within the framework of the Global Burden of Disease Project [1, 4–7].

X59 is a typical example of a garbage code. The use of this code in cause of death statistics varies greatly among countries. In a study by Lu et al. from 2007, the proportion of unintentional injury deaths coded with X59 varied from 7 to 33% in the four countries included in the study [8]. The cause of death statistics have low quality if a large proportion of deaths are assigned X59. Bhalla et al. argued that the data concerning injury deaths were good if less than 20% of the deaths were assigned a garbage code, and found that in this respect only 20 out of 83 countries had high-quality data [9].

Several studies have directly or indirectly shown that a significant proportion of unspecified injury deaths represent accidental falls in the elderly [10–13].

Aim

The aim of this study was to explore the use of the ICD-10 code X59 for injury deaths lacking information on external cause in Norway during 2005–2014. First, we wanted to find characteristics for the use of X59 as underlying cause of death in Norway. Second, using deaths with known external cause of death, we aimed to develop a classification algorithm to place the X59 deaths in the most appropriate external cause groups (target groups), and finally, compare the results of the redistribution with a query to the certifying doctors in Norway regarding the X59-coded deaths for the calendar year 2015.

Methods

The Norwegian Cause of Death Registry contains individual data on all deaths among Norwegian residents in Norway and abroad, and, starting in the year 2012, information on deaths among foreigners who died in Norway [14]. The registry uses the IRIS software [15] with the Automated Classification of Medical Entities (ACME) module [16] for semiautomatic coding. ACME applies the rules in ICD-10 for selection of the underlying cause of death [3]. We used data from the Norwegian Cause of Death Registry for all deaths among Norwegian residents with an external cause of death for the years 2005–2014 ($N = 24{,}963$). From the information available, we used the following variables: calendar year of death in two categories (2005–2009 and 2010–2014), age in 10-year groups, sex, underlying cause of death (ICD-10 code), the nature of injury (ICD-10 code), the place of death, the scene of injury, and whether an autopsy (forensic or medical) was performed. The categories for underlying cause of death, the nature of injury, and the place of death are shown in Table 1. Where there was more than one injury registered on the death certificate, we used the injury considered as most serious according to the priority list in ICD-10 (main injury) [3]. We chose not to include deaths coded with Y34 ("Unspecified event, undetermined intent") in the X59 group, as Y34 was used only two times during the entire study period, and codes in the range Y10–34 were used only 15 times. Information on the place of occurrence of the injury was missing in 40% of the deaths, so we decided to use this as a dichotomous variable to indicate whether that information was available or not.

We retrieved tabular cause-of-death data at the ICD-10 three- or four-character level for the years 2005 to 2015 for all available countries from the WHO Mortality Database [17]. For each location, we calculated the mean fractions of all external causes of death (ICD-10 code V01-Y98.9) coded with X59 (X59, X59.0 or X59.9) and with Y34 (Y34 or Y34.0) over the available years.

Predictors for X59 as the underlying cause of death

We used multiple logistic regression to study predictors of X59 coded deaths. The explanatory variables were

Table 1 Categories of external underlying cause of death, nature of injury, and place of death

External underlying cause of death	ICD-10 codes
1. Road traffic accidents	V00 – V89.9, Y85.0
2. Accidental falls	W00 – W19.9
3. Accidental poisonings	X40 – X49.9
4. Other accidents and events of undetermined intent	V90 – V99, W20 – X39.9, X50 – X58, Y10 – Y84, Y85.9 – Y86, Y87.2 – Y89.9
5. Exposure to unspecified factor (X59)	X59, X59.0, X59.9
6. Intentional self-harm (suicide)	X60 – X84, Y87.0
7. Assault (homicide)	X85 – Y09, Y87.1
Nature of injury	
1. Head and neck injuries	S00 – S19.9
2. Thoracic injuries	S20 – S29.9
3. Injuries to abdomen and pelvis	S30 – S39.9
4. Injuries to hip and thigh	S70 – S79.9
5. Other mechanical injuries, multitrauma	S40 – S69.9, S80 – T14.9
6. Poisoning	T36 – T65.9
7. Suffocation/drowning	T17 – T17.9, T71, T75.1
8. Other injuries, sequelae	T15 – T16, T18 – T35.7, T66 – T70.9, T73 – T75.0, T75.2 – T98.3
Place of death	
1. At home	At home
2. Hospital	Somatic and psychiatric hospitals
3. Nursing home	Nursing homes, other health care institutions
4. Other known	Other known, during transport
5. Unknown	Unknown, abroad

age, sex, nature of injury (eight categories), place of death (five categories), knowledge about the scene of injury (yes/no), whether an autopsy was performed (no autopsy, forensic autopsy, and medical autopsy) and calendar year of death in two groups. We used six age groups – below 50 years, 10-year groups up to 89, and 90 and above – in order to have sufficiently large groups.

First, we investigated each independent variable alone (univariate) before we entered all variables into a multiple predictors model. All the variables except calendar year of death had a significant effect in the univariate analyses. We used a stepwise approach in developing the final model, keeping the variables that had a significant explanatory value based on likelihood ratio, and using a p value of less than 0.10 as a guideline. The effects are shown as odds ratios with 95% confidence intervals. For each variable, the likelihood ratio statistic (− 2 log likelihood) and two-sided p values are shown.

Redistribution of X59 cases to specific external cause groups

Redistribution is the process of reclassifying the cases with garbage codes to more informative causes of death (target groups). We developed a multinomial logistic regression model [18] with the same set of covariates as in the prediction model, except for age, where we used all 10-year age groups in the categorical variable. In contrast to the X59 deaths, a substantial number (44%) of the other injury deaths occurred in persons below 50 years. The age profile varied between the different cause groups as well, so we retained all the age groups below 50. As target groups, we used the following categories: road traffic accidents, accidental falls, accidental poisonings, other accidents and events of undetermined intent, intentional self-harm (suicide), and assault (homicide). The choice of target groups was based on the observation that accidental falls, accidental poisonings, road traffic accidents, and suicides are the largest groups of external causes of death in Norway. We chose to include intentional injuries (suicides and homicides) as well as unintentional injuries among the target groups to allow for the possibility that some of the X59 deaths could be redistributed to intentional injuries. In addition to the groups mentioned above, there are a number of small groups of injuries which were gathered in "Other/unspecified". We used road traffic accidents as the reference outcome.

To develop a redistribution algorithm, we first excluded the deaths with X59 coded as the underlying cause of death from the dataset. The remaining 18,523 cases were randomly split into a training dataset (67%) and test dataset (33%). We then developed a multinomial regression model on the training dataset and applied it to the test dataset. For each death, we chose as the target code the external cause group with the highest probability, regardless of level.

The performance of the model on the test dataset was evaluated by calculating overall accuracy and Cohen's kappa. If the distribution is unbalanced, with the majority of cases in one group, unadjusted overall accuracy will be artificially high, and kappa will give a more conservative measure [18]. We also calculated likelihood ratio for the difference between the full model and reduced models where we excluded one variable at a time. For each target group, we calculated sensitivity and specificity for a case being placed in this group versus all other groups. Then we applied the model on the X59-coded deaths to predict the target group for each individual death. This process was repeated 1000 times with new separation into training and test datasets, and

the median and inter-quartile range of the results were calculated.

Query to the certifying doctors

As part of the regular operation of the Norwegian Cause of Death Registry, a quality assurance project was carried out during 2015–2016 on deaths coded X59 that occurred in the calendar year 2015. A query letter was sent to the certifying doctors for X59-coded deaths, collecting information about the circumstances of the injury. We used the replies to identify the external factor causing the death. By the end of the year 2016, we identified 32 additional cases where no query letter had been sent. In addition, we searched for cases where another type of query letter had been sent, and where the underlying cause of death was X59 (see Fig. 1).

Statistical analysis

For statistical analysis, we used the R software [19]. For binary logistic regression, we calculated odds ratios with 95% confidence intervals, likelihood ratio statistics (−2LL), and two-sided p values. We chose to retain an explanatory variable in the final model if the p value was less than 0.10. For multinomial regression, we used the "nnet" package [20]. A two-sided p value < 0.05 was considered statistically significant. We used Eurostat's European Standard Population (ESP2013) for age standardization [21].

Results

The total number of deaths among Norwegian residents in 2005–2014 was 413,838, of which 24,963 (6.0%) had an external cause of death. The general characteristics of the data material are shown in Table 2.

Predictors for use of the ICD-10 code X59

For the years 2005–2014, 6440 (1.6% of all deaths and 25.8% of the injury deaths) among Norwegian residents were coded with X59 (X59, X59.0, or X59.9) as the underlying cause of death. The results from the logistic regression models for each explanatory variable (unadjusted) are given in Table 3. All the investigated variables had a statistically significant association with X59, except calendar year of

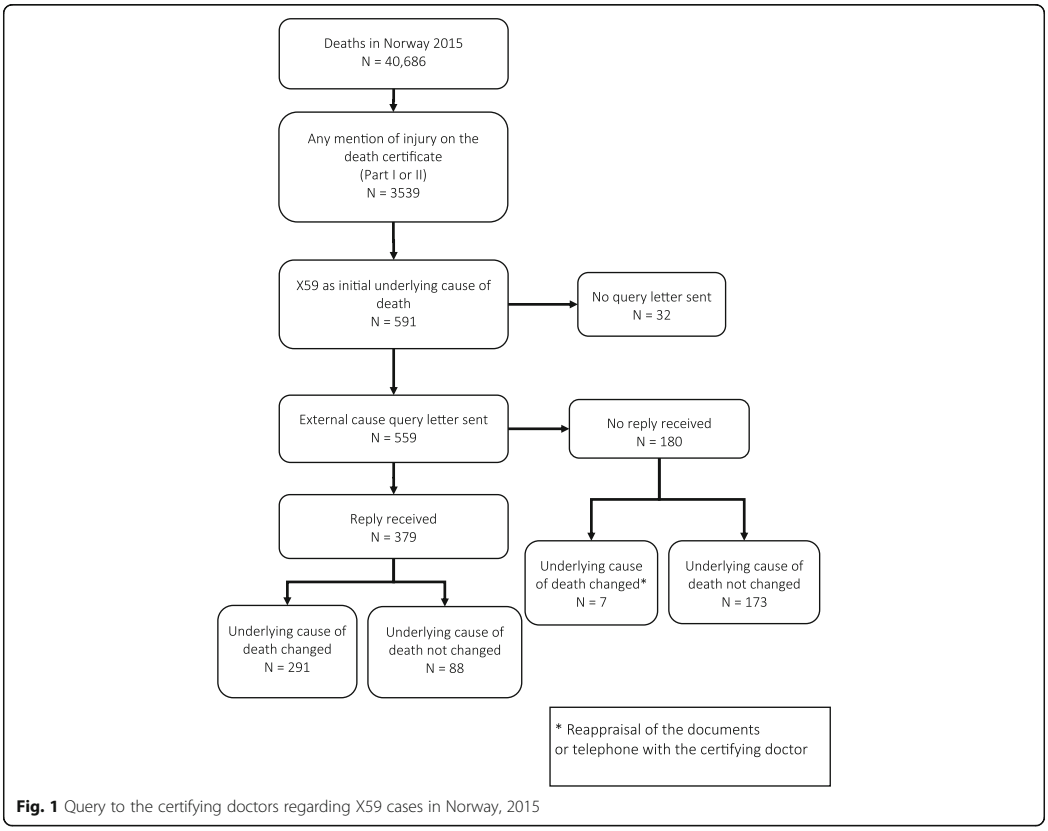

Fig. 1 Query to the certifying doctors regarding X59 cases in Norway, 2015

Table 2 Characteristics of injury deaths in Norway, 2005–2014

	N (%)	Females (%)	Age (yrs) median (IQR)	Dying in health care institutions (%)	Main injury in hip/thigh region (%)
Road traffic accidents	2211 (8.9)	570 (25.8)	44 (25–64)	29.7	0.6
Accidental falls	4218 (16.9)	2082 (49.4)	85 (76–90)	82.6	31.6
< 70 yrs	737	160 (21.7)	57 (46–64)	51.0	4.1
≥ 70 yrs	3481	1922 (55.2)	87 (82–91)	89.2	37.4
Accidental poisonings	3329 (13.3)	882 (26.5)	42 (31–53)	14.2	0
Other accidents and events of undetermined intent	2930 (11.7)	942 (32.2)	61 (43–79)	36.7	1.3
Exposure to unspecified factor (X59)	6440 (25.8)	3970 (61.6)	88 (83–92)	93.1	79.2
Intentional self-harm (suicide)	5412 (21.7)	1574 (29.1)	45 (31–58)	10.4	0
Assault (homicide)	423 (1.7)	178 (42.1)	35 (21–51)	15.6	0.7
Total	**24,963 (100)**	**10,198 (40.9)**	**66 (42–86)**	**49.3**	**26.0**

Source: Norwegian Cause of Death Registry

death. There was a predominance of women (OR 3.17, 95% CI 2.99–3.37) and persons of advanced age (85.6% of the persons with X59 were 80 years or older, compared to 22.5% in the group with known external cause of death). Seventy-nine percent had injuries in the hip or thigh region (OR 36.0, 95% CI 32.0–40.7). Fifty-five percent died in a nursing home (OR 40.8, 95% CI 35.9–40.7). Only 3.9% underwent an autopsy, and in 89.5% of the cases there was no information on the scene of injury. Based on these results, it seems like the typical X59 death occurred in an elderly woman with an injury (fracture) in the hip or thigh region, dying in a nursing home. In the multiple predictors model, also shown in Table 3, we found that the strongest predictor was the nature of injury, followed by lack of knowledge about the scene of injury.

Redistribution

We used multinomial logistic regression to redistribute X59 deaths to the most likely non-garbage code. We split the non-X59 cases into training and test sets and developed the regression model on the training set. The performance of the model was evaluated on the test set before we applied the model on the X59 cases. This procedure was repeated 1000 times. The median overall accuracy of prediction on the test set was 0.71, kappa 0.64. For the classification fall/not fall, the sensitivity was 0.85 and the specificity 0.96. The most important variables were the nature of injury, followed by the place of death and the age of the deceased (see Table 4). We found that almost all of the X59 cases (97.4%) were to be redistributed to accidental falls. This meant that for the 10-year study period, the number of deaths due to accidental falls increased by 148.7%, from 4218 to 10,490 deaths (Table 5 and Fig. 2). The mean age-standardized death rate from accidental falls for the years 2005–2014 increased from 10.3 per 100,000 to 25.9 per 100,000.

All cases except one (5102 of 5103) with hip and thigh injuries were redistributed to accidental falls. For the cases redistributed to accidental falls, the median age was 88 years and 63% were women. In comparison, for those being redistributed to road traffic accidents, the median age was 57 years and 21% were women, and for suicides the median age was 57 years and 15% were women. Further details of the redistribution results are given in Table 6.

Query to the certifying doctors

Of the 40,686 deaths among Norwegian residents in 2015, 3539 had an injury mentioned on the death certificate, either in part I or part II. For the X59 cases, we sent 559 query letters to the certifying doctors, either directly or via the chief municipal medical officer (Fig. 1). We identified 32 additional cases as previously described, making a total of 591 cases and 1.5% of all deaths among Norwegian residents this year. The median age among the cases was 88 years, with an interquartile range of 9, and 339 (57.3%) were women. Of the total, 433 (73.3%) had a hip or thigh injury, 539 (96.0%) died in a health care institution, and only 10 (1.7%) underwent an autopsy.

The response rate was 67.8%. Eighty-eight (23.2% of the 379 replies) did not give any useful information, but 291 cases (76.8%) could be assigned a new and more specific underlying cause of death. The cause in the majority of these cases (257 of 291, 88.3%) was accidental falls. Altogether, we could reclassify 298/591 (50.4%) of the X59 cases. For details on the revised causes of death, see Table 7 and Fig. 3.

In the group where the quality assurance process gave a new underlying cause of death (298 cases), taking into account the nature of the injury, we established that 258 out of 284 (90.8%) with a mechanical type of injury (S00-T14.9) died from an accidental

Table 3 Predictors for X59-coded deaths

Explanatory variable	All external cause (%) N = 24,963	X59 (%) *N* = 6440	Not X59 (%) *N* = 18,523	Single predictor models				Multiple predictor model			
				OR (95% CI)		LR stat*	*P* value	OR (95% CI)		LR stat*	*P* value
Gender						1537	< 0.001			4.9	0.03
Male	14,765 (59.1)	2470 (38.4)	12,295 (66.4)	1 (ref.)				1 (ref.)			
Female	10,198 (40.9)	3970 (61.6)	6228 (33.6)	3.17	(2.99–3.37)			1.14	(1.01–1.27)		
Age						10,182	< 0.001			77.2	< 0.001
0–49 yrs	8219 (32.9)	64 (1.0)	8155 (44.0)	0.03	(0.02–0.03)			0.55	(0.37–0.82)		
50–59 yrs	2677 (10.7)	69 (1.1)	2608 (14.1)	1 (ref.)				1 (ref.)			
60–69 yrs	2100 (8.4)	143 (2.2)	1957 (10.6)	2.76	(2.07–3.72)			1.44	(0.99–2.11)		
70–79 yrs	2281 (9.1)	653 (10.1)	1628 (8.8)	15.2	(11.8–19.7)			1.89	(1.34–2.69)		
80–89 yrs	5858 (23.5)	3112 (48.3)	2746 (14.8)	42.8	(33.8–55.2)			2.00	(1.44–2.80)		
90+ yrs	3828 (15.3)	2399 (37.7)	1429 (7.7)	63.5	(49.9–82.0)			1.64	(1.17–2.32)		
Place of death						9331	< 0.001			182	< 0.001
At home	5889 (23.6)	312 (4.8)	5577 (30.1)	1 (ref.)				1 (ref.)			
Hospital	7222 (28.9)	2455 (38.1)	4767 (25.7)	9.21	(8.15–10.4)			0.63	(0.51–0.78)		
Nursing home	5088 (20.4)	3538 (54.9)	1550 (8.4)	40.8	(35.9–46.5)			1.22	(0.97–1.52)		
Other known	5020 (20.1)	44 (0.7)	4976 (26.9)	0.16	(0.11–0.22)			0.21	(0.14–0.31)		
Unknown	1744 (7.0)	91 (1.4)	1653 (8.9)	0.98	(0.77–1.25)			0.46	(0.32–0.66)		
Autopsy						6792	< 0.001			51.9	< 0.001
No autopsy	14,534 (58.2)	6189 (96.1)	8345 (45.1)	1 (ref.)				1 (ref.)			
Forensic	9695 (38.8)	104 (1.6)	9591 (51.8)	0.02	(0.01–0.02)			0.43	(0.33–0.57)		
Medical	734 (2.9)	147 (2.3)	587 (3.2)	0.39	(0.28–0.41)			0.53	(0.40–0.72)		
Nature of injury						14,759	< 0.001			3787	< 0.001
Head/neck	4244 (17.0)	392 (6.1)	3852 (20.8)	1 (ref.)				1 (ref.)			
Thorax	1055 (4.2)	134 (2.1)	921 (5.0)	1.43	(1.16–1.76)			1.65	(1.26–2.17)		
Abdomen/pelvis	665 (2.7)	341 (5.3)	324 (1.7)	10.3	(8.61–12.4)			4.05	(3.17–5.19)		
Hip/thigh	6495 (26.0)	5103 (79.2)	1392 (7.5)	36.0	(32.0–40.7)			12.1	(10.4–14.2)		
Other mechanical injury	2427 (9.7)	436 (6.8)	1991 (10.7)	2.15	(1.86–2.49)			1.72	(1.42–2.09)		
Poisoning	5010 (20.1)	3 (0.05)	5007 (27.0)	0.006	(0.001–0.02)			0.009	(0.002–0.02)		
Suffocation/drowning	4132 (16.6)	6 (0.1)	4126 (22.3)	0.01	(0.006–0.03)			0.02	(0.006–0.03)		
Other/sequelae	935 (3.7)	25 (0.4)	910 (4.9)	0.27	(0.18–0.40)			0.07	(0.04–0.10)		
Scene of injury						9224	< 0.001			3184	< 0.001
Unknown	10,081 (40.4)	5762 (89.5)	4319 (23.3)	1 (ref.)				1 (ref.)			

Table 3 Predictors for X59-coded deaths *(Continued)*

Explanatory variable	All external cause (%) N = 24,963	X59 (%) *N* = 6440	Not X59 (%) *N* = 18,523	Single predictor models				Multiple predictor model			
				OR (95% CI)		LR stat*	*P* value	OR (95% CI)		LR stat*	*P* value
Known	14,882 (59.6)	678 (10.5)	14,204 (76.7)	0.04	(0.03–0.04)			0.05	(0.04–0.05)		
Calendar year of death						0.008	0.93			3.1	0.07
2005–2009	12,265 (49.1)	3161 (49.1)	9104 (49.1)	1 (ref.)				1 (ref.)			
2010–2014	12,698 (50.9)	3279 (50.9)	9419 (50.9)	1.00	(0.95–1.06)			0.91	(0.83–1.01)		

Logistic regression analysis, data from the Norwegian Cause of Death Registry, 2005–2014
*LR stat: Likelihood ratio statistic (−2 logL)

Table 4 Multinomial logistic regression model for redistribution of X59 deaths

Complete model	Accuracy (mean(SD))	Kappa (mean(SD))	LR stat (mean(SD))*	p value
	0.712 (0.01)	0.636 (0.01)	Ref.	
Reduced models				
Without (one at a time)				
Nature of injury	0.494 (0.01)	0.341 (0.01)	10,582 (147)	< 0.001
Place of death	0.673 (0.01)	0.586 (0.01)	1563 (61)	< 0.001
Age	0.690 (0.01)	0.607 (0.01)	1298 (56)	< 0.001
Autopsy	0.706 (0.01)	0.629 (0.01)	366 (26)	< 0.001
Scene of injury	0.704 (0.01)	0.627 (0.01)	309 (27)	< 0.001
Gender	0.712 (0.01)	0.636 (0.01)	199 (22)	< 0.001
Calendar year of death	0.711 (0.01)	0.635 (0.01)	33 (8)	< 0.001

Data from the Norwegian Cause of Death Registry, 2005–2014
Based on 1000 repetitions of random division into new training and test sets. The models were developed on the training sets and evaluated on the test sets
*The likelihood ratio statistic (−2 logL) is computed by comparing the full model to the model *without* the variable in question. The higher the LR statistics, the more the model is weakened by excluding the variable in question

fall. In the group with hip/thigh injuries (ICD-10 code S70-S79.9) 202 out of 214 (94.4%) were reclassified to falls.

Use of X59 in the WHO mortality database

We analyzed data from the WHO Mortality Database for the years 2005–2014. Causes of death at the ICD-10 three- or four-character level were available for 125 countries and territories for at least one of the years. The fraction of all external causes of death coded with X59 varied from 0 to 42.1%, mean 6.4%. Use of X59 was most prevalent in Georgia (42.1%), Italy (31.4%), and Norway (26.0%). In eight locations, the X59 fraction was more than 20%, and in 76 locations below 5%. The fraction of all external causes of death coded with Y34 varied from 0 to 82.6%, highest in Azerbaijan (82.6%), Maldives (76.2%), and Bosnia and Herzegovina (54.4%). In Norway, the Y34 fraction was 0%. No countries had both a high X59 fraction and a high Y34 fraction.

Discussion

We used data from the Norwegian Cause of Death Registry for the years 2005–2014 to investigate predictors for a death to be assigned the ICD-10 code X59 ("Exposure to unspecified factor") as the underlying cause of death. One-quarter of the deaths due to external causes lacked information on the circumstances leading to the fatal injury. Using data from the WHO Mortality Database, we showed that Norway is among the countries with the most prevalent use of X59 in external causes. For Norway, we developed a multinomial logistic regression model to reclassify the X59 deaths to a specific external cause group. Using this model, we estimated that 97% of the X59 deaths were accidental falls. We also sent query letters to the certifying doctors regarding the X59 cases in 2015. In 88% of the cases where we could assign a more specific external cause of death, this was an accidental fall.

Although our study is limited to the ICD-10 period in Norway, it is useful to compare the function and place in the classification system for X59 with similar codes in the previous ICD revision. In ICD-9, the code E887

Table 5 Results of redistribution of X59 deaths to specific external cause groups

	Before redistribution	Number redistributed (mean [SD])	% of X59	After redistribution	Change %	Sensitivity (mean [SD])	Specificity (mean [SD])
Total	18,523	6440	100.0	24,963			
Road traffic accidents	2211	24.2 (1.10)	0.4	2235.2	1.1	0.60 (0.01)	0.96 (< 0.01)
Accidental falls	4218	6271.9 (2.26)	97.4	10,489.9	148.7	0.85 (0.01)	0.96 (< 0.01)
Accidental poisonings	3329	3.0 (0.00)	0.0	3332.0	0.1	0.69 (0.01)	0.99 (< 0.01)
Other accidents and events of undetermined intent	2930	27.6 (0.50)	0.4	2957.6	0.9	0.73 (0.02)	0.91 (< 0.01)
Suicide	5412	107.8 (2.34)	1.7	5519.8	2.0	0.67 (0.01)	0.84 (< 0.01)
Homicide	423	5.6 (1.17)	0.1	428.6	1.3	0.41 (0.06)	0.98 (< 0.01)

Data from the Norwegian Cause of Death Registry 2005–2014
Based on 1000 repetitions of multinomial logistic regression. Overall accuracy 0.71 (0.01), kappa 0.64 (0.01) (mean [SD])

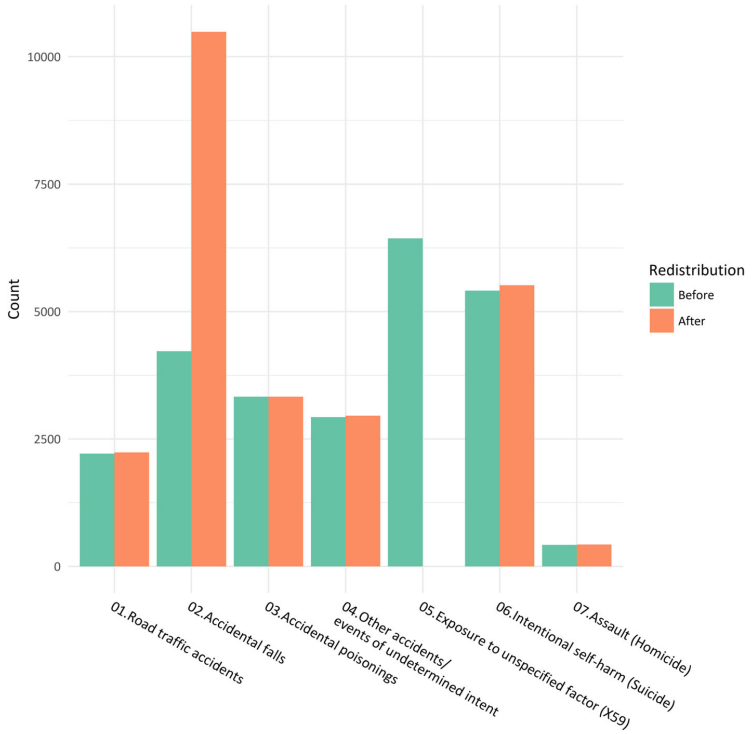

Fig. 2 Results of redistribution of X59 cases in Norway, 2005–2014. Number of external causes of death in Norway, 2005–2014, before and after redistribution of X59 cases

("Fracture, cause unspecified"), was used in cases where there was information that there had been a fracture, but without information on the circumstances around the injury. E887 was included in the "Falls" group and therefore often tabulated together with accidental falls. The ICD-10 code closest to E887 was initially X59 ("Exposure to unspecified factor"). Unlike E887, X59 included all kinds of injury and exposure, not only fractures. Also unlike E887, X59 is not included in the "Falls" group, but in the group "Accidental exposure to other and unspecified factors". This could potentially lead to shifts in the total number of deaths classified as accidental falls. In an ICD-10 update in effect since 2006, X59 was subdivided into X59.0 ("Exposure to unspecified factor causing fracture") and X59.9 ("Exposure to unspecified factor causing other and unspecified injury"). The code X59.0 would then include the same deaths as ICD-9 E887 (but not be included in the "Falls" group).

Norway has used ICD-10 for mortality coding since 1996. For the years 1996–2004, there was a national guideline stating that if a death certificate stated fracture of the femur (ICD-10 code S72) as the main injury, but without mention of the circumstances, the underlying cause of death should be coded as W19 ("Unspecified fall"). In 2005, this guideline was removed, and such cases would be assigned X59 as the underlying cause of death [22]. Similar rules for coding, tabulation, or presenting of statistics have been implemented in several countries, for instance Australia, to ensure continuity in the cause of death statistics [10].

Redistribution of X59 deaths to a specific external cause

Several studies have directly or indirectly shown that a large proportion of unspecified injury deaths represent accidental falls in the elderly. Hu and Mamady found that in the US in 1999–2010 there was a clear negative correlation between the unspecified unintentional injury mortality in the elderly and the mortality from accidental falls [13]. During the study period, the proportion of unintentional injuries with unspecified circumstances (X59) decreased and the death rate from accidental falls increased. When they adjusted for the improved specificity of reporting of injury deaths, the increase of fall

Table 6 Detailed results of redistribution of X59 deaths to specific external cause groups

	N	Traffic accidents (mean [SD])	Accidental falls (mean [SD])	Accidental poisonings (mean [SD])	Other/undetermined (mean [SD])	Suicide (mean [SD])	Homicide (mean [SD])
Nature of injury							
01.Head/neck	392	14.2 (0.75)	319.6 (1.14)	0 (0)	0 (0.03)	56.1 (0.85)	2.1 (0.37)
02.Thorax	134	1.4 (0.48)	125.5 (0.73)	0 (0)	0 (0)	6.2 (0.93)	1.0 (0.04)
03.Abdomen/pelvis	341	1.1 (0.24)	334.6 (0.96)	0 (0)	0 (0)	3.3 (1.37)	2.0 (0.91)
04.Hip/thigh	5103	0 (0)	5101.9 (0.36)	0 (0)	0.6 (0.50)	0 (0)	0.5 (0.69)
05.Other mechanical injury	436	7.5 (0.64)	390.2 (1.20)	0 (0)	0 (0)	38.3 (1.02)	0 (0)
06.Poisoning	3	0 (0)	0 (0)	3.0 (0)	0 (0)	0 (0)	0 (0)
07.Suffocation/drowning	6	0 (0)	0 (0)	0 (0)	2.0 (0)	4 (0)	0 (0)
08.Other	25	0 (0)	0 (0)	0 (0)	25.0 (0)	0 (0)	0 (0)
Age group							
0–49 years	64	10.2 (0.4)	8.2 (0.84)	2.0 (0)	4.0 (0.03)	36.7 (1.15)	3.0 (0.85)
50–69 years	212	9.8 (0.76)	146.8 (1.39)	1.0 (0)	3.6 (0.50)	48.2 (1.26)	2.6 (0.86)
70+ years	6164	4.2 (0.68)	6116.9 (1.35)	0 (0)	20.0 (0)	23.0 (1.25)	0 (0)
Total	**6440**	**24.2 (1.13)**	**6271.8 (2.19)**	**3.0 (0)**	**27.6 (0.50)**	**107.9 (2.28)**	**5.6 (1.26)**

Data from the Norwegian Cause of Death Registry, 2005–2014
Based on 1000 repetitions of multinomial logistic regression

deaths was 61% instead of 77%. Gagné et al. also found a similar relationship in Quebec, Canada, for the years 2000–2009 [12]. The mortality rate for certified accidental falls in persons above 65 years increased and the rate for presumed falls (X59 as underlying cause of death plus mention of fracture on the death certificate) declined. The sum of the death rates due to certified and presumed falls was more or less stable in women and decreased slightly in men. In Australia, Harrison and Kreisfeld used the same definition of presumed fall and estimated that half of the deaths due to accidental falls were missing from the conventional cause of death statistics. The age distribution was similar to the conventional fall group, and 73% had hip fractures [10]. In Sweden, Johansson and Westerling found that the number of deaths due to accidental falls in Sweden in 1995 would increase by 57% if discharge information from hospitalizations within one year prior to death was added to the information on the death certificates [23].

Table 7 Results from the X59 query at the Norwegian Cause of Death Registry for the 2015 data year

Revised cause of death	Reply received, $N = 379$	Reply not received, $N = 180$
Non-injury cause of death	15	2
Road traffic accidents	1	0
Accidental falls	257	2
Accidental poisonings	0	2
Other accidents and events of undetermined intent	3	0
Intentional self-harm (suicide)	15	1
Assault (homicide)	0	0
Not reclassified	88	173

In addition, there were 32 cases where no query was sent

Some of the X59-coded deaths in our study were redistributed to suicides, about 10 per year (1.7%), and two to three to road traffic accidents (0.4%). The rest, 0.5%, were distributed over the remaining groups. It is generally believed that official statistics miss some of the suicides, because of missing or incorrect information on the death certificates [24]. For example, the death may be classified as an accident instead of a suicide.

Bhalla and Harrison have expressed some concern that the Global Burden of Disease project redistributes too many deaths to road traffic accidents [25]. In our study, we have not found that a large proportion of X59 deaths represent road traffic accidents.

Selection of target groups

In choosing the target groups for redistribution of X59, we have included all external causes, not only accidents. This means that some of the X59 cases might be redistributed to suicides or homicides. This is the same approach as in the Global Burden of Disease study, where the target groups for X59 are all injuries ([1]Appendix section 2.4). We did not include non-injury causes of death as target groups. When querying the certifying doctors, we realized that some of the injury deaths could have a disease as the underlying cause of death, and the injury was reclassified as a contributory cause of death. In the query, this occurred with 17 out of the 298 deaths (5.7%) where we could assign a new underlying cause of

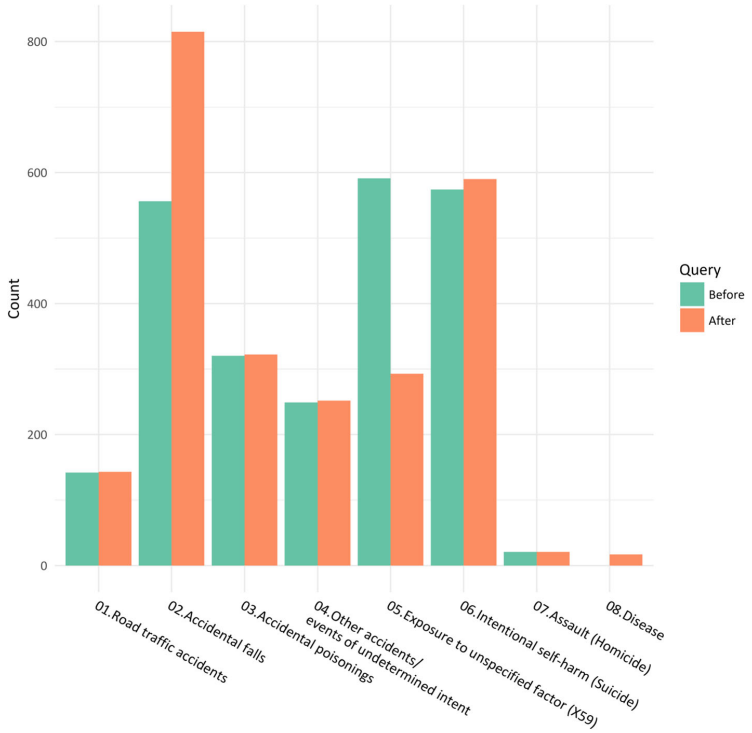

Fig. 3 Results of query to the certifying doctors regarding X59 cases in Norway, 2015. Number of external causes of death in Norway 2015 before and after querying the X59 cases. The total value for cases with a non-injury cause of death is not shown in the graph, only the number allocated after the query project

death. It is not always possible to decide whether a medical condition such as a myocardial infarction is a complication to the injury or a completely separate condition.

Query to the certifying doctors

We found that for 88% of the X59 cases where we received additional information from the certifying doctors, the cause of death could be reclassified as accidental fall. This is slightly lower than the result from redistribution by regression (97%). We noted that a substantial number of the doctors did not regard a hip fracture as an accident and did not understand the purpose of our query about the circumstances of the injury. Many of the certifying doctors were either affiliated with nursing homes or were general practitioners on call, and had probably limited information about the event that had given rise to the injury.

There may be several explanations for missing information on the circumstances of an injury. Death due to a hip fracture often occurs days or weeks after the incident, perhaps at a nursing home or another institution. Thus, the doctor certifying the death may not have all the relevant information on the circumstances of the injury and the focus may be on the patient's condition at the time close to death (the immediate cause of death), often a non-surgical complication, such as heart failure or pneumonia. Many elderly people have several diseases, and it can be difficult to decide which condition had the largest impact on the cause of death. Some doctors do not regard a low-level fall with a hip fracture as an accident or an external cause. In addition, many doctors are not fully familiar with the WHO instructions for cause of death certification.

Strengths and limitations

A strength of this study is that it is population-based and includes all deaths with external causes among Norwegian residents for a recent 10-year period.

In contrast to the redistribution efforts by the Global Burden of Disease project [1], we had all the information

on the death certificates available when we developed the redistribution model. Especially information on the nature of injury and the place of death contributed to the classification. This made it possible to perform redistribution on individual-level instead of group-level estimates. The World Health Organization also has a similar group-level approach in estimating causes of death but does not include X59 as an ill-defined code to be redistributed [26].

Even if the overall accuracy and kappa value for the redistribution model were 0.71 and 0.64, respectively, the discriminatory performance for the distinction "fall/not fall" had a sensitivity of 0.85 and specificity 0.96. The results were stable when we repeated the calculations 1000 times with new training and test sets.

Another strength of our study is that in addition to the analyses on available registry data, we performed a query of the certifying doctors. The results of this query strongly support the findings from the redistribution by multinomial logistic regression. A limitation of the query is that we received useful additional information in only 49.2% (291/591) of the X59 cases identified.

Generalizability and implications

We believe that our approach could be used in other countries. Multinomial logistic regression is a well-known method for classification, and the procedure with splitting the data in a training and a test set, developing the model on the training set, and validating it on the test set is a recognized approach [18]. The exact importance of the different variables (and which variables should be included in the final model) and the performance of the model will vary among locations. The model must therefore be customized and evaluated in the specific setting where it is to be used. The results from the redistribution will also vary according to the local pattern of use of X59 (or other uninformative codes). One cannot directly claim from our observations in Norway that the majority of X59-coded deaths generally represent accidental falls. In other countries, a substantial part of X59-coded deaths might well be in another age segment and represent different causes of death than in Norway.

Our findings strongly suggest that the mortality from accidental falls is underestimated in official Norwegian statistics. Based on our estimates, the number of deaths due to falls in the study period should be nearly 150% higher than the official figures, and the actual death rate due to accidental falls among Norwegian residents should be about 25 deaths per 100,000 population, instead of the recorded 10.3/100,000. To reduce the number of X59 deaths and achieve more correct statistics, it is important to have efficient routines for querying the certifying doctors.

Conclusions

One-quarter of the death certificates for Norwegians with an external cause of death lacked information on the circumstances leading to the injury. This is a serious flaw in the cause of death statistics. The majority of these cases were elderly women with hip injuries, dying in nursing homes. Both in redistribution with regression methods and in a query to the certifying doctors we found that almost all of these cases of X59-coded deaths represented accidental falls.

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Availability of data and materials

According to Norwegian data privacy regulations, it is not possible to make the data publicly available. Researchers wishing to replicate or expand the study may seek approval from the Committee for Medical Research Ethics.

Authors' contributions

CLE and SEV conceived the study and drafted the manuscript. CLE performed the analyses. All authors have critically read, commented on, and approved the manuscript.

Ethics approval and consent to participate

The study using registry data from 2005 to 2014 was approved by the Regional Committee for Medical Research Ethics. The query on data from 2015 was performed as part of the quality assurance of the Norwegian Cause of Death Registry and as such did not require further approval.

Consent for publication

Not applicable.

Competing interests

The authors declare that there are no competing interests.

Publisher's Note

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Paper III

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ORIGINAL ARTICLE

Forensic autopsies in Norway 1996–2017: A retrospective study of factors associated with deaths undergoing forensic autopsy

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Abstract

Aims: Forensic autopsies are important for the investigation of deaths with a legal or public-health interest, as well as being a source for cause-of-death statistics. The aim of this study was to investigate the use of forensic autopsies in Norway, with a special emphasis on geographical variation. *Methods:* Data from the Norwegian Cause of Death Registry for the years 1996–2017 included 920,232 deaths and 37,398 forensic autopsies. We used logistic regression to identify factors that were associated with the proportion of forensic autopsies, grouped according to the registered cause of death. Explanatory variables were age and sex, place of death, police district, population size and urbanity level of the municipality and distance to the autopsy facility. *Results:* The proportion of deaths undergoing forensic autopsy was 4.1%, with the highest being homicides (96.6%) and the lowest being deaths from natural causes (1.7%). Variation between police districts was 0.9–7.8%, and the span persisted during the study period. The most important explanatory variables across the strata were place of death (there were few autopsies of deaths in health-care facilities), police district and age of the deceased. Distance to the autopsy facility, sex, population size and the level of urbanity had only a minor influence. The variation between police districts was not fully accounted for by the other investigated factors. ***Conclusions:*** **Unjustified differences in the frequency of autopsies may lead to insufficient investigation of possible unnatural deaths. In worst-case scenarios, homicides or other criminal cases might remain undetected. It may also introduce spurious shifts in the cause-of-death statistics.**

Keywords: *Forensic autopsy, cause of death statistics*

Introduction

A forensic autopsy is part of the investigation of a death that to some degree is of public interest. The most important function is to investigate a possible criminal cause of death. Different states and countries have different death investigation systems, but they all aim to cover outright homicides and deaths that might be disguised criminal cases. Many jurisdictions include deaths where the suspicion of homicide is low but where there is a public interest in investigating or documenting the cause of death. Among these are deaths caused by recklessness or negligence, such as traffic accidents, workplace accidents or medical misadventure, or deaths that have important public-health issues, such as suicides or deaths related to drug abuse [1].

As rules may vary between locations, the number of deaths eligible for a forensic autopsy also varies. The number of deaths that actually undergo a forensic autopsy also depends on compliance with the regulations.

In Norway, Igeltjørn and Nordrum [2] found that the proportion of forensic autopsies for road traffic accidents in two neighbouring counties varied from 49% to 70%. Frost et al. [3] found differences in the proportion of forensic autopsies between the same two counties according to age, sex and cause of death.

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For example, the proportion of autopsies for suicides varied from 11% to 91%. In Denmark, Winkel et al. [4] found that the proportion of forensic autopsies for sudden death in young people varied from 60% to 88% between regions. Finland has had one of the highest proportions of forensic autopsy in the world (23.8% in 2004), but even there, differences have been noticed in the proportion of autopsies between geographical regions, as well as a decreasing proportion as the age of the deceased increased [5]. In Austria, there was a lower proportion of non-forensic autopsies for people dying at home in regions distant from autopsy facilities [6].

In Norway, the police must be notified if a death has a possible non-natural cause [7–10]. This includes all injury deaths, as well as sudden and unexpected deaths, deaths in custody, medical misadventures and children dying outside health-care facilities. Based on the information received, the police decide whether to initiate an investigation and request a forensic autopsy [11,12].

According to The Norwegian Board of Forensic Medicine, the forensic autopsy rate varies between geographical regions in Norway [13], but no thorough analysis has yet been performed of factors that might influence the request of a forensic autopsy.

The aim of this study was to examine the use of forensic autopsies in Norway for the years 1996–2017. We sought to describe variations in the autopsy proportions in different geographical locations and causes of death, and to explore possible explanatory factors such as: sex, age, (type of) place of death, police district, the population size and level of urbanity of the municipality and distance to the autopsy facility.

Methods

Data materials

The Norwegian Cause of Death Registry (NCoDR) at the Norwegian Institute of Public Health [14] supplied data concerning all deaths among Norwegian residents for the years 1996–2017 (N=930,589). We chose to use 1996 as the start of the study period, as the information on autopsies is incomplete for earlier years. We used the following variables: calendar year of death, sex, age at death, underlying cause of death (ICD-10 code), the (type of) place of death, the municipality where the death took place, whether an autopsy (forensic or medical) was performed and the autopsy laboratory. Additional data on the number of forensic autopsies were collected from the Norwegian Board of Forensic Medicine [13] and the Norwegian Society of Pathology [15]. The categories for grouping the underlying cause of death and the (type of) place of death are shown in the Supplemental Tables.

We collected population data from Statistics Norway [16]. Each municipality is classified on a six-level population scale and a seven-level urbanity–rurality (centrality) index. This is a compound scale based on the distance to population centres and the size of these centres. We retrieved map data from the Norwegian Mapping Authority [17] and information about which municipalities are included in each police district from the National Police Directorate [18]. During the study period, there were some adjustments in the structure of municipalities and police districts in Norway. To ensure comparability, we recoded the geographical and population data to the structure as it was in 2012.

We calculated the distance by road from the centre of the municipality of death to the autopsy facility serving the police district using a web service at the Norwegian Public Roads Authority [19]. Due to some shifts in the autopsy facilities serving each police district, the distance to the facility performing the most autopsies from each municipality was used as a default for the entire period.

Ethical approval

The project was approved by the Regional Committee for Medical and Health Research Ethics and in consultation with the Data Protection Officer at Stavanger University Hospital.

Methods

We used multiple logistic regression to investigate factors that could influence the probability of a forensic autopsy being performed. We partitioned the data into eight groups by the registered underlying cause of death. Explanatory variables were: calendar year of death in three periods, sex, age at death in 10-year groups, (type of) place of death in five groups, police district (N=27), population of the municipality in six groups, centrality index (seven-level scale) and distance to autopsy facility in 50 km intervals. Since the effects were not linear across the levels, all factors were used as unordered categorical variables.

First, we investigated each independent variable alone (univariate) before we entered all variables into a multiple predictors model. We used R v 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria) with additional packages from the tidyverse collection [20], sf [21] and logistf [22] for all analyses. For logistic regression, we calculated odds ratios with 95% confidence intervals, likelihood ratio statistics (–2LogLikelihood) and two-sided p-values, with <0.05 considered statistically significant. To avoid unstable estimates caused by separation, we used

Table I. Proportions of forensic autopsies according to different causes of death.

Cause of death	Autopsies	Deaths	Proportion undergoing forensic autopsy (%)	Percentage of all forensic autopsies (%)
1. Natural	14,341	830,410	1.7	38.3
2. Ill-defined	889	30,082	3.0	2.4
3. Traffic accidents	2946	5632	52.3	7.9
4. Accidental falls	1050	20,307	5.2	2.8
5. Accidental poisonings	6090	7719	78.9	16.3
6. Other external causes of death	3602	9097	39.6	9.6
7. Suicide	7642	11,992	63.7	20.4
8. Homicide	844	874	96.6	2.3
Missing cause of death	0	4401	0	0

Data from the Norwegian Cause of Death Registry, 1996–2017.

Firth's penalised likelihood method [23]. Binomial uncertainty intervals were calculated by Wilson's interval method.

Results

Deaths and forensic autopsies

For the years 1996–2017, there were 930,589 deaths registered in the NCoDR. The total number of forensic autopsies reported to the NCoDR was 37,404 (4.1% of all deaths). After exclusion of deaths abroad or outside mainland Norway and deaths lacking information on the municipality or cause of death, 920,232 total deaths and 37,398 forensic autopsies remained.

The proportion of deaths undergoing forensic autopsy has been reasonably stable, ranging between 3.7% and 4.5% during the study period. There was no significant trend (Cochran–Armitage test for trend, χ^2=0.07, p=0.79). The forensic autopsy rate (the number of forensic autopsies per 100,000 people) declined from 44.5 in 1998 to 30.5 in 2017.

The proportion of forensic autopsies varies between different causes of death. Almost all (96.6%) registered homicides undergo forensic autopsy, whereas around two out of three (63.7%) of suicides, approximately half (52.7%) of traffic deaths and only a few accidental falls (5.2%; Table I) are subject to autopsy. Only 1.7% of deaths from natural causes undergo forensic autopsy. However, they still constitute the single largest group of the autopsies (14,341; 38% of all forensic autopsies).

Age and sex

The median age of the deceased undergoing forensic autopsy was 50 years compared to 82 years for those not autopsied. In the age group 20–29 years, 59.5% of the deceased underwent forensic autopsy compared to 0.2% in the age group 90+. A total of 2.3% of deceased women and 6.0% of deceased men underwent forensic autopsy.

(Type of) place of death

Very few deaths in health-care institutions (1.3% in hospitals and 0.1% in nursing homes) underwent forensic autopsy. The proportion was higher for those dying at home (12.9%) and highest for those dying at other locations (36.2% dying at other known location, 27.9% where the location was not specified).

Police districts

The proportion of forensic autopsies varies by a factor of almost nine from the police district with the highest proportion (Hordaland, 7.9%) to that with the lowest proportion (Gudbrandsdal, 0.9%; coefficient of variation (CV) 51%; Figure 1, map). The variation between police districts did not become smaller during the study period (Table II); the CV in both parts of the study period was 53%. Even if there were some changes in the autopsy proportion within each police district, no district changed rank from the highest to lowest third or vice versa. We also found a large variation between districts for the autopsy proportion for different causes of death. This was most pronounced for road traffic accidents and suicides (Figure 2).

Municipalities and distance to autopsy facilities

Municipalities with more than 50,000 residents had a higher autopsy proportion (5.7%) compared to smaller municipalities (3.0%). The same holds for the most centrally located municipalities (5.3% compared to 2.8% in the rest) and those situated <50 km from the autopsy facilities (5.7% compared to 2.9% in the rest). Apart from this, we did not find

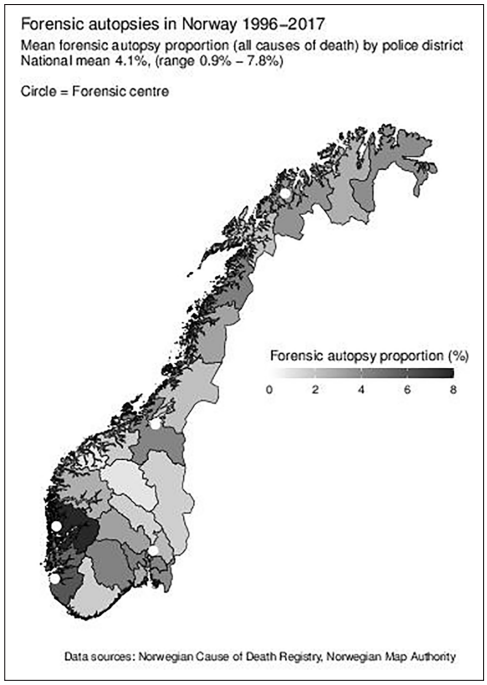

Figure 1. Proportion of forensic autopsies by police district.

a clear gradient within the smaller or more rural municipalities.

Group-wise analyses

A summary of the findings is presented in Table III. We performed separate analyses for the eight cause-of-death groups. For deaths due to natural causes, accidental poisonings and other external causes, the (type of) place of death was the most important factor influencing autopsy, with a low proportion in deaths in health-care institutions. For ill-defined causes of death and accidental falls, age was the most important factor, with the proportion of autopsies falling steeply at ages >60. For deaths due to traffic accidents and suicides, the police district was the most important explanatory factor. For homicides, almost all deaths underwent autopsy, and none of the explanatory factors were associated with the use of forensic autopsy. The exception was (type of) place of death, with fewer autopsies of deaths in nursing homes. However, the numbers are very small (two out of four deaths classified as homicides). It is noteworthy that the police district was among the top three explanatory factors in all cause-of-death groups (homicides excluded), whereas variables related to population size, the rurality of the municipality and distance to the autopsy facility seemed to have only a minor influence. For detailed results, see the Supplemental Material.

Discussion

In this population-based retrospective observational study, we used data from the NCoDR for the years 1996–2017 to investigate factors that might influence the utilisation of forensic autopsies. In the analyses, we used logistic regression, divided into groups by the registered cause of death. The proportion of forensic autopsies varied greatly with the cause of death. Overall, the three most important explanatory factors across the strata were the (type of) place of death, followed by the police district where the death took place and the age of the deceased.

Strength and limitations

The major strength of the study is the population-based design using individual data for >98% of Norwegian residents dying in Norway in the study period. The coverage and quality of demographic data in the NCoDR is very good, and the quality of medical data, such as the underlying cause of death, is also considered good [14]. Although the reporting of autopsy results to the NCoDR is compulsory, there is some discrepancy between data from the NCoDR, the Norwegian Board of Forensic Medicine and the Norwegian Society of Pathology. Some of this discrepancy is due to deaths of non-residents not included in the NCoDR. Also, failure to report from the autopsy departments and erroneous registration of medical versus forensic autopsies at the NCoDR may contribute. We estimate that around 5% of the forensic autopsy reports are missing in our data, contributing to a slight underestimation of the proportion of forensic autopsies. If the data are not missing at random, this could introduce bias in the results.

The perceived cause of death is the major determinant for whether the physician viewing the body decides to notify the police, and this is equally important when the police decide to request a forensic autopsy. To date, neither the NCoDR nor the Norwegian Police Directorate has comprehensive figures for how many deaths are reported from physicians to the police. If a notifiable death is not sent for autopsy, in principle, we cannot tell whether this is because the police have not been notified by the doctor or if the police have declined the autopsy. The

Table II. Proportions of forensic autopsies according to police district and time periods.

	1996–2017				1996–2006 (First part of study period)				2007–2017 (Last part of study period)			
	All ages		0–59 years		All ages		0–59 years		All ages		0–59 years	
	% (95% CI)	Rank	% (95% CI)	Rank	% (95% CI)	Rank	% (95% CI)	Rank	% (95% CI)	Rank	% (95% CI)	Rank
Hordaland	7.8 (7.6–8.0)	1	38.0 (37.0–39.1)	1	8.3 (8.1–8.6)	1	36.3 (35.0–37.8)	2	7.3 (7.1–7.6)	2	39.9 (38.4–41.3)	1
Oslo	7.3 (7.2–7.5)	2	32.9 (32.2–33.6)	4	6.9 (6.7–7.1)	2	31.8 (30.9–32.8)	5	7.8 (7.6–8.1)	1	34.3 (33.3–35.4)	4
Rogaland	5.9 (5.7–6.2)	3	31.7 (30.5–32.9)	5	5.2 (4.9–5.5)	4	29.4 (27.7–31.0)	7	6.7 (6.4–7.0)	3	34.3 (32.5–36.1)	5
Haugaland og Sunnhordland	5.4 (5.1–5.7)	4	37.5 (35.6–39.4)	2	5.5 (5.1–6.0)	3	38.2 (35.7–40.8)	1	5.3 (4.9–5.7)	4	36.6 (33.8–39.5)	2
Asker og Bærum	4.6 (4.3–4.9)	5	34.0 (32.0–36.1)	3	5.0 (4.6–5.4)	6	32.9 (30.3–35.7)	4	4.2 (3.9–4.6)	9	35.4 (32.4–38.5)	3
Søndre Buskerud	4.3 (4.1–4.6)	6	28.5 (27.1–29.9)	8	4.2 (3.9–4.5)	10	26.3 (24.5–28.2)	9	4.5 (4.2–4.8)	5	31.0 (28.9–33.1)	8
Telemark	4.3 (4.1–4.5)	7	31.3 (29.8–32.8)	6	4.4 (4.1–4.7)	9	30.7 (28.8–32.7)	6	4.3 (4.0–4.6)	8	32.1 (29.9–34.4)	6
Salten	4.3 (4.0–4.6)	8	26.4 (24.4–28.5)	10	4.2 (3.8–4.7)	11	23.8 (21.2–26.6)	13	4.4 (4.0–4.9)	6	29.4 (26.4–32.7)	9
Follo	4.2 (3.9–4.5)	9	30.8 (28.8–32.9)	7	5.0 (4.6–5.5)	5	33.1 (30.3–36.0)	3	3.5 (3.1–3.9)	12	28.1 (25.2–31.1)	10
Sør-Trøndelag	4.2 (4.0–4.4)	10	25.4 (24.3–26.5)	11	4.0 (3.8–4.3)	12	24.3 (22.9–25.8)	11	4.4 (4.1–4.6)	7	26.6 (25.0–28.3)	12
Østfold	3.9 (3.8–4.1)	11	27.2 (26.0–28.5)	9	3.8 (3.5–4.0)	13	24.0 (22.5–25.6)	12	4.1 (3.9–4.4)	10	31.4 (29.5–33.4)	7
Østfinnmark	3.9 (3.4–4.4)	12	24.9 (21.9–28.1)	13	4.8 (4.1–5.6)	7	28.1 (24.0–32.5)	8	2.9 (2.4–3.6)	14	20.2 (16.0–25.1)	17
Troms	3.7 (3.4–3.9)	13	19.2 (17.8–20.6)	17	4.5 (4.1–4.8)	8	20.9 (19.1–22.8)	15	2.9 (2.6–3.2)	15	16.9 (15.1–19.0)	21
Nordre Buskerud	3.1 (2.9–3.4)	14	25.1 (23.1–27.2)	12	3.0 (2.7–3.4)	16	23.2 (20.6–26.1)	14	3.3 (2.9–3.6)	13	27.0 (24.1–30.1)	11
Helgeland	3.0 (2.8–3.3)	15	23.0 (20.9–25.3)	14	3.5 (3.1–3.9)	14	25.1 (22.2–28.2)	10	2.5 (2.2–2.9)	18	20.3 (17.3–23.6)	16
Vestfold	2.9 (2.7–3.0)	16	20.5 (19.4–21.7)	16	2.3 (2.1–2.5)	20	16.0 (14.6–17.5)	20	3.5 (3.3–3.8)	11	26.4 (24.5–28.4)	13
Sogn og Fjordane	2.7 (2.5–2.9)	17	22.2 (20.3–24.3)	15	2.6 (2.4–2.9)	17	20.8 (18.3–23.4)	16	2.8 (2.5–3.1)	16	24.0 (21.2–27.2)	14
Vestfinnmark	2.7 (2.3–3.1)	18	16.4 (14.2–18.8)	20	3.2 (2.7–3.9)	15	18.7 (15.7–22.1)	18	2.1 (1.7–2.6)	21	13.3 (10.4–16.8)	24
Romerike	2.3 (2.2–2.5)	19	14.4 (13.4–15.5)	22	1.9 (1.7–2.1)	22	11.4 (10.2–12.8)	24	2.7 (2.5–2.9)	17	17.5 (16.0–19.1)	20
Midtre Hålogaland	2.1 (2.0–2.3)	20	18.6 (17.0–20.3)	18	2.4 (2.2–2.7)	18	19.2 (17.2–21.5)	17	1.8 (1.6–2.1)	22	17.7 (15.3–20.3)	19
Nord-Trøndelag	2.1 (1.9–2.2)	21	17.6 (16.0–19.2)	19	1.9 (1.7–2.1)	23	16.7 (14.7–18.8)	19	2.2 (2.0–2.5)	20	18.6 (16.4–21.1)	18
Nordmøre og Romsdal	1.8 (1.7–2.0)	22	16.3 (14.7–18.0)	21	1.4 (1.2–1.6)	24	11.6 (9.8–3.7)	23	2.3 (2.0–2.6)	19	22.0 (19.3–24.9)	15
Agder	1.7 (1.6–1.8)	23	12.6 (11.7–13.4)	25	2.3 (2.2–2.5)	19	15.4 (14.2–16.7)	21	1.1 (1.0–1.2)	27	9.0 (8.0–10.2)	27
Vestoppland	1.6 (1.4–1.7)	24	12.6 (11.3–14.0)	24	1.4 (1.2–1.6)	25	10.5 (8.9–12.2)	25	1.8 (1.6–2.1)	23	15.1 (13.1–17.4)	22
Hedmark	1.6 (1.5–1.7)	25	12.7 (11.7–13.8)	23	2.0 (1.8–2.2)	21	15.0 (13.6–16.5)	22	1.1 (1.0–1.3)	26	9.8 (8.5–11.2)	26
Sunnmøre	1.0 (0.9–1.2)	26	8.8 (7.7–10.1)	26	0.6 (0.4–0.7)	27	4.2 (3.2–5.5)	27	1.5 (1.3–1.7)	24	13.9 (12.0–16.1)	23
Gudbrandsdal	0.9 (0.8–1.0)	27	7.9 (6.7–9.4)	27	0.6 (0.5–0.8)	26	4.6 (3.4–6.2)	26	1.2 (1.0–1.5)	25	12.2 (9.9–14.9)	25

Proportion of deaths undergoing forensic autopsy in Norway 1996–2017. Data from the Norwegian Cause of Death Registry, 1996–2017, for the periods 1996–2017, 1996–2006 and 2007-2017, in all ages combined and age at death <60 years of age.
CI: confidence interval.

Figure 2. Proportion of forensic autopsies by cause of death and police district.

very large variation between police districts suggests that factors relating to local procedures and attitudes of the police are important.

We do not know the physician's initial assessment, and the registered cause of death in the NCoDR is influenced by the autopsy results (or lack thereof). Using the registered cause of death as an explanatory variable in the logistic regression might thus be methodologically unsound. To estimate the impact of the other explanatory variables in different scenarios, we divided the data according to the underlying cause of death. A major limitation of this study is that the registered cause of death might be wrong, especially when no autopsy has been performed. Indeed, classification of cause of death to the ill-defined group might be the result of a lack of autopsy, as shown by Ylijoki-Sørensen et al. [24]. Our study was not designed to ascertain misclassification due to a lack of autopsy.

For some characteristics, we noticed separation, with all observations falling into the same group (autopsy proportion either 0% or 100%). This can introduce problems in the estimation of the coefficients, giving very large confidence intervals. To avoid this, we used Firth's bias reduction in the regressions [23].

Discussion of results

The explanatory variables can be divided into three main groups.

Table III. Summary of group-wise logistic regression.

Autopsy frequency (%)	Natural causes of death		Ill-defined causes of death		Traffic accidents		Accidental falls		Accidental poisonings		Other external causes of death		Suicides		Homicides	
	1.7		3.0		52.3		5.2		78.9		39.6		63.7		96.6	
	LR stat.	*p*-Value	LR stat.	*p*-Value	LR stat.	*p*-Value	LR stat.	*p*-Value	LR stat.	*p*-Value	LR stat.	*p*-Value	LR stat.	*p*-Value	LR stat.	*p*-Value
Year of death	264	<0.001	72	<0.001	31	<0.001	5	0.09	8	0.02	4	0.11	74	<0.001	3	0.21
Sex	220	<0.001	5	0.03	2	0.18	9	<0.001	3	0.10	0.3	0.60	37	<0.001	0.4	0.55
Age group	15033	<0.001	1426	<0.001	9	0.40	1082	<0.001	385	<0.001	706	<0.001	160	<0.001	10	0.33
Place of death	27603	<0.001	266	<0.001	300	<0.001	886	<0.001	1010	<0.001	1728	<0.001	585	<0.001	13	0.01
Police district	2820	<0.001	356	<0.001	843	<0.001	233	<0.001	454	<0.001	353	<0.001	1847	<0.001	33	0.16
Population	503	<0.001	61	<0.001	12	0.04	11	0.06	6	0.47	9	0.10	26	<0.001	5	0.45
Centrality	61	<0.001	5	0.49	8	0.27	6	0.43	10	0.14	5	0.61	9	0.19	7	0.28
Distance	17	0.08	28	0.002	29	<0.001	11	0.35	9	0.51	17	0.07	57	<0.001	11	0.37

Likelihood ratio statistic (rounded) and *p*-value for each explanatory variable. The likelihood ratio statistic (−2 logL) is computed by comparing the full model to the model *without* the variable in question. The higher the LR statistics, the more the model is weakened by excluding the variable in question.
For detailed description, see supplementary material.
Data from The Norwegian Cause of Death Registry, 1996–2017.
Age: 10-year groups; place of death: five categories; police districts: *N*=27; population size: six groups; centrality index: seven levels; distance from place of death to autopsy facility: 50 km groups.

Factors related to the cause and circumstances around the death. One could argue that the only legitimate factors when requesting a forensic autopsy are the circumstances and perceived cause of death. We would expect a variation in the autopsy proportion between different causes of death as well as the (type of) place of death. Essentially all homicides, but only 1.7% of deaths from natural causes are sent for autopsy. Hasselqvist and Rammer found that 7.5% of the homicides in Sweden were not discovered until autopsy [25]. Even in deaths from external causes, few cases undergo autopsy if the death occurs in a health-care institution, probably reflecting more information about the injuries and circumstances.

Demographic factors – age and sex. The proportion of autopsies falls steeply with age. This can in part be explained by a higher frequency of external causes of death in the young. However, in several cause-of-death groups, age is an important explanatory factor, even in the multi-predictor models. In accidental falls, the largest group is low-level, low-energy falls in the elderly [26]. We believe that many of these deaths are not reported to the police, and even if the police are notified, an autopsy is seldom requested. The age gradient in accidental poisonings and suicides might be more problematic, as investigating deaths in the elderly should be as important as in the young. More than twice as many men as women underwent forensic autopsy, but men are more likely than women to suffer an external cause of death. In the group-wise, multi-predictor regressions, sex was among the least important factors.

Geographic factors – police district and municipalities. In all groups, police district was among the top three explanatory factors. Within some cause-of-death groups, notably traffic accidents and suicides, the variation in autopsy proportion between districts was very large (Figure 2). In traffic accidents, the range was from 6.5% to 87.2%. This observation may reflect a number of more or less unidentified factors, including local attitudes, habits, procedures, economic priorities and so on. One aspect could be attitudes towards the purpose of investigating deaths. Is the forensic procedure viewed as a means to examine possible criminal cases only, or does the task include public health, preventive measures, the relatives' needs, and cause-of-death statistics? We also speculate that a close communication between the police authorities and, on the one hand, the doctors in the community reporting deaths and, on the other hand, the forensic pathologists performing the autopsies could stimulate a broader understanding of the different goals of an autopsy. In 2016, the number of police districts was reduced from 27 to 12, and in 2020, compulsory forensic autopsy of all traffic deaths was introduced. Time will tell if these changes will reduce the geographic variation in forensic autopsies.

Currently, >95% of forensic autopsies in Norway are performed in Oslo, Bergen, Trondheim, Tromsø and Stavanger. The expenditure for a forensic autopsy consists partly of the transport to the autopsy facilities, and this must be covered by the requesting police district. When the distance is substantial, the transport costs may supersede the fee for the autopsy itself. In the unstratified introductory analyses, there was a tendency for the autopsy proportion to be higher in the large and most central municipalities, closest to the autopsy facilities, but in the group-wise, multi-predictor models, these factors had a low influence, contrary to common belief. In some strata, the effect was not statistically significant; in others, the influence was minor compared to other factors. Some police districts with large transport distances have higher autopsy frequencies than districts close to the autopsy facility (Figure 1).

Implications of the study

The two major areas of implications concern the protection of the legal rights of the individual and trust in the judicial system, and the quality of the cause-of-death statistics. Ideally, the decision about starting an investigation should be influenced solely by the circumstances around the death (or the discovery of the body). If unjustified differences in the frequency of autopsies lead to insufficient investigation of possible unnatural deaths, this may in worst-case scenarios mean that criminal cases remain undetected. As the results from forensic autopsies are important sources for cause-of-death statistics, variations in autopsy frequency might lead to suboptimal quality of statistics and introduce spurious shifts (e.g. over time or between geographical regions). As a result, this could lead to misleading information for surveillance, quality analysis, prevention and research.

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Supplemental material

Supplemental material for this article is available online.

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Forensic autopsies in Norway 1996-2017 – a retrospective study of factors correlated with the autopsy frequency

Supplementary tables

Notifiable deaths in Norway

Deaths in Norway where the police is to be notified (regulation FOR-2000-12-21-1378)
Homicide or other forms for assault*
Suicide or self-inflicted injury
Accidents (e.g. fire, avalanche, lightning, drowning, fall, transport accident)
Occupational accident or injury
Medical misadventure, accident or neglect
Drug abuse
Sudden and unexpected death of unknown cause
Deaths in custody
Unidentified body*
Children below 18 years with unknown cause of death, dying outside health care institution* (regulation FOR-1985-06-28-1679, §13-2)
(*Autopsy mandatory)

Definitions

Underlying cause of death	**ICD-10 codes**
1. Natural	A00-Q99 (except F11-F12, F14-F16, F19), R95
2. Ill-defined	R00-R99 (except R95)
3. Traffic accidents	V00-V89, Y85.0
4. Accidental falls	W00-W19, X59 in combination with S72
5. Accidental poisonings	X40-X49, F11-F12, F14-F16, F19
6. Other accidents and events of undetermined intent	V90 – V99, W20 – X39.9, X50 – X59, Y10 – Y84, Y85.9 – Y86, Y87.2 – Y89.9
7. Intentional self-harm (suicide)	X60 – X84, Y87.0
8. Assault (homicide)	X85 – Y09, Y87.1
Place of death	
1. At home	At home
2. Hospital	Somatic and psychiatric hospitals
3. Nursing home	Nursing homes, other health care institutions
4. Other known	Other known, during transport
5. Unknown	Unknown, abroad

Overview of results

All causes of death

		All deaths	Forensic autopsies	Per cent
Total		**920232**	**37398**	**4.1**

Variable	Level	All deaths	Forensic autopsies	Per cent	Autopsies per 100,000	Level	All deaths	Forensic autopsies	Per cent
Year	1996	43636	1813	4.2	41.4	1996-2002	308193	12833	4.2
	1997	44373	1940	4.4	44.0	2003-2010	329364	12784	3.9
	1998	43966	1972	4.5	44.5	2011-2017	282675	11781	4.2
	1999	44834	1775	4.0	39.8				
	2000	43682	1884	4.3	42.0				
	2001	43666	1715	3.9	38.0				
	2002	44036	1734	3.9	38.2				
	2003	42177	1626	3.9	35.6				
	2004	40816	1600	3.9	34.9				
	2005	40759	1599	3.9	34.6				
	2006	40872	1552	3.8	33.3				
	2007	41556	1584	3.8	33.6				
	2008	41300	1607	3.9	33.7				
	2009	40950	1621	4.0	33.6				
	2010	40934	1595	3.9	32.6				
	2011	40759	1659	4.1	33.5				
	2012	41349	1531	3.7	30.5				
	2013	40475	1630	4.0	32.1				
	2014	39728	1652	4.2	32.2				
	2015	40075	1812	4.5	34.9				
	2016	40128	1733	4.3	33.1				
	2017	40161	1764	4.4	33.4				
Sex	Male	446396	26648	6.0					
	Female	473836	10750	2.3					
Age group	0-9	5634	1045	18.6					
	10-19	3009	1429	47.5					
	20-29	7536	4484	59.5					
	30-39	10865	5170	47.6					
	40-49	22138	6196	28.0					
	50-59	51013	7082	13.9					
	60-69	100033	5918	5.9					
	70-79	202944	3791	1.9					
	80-89	344250	1997	0.6					
	90+	172810	286	0.2					
Place of death	At_home	139839	18006	12.9					
	Hospital	343972	4530	1.3					
	Nursing_home	393353	437	0.1					
	Other_known	29003	10508	36.2					

	Unknown	14065	3917	27.9	
Cause of death	1.Natural	830154	14339	1.7	
	2.Ill-defined	30074	889	3.0	
	3.Traffic_acc	5631	2946	52.3	
	4.Acc_falls	20306	1050	5.2	
	5.Acc_poisonings	7719	6090	78.9	
	6.Other_ext	9094	3601	39.6	
	7.Suicide	11984	7639	63.7	
	8.Homicide	874	844	96.6	
	Missing	4396	0	0.0	
Police district	Agder	52658	906	1.7	
	Asker og Bærum	22681	1041	4.6	
	Follo	17782	751	4.2	
	Gudbrandsdal	17935	160	0.9	
	Haugaland og Sunnhordland	24705	1334	5.4	
	Hedmark	48116	754	1.6	
	Helgeland	15874	481	3.0	
	Hordaland	77839	6096	7.8	
	Midtre Hålogaland	26694	570	2.1	
	Nord-Trøndelag	27846	572	2.1	
	Nordmøre og Romsdal	23753	433	1.8	
	Nordre Buskerud	18894	593	3.1	
	Oslo	108425	7955	7.3	
	Rogaland	45987	2736	5.9	
	Romerike	41148	959	2.3	
	Salten	15861	684	4.3	
	Sogn og Fjordane	22019	595	2.7	
	Sunnmøre	24738	253	1.0	
	Søndre Buskerud	37658	1637	4.3	
	Sør-Trøndelag	54320	2277	4.2	
	Telemark	38780	1673	4.3	
	Troms	22870	842	3.7	
	Vestfinnmark	7323	195	2.7	
	Vestfold	43670	1257	2.9	
	Vestoppland	25988	412	1.6	
	Østfinnmark	6234	242	3.9	
	Østfold	50434	1990	3.9	
Municipality population	<2000	24640	860	3.5	
	2000-4999	81893	2943	3.6	
	5000-9999	107207	3288	3.1	
	10000-19999	137192	4308	3.1	
	20000-49999	221488	6049	2.7	(0-49999 collated 3.0 %)
	50000+	347812	19950	5.7	
Urbanity index	0B (Most rural)	95353	2903	3	
	0A	23694	865	3.7	
	1B	38087	1030	2.7	

	1A	36127	1057	2.9	
	2B	72187	1739	2.4	
	2A	192061	5400	2.8	(0B-2A collated 2.8%)
	3A (Most urban)	462723	24404	5.3	
Distance	0-49	383673	21944	5.7	
to autopsy	50-99	143128	5053	3.5	
facility (km)	100-149	159915	4486	2.8	
	150-199	62029	2182	3.5	
	200-249	35361	973	2.8	
	250-299	26809	472	1.8	
	300-349	45282	897	2.0	
	350-399	27045	472	1.8	
	400-449	16387	332	2.0	
	450-499	13328	335	2.5	
	> 500	7275	252	3.5	(50-500+ collated 2.9%)

Stratified logistic regression

1. Natural causes of death

		Deaths	Forensic autopsies	Per cent							
Total		**830154**	**14339**	**1.7**							
Variable	**Level**	**Deaths**	**For.aut.**	**Per cent**	**OR (univariate)**	**95% CI**	**LRT (univariate)**	**p value**	**OR (multi predictor)**	**95% CI**	**LRT (multi predictor)**	**p value**
Year	1996-2002	279172	4907	1.8	1	Ref.	48.4	< 0.001	1	Ref.	264.4	< 0.001
	2003-2010	297300	4763	1.6	0.91	(0.87-0.95)			1.02	(0.97-1.07)		
	2011-2017	253682	4669	1.8	1.05	(1.01-1.09)			1.42	(1.36-1.49)		
Sex	Male	398889	10060	2.5	1	Ref.	2920	< 0.001	1	Ref.	220.2	< 0.001
	Female	431265	4279	1.0	0.39	(0.37-0.40)			0.73	(0.70-0.77)		
Age	20-29	1887	391	20.7	1	Ref.	28075	< 0.001	1	Ref.	15033	< 0.001
	0-9	5117	761	14.9	0.67	(0.58-0.77)			1.08	(0.92-1.28)		
	10-19	1045	183	17.5	0.81	(0.67-0.99)			0.87	(0.68-1.10)		
	30-39	4890	841	17.2	0.79	(0.70-0.91)			0.79	(0.67-0.94)		
	40-49	15671	1953	12.5	0.54	(0.48-0.61)			0.47	(0.40-0.54)		
	50-59	44050	3333	7.6	0.31	(0.28-0.35)			0.26	(0.23-0.30)		
	60-69	93084	3562	3.8	0.15	(0.14-0.17)			0.14	(0.12-0.16)		
	70-79	191927	2225	1.2	0.04	(0.04-0.05)			0.05	(0.05-0.06)		
	80-89	319518	960	0.3	0.01	(0.01-0.01)			0.02	(0.02-0.02)		
	90 and above	152965	130	0.1	0.003	(0-0.004)			0.01	(0.01-0.01)		
Place of death	At_home	114106	8848	7.8	1	Ref.	36752	< 0.001	1	Ref.	27602	< 0.001
	Hospital	325663	1829	0.6	0.07	(0.06-0.07)			0.04	(0.04-0.04)		
	Nursing_home	366813	214	0.1	0.01	(0.01-0.01)			0.02	(0.01-0.02)		
	Other_known	13787	2096	15.2	2.13	(2.03-2.24)			1.92	(1.80-2.03)		
	Unknown	9785	1352	13.8	1.91	(1.79-2.03)			2.10	(1.95-2.26)		
Police district	Agder	47483	255	0.5	1	Ref.	6036	< 0.001	1	Ref.	2820	< 0.001
	Asker og Bærum	20569	388	1.9	3.56	(3.04-4.17)			3.08	(2.32-4.08)		
	Follo	15759	218	1.4	2.60	(2.17-3.12)			2.73	(2.03-3.68)		
	Gudbrandsdal	16145	56	0.3	0.65	(0.48-0.86)			1.14	(0.77-1.67)		
	Haugaland og Sunnhordland	22500	505	2.2	4.25	(3.66-4.95)			8.09	(6.26-10.48)		
	Hedmark	43188	251	0.6	1.08	(0.91-1.29)			1.93	(1.47-2.53)		
	Helgeland	14326	162	1.1	2.12	(1.74-2.58)			3.59	(2.59-4.97)		
	Hordaland	69835	3009	4.3	8.32	(7.34-9.49)			12.57	(9.7-16.33)		
	Midtre Hålogaland	24258	197	0.8	1.52	(1.26-1.83)			2.69	(2.11-3.43)		
	Nord-Trøndelag	25223	225	0.9	1.67	(1.39-2.00)			2.36	(1.79-3.09)		
	Nordmøre og Romsdal	21457	133	0.6	1.16	(0.94-1.42)			1.87	(1.39-2.51)		
	Nordre Buskerud	16685	170	1.0	1.91	(1.57-2.32)			3.00	(2.23-4.04)		
	Oslo	95933	3048	3.2	6.07	(5.35-6.91)			5.95	(4.59-7.74)		
	Rogaland	41720	1069	2.6	4.86	(4.25-5.59)			5.46	(4.20-7.13)		
	Romerike	37429	321	0.9	1.60	(1.36-1.89)			2.33	(1.75-3.10)		
	Salten	14237	240	1.7	3.18	(2.66-3.79)			4.90	(3.50-6.86)		
	Sogn og Fjordane	20349	215	1.1	1.98	(1.65-2.37)			3.35	(2.57-4.37)		
	Sunnmøre	22806	78	0.3	0.64	(0.49-0.82)			1.03	(0.74-1.43)		

	Søndre Buskerud	34027	611	1.8	3.38	(2.93-3.92)			4.03	(3.09-5.28)	
	Sør-Trøndelag	48804	860	1.8	3.32	(2.89-3.82)			3.71	(2.85-4.85)	
	Telemark	35241	600	1.7	3.20	(2.77-3.72)			5.11	(3.98-6.58)	
	Troms	20680	294	1.4	2.67	(2.26-3.16)			2.49	(1.88-3.30)	
	Vestfinnmark	6529	49	0.8	1.41	(1.03-1.90)			1.47	(1.01-2.13)	
	Vestfold	39719	418	1.1	1.97	(1.69-2.30)			3.44	(2.62-4.52)	
	Vestoppland	23346	123	0.5	0.98	(0.79-1.22)			1.58	(1.17-2.14)	
	Østfinnmark	5607	80	1.4	2.69	(2.08-3.45)			6.50	(3.65-11.67)	
	Østfold	46299	764	1.7	3.10	(2.70-3.58)			4.15	(3.16-5.46)	
Municipality population	< 2000	21851	284	1.3	1	Ref.	2414	< 0.001	1	Ref.	503.5 < 0.001
	2000-4999	72689	1041	1.4	1.10	(0.97-1.26)			0.94	(0.81-1.09)	
	5000-9999	95302	1123	1.2	0.90	(0.79-1.03)			1.01	(0.87-1.19)	
	10000-19999	124273	1455	1.2	0.90	(0.79-1.02)			1.01	(0.86-1.19)	
	20000-49999	202375	2171	1.1	0.82	(0.73-0.93)			1.36	(1.16-1.61)	
	> 50000	313664	8265	2.6	2.05	(1.83-2.32)			2.36	(2.00-2.79)	
Urbanity index	0B (Most rural)	85268	997	1.2	1	Ref.	1974	< 0.001	1	Ref.	60.5 < 0.001
	0A	20922	315	1.5	1.29	(1.14-1.47)			1.01	(0.85-1.19)	
	1B	34799	388	1.1	0.95	(0.85-1.07)			1.58	(1.35-1.84)	
	1A	32816	360	1.1	0.94	(0.83-1.06)			1.27	(1.06-1.52)	
	2B	65772	596	0.9	0.77	(0.70-0.86)			1.22	(1.05-1.42)	
	2A	175243	1938	1.1	0.94	(0.88-1.02)			0.99	(0.85-1.16)	
	3A (Most urban)	415334	9745	2.3	2.03	(1.90-2.17)			1.35	(1.14-1.59)	
Distance to autopsy facility (km)	0-49	344784	8943	2.6	1	Ref.	2932	< 0.001	1	Ref.	16.7 0.08
	50-99	129393	1800	1.4	0.53	(0.50-0.56)			0.90	(0.82-1.00)	
	100-149	144691	1601	1.1	0.42	(0.40-0.44)			0.96	(0.84-1.11)	
	150-199	55959	768	1.4	0.52	(0.49-0.56)			1.08	(0.91-1.29)	
	200-249	31962	356	1.1	0.42	(0.38-0.47)			1.11	(0.90-1.37)	
	250-299	24281	137	0.6	0.21	(0.18-0.25)			1.00	(0.76-1.32)	
	300-349	41197	299	0.7	0.27	(0.24-0.31)			0.97	(0.75-1.27)	
	350-399	24521	143	0.6	0.22	(0.19-0.26)			0.91	(0.65-1.27)	
	400-449	14709	102	0.7	0.26	(0.22-0.32)			0.88	(0.62-1.24)	
	450-499	12091	108	0.9	0.34	(0.28-0.41)			0.83	(0.57-1.21)	
	> 500	6566	82	1.2	0.48	(0.38-0.59)			0.55	(0.30-0.97)	

2. Ill-defined causes of death

		Deaths	Forensic autopsies	Per cent								
Total		**30074**	**889**	**3.0**								
Variable	**Level**	**Deaths**	**For.aut.**	**Per cent**	**OR (univariate)**	**95% CI**	**LRT (univariate)**	**p value**	**OR (multi predictor)**	**95% CI**	**LRT (multi predictor)**	**p value**
Year	1996-2002	10049	397	4.0	1	Ref.	50.9	< 0.001	1	Ref.	71.5	< 0.001
	2003-2010	10642	250	2.3	0.59	(0.50-0.69)			0.47	(0.39-0.57)		
	2011-2017	9383	242	2.6	0.64	(0.55-0.76)			0.54	(0.45-0.66)		
Sex	Male	11842	538	4.5	1	Ref.	166.5	< 0.001	1	Ref.	4.67	0.03
	Female	18232	351	1.9	0.41	(0.36-0.47)			1.21	(1.02-1.43)		
Age	20-29	81	55	67.9	1	Ref.	1926	< 0.001	1	Ref.	1425	< 0.001
	0-9	35	20	57.1	0.63	(0.28-1.42)			0.39	(0.15-1.03)		
	10-19	26	19	73.1	1.24	(0.49-3.41)			2.41	(0.78-8.18)		
	30-39	165	72	43.6	0.37	(0.21-0.64)			0.38	(0.19-0.74)		
	40-49	410	108	26.3	0.17	(0.10-0.28)			0.09	(0.05-0.17)		
	50-59	1144	154	13.5	0.07	(0.04-0.12)			0.04	(0.02-0.07)		
	60-69	1981	96	4.8	0.02	(0.01-0.04)			0.008	(0-0.02)		
	70-79	4312	173	4.0	0.02	(0.01-0.03)			0.004	(0-0.008)		
	80-89	10764	163	1.5	0.01	(0 -0.01)			0.003	(0-0.005)		
	90 and above	11156	29	0.3	0.001	(0-0.002)			0.001	(0-0.003)		
Place of death	At_home	11275	658	5.8	1	Ref.	1207	< 0.001	1	Ref.	266.2	< 0.001
	Hospital	925	23	2.5	0.42	(0.27-0.62)			0.30	(0.17-0.51)		
	Nursing_home	14948	8	0.1	0.01	(0-0.02)			0.04	(0.02-0.08)		
	Other_known	1817	92	5.1	0.86	(0.69-1.08)			0.61	(0.46-0.80)		
	Unknown	1109	108	9.7	1.75	(1.40-2.15)			1.75	(1.33-2.29)		
Police district	Agder	1836	14	0.8	1	Ref.	750.4	< 0.001	1	Ref.	356.4	< 0.001
	Asker og Bærum	646	10	1.5	2.07	(0.91-4.58)			1.49	(0.33-7.19)		
	Follo	690	8	1.2	1.57	(0.64-3.60)			2.24	(0.47-11.1)		
	Gudbrandsdal	644	5	0.8	1.08	(0.37-2.75)			1.06	(0.17-6.64)		
	Haugaland og Sunnhordland	620	5	0.8	1.12	(0.38-2.86)			4.30	(0.90-20.6)		
	Hedmark	1681	14	0.8	1.09	(0.52-2.29)			2.47	(0.63-10.5)		
	Helgeland	452	2	0.4	0.70	(0.14-2.28)			0.65	(0.07-4.97)		
	Hordaland	2929	307	10.5	14.74	(9.01-26.21)			16.8	(4.37-71.3)		
	Midtre Hålogaland	784	8	1.0	1.38	(0.56-3.16)			3.70	(0.94-13.8)		
	Nord-Trøndelag	998	19	1.9	2.50	(1.27-5.05)			10.8	(2.81-44.9)		
	Nordmøre og Romsdal	925	3	0.3	0.48	(0.12-1.38)			1.24	(0.21-6.64)		
	Nordre Buskerud	850	6	0.7	0.97	(0.36-2.36)			2.35	(0.46-12.2)		
	Oslo	3977	221	5.6	7.41	(4.51-13.23)			4.28	(1.11-18.2)		
	Rogaland	1262	56	4.4	5.89	(3.38-10.93)			6.27	(1.59-27.2)		
	Romerike	1106	21	1.9	2.49	(1.28-4.97)			2.90	(0.68-13.3)		
	Salten	472	19	4.0	5.40	(2.73-10.94)			15.2	(2.32-105.9)		
	Sogn og Fjordane	516	5	1.0	1.35	(0.46-3.44)			3.06	(0.55-16.0)		
	Sunnmøre	619	0	0	0.10	(0-0.76)			0.06	(0-0.80)		
	Søndre Buskerud	1223	27	2.2	2.89	(1.55-5.63)			4.99	(1.22-22.1)		
	Sør-Trøndelag	2167	35	1.6	2.09	(1.16-3.99)			1.59	(0.39-7.04)		

	Telemark	1217	23	1.9	2.47	(1.29-4.89)			4.57	(1.24-18.5)		
	Troms	573	15	2.6	3.49	(1.69-7.26)			2.15	(0.50-9.89)		
	Vestfinnmark	221	3	1.4	2.01	(0.52-5.88)			7.71	(1.27-40.8)		
	Vestfold	1191	21	1.8	2.31	(1.19-4.61)			7.41	(1.86-32.4)		
	Vestoppland	1040	6	0.6	0.79	(0.29-1.92)			2.02	(0.42-9.84)		
	Østfinnmark	167	3	1.8	2.67	(0.69-7.83)			65.4	(6.03-832.7)		
	Østfold	1268	33	2.6	3.41	(1.87-6.53)			6.97	(1.65-31.9)		
Municipality population	< 2000	1064	10	0.9	1	Ref.	516.5	< 0.001	1	Ref.	60.8	< 0.001
	2000-4999	3640	30	0.8	0.85	(0.43-1.8)			0.92	(0.40-2.27)		
	5000-9999	4412	43	1.0	1.00	(0.53-2.08)			1.21	(0.52-3.01)		
	10000-19999	4361	69	1.6	1.63	(0.89-3.31)			1.25	(0.54-3.13)		
	20000-49999	5597	88	1.6	1.61	(0.89-3.26)			1.20	(0.50-3.10)		
	> 50000	11000	649	5.9	6.30	(3.6-12.43)			4.38	(1.85-11.2)		
Urbanity index	0B (Most rural)	3799	33	0.9	1	Ref.	310.6	< 0.001	1	Ref.	5.41	0.49
	0A	1242	12	1.0	1.14	(0.57-2.14)			1.64	(0.61-4.26)		
	1B	982	11	1.1	1.33	(0.65-2.53)			0.72	(0.27-1.83)		
	1A	1137	18	1.6	1.86	(1.03-3.25)			1.72	(0.63-4.66)		
	2B	2039	27	1.3	1.54	(0.92-2.55)			1.43	(0.59-3.46)		
	2A	5335	81	1.5	1.74	(1.18-2.65)			0.97	(0.39-2.46)		
	3A (Most urban)	15540	707	4.5	5.36	(3.85-7.74)			1.21	(0.46-3.22)		
Distance to autopsy facility (km)	0-49	12431	686	5.5	1	Ref.	500.5	< 0.001	1	Ref.	27.7	0.002
	50-99	4562	72	1.6	0.28	(0.21-0.35)			0.61	(0.35-1.05)		
	100-149	5303	62	1.2	0.20	(0.16-0.26)			0.61	(0.29-1.29)		
	150-199	2264	25	1.1	0.19	(0.13-0.28)			1.08	(0.40-2.90)		
	200-249	1272	11	0.9	0.16	(0.08-0.27)			1.35	(0.39-4.50)		
	250-299	939	6	0.6	0.12	(0.05-0.24)			0.47	(0.09-2.20)		
	300-349	1324	13	1.0	0.18	(0.10-0.29)			0.53	(0.13-2.31)		
	350-399	931	3	0.3	0.06	(0.02-0.16)			1.56	(0.22-10.1)		
	400-449	517	3	0.6	0.12	(0.03-0.29)			0.87	(0.12-6.33)		
	450-499	316	7	2.2	0.41	(0.18-0.80)			2.58	(0.33-21.0)		
	> 500	215	1	0.5	0.12	(0.01-0.43)			0.04	(0-0.66)		

3. Traffic accidents

		Deaths	Forensic autopsies	Per cent								
Total		**5631**	**2946**	**52.3**								
Variable	**Level**	**Deaths**	**For.aut.**	**Per cent**	**OR (univariate)**	**95% CI**	**LRT (univariate)**	**p value**	**OR (multi predictor)**	**95% CI**	**LRT (multi predictor)**	**p value**
Year	1996-2002	2398	1228	51.2	1	Ref.	30.2	< 0.001	1	Ref.	30.9	< 0.001
	2003-2010	2094	1041	49.7	0.94	(0.84-1.06)			0.87	(0.76-1.00)		
	2011-2017	1139	677	59.4	1.40	(1.21-1.61)			1.42	(1.20-1.69)		
Sex	Male	4134	2159	52.2	1	Ref.	0.05	0.82	1	Ref.	1.76	0.18
	Female	1497	787	52.6	1.01	(0.90-1.14)			1.10	(0.96-1.26)		
Age	20-29	1112	615	55.3	1	Ref.	29.1	< 0.001	1	Ref.	9.2	0.41
	0-9	156	73	46.8	0.71	(0.51-0.99)			0.70	(0.47-1.04)		
	10-19	729	404	55.4	1.00	(0.83-1.21)			1.01	(0.81-1.25)		
	30-39	686	377	55.0	0.99	(0.81-1.19)			1.10	(0.88-1.37)		
	40-49	643	352	54.7	0.98	(0.80-1.19)			1.04	(0.83-1.30)		
	50-59	610	313	51.3	0.85	(0.70-1.04)			0.92	(0.73-1.16)		
	60-69	543	269	49.5	0.79	(0.65-0.97)			0.93	(0.73-1.17)		
	70-79	641	297	46.3	0.70	(0.57-0.85)			0.89	(0.70-1.11)		
	80-89	461	227	49.2	0.78	(0.63-0.97)			1.07	(0.82-1.39)		
	90 and above	50	19	38.0	0.50	(0.28-0.88)			0.67	(0.34-1.30)		
Place of death	At_home	85	31	36.5	1	Ref.	158.5	< 0.001	1	Ref.	295.9	< 0.001
	Hospital	1649	747	45.3	1.43	(0.92-2.27)			0.74	(0.44-1.28)		
	Nursing_home	97	12	12.4	0.25	(0.12-0.52)			0.18	(0.08-0.40)		
	Other_known	3494	1946	55.7	2.17	(1.40-3.42)			2.86	(1.70-4.87)		
	Unknown	306	210	68.6	3.77	(2.30-6.28)			3.68	(2.06-6.66)		
Police district	Agder	420	95	22.6	1	Ref.	1132	< 0.001	1	Ref.	831.2	< 0.001
	Asker og Bærum	52	39	75.0	9.97	(5.29-19.92)			5.77	(2.52-13.69)		
	Follo	150	94	62.7	5.70	(3.83-8.56)			3.02	(1.63-5.63)		
	Gudbrandsdal	143	8	5.6	0.21	(0.10-0.42)			0.16	(0.06-0.39)		
	Haugaland og Sunnhordland	125	109	87.2	22.62	(13.18-41.1)			30.47	(15.22-63.59)		
	Hedmark	375	114	30.4	1.49	(1.09-2.05)			1.25	(0.78-2.03)		
	Helgeland	105	70	66.7	6.77	(4.29-10.86)			5.81	(2.68-12.74)		
	Hordaland	400	344	86.0	20.78	(14.57-30.09)			17.51	(9.78-31.67)		
	Midtre Hålogaland	151	89	58.9	4.88	(3.30-7.28)			4.27	(2.45-7.48)		
	Nord-Trøndelag	167	65	38.9	2.18	(1.48-3.20)			1.62	(0.94-2.80)		
	Nordmøre og Romsdal	141	53	37.6	2.06	(1.37-3.10)			2.07	(1.16-3.68)		
	Nordre Buskerud	171	65	38.0	2.10	(1.43-3.07)			1.49	(0.84-2.64)		
	Oslo	626	355	56.7	4.46	(3.39-5.91)			4.21	(2.41-7.38)		
	Rogaland	289	251	86.9	22.27	(14.95-33.91)			18.61	(10.09-34.83)		
	Romerike	218	113	51.8	3.67	(2.59-5.22)			2.31	(1.29-4.18)		
	Salten	110	80	72.7	9.00	(5.65-14.65)			8.47	(3.82-19.2)		
	Sogn og Fjordane	152	86	56.6	4.43	(3.00-6.59)			4.64	(2.64-8.21)		
	Sunnmøre	134	27	20.1	0.87	(0.53-1.39)			0.90	(0.47-1.72)		
	Søndre Buskerud	203	113	55.7	4.27	(3.00-6.13)			2.92	(1.66-5.16)		
	Sør-Trøndelag	344	218	63.4	5.89	(4.31-8.11)			4.83	(2.77-8.50)		

	Telemark	210	148	70.5	8.10	(5.6-11.83)			9.21	(5.4-15.87)			
	Troms	243	122	50.2	3.44	(2.45-4.84)			2.85	(1.60-5.10)			
	Vestfinnmark	81	24	29.6	1.45	(0.85-2.43)			0.77	(0.37-1.60)			
	Vestfold	208	88	42.3	2.50	(1.75-3.58)			3.47	(1.98-6.13)			
	Vestoppland	159	26	16.4	0.68	(0.41-1.07)			0.67	(0.35-1.23)			
	Østfinnmark	49	18	36.7	2.00	(1.06-3.68)			0.78	(0.18-3.07)			
	Østfold	205	132	64.4	6.14	(4.28-8.89)			6.65	(3.64-12.25)			
Municipality population	< 2000	251	132	52.6	1	Ref.	121.9	< 0.001	1	Ref.	11.8	0.04	
	2000-4999	826	417	50.5	0.92	(0.69-1.22)			0.91	(0.64-1.29)			
	5000-9999	863	397	46.0	0.77	(0.58-1.02)			0.83	(0.58-1.18)			
	10000-19999	913	513	56.2	1.16	(0.87-1.53)			1.03	(0.69-1.52)			
	20000-49999	1064	442	41.5	0.64	(0.49-0.84)			0.76	(0.51-1.13)			
	> 50000	1714	1045	61.0	1.41	(1.08-1.84)			1.15	(0.73-1.80)			
Urbanity index	0B (Most rural)	868	406	46.8	1	Ref.	133.8	< 0.001	1	Ref.	7.5	0.27	
	0A	197	121	61.4	1.81	(1.32-2.48)			1.11	(0.72-1.72)			
	1B	254	128	50.4	1.16	(0.87-1.53)			1.04	(0.71-1.53)			
	1A	276	145	52.5	1.26	(0.96-1.65)			1.47	(0.94-2.32)			
	2B	428	198	46.3	0.98	(0.78-1.24)			1.15	(0.78-1.69)			
	2A	921	363	39.4	0.74	(0.61-0.89)			0.88	(0.57-1.34)			
	3A (Most urban)	2687	1585	59.0	1.64	(1.40-1.91)			1.08	(0.70-1.66)			
Distance to autopsy facility (km)	0-49	2063	1306	63.3	1	Ref.	319.5	< 0.001	1	Ref.	28	0.002	
	50-99	938	518	55.2	0.71	(0.61-0.84)			0.67	(0.51-0.88)			
	100-149	920	402	43.7	0.45	(0.38-0.53)			0.56	(0.38-0.84)			
	150-199	469	266	56.7	0.76	(0.62-0.93)			0.75	(0.46-1.22)			
	200-249	312	133	42.6	0.43	(0.34-0.55)			0.51	(0.30-0.86)			
	250-299	192	39	20.3	0.15	(0.10-0.21)			0.35	(0.18-0.67)			
	300-349	309	106	34.3	0.30	(0.24-0.39)			0.72	(0.41-1.26)			
	350-399	197	60	30.5	0.26	(0.18-0.35)			0.47	(0.24-0.91)			
	400-449	90	38	42.2	0.43	(0.28-0.65)			0.94	(0.43-2.06)			
	450-499	92	58	63.0	0.98	(0.64-1.52)			0.86	(0.37-2.04)			
	> 500	49	20	40.8	0.40	(0.22-0.71)			1.69	(0.41-7.51)			

4. Accidental falls

		Deaths	Forensic autopsies	Per cent								
Total		**20306**	**1050**	**5.2**								
Variable	**Level**	**Deaths**	**For.aut.**	**Per cent**	**OR (univariate)**	**95% CI**	**LRT (univariate)**	**p value**	**OR (multi predictor)**	**95% CI**	**LRT (multi predictor)**	**p value**
Year	1996-2002	6199	352	5.7	1	Ref.	6.03	0.05	1	Ref.	4.78	0.09
	2003-2010	6906	357	5.2	0.91	(0.78-1.05)			0.84	(0.68-1.03)		
	2011-2017	7201	341	4.7	0.83	(0.71-0.96)			1.03	(0.84-1.27)		
Sex	Male	8870	774	8.7	1	Ref.	410.2	< 0.001	1	Ref.	8.93	0.002
	Female	11436	276	2.4	0.26	(0.22-0.30)			0.75	(0.63-0.91)		
Age	20-29	114	70	61.4	1	Ref.	3015	< 0.001	1	Ref.	1069	< 0.001
	0-9	16	6	37.5	0.39	(0.13-1.09)			0.45	(0.12-1.59)		
	10-19	50	28	56.0	0.80	(0.41-1.57)			1.04	(0.48-2.27)		
	30-39	121	71	58.7	0.89	(0.53-1.50)			0.95	(0.51-1.75)		
	40-49	231	127	55.0	0.77	(0.49-1.21)			1.04	(0.61-1.77)		
	50-59	468	220	47.0	0.56	(0.37-0.85)			0.75	(0.46-1.22)		
	60-69	813	205	25.2	0.21	(0.14-0.32)			0.34	(0.21-0.55)		
	70-79	2782	168	6.0	0.04	(0.03-0.06)			0.10	(0.06-0.16)		
	80-89	9227	128	1.4	0.01	(0.01-0.01)			0.03	(0.02-0.05)		
	90 and above	6484	27	0.4	0.003	(0-0.005)			0.01	(0.01-0.02)		
Place of death	At_home	1306	338	25.9	1	Ref.	2457	< 0.001	1	Ref.	872.4	< 0.001
	Hospital	9786	343	3.5	0.10	(0.09-0.12)			0.09	(0.07-0.12)		
	Nursing_home	8470	23	0.3	0.01	(0.01-0.01)			0.02	(0.01-0.04)		
	Other_known	524	254	48.5	2.69	(2.18-3.33)			1.22	(0.90-1.65)		
	Unknown	220	92	41.8	2.06	(1.53-2.76)			2.08	(1.39-3.10)		
Police district	Agder	1116	22	2.0	1	Ref.	386.1	< 0.001	1	Ref.	226.2	< 0.001
	Asker og Bærum	609	18	3.0	1.52	(0.81-2.83)			2.89	(0.87-9.75)		
	Follo	335	13	3.9	2.04	(1.00-3.99)			2.77	(0.78-9.99)		
	Gudbrandsdal	438	5	1.1	0.62	(0.22-1.47)			0.50	(0.12-2.09)		
	Haugaland og Sunnhordland	517	35	6.8	3.58	(2.1-6.22)			11.81	(4.09-35.44)		
	Hedmark	937	12	1.3	0.66	(0.32-1.30)			1.62	(0.52-5.15)		
	Helgeland	345	11	3.2	1.67	(0.79-3.37)			4.26	(1.01-18.04)		
	Hordaland	1614	196	12.1	6.74	(4.42-10.78)			15.21	(5.49-44.11)		
	Midtre Hålogaland	556	20	3.6	1.86	(1.01-3.42)			2.33	(0.81-6.75)		
	Nord-Trøndelag	574	20	3.5	1.80	(0.97-3.31)			4.10	(1.39-12.39)		
	Nordmøre og Romsdal	530	16	3.0	1.56	(0.81-2.96)			0.95	(0.31-2.97)		
	Nordre Buskerud	446	16	3.6	1.86	(0.96-3.54)			3.77	(1.16-12.52)		
	Oslo	2606	214	8.2	4.36	(2.87-6.96)			6.63	(2.38-19.31)		
	Rogaland	956	91	9.5	5.14	(3.28-8.42)			12.51	(4.43-36.96)		
	Romerike	1081	33	3.1	1.55	(0.91-2.70)			3.22	(1.05-10.23)		
	Salten	362	21	5.8	3.06	(1.67-5.62)			3.23	(0.73-14.7)		
	Sogn og Fjordane	466	27	5.8	3.04	(1.73-5.42)			2.06	(0.75-5.84)		
	Sunnmøre	554	8	1.4	0.76	(0.32-1.62)			0.46	(0.13-1.55)		
	Søndre Buskerud	853	22	2.6	1.32	(0.73-2.39)			2.26	(0.74-7.11)		
	Sør-Trøndelag	1203	69	5.7	2.98	(1.87-4.93)			5.30	(1.86-15.78)		

	Telemark	846	38	4.5	2.32	(1.38-3.98)			5.98	(2.18-17.01)		
	Troms	476	36	7.6	4.03	(2.37-6.99)			3.04	(1.01-9.45)		
	Vestfinnmark	143	4	2.8	1.57	(0.49-4.01)			1.55	(0.33-6.55)		
	Vestfold	976	38	3.9	2.00	(1.19-3.43)			4.99	(1.71-15.18)		
	Vestoppland	608	11	1.8	0.94	(0.44-1.88)			2.28	(0.69-7.63)		
	Østfinnmark	102	9	8.8	4.94	(2.15-10.57)			163.0	(5.94-4252.3)		
	Østfold	1057	45	4.3	2.19	(1.32-3.71)			5.17	(1.65-16.72)		
Municipality population	< 2000	408	29	7.1	1	Ref.	139.7	< 0.001	1	Ref.	10.14	0.07
	2000-4999	1451	78	5.4	0.74	(0.48-1.16)			1.35	(0.69-2.67)		
	5000-9999	2118	94	4.4	0.60	(0.40-0.94)			1.51	(0.77-2.99)		
	10000-19999	3069	102	3.3	0.44	(0.29-0.69)			1.25	(0.61-2.60)		
	20000-49999	5197	165	3.2	0.42	(0.29-0.65)			1.76	(0.83-3.75)		
	> 50000	8063	582	7.2	1.00	(0.69-1.50)			2.48	(1.16-5.37)		
Urbanity index	0B (Most rural)	1736	93	5.4	1	Ref.	85.6	< 0.001	1	Ref.	5.94	0.43
	0A	430	32	7.4	1.43	(0.94-2.15)			1.23	(0.55-2.74)		
	1B	878	33	3.8	0.70	(0.46-1.03)			1.40	(0.70-2.76)		
	1A	748	31	4.1	0.77	(0.50-1.15)			1.19	(0.51-2.74)		
	2B	1623	53	3.3	0.60	(0.42-0.84)			1.92	(0.98-3.77)		
	2A	4256	138	3.2	0.59	(0.45-0.78)			0.98	(0.46-2.09)		
	3A (Most urban)	10635	670	6.3	1.18	(0.95-1.49)			0.88	(0.40-1.94)		
Distance to autopsy facility (km)	0-49	9014	626	6.9	1	Ref.	122.7	< 0.001	1	Ref.	10.13	0.43
	50-99	3021	122	4.0	0.57	(0.46-0.69)			0.86	(0.52-1.41)		
	100-149	3470	120	3.5	0.48	(0.39-0.59)			0.54	(0.28-1.06)		
	150-199	1283	69	5.4	0.77	(0.59-0.98)			0.90	(0.39-2.07)		
	200-249	682	27	4.0	0.56	(0.37-0.81)			0.62	(0.24-1.63)		
	250-299	560	16	2.9	0.41	(0.24-0.64)			0.75	(0.23-2.42)		
	300-349	979	29	3.0	0.42	(0.28-0.59)			0.75	(0.26-2.19)		
	350-399	516	11	2.1	0.30	(0.16-0.52)			0.65	(0.16-2.68)		
	400-449	327	13	4.0	0.57	(0.32-0.96)			0.62	(0.15-2.49)		
	450-499	328	8	2.4	0.36	(0.16-0.66)			0.37	(0.07-1.83)		
	> 500	126	9	7.1	1.08	(0.52-2.00)			0.04	(0-1.08)		

5. Accidental poisonings

		Deaths	Forensic autopsies	Per cent								
Total		**7719**	**6090**	**78.9**								
Variable	**Level**	**Deaths**	**For.aut.**	**Per cent**	**OR (univariate)**	**95% CI**	**LRT (univariate)**	**p value**	**OR (multi predictor)**	**95% CI**	**LRT (multi predictor)**	**p value**
Year	1996-2002	2363	1961	83.0	1	Ref.	36.7	< 0.001	1	Ref.	7.54	0.02
	2003-2010	2984	2319	77.7	0.72	(0.62-0.82)			0.84	(0.70-1.00)		
	2011-2017	2372	1810	76.3	0.66	(0.57-0.76)			1.04	(0.86-1.26)		
Sex	Male	5734	4624	80.6	1	Ref.	39.5	< 0.001	1	Ref.	2.72	0.1
	Female	1985	1466	73.9	0.68	(0.60-0.76)			1.14	(0.98-1.34)		
Age	20-29	1551	1374	88.6	1	Ref.	694.9	< 0.001	1	Ref.	384.5	< 0.001
	0-9	4	4	100	1.16	(0.12-154.3)			1.53	(0.11-225.1)		
	10-19	142	133	93.7	1.81	(0.97-3.82)			3.73	(1.74-8.86)		
	30-39	2088	1785	85.5	0.76	(0.62-0.93)			0.66	(0.52-0.83)		
	40-49	1796	1413	78.7	0.48	(0.39-0.58)			0.44	(0.35-0.55)		
	50-59	1268	950	74.9	0.39	(0.31-0.47)			0.30	(0.24-0.38)		
	60-69	533	342	64.2	0.23	(0.18-0.29)			0.18	(0.13-0.24)		
	70-79	180	62	34.4	0.07	(0.05-0.10)			0.07	(0.05-0.11)		
	80-89	112	17	15.2	0.02	(0.01-0.04)			0.04	(0.02-0.07)		
	90 and above	45	10	22.2	0.04	(0.02-0.07)			0.09	(0.04-0.20)		
Place of death	At_home	3752	3107	82.8	1	Ref.	1250	< 0.001	1	Ref.	1009	< 0.001
	Hospital	1052	394	37.5	0.12	(0.11-0.14)			0.07	(0.06-0.09)		
	Nursing_home	166	83	50.0	0.21	(0.15-0.28)			0.23	(0.15-0.34)		
	Other_known	1967	1781	90.5	1.98	(1.67-2.36)			1.52	(1.25-1.85)		
	Unknown	782	725	92.7	2.62	(2.00-3.51)			2.37	(1.76-3.25)		
Police district	Agder	350	163	46.6	1	Ref.	962.8	< 0.001	1	Ref.	453.9	< 0.001
	Asker og Bærum	236	202	85.6	6.73	(4.48-10.35)			11.68	(4.81-28.84)		
	Follo	175	126	72.0	2.93	(1.99-4.36)			2.92	(1.25-6.89)		
	Gudbrandsdal	66	30	45.5	0.96	(0.56-1.62)			2.47	(0.93-6.65)		
	Haugaland og Sunnhordland	227	204	89.9	9.98	(6.31-16.41)			30.47	(13.54-70.31)		
	Hedmark	210	109	51.9	1.24	(0.88-1.74)			2.38	(1.19-4.78)		
	Helgeland	59	51	86.4	6.95	(3.43-15.83)			22.08	(5.79-94.9)		
	Hordaland	842	770	91.4	12.19	(8.9-16.86)			34.75	(15.56-78.53)		
	Midtre Hålogaland	82	56	68.3	2.45	(1.49-4.11)			5.83	(2.53-13.71)		
	Nord-Trøndelag	93	59	63.4	1.98	(1.24-3.19)			4.80	(2.15-10.91)		
	Nordmøre og Romsdal	104	59	56.7	1.50	(0.97-2.34)			2.96	(1.24-7.06)		
	Nordre Buskerud	109	77	70.6	2.73	(1.74-4.38)			3.87	(1.65-9.18)		
	Oslo	2141	1941	90.7	11.1	(8.61-14.35)			22.21	(10.13-49.2)		
	Rogaland	440	372	84.5	6.24	(4.49-8.74)			19.61	(8.75-44.5)		
	Romerike	299	158	52.8	1.28	(0.94-1.75)			1.95	(0.86-4.46)		
	Salten	104	80	76.9	3.77	(2.32-6.31)			20.54	(6.34-68.35)		
	Sogn og Fjordane	53	43	81.1	4.75	(2.43-10.11)			20.85	(7.05-67.32)		
	Sunnmøre	79	35	44.3	0.91	(0.56-1.49)			1.52	(0.61-3.81)		
	Søndre Buskerud	401	317	79.1	4.31	(3.14-5.95)			7.26	(3.3-16.14)		
	Sør-Trøndelag	337	274	81.3	4.96	(3.53-7.03)			11.29	(4.97-25.91)		

	Telemark	277	239	86.3	7.13	(4.83-10.76)			22.27	(10.11-49.88)		
	Troms	119	80	67.2	2.34	(1.52-3.64)			7.30	(3.04-17.72)		
	Vestfinnmark	35	16	45.7	0.97	(0.48-1.93)			2.48	(0.84-7.31)		
	Vestfold	317	198	62.5	1.90	(1.40-2.60)			4.55	(2.16-9.68)		
	Vestoppland	135	76	56.3	1.47	(0.99-2.20)			2.81	(1.29-6.16)		
	Østfinnmark	39	25	64.1	2.02	(1.04-4.06)			16.91	(2.67-129.0)		
	Østfold	390	330	84.6	6.26	(4.46-8.9)			22.27	(9.67-51.97)		
Municipality	< 2000	87	54	62.1	1	Ref.	324.6	< 0.001	1	Ref.	4.58	0.47
population	2000-4999	302	210	69.5	1.40	(0.85-2.29)			1.06	(0.57-1.97)		
	5000-9999	512	361	70.5	1.47	(0.91-2.34)			1.37	(0.72-2.57)		
	10000-19999	786	572	72.8	1.64	(1.03-2.58)			1.47	(0.76-2.83)		
	20000-49999	1581	1066	67.4	1.27	(0.81-1.97)			1.59	(0.82-3.02)		
	> 50000	4451	3827	86.0	3.77	(2.41-5.81)			1.67	(0.83-3.33)		
Urbanity	0B (Most rural)	333	226	67.9	1	Ref.	197.5	< 0.001	1	Ref.	9.66	0.14
index	0A	84	63	75.0	1.40	(0.83-2.45)			1.45	(0.69-3.12)		
	1B	129	93	72.1	1.22	(0.78-1.91)			1.20	(0.63-2.35)		
	1A	192	124	64.6	0.86	(0.59-1.26)			1.11	(0.55-2.25)		
	2B	337	226	67.1	0.96	(0.70-1.33)			1.05	(0.60-1.83)		
	2A	1311	916	69.9	1.10	(0.85-1.42)			1.01	(0.54-1.90)		
	3A (Most urban)	5333	4442	83.3	2.37	(1.85-3.00)			1.90	(0.99-3.61)		
Distance	0-49	4710	4005	85.0	1	Ref.	374.5	< 0.001	1	Ref.	9.19	0.51
to autopsy	50-99	939	722	76.9	0.59	(0.49-0.70)			0.89	(0.63-1.27)		
facility (km)	100-149	994	679	68.3	0.38	(0.32-0.44)			1.23	(0.76-2.00)		
	150-199	318	245	77.0	0.59	(0.45-0.78)			1.71	(0.86-3.43)		
	200-249	116	84	72.4	0.46	(0.31-0.70)			2.22	(0.99-5.04)		
	250-299	130	69	53.1	0.20	(0.14-0.28)			1.80	(0.74-4.42)		
	300-349	244	127	52.0	0.19	(0.15-0.25)			1.45	(0.65-3.24)		
	350-399	122	67	54.9	0.21	(0.15-0.31)			1.41	(0.56-3.60)		
	400-449	59	32	54.2	0.21	(0.12-0.35)			1.68	(0.58-4.87)		
	450-499	46	36	78.3	0.61	(0.32-1.29)			0.80	(0.20-3.25)		
	> 500	41	24	58.5	0.25	(0.13-0.46)			0.42	(0.06-2.61)		

6. Other external causes of death

		Deaths	Forensic autopsies	Per cent								
Total		**9094**	**3601**	**39.6**								
Variable	**Level**	**Deaths**	**For.aut.**	**Per cent**	**OR (univariate)**	**95% CI**	**LRT (univariate)**	**p value**	**OR (multi predictor)**	**95% CI**	**LRT (multi predictor)**	**p value**
Year	1996-2002	3028	1307	43.2	1	Ref.	24.14	< 0.001	1	Ref.	4.36	0.11
	2003-2010	3368	1280	38.0	0.81	(0.73-0.89)			0.90	(0.79-1.04)		
	2011-2017	2698	1014	37.6	0.79	(0.71-0.88)			1.05	(0.90-1.22)		
Sex	Male	5659	2720	48.1	1	Ref.	462.3	< 0.001	1	Ref.	0.27	0.6
	Female	3435	881	25.6	0.37	(0.34-0.41)			1.04	(0.90-1.19)		
Age	20-29	524	380	72.5	1	Ref.	2487	< 0.001	1	Ref.	699.1	< 0.001
	0-9	220	134	60.9	0.59	(0.42-0.82)			0.86	(0.58-1.26)		
	10-19	225	145	64.4	0.69	(0.49-0.96)			0.69	(0.47-1.01)		
	30-39	634	455	71.8	0.96	(0.74-1.25)			0.89	(0.66-1.19)		
	40-49	838	592	70.6	0.91	(0.72-1.16)			0.80	(0.61-1.06)		
	50-59	1046	669	64.0	0.67	(0.53-0.85)			0.62	(0.47-0.81)		
	60-69	1099	547	49.8	0.38	(0.30-0.47)			0.41	(0.31-0.53)		
	70-79	1276	367	28.8	0.15	(0.12-0.19)			0.20	(0.15-0.26)		
	80-89	2047	268	13.1	0.06	(0.05-0.07)			0.12	(0.09-0.16)		
	90 and above	1185	44	3.7	0.01	(0.01-0.02)			0.04	(0.03-0.07)		
Place of death	At_home	1603	986	61.5	1	Ref.	3603	< 0.001	1	Ref.	1713	< 0.001
	Hospital	2476	451	18.2	0.14	(0.12-0.16)			0.09	(0.07-0.10)		
	Nursing_home	1967	42	2.1	0.01	(0.01-0.02)			0.02	(0.02-0.03)		
	Other_known	2581	1746	67.6	1.31	(1.15-1.49)			0.98	(0.84-1.16)		
	Unknown	467	376	80.5	2.58	(2.02-3.32)			2.41	(1.82-3.21)		
Police district	Agder	557	142	25.5	1	Ref.	435.6	< 0.001	1	Ref.	349.8	< 0.001
	Asker og Bærum	187	76	40.6	2.00	(1.41-2.83)			3.91	(1.95-7.85)		
	Follo	186	75	40.3	1.97	(1.39-2.80)			2.43	(1.21-4.88)		
	Gudbrandsdal	152	21	13.8	0.48	(0.28-0.77)			0.40	(0.18-0.85)		
	Haugaland og Sunnhordland	281	169	60.1	4.39	(3.25-5.97)			6.20	(3.53-10.95)		
	Hedmark	391	88	22.5	0.85	(0.63-1.15)			0.94	(0.56-1.57)		
	Helgeland	205	88	42.9	2.20	(1.57-3.07)			2.26	(1.17-4.41)		
	Hordaland	827	441	53.3	3.33	(2.64-4.22)			7.02	(4.04-12.21)		
	Midtre Hålogaland	302	105	34.8	1.56	(1.15-2.11)			1.81	(1.09-3.02)		
	Nord-Trøndelag	273	86	31.5	1.35	(0.98-1.85)			1.70	(0.98-2.94)		
	Nordmøre og Romsdal	294	72	24.5	0.95	(0.68-1.31)			0.79	(0.46-1.37)		
	Nordre Buskerud	203	78	38.4	1.82	(1.30-2.56)			2.15	(1.18-3.95)		
	Oslo	1025	455	44.4	2.33	(1.86-2.93)			6.05	(3.46-10.63)		
	Rogaland	385	196	50.9	3.02	(2.30-3.99)			5.41	(3.00-9.80)		
	Romerike	320	98	30.6	1.29	(0.95-1.75)			1.49	(0.80-2.78)		
	Salten	188	96	51.1	3.04	(2.16-4.29)			3.65	(1.76-7.63)		
	Sogn og Fjordane	235	93	39.6	1.91	(1.38-2.64)			2.51	(1.45-4.35)		
	Sunnmøre	242	45	18.6	0.67	(0.46-0.97)			0.59	(0.32-1.06)		
	Søndre Buskerud	327	145	44.3	2.32	(1.74-3.11)			3.79	(2.08-6.92)		
	Sør-Trøndelag	531	233	43.9	2.28	(1.77-2.95)			3.91	(2.22-6.90)		

	Telemark	373	180	48.3	2.72	(2.06-3.60)			4.89	(2.88-8.34)		
	Troms	313	116	37.1	1.72	(1.28-2.32)			1.63	(0.91-2.93)		
	Vestfinnmark	130	52	40.0	1.95	(1.31-2.90)			1.48	(0.78-2.79)		
	Vestfold	446	163	36.5	1.68	(1.28-2.21)			2.04	(1.18-3.53)		
	Vestoppland	197	59	29.9	1.25	(0.87-1.79)			1.29	(0.71-2.35)		
	Østfinnmark	92	45	48.9	2.79	(1.78-4.38)			2.69	(0.97-7.56)		
	Østfold	432	184	42.6	2.16	(1.66-2.84)			3.73	(2.07-6.72)		
Municipality population	< 2000	392	179	45.7	1	Ref.	63.7	< 0.001	1	Ref.	9.24	0.1
	2000-4999	1154	530	45.9	1.01	(0.8-1.27)			1.18	(0.87-1.60)		
	5000-9999	1165	433	37.2	0.70	(0.56-0.89)			1.27	(0.91-1.77)		
	10000-19999	1285	532	41.4	0.84	(0.67-1.06)			1.60	(1.11-2.31)		
	20000-49999	1929	642	33.3	0.59	(0.48-0.74)			1.61	(1.10-2.36)		
	> 50000	3169	1285	40.5	0.81	(0.66-1.00)			1.49	(0.99-2.25)		
Urbanity index	0B (Most rural)	1316	551	41.9	1	Ref.	36.8	< 0.001	1	Ref.	4.44	0.61
	0A	283	125	44.2	1.10	(0.85-1.42)			0.91	(0.60-1.38)		
	1B	418	166	39.7	0.92	(0.73-1.14)			1.09	(0.76-1.58)		
	1A	339	133	39.2	0.90	(0.70-1.14)			1.45	(0.91-2.31)		
	2B	769	259	33.7	0.71	(0.59-0.85)			1.18	(0.85-1.66)		
	2A	1666	585	35.1	0.75	(0.65-0.87)			1.12	(0.75-1.68)		
	3A (Most urban)	4303	1782	41.4	0.98	(0.87-1.11)			1.15	(0.76-1.74)		
Distance to autopsy facility (km)	0-49	3543	1505	42.5	1	Ref.	96.2	< 0.001	1	Ref.	16.8	0.08
	50-99	1348	563	41.8	0.97	(0.86-1.10)			0.87	(0.64-1.17)		
	100-149	1504	558	37.1	0.80	(0.71-0.09)			0.69	(0.47-1.02)		
	150-199	695	308	44.3	1.08	(0.91-1.27)			0.92	(0.57-1.49)		
	200-249	428	175	40.9	0.94	(0.76-1.15)			0.90	(0.54-1.52)		
	250-299	297	80	26.9	0.50	(0.38-0.65)			0.81	(0.44-1.49)		
	300-349	487	146	30.0	0.58	(0.47-0.71)			0.69	(0.39-1.22)		
	350-399	317	85	26.8	0.50	(0.38-0.64)			0.57	(0.29-1.10)		
	400-449	208	66	31.7	0.63	(0.47-0.85)			0.48	(0.24-0.96)		
	450-499	163	66	40.5	0.92	(0.67-1.27)			1.07	(0.49-2.35)		
	> 500	104	49	47.1	1.21	(0.82-1.78)			0.67	(0.24-1.88)		

7. Suicides

		Deaths	Forensic autopsies	Per cent							
Total		**11984**	**7639**	**63.7**							
Variable	**Level**	**Deaths**	**For.aut.**	**Per cent**	**OR (univariate)**	**95% CI**	**LRT (univariate)**	**p value**	**OR (multi predictor)**	**95% CI**	**LRT (multi predictor)**	**p value**
Year	1996-2002	3769	2402	63.7	1	Ref.	74.04	< 0.001	1	Ref.	74.12	< 0.001
	2003-2010	4212	2498	59.3	0.83	(0.76-0.91)			0.70	(0.63-0.79)		
	2011-2017	4003	2739	68.4	1.23	(1.12-1.35)			1.15	(1.02-1.30)		
Sex	Male	8561	5278	61.7	1	Ref.	57.56	< 0.001	1	Ref.	36.62	< 0.001
	Female	3423	2361	69.0	1.38	(1.27-1.51)			1.40	(1.26-1.56)		
Age	20-29	2057	1444	70.2	1	Ref.	193.7	< 0.001	1	Ref.	160.4	< 0.001
	0-9	2	1	50.0	0.42	(0.02-10.75)			0.35	(0-29.65)		
	10-19	674	409	60.7	0.66	(0.55-0.79)			0.76	(0.61-0.96)		
	30-39	2061	1407	68.3	0.91	(0.80-1.04)			0.89	(0.75-1.05)		
	40-49	2291	1504	65.6	0.81	(0.71-0.92)			0.74	(0.63-0.87)		
	50-59	2084	1334	64.0	0.76	(0.66-0.86)			0.68	(0.58-0.80)		
	60-69	1395	833	59.7	0.63	(0.55-0.73)			0.56	(0.47-0.67)		
	70-79	904	468	51.8	0.46	(0.39-0.54)			0.45	(0.37-0.55)		
	80-89	456	216	47.4	0.38	(0.31-0.47)			0.27	(0.20-0.35)		
	90 and above	60	23	38.3	0.26	(0.15-0.44)			0.16	(0.08-0.32)		
Place of death	At_home	6145	3736	60.8	1	Ref.	336.6	< 0.001	1	Ref.	585.4	< 0.001
	Hospital	1202	601	50.0	0.64	(0.57-0.73)			0.21	(0.17-0.25)		
	Nursing_home	121	53	43.8	0.50	(0.35-0.72)			0.42	(0.26-0.69)		
	Other_known	3326	2290	68.9	1.43	(1.30-1.56)			1.52	(1.35-1.70)		
	Unknown	1190	959	80.6	2.68	(2.30-3.12)			2.74	(2.27-3.31)		
Police district	Agder	688	162	23.5	1	Ref.	4280	< 0.001	1	Ref.	1847	< 0.001
	Asker og Bærum	304	287	94.4	54.82	(33.55-95.48)			26.88	(13.79-54.52)		
	Follo	372	200	53.8	3.78	(2.89-4.95)			1.78	(1.08-2.95)		
	Gudbrandsdal	195	31	15.9	0.61	(0.40-0.92)			0.32	(0.17-0.61)		
	Haugaland og Sunnhordland	320	288	90.0	29.22	(19.75-44.54)			31.89	(18.7-55.51)		
	Hedmark	591	142	24.0	1.03	(0.79-1.33)			0.95	(0.62-1.47)		
	Helgeland	190	87	45.8	2.74	(1.96-3.84)			4.23	(2.37-7.59)		
	Hordaland	1032	962	93.2	44.62	(33.27-60.63)			27.62	(16.68-46.13)		
	Midtre Hålogaland	243	85	35.0	1.75	(1.27-2.40)			2.31	(1.46-3.66)		
	Nord-Trøndelag	297	91	30.6	1.43	(1.06-1.94)			0.92	(0.58-1.47)		
	Nordmøre og Romsdal	240	88	36.7	1.88	(1.37-2.58)			2.05	(1.24-3.39)		
	Nordre Buskerud	251	102	40.6	2.22	(1.63-3.02)			1.65	(1.00-2.73)		
	Oslo	1614	1508	93.4	46.19	(35.62-60.43)			25.92	(15.74-42.92)		
	Rogaland	717	656	91.5	34.92	(25.64-48.27)			22.65	(13.55-38.19)		
	Romerike	488	187	38.3	2.02	(1.57-2.60)			1.04	(0.63-1.70)		
	Salten	200	139	69.5	7.40	(5.24-10.54)			5.02	(2.64-9.62)		
	Sogn og Fjordane	190	118	62.1	5.32	(3.79-7.52)			5.14	(3.17-8.41)		
	Sunnmøre	243	43	17.7	0.70	(0.48-1.01)			0.74	(0.43-1.27)		
	Søndre Buskerud	541	375	69.3	7.33	(5.70-9.48)			3.98	(2.48-6.40)		
	Sør-Trøndelag	678	556	82.0	14.8	(11.41-19.33)			8.46	(5.22-13.8)		

	Telemark	505	412	81.6	14.38	(10.85-19.23)			14.6	(9.31-23.08)	
	Troms	301	157	52.2	3.54	(2.66-4.72)			2.08	(1.26-3.45)	
	Vestfinnmark	108	38	35.2	1.76	(1.14-2.70)			1.72	(0.93-3.18)	
	Vestfold	684	303	44.3	2.58	(2.05-3.26)			2.32	(1.48-3.66)	
	Vestoppland	324	93	28.7	1.31	(0.97-1.76)			1.21	(0.76-1.95)	
	Østfinnmark	104	53	51.0	3.37	(2.21-5.16)			4.36	(1.66-11.26)	
	Østfold	564	476	84.4	17.56	(13.23-23.53)			12.85	(7.74-21.46)	
Municipality population	< 2000	314	157	50.0	1	Ref.	1694	< 0.001	1	Ref.	25.71	< 0.001
	2000-4999	1218	587	48.2	0.93	(0.73-1.19)			0.85	(0.63-1.16)	
	5000-9999	1443	688	47.7	0.91	(0.71-1.16)			1.10	(0.80-1.51)	
	10000-19999	1875	965	51.5	1.06	(0.83-1.35)			1.16	(0.83-1.62)	
	20000-49999	2610	1353	51.8	1.08	(0.85-1.36)			1.36	(0.97-1.90)	
	> 50000	4524	3889	86.0	6.12	(4.83-7.76)			1.60	(1.10-2.31)	
Urbanity index	0B (Most rural)	1157	544	47.0	1	Ref.	905.4	< 0.001	1	Ref.	8.78	0.19
	0A	298	181	60.7	1.74	(1.35-2.26)			0.76	(0.52-1.10)	
	1B	393	194	49.4	1.10	(0.87-1.38)			1.01	(0.72-1.40)	
	1A	458	214	46.7	0.99	(0.80-1.23)			0.86	(0.58-1.28)	
	2B	804	333	41.4	0.80	(0.66-0.96)			0.73	(0.54-0.99)	
	2A	2379	1271	53.4	1.29	(1.12-1.49)			0.69	(0.49-0.96)	
	3A (Most urban)	6495	4902	75.5	3.47	(3.05-3.94)			0.72	(0.51-1.03)	
Distance to autopsy facility (km)	0-49	5307	4373	82.4	1	Ref.	1905	< 0.001	1	Ref.	56.85	< 0.001
	50-99	1917	1169	61.0	0.33	(0.30-0.37)			0.71	(0.57-0.87)	
	100-149	1993	967	48.5	0.20	(0.18-0.23)			0.48	(0.36-0.63)	
	150-199	760	465	61.2	0.34	(0.29-0.40)			0.50	(0.34-0.73)	
	200-249	423	167	39.5	0.14	(0.11-0.17)			0.36	(0.23-0.55)	
	250-299	308	108	35.1	0.12	(0.09-0.15)			0.50	(0.30-0.84)	
	300-349	515	142	27.6	0.08	(0.07-0.10)			0.36	(0.22-0.58)	
	350-399	331	92	27.8	0.08	(0.06-0.11)			0.40	(0.23-0.70)	
	400-449	182	57	31.3	0.10	(0.07-0.13)			0.32	(0.18-0.59)	
	450-499	141	43	30.5	0.09	(0.06-0.13)			0.15	(0.07-0.29)	
	> 500	107	56	52.3	0.23	(0.16-0.35)			0.35	(0.13-0.91)	

8. Homicides

		Deaths	Forensic autopsies	Per cent								
Total		**874**	**844**	**96.6**								
Variable	**Level**	**Deaths**	**For.aut.**	**Per cent**	**OR (univariate)**	**95% CI**	**LRT (univariate)**	**p value**	**OR (multi predictor)**	**95% CI**	**LRT (multi predictor)**	**p value**
Year	1996-2002	292	279	95.5	1	Ref.	2.41	0.3	1	Ref.	3.11	0.21
	2003-2010	282	276	97.9	2.05	(0.82-5.69)			2.43	(0.85-8.25)		
	2011-2017	300	289	96.3	1.22	(0.54-2.76)			1.07	(0.4-3.24)		
Sex	Male	512	495	96.7	1	Ref.	0.06	0.81	1	Ref.	0.36	0.55
	Female	362	349	96.4	0.91	(0.45-1.92)			0.77	(0.32-1.83)		
Age	20-29	162	155	95.7	1	Ref.	10.2	0.33	1	Ref.	10.2	0.33
	0-9	46	46	100	4.49	(0.53-586.2)			3.00	(0.33-462.8)		
	10-19	110	108	98.2	2.09	(0.55-11.37)			1.43	(0.33-8.44)		
	30-39	171	162	94.7	0.83	(0.30-2.20)			0.96	(0.30-2.86)		
	40-49	154	147	95.5	0.95	(0.33-2.73)			1.72	(0.50-5.95)		
	50-59	111	109	98.2	2.11	(0.55-11.47)			5.46	(0.87-54.71)		
	60-69	64	64	100	6.22	(0.74-811.9)			9.68	(0.84-1949.1)		
	70-79	32	31	96.9	1.01	(0.21-9.84)			4.75	(0.54-645.6)		
	80-89	20	18	90.0	0.36	(0.09-2.02)			1.28	(0.22-9.95)		
	90 and above	4	4	100	0.43	(0.04-59.51)			0.12	(0.01-18.38)		
Place of death	At_home	309	302	97.7	1	Ref.	12.1	0.02	1	Ref.	13.11	0.01
	Hospital	147	142	96.6	0.64	(0.21-2.08)			0.54	(0.14-2.09)		
	Nursing_home	4	2	50.0	0.02	(0-0.18)			0.01	(0-0.12)		
	Other_known	314	303	96.5	0.65	(0.25-1.64)			0.51	(0.17-1.39)		
	Unknown	100	95	95.0	0.43	(0.14-1.40)			0.36	(0.10-1.31)		
Police district	Agder	57	53	93.0	1	Ref.	40.0	0.04	1	Ref.	33.2	0.16
	Asker og Bærum	21	21	100	3.62	(0.36-487.1)			0.43	(0-896.3)		
	Follo	18	17	94.4	0.98	(0.17-10.27)			0.09	(0-102.5)		
	Gudbrandsdal	4	4	100	0.76	(0.06-106.3)			0.06	(0-525.9)		
	Haugaland og Sunnhordland	19	19	100	3.28	(0.33-442.3)			0.58	(0-560.2)		
	Hedmark	24	24	100	4.12	(0.41-554.2)			5.56	(0-10473)		
	Helgeland	10	10	100	1.77	(0.17-240.7)			0.02	(0-84.25)		
	Hordaland	67	67	100	11.36	(1.17-1517)			4.01	(0-11929)		
	Midtre Hålogaland	11	10	90.9	0.59	(0.10-6.31)			0.03	(0-57.81)		
	Nord-Trøndelag	7	7	100	1.26	(0.11-173.5)			0.48	(0-220.82)		
	Nordmøre og Romsdal	10	9	90.0	0.53	(0.08-5.74)			0.54	(0-78.35)		
	Nordre Buskerud	79	79	100	13.37	(1.38-1786)			3.59	(0-7508)		
	Oslo	216	213	98.6	5.13	(1.21-23.56)			0.68	(0-512.6)		
	Rogaland	47	45	95.7	1.53	(0.32-9.12)			0.33	(0-202.42)		
	Romerike	32	28	87.5	0.53	(0.13-2.21)			0.03	(0-33.76)		
	Salten	9	9	100	1.60	(0.15-218.3)			0.01	(0-211.7)		
	Sogn og Fjordane	8	8	100	1.43	(0.13-195.9)			0.98	(0-735.5)		
	Sunnmøre	17	17	100	2.94	(0.29-397.5)			0.40	(0-432.2)		
	Søndre Buskerud	27	27	100	4.63	(0.47-621.4)			0.26	(0-596.2)		
	Sør-Trøndelag	36	32	88.9	0.61	(0.15-2.51)			0.10	(0-68.81)		

	Telemark	35	33	94.3	1.13	(0.24-6.76)			0.14	(0-37.01)		
	Troms	25	22	88	0.54	(0.12-2.59)			0.06	(0-41.28)		
	Vestfinnmark	11	9	81.8	0.32	(0.06-2.04)			0.001	(0-2.86)		
	Vestfold	28	28	100	4.79	(0.48-643.8)			0.10	(0-217.89)		
	Vestoppland	18	18	100	3.11	(0.31-419.9)			0.09	(0-229.39)		
	Østfinnmark	11	9	81.8	0.32	(0.06-2.04)			0.001	(0-10.55)		
	Østfold	27	26	96.3	1.49	(0.26-15.37)			0.06	(0-297.82)		
Municipality population	< 2000	16	15	93.8	1	Ref.	7.65	0.18	1	Ref.	4.73	0.45
	2000-4999	50	50	100	9.77	(0.5-1456)			11.64	(0.12-78019)		
	5000-9999	154	149	96.8	2.63	(0.26-14.43)			0.98	(0.01-30.92)		
	10000-19999	108	100	92.6	1.14	(0.12-5.65)			0.94	(0.01-15.93)		
	20000-49999	127	122	96.1	2.16	(0.21-11.84)			2.31	(0.02-67.8)		
	> 50000	419	408	97.4	3.44	(0.36-15.97)			1.33	(0.01-25.98)		
Urbanity index	0B (Most rural)	56	53	94.6	1	Ref.	3.87	0.69	1	Ref.	7.38	0.28
	0A	17	16	94.1	0.72	(0.11-7.81)			0.16	(0-33.36)		
	1B	18	17	94.4	0.76	(0.12-8.26)			5.60	(0.28-1629)		
	1A	33	32	97	1.42	(0.22-15.1)			0.001	(0-2.39)		
	2B	49	47	95.9	1.24	(0.23-7.74)			0.83	(0.01-63.59)		
	2A	113	108	95.6	1.29	(0.29-5.04)			0.06	(0-5.45)		
	3A (Most urban)	588	571	97.1	2.14	(0.55-6.26)			0.11	(0-146.4)		
Distance to autopsy facility (km)	0-49	515	500	97.1	1	Ref.	18.5	0.05	1	Ref.	10.9	0.37
	50-99	89	87	97.8	1.08	(0.33-5.54)			5.24	(0.42-7475)		
	100-149	97	97	100	6.04	(0.8-773.3)			6.96	(0.11-4124)		
	150-199	39	36	92.3	0.32	(0.11-1.28)			0.21	(0-33.43)		
	200-249	22	20	90.9	0.25	(0.07-1.34)			0.01	(0-15.33)		
	250-299	18	17	94.4	0.36	(0.08-3.41)			0.16	(0-715.1)		
	300-349	38	35	92.1	0.31	(0.10-1.25)			0.23	(0-172.1)		
	350-399	12	11	91.7	0.24	(0.05-2.28)			0.07	(0-126.7)		
	400-449	22	21	95.5	0.44	(0.10-4.16)			0.43	(0-1540)		
	450-499	9	9	100	0.59	(0.07-77.1)			0.44	(0-7725)		
	> 500	13	11	84.6	0.14	(0.04-0.78)			2.34	(0-555802)		

Errata for Quality aspects of the Norwegian cause of death statistics

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Thesis for the degree philosophiae doctor (PhD)

at the University of Bergen

10.2.23 Christian Lycke Ellingsen

(date and sign. of candidate)

10.02.23.

(date and sign. of faculty)

Errata

Page 7 Misspelling: "diagnostics codes" – corrected to "diagnostic codes"

Page 21 Misspelling: "(1897-1883)" – corrected to "(1807-1883)"

Page 35 Misspelling: "(284-322)" – corrected to "(384-322)"

Page 64 Misspelling: "… these deaths were subsequently coded with X59.9 …" - corrected to "X59.0"

Page 126 Linguistic correction: "coverage" – corrected to "completeness"

Page 156 Reference: "Gyldendal Damm Akademisk" – corrected to "Cappelen Damm Akademisk"

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