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The power of empirical data; lessons from the clinical registry initiatives in Scandinavian cancer care

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ABSTRACT

Background: In Scandinavia, there is a strong tradition for research and quality monitoring based on registry data. In Denmark, Norway and Sweden, 63 clinical registries collect data on disease characteristics, treatment and outcome of various cancer diagnoses and groups based on process-related and outcome-related variables.

Aim: We describe the cancer-related clinical registries, compare organizational structures and quality indicators and provide examples of how these registries have been used to monitor clinical performance, develop prediction models, assess outcome and provide quality benchmarks. Further, we define unmet needs such as inclusion of patient-reported outcome variables, harmonization of variables and barriers for data sharing.

Results and conclusions: The clinical registry framework provides an empirical basis for evidence-based development of high-quality and equitable cancer care. The registries can be used to follow implementation of new treatment principles and monitor patterns of care across geographical areas and patient groups. At the same time, the lessons learnt suggest that further developments and coordination are needed to utilize the full potential of the registry initiative in cancer care.

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Epidemiology; quality registries; health data; malignancies; parameter; outcome

Introduction

In Scandinavia, there is a strong tradition for registry-based research and health care development based on monitoring of quality variables. Some of the first national, population-based cancer registries with data on incident primary malignancies were started here. The first registry was initiated in Denmark in 1943, followed by Norway and Finland in 1952, Iceland in 1954, Sweden in 1958 and later cancer registries were also developed for Greenland in 1973 and for the Faroe Islands in 1966 [1,2]. Based on these registries, cancer statistics for more than 50 cancer types are collected in the interactive Nordcan database that allows calculations of e.g., incidence, prevalence, and relative survival on national and regional levels [3].

Denmark, Norway and Sweden have over the past two decades invested massively in the establishment of complementary clinical registries, also referred to as quality registries or clinical quality registries, with 248 such registries currently available for various diseases [4]. In cancer care, quality parameters are reported into 25 Danish, 8 Norwegian and 30 Swedish diagnosis-specific clinical registries. Additionally, all

three countries have special registries for cancer screening and in Denmark and in Sweden data from specialized palliative care are captured into palliative care registries. The clinical registries provide real-time data to follow implementation of evidence-based principles of care, monitor quality of care and contribute to high quality care and equity in care [5]. These registries also constitute an empirical basis for data-driven improvements and an important resource for registry-based research. The clinical registers are independent of, albeit to variable degrees linked to, the national cancer registries and these data sources are complementary, each with their strengths relative to the aims, design and purposes of a study. Whereas the cancer registries are preferred sources for studies of cancer incidence and prevalence, the clinical registries contain more detailed data for assessment of diagnostic paths and principles, treatment patterns, prognostic factors, outcome and late effects. Clinical registry data may be particularly relevant in areas where evidence from randomized studies is lacking and where population approaches are relevant [6–9]. Nation-wide coverage, high completeness rates and possibilities for record linkage to

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other population-based registries allow for comprehensive investigations and subgroup analyses.

We review the development and implementation of cancer-related clinical registries in Denmark, Norway and Sweden with a focus on similarities and differences e.g., in organization, administrative support, selection of quality indicators, principles for reporting and follow-up, inclusion of patient-reported measures, benchmarking and registry-based research.

Setting and organization

Denmark, Norway and Sweden have a long tradition of collaborative clinical trials and research studies, motivated by limited-sized populations and similar health care systems. The countries are recognized as a stronghold for epidemiologic research based unique personal identifiers that allow for record linkage within population-based registry networks [10]. Specialized care is largely public and provided by 5 regions in Denmark, 4 health trusts in Norway and by 21 regions in Sweden. All three countries have national cancer plans or strategies that are defined by the central governments and surveilled by the health authorities. State-of-the-art cancer care, from diagnostics through treatment, follow-up, rehabilitation and palliative care, is defined in regularly updated national guidelines with responsibility from national, multidisciplinary and multi-professional expert groups. In 2008, Denmark was the first country to standardize and expedite diagnostic paths through 29 cancer care pathways that define investigations and define maximal lead times. Similar systems have since 2015 been implemented also in Norway and Sweden [11,12]. The organizations and responsibilities for the clinical cancer registry initiatives differ somewhat between Denmark, Norway and Sweden.

In Denmark there are 25 clinical registries devoted to specific cancer diagnoses or groups of malignancies (Table 1). The registries are regulated by the government and managed by the Danish Clinical Quality Program and Clinical Registries (RKKP). The registries are authorized by the Board for Health Data and should respond to criteria for national coverage and contribution to quality development (Table 2).

Denmark does not have a formal registry certification system, but the registries and their variables are reviewed and categorized with consideration of factors such as interdisciplinarity, health care sectors involved, clinical effect, links to clinical guidelines, data coverage and research potential every third year. At present, 4 cancer-related clinical registries have reached the highest category. In Denmark, the Board of Health and Welfare defines an overall plan for responsibilities in cancer treatment and defines standards in select areas, e.g., side-effects after surgery for breast cancer and rehabilitation following treatment for prostate cancer. The broader responsibility to define and update clinical guidelines rests with 24 national multidisciplinary groups with members endorsed by various professional organizations. These multidisciplinary groups act as steering groups for the clinical registries and also engage in research within their respective areas of expertise. The steering groups advice on the operations, review, define and update quality variables and approve data access. The RKKP is responsible for the strategic direction, technical competences, data handling, quality control, basic statistics and epidemiologic analyses and delivers data for quality evaluations and research projects.

In Norway 8 clinical registries for cancer have been awarded national registry status (Table 1). Certification has until now been in four categories defined by documentation and routines, coverage, completeness, reporting, development plan, use of registry data for research. The 8 cancer-related registries are placed in the second highest category. Recently, additional criteria have been implemented to evaluate registry-based quality improvements (Table 2). The Cancer Registry of Norway (CRN) is responsible for the administration of the clinical cancer-related registries, including data storage, approvals of data access, statistical analyses and annual reports. Each registry is assigned a quality assistant at the CRN and has an advisory board to which regional members are appointed by the regional health trust leaderships. The advisory groups define and review variables and provide advice to the CRN on data access and registry development.

In Sweden the 30 cancer-related clinical registries are formally run through the Swedish Association of Local

Table 1. Overview of the cancer-related clinical quality registries in Denmark, Norway and Sweden.

Responsibilities and provisions	Denmark	Norway	Sweden
Data custodian	Danish regions	Norwegian health funds	Swedish regions
Responsible body/authority	National Board of Health Data	Cancer Registry of Norway	the Swedish Association of Local Authorities and Regions
Registry organization	the Danish Clinical Quality Program and Clinical Registries	Cancer Registry of Norway	Regional Cancer Centers
Fraction of all registries related to cancer diagnoses	25/88	8/54	30/106
Registries startup years	1977–2013	1993–2013	1997–2016
Cancer screening registries	3	2	3
Responsibility for endorsement of steering group	Professional organizations	Regional health care trusts	Swedish Regions
Standardized annual report	partly	yes	yes
Quality parameters at hospital level	yes	yes	yes
Interactive online reports	no	planned	yes*
Quality data in patient format	no	yes	partly
Future development plan and parameters defined	no	yes	partly
Patient-representation in steering groups	partly	no	yes
Patient-reported data in clinical registries	partly	partly	partly
English summaries available	no	yes	partly

*Gradually rolled out, at present available for 23 registries.

Table 2. Certification principles and levels in the cancer-related clinical registries in Norway, Denmark and Sweden.

Certification level	Criteria
Norway	
Registry status	
1	Criteria for national status, method description for variables and completeness, defined quality indicators, describes relevant analyses to reach aims, describes report formats for relevant groups, has established routines for data capture, annual report, updated development plan
2	as #1 + secures data from all health regions, presents quality indicator on national level, has a plan for analyses of completeness, has a plan for analyses and reports of results at unit-level to participating units, updated development plan
3	as #2 + documents completeness of quality indicators, documents completeness of minimum 60% during the two recent years, annual interactive presentation of quality indicators on the website www.kvalitetsregistre.no , provides participating units with own aggregated and national data, presents participating units' compliance with the most important clinical guidelines, updated development plan
4	as #3 + has documented correct and reliable data during 5 years, documents completeness of minimum 80% during the two recent two years, provides participating units with personalized results and aggregated national results, uses data scientifically, presents PROM/PREM
Quality improvements	
C	Does not fulfill the requirements for level B.
B	Documents results based in quality improvements initiated within three years. These initiatives should be based on registry data.
A	Documents identification of areas for improvement and initiated or continuous patient-related quality improvements.
Denmark	No formal certification system applies. For authorization the registries should have regional or national coverage, should contribute to development of quality in health care, should define inclusion and exclusion criteria and should be supported by relevant professional groups. The registries are reviewed and categorized every third year with consideration of e.g. interdisciplinarity, health care sectors involved, clinical effect, links to clinical guidelines, data completeness and research potential.
Sweden	
3	Tested, reliable data collection, preliminary analyses and development, basic on-line data reports, work to develop data report functions, adheres to national standards, data validation plan, plan for user/patient collaboration, annual report, variable list.
2	Data of high quality and a plan for reaching level 2 within 4 years. Completeness of a minimum 60%.
1	Completeness above 85%. Validation of data quality, including analysis of missing data. Should report a plan to the Medical Research Council with tools for how to search and match information on a meta level.

Authorities and Regions to which the quality registry steering groups report (Table 1). The responsibility for the daily administration of the registries is shared between the six Regional Cancer Centers (RCCs). A certification system determines the yearly funding and possibilities for development of content variables and functionalities. Registries are certified in three categories based on completeness, timeliness, validity, use for quality improvement, innovation and research output (Table 2). At present, 4 cancer-related registries are certified at the highest level. Registries not yet formally certified should have a development plan and should be linked to a RCC. The registry steering groups define and review variables, contribute to various types of data reports and evaluate and approve applications for data access. These groups have strong links to the national multiprofessional groups responsible for standards of care to ensure coordination between clinical guidelines and quality indicators. Administrative and analytical services are provided by the RCCs that, under the leadership of a national quality registry coordinator, provide a framework for coordinated database development and administrative and statistical support.

In all three countries the coordinating registry organizations, i.e., the RKKP in Denmark, the CRN in Norway and the RCCs in Sweden strive to find an optimal balance between ambitions and available resources to support data collection,

validate of content, development of technical solutions, communication of the results to different target groups and stakeholders and support for quality improvement initiatives based on clinical registry data.

Data capture

The health care regions/facilities are the formal data custodians and are responsible for collecting data and monitoring data quality. The steering/advisory groups suggest and define quality variables in collaboration with the registry organizations that also implement changes following approval by the governing bodies. In Denmark and in Norway, the registries largely receive data through automated transfer, though information on treatment and follow-up, e.g., radiotherapy, oncology medicines, and patient-reported outcome (PRO) partially require manual reporting [13].

In Denmark, variables from e-health systems and national population-based registries such as the Patient Registry, the Pathology Registry, the Causes of Death Registry and the Central Person Registry are automatically transferred. There is no formal link to the Danish Cancer Registry, which is under the responsibility of the Health Data Authority. This precludes use of the Cancer Registry e.g., to monitor

completeness and to distinguish between incident and recurrent tumors.

In Norway, all clinical notifications are collected through a national portal to which all 10 radiotherapy units also provide data with high completeness. The pathology reports are not yet fully standardized and predominantly manually coded at the Cancer Registry. The CRN also collects information on country of birth through links to the population registry. Standardized linkage to 8 population registries, e.g., the Causes of Death Registry, the national Patient Registry and the Population Registry, are performed on a monthly basis to validate and enrich clinical registry data.

In Sweden, data are largely entered manually though ongoing initiatives automated data transfer from e-health systems. The mandatory reporting of cancer notifications to the national Cancer Registry is linked to the reporting to the clinical registries, which allows estimates of completeness and distinction between incident and recurrent tumors. Data are regularly linked to the Population Registry and to the Causes of Death Registry. Additional registry links to enrich the data require specific approvals are typically carried out within research and improvement projects.

Clinical variables and data quality

The clinical registries typically contain basic demographic information with personal identifiers, tumor-related variables and define a variable number of process-related (e.g., multidisciplinary treatment conference, preoperative radiotherapy, radical surgery) and outcome-related (e.g., local recurrence, survival measures, late side effects) variables (Table 3). Data quality has several dimensions related to completeness, timeliness, comparability and validity. Quality control occurs at three levels; as part of central validation e.g., for personal identifiers and hospital codes, as part of the administrative curation of data at the registry organizations, e.g., for dates and missing data, performed by the RKKP, the CRN and the RCCs and as part of quality control studies of core variables. Most cancer-related clinical registries have completeness rates exceeding 95% when compared to registered diagnoses in the national cancer registries and in patient-administrative systems (Table 3) [14–26]. Differences in diagnostic criteria and alternative treatment routes may explain missed inclusion in the clinical registries. Based on links to national patient registries, data on treatment and follow-up show completeness rates of 81–98% [19,23]. In the startup phases several registries showed suboptimal timeliness, but this aspect has significantly improved in recent years and is further supported by automated data transfer. Validation studies are crucial to improve data quality and detect differences in coding systems and algorithms and incompatibilities between different data sources. In the Swedish registries for gynecologic cancer, breast cancer, prostate cancer and gastro-esophageal cancer validation studies focused on core variables in 400–800 patients have shown 82–91% agreement on individual data point level, which demonstrates a need for continuous quality assurance initiatives [17,20,24–26].

Comparability is at present only partially possible between countries and diagnoses due to heterogeneity in choice of variables and parameters. In this regard it is striking that the Danish and the Norwegian registries for breast cancer define 10 quality indicators, compared to 35 in the Swedish registry, that the acute leukemia registries in Denmark contain 23 indicators whereas that in Sweden has 3 and that the Danish and Norwegian prostate cancer registries define 6–8 quality indicators while the Swedish prostate cancer registry defines 68 (Table 3). The variability in parameters related to follow-up and outcome can be exemplified from Denmark where only two registries, in breast cancer and malignant melanoma, contain follow-up variables, 7 registries contain information on recurrence and 20 registries contain a survival measure. Outcome-related variables differ between the countries with 45% of the 337 variables in Denmark relate to outcome, 34% of 86 variables in Norway and 7% of 455 variables in Sweden (Table 3).

Many clinical registries have been initiated as treatment registries in surgical departments, which is reflected in a predominance of surgery-related variables and relatively few variables in diagnostics, medical oncology, radiotherapy, follow-up and rehabilitation. The scarcity of variables within medical oncology implies that the possibility to follow e.g., access to, effects and side-effects of new medical treatments through the clinical registries is limited. To meet these needs, a registry module for cancer medicines containing 7 key indicators has been developed and implemented in Sweden to capture data on 23 prioritized cancer drugs. In Norway the INSPIRE project aims to grant regular reporting on medications from the hospital-based systems. In Denmark, a research project develops modules for oncologic drugs in select registries, e.g., breast cancer, melanoma and renal cancer. Inclusion of rehabilitation-related parameters also differ between diagnoses and represents an area where generic solutions could be sought to benefit all registries. Data on patients treated within clinical trials are collected by some registries, but this information is neither consistently collected nor broadly available. Lack of variables related to rehabilitation has been identified as an area for development. Though generic variables have been defined in Sweden, implementation in the clinical registries has been slow. Collection of patient-reported data also remains to be defined and implemented in most clinical registries.

Report formats

Report formats are under continuous development to meet the requirements of various target groups. Traditional registry reports are diagnosis-specific and provide data overviews on the indicators at hospital and regional levels. Such annual reports are generated with support from the registry centers, i.e., RKKP in Denmark, the CRN in Norway and the RCCs in Sweden. The support from the registry centers contribute to an increasing streamlining of statistical methods, analyses and data visualization formats with e.g., tables, bar charts, funnel plots, trend analysis and hospital ranks. In recent years there has been an increased focus on user-friendly

Table 3. Overview of the cancer-related clinical registries in Denmark, Norway and Sweden.

Clinical registry/subregistry	Denmark				Norway				Sweden			
	Year Initiated	Completeness (%)	Process Parameters	Outcome Parameters	Year Initiated	Completeness (%)	Process Parameters	Outcome Parameters	Year Initiated	Completeness (%)	Process Parameters	Outcome Parameters
Acute leukemia (AML and ALL)	2000	98%	7	16	-	-	-	-	1997	100%	2	1
Breast cancer	1977	94%	9	1	2005	100%	9	1	2008	100%	34	1
Brain tumors ^a	2009	100%	7	3	-	-	-	-	1999	87%	6	0
Childhood cancer	1985	100%	2	3	2001	96%	3	8	2011	90%	10	0
Chronic lymphocytic leukemia	2005	100%	10	11	-	-	-	-	2007	>95%	4	0
Chronic myeloproliferative diseases	2005	99%	5	4	-	-	-	-	2002	98%	3	0
Colorectal cancer	2001	95%	14	2	1993/2007	99%	7	5	1995/2007	100%	16	5
Anal cancer	-	-	-	-	-	-	-	-	2015	90%	16	1
Eye tumors	2011	NA	12	2	-	-	-	-	-	-	-	-
Gastric and esophageal cancer	2003	98%	6	5	-	-	-	-	2006	95%	27	5
Gynecologic cancer	2005	89%	-	-	-	-	-	-	-	96%	-	-
Cervical cancer, vaginal cancer	-	-	1	2	-	-	-	-	2011	-	6	1
Endometrial cancer, uterine sarcoma	-	-	2	0	-	-	-	-	2010	-	3	0
Ovarian cancer	-	-	6	3	2013	97%	7	1	2008	-	6	2
Vulvar cancer	-	-	1	0	-	-	-	-	2012	-	4	1
Trophoblastic tumors	-	-	2	0	-	-	-	-	-	-	-	-
Head and neck cancer	1976	109% ^c	9	7	-	-	-	-	2008	94%	14	0
Hepatobiliary cancer ^b	2013	100%	2	4	-	-	-	-	2008	96%	17	2
Kidney cancer	2010	86%	7	5	-	-	-	-	2005	97%	21	0
Lung cancer ^d	2000	95%	4	8	2013	97%	8	4	2002	85%	8	0
Lymphoma	2000	99%	8	8	2013	97%	6	9	2000	95%	4	1
Myeloproliferative disorders	-	-	11	0	-	-	10	-	2008	83%	1	0
Melanoma of the skin	1985	95%	6	21	2008	100%	-	-	2003	97%	20	0
Myeloma	2005	96%	6	4	-	-	-	-	2008	98%	6	0
Myelodysplastic syndrome	2010	94%	6	4	-	-	-	-	2009	>95%	5	1
Myeloproliferative disorders	2005	99%	5	4	-	-	-	-	2008	98%	10	2
Neuroendocrine abdominal tumors	-	-	-	-	-	-	-	-	2017	NA	2	2
Non-melanoma skin cancer	2010	80%	-	-	-	-	-	-	-	-	-	-
Pancreatic cancer	2011	100%	2	4	-	-	-	-	2010	95%	6	1
Penile cancer	2011	100%	7	10	-	-	-	-	2010	94%	13	0
Prostate cancer	2010	67%	6	0	2003	99%	7	1	2000	96%	68	0
Sarcoma	2009	NA	6	2	-	-	-	-	-	-	-	-
Soft tissue sarcoma	-	-	-	-	-	-	-	-	1986	95%	6	0
Abdominal sarcoma	-	-	-	-	-	-	-	-	2008	NA	NA	NA
Skin cancer, non-melanoma	2015	80%	14	0	-	-	-	-	-	-	-	-
Testis cancer	1984/2014	100%	7	4	-	-	-	-	1981	100%	8	3
Thyroid cancer	^e	-	-	-	-	-	-	-	2013	73%	11	0
Urinary bladder and urinary tract cancer	2000	100%	3	17	-	-	-	-	1997	98%	71	3

^aIn Sweden also includes intradural and meningeal cancers. ^bIn Sweden also includes liver metastases. ^cRefers to different basis for inclusion in the clinical registry and the National Cancer Registry. ^dIn Sweden also includes mesothelioma. ^eIn Denmark included in the head and neck cancer registry.

report formats, which are likely to raise interest and stimulate engagement in quality work based on registry data. In Denmark, the RKKP has, in collaboration with the Danish regions and patient organizations, developed a quality manual support data quality work and data-driven actions. In Norway, the CRN provides standardized annual reports with an attractive and reader-friendly format. In Sweden, score-board formats are used across various registries to provide decision-makers with snapshots of nationally prioritized key performance indicators. The annual reports are largely standardized and the RCCs are in a process of gradually rolling out online accessible and user-designated reports. These interactive reports will partly substitute the annual reports, which will rather provide overviews and updates of ongoing initiatives and developments [27].

Based on relevant information governance regulations and approvals, the clinical registries can provide data at individual, anonymized or aggregate levels to accommodate researchers, health providers, authorities and the private sector. In all three countries, detailed data are primarily meant for local and/or regional quality monitoring and improvement initiatives. Such access requires log-in and is typically granted to responsible health professionals who can view data from their respective registry and hospital/region. Researchers, independent investigators and media may request more detailed data to allow independent analyses for statistical purposes. Aggregate data may also be provided from the clinical registries to the Life Science industry as has been done for e.g., melanoma in Norway and prostate cancer in Sweden. To support and safeguard such collaborations, the Swedish Regions and Municipalities, have established a frame agreement for how the Life Science sector can access and use clinical register data.

Monitoring changing principles of care

Registry-based quality data is an important resource for quality monitoring of e.g., diagnostic principles, waiting times, treatment patterns, implementation of new therapies, acute complications, long-term side effects and outcome in different clinical subgroups. Several clinical registries have collected data for more than 10 years and thus enable studies of the effects from modified principles of care. Increasing survival rates have been documented in several tumor types, but registry data have also shed light on developments that call for attention e.g., advanced-stage diagnosis and increasing death rates in melanoma and variable adherence to active surveillance recommendations in prostate cancer [28,29]. A series of studies have documented that provision of care according to national guidelines positively influence clinical outcomes. Effects from refined diagnostics, e.g., increasing use of preoperative MRI and improved quality of pathology reports have been demonstrated to influence resection rates, local recurrence rates and survival in e.g., breast cancer, colorectal cancer, gastroesophageal cancer and melanoma [30–39]. In e.g., colorectal cancer, lung cancer and urinary bladder cancer, registry data have been used to demonstrate increasing survival rates in large cohorts

[30,34,39–42]. In renal cancer, altered principles of care, including standardized histology reports, preoperative CT of the chest, partial nephrectomy for patients with T1a tumors, minimally invasive surgery and nephron-sparing procedures have been documented and parallels improving survival rates [22,43].

The effects of structural changes and implementation of new treatment guidelines can be followed in the clinical registries. Registry data from Norway and Sweden show that an increasing fraction of patients with colorectal cancer, gastroesophageal cancer and urinary bladder cancer undergo surgery at high-volume hospitals with fewer hospitals performing such surgeries [30,36,44]. Information from clinical registries also document that laparoscopic surgery for colorectal cancer and early-stage cervical cancer is safe with favorable survival rates [45,46]. Registry studies show that fertility-sparing *versus* radical surgery for stage I ovarian cancer result in excellent (98%) 5-year survival rates in both groups, albeit with fewer recurrences in the former groups [47]. Optimal management of early-stage tumors is an area of debate where the registries have provided relevant data on favorable results in early-stage renal cell cancer and the use of transanal endoscopic microsurgery in T1 rectal cancer [28,48]. Clinical registry data can also be applied to build prediction models based on complex clinical information such as consultations, imaging, biomarkers and tumor data, to define patient groups that can be spared adjuvant treatment or need of intensified surveillance and/or rehabilitation [49–55]. The similarities in registry structures allow for pooling of data sets to reach sufficient power with a recent example from colon cancer, where the impact from anastomotic leaks was studied in close to 23,000 patients from Denmark, Norway and Sweden with anastomotic leaks in 3.7% and an adverse effect on survival in stage III tumors [56].

A growing number of studies assess long-term effects and complication rates. In lung cancer, the influence of comorbidities on more frequent treatment complications in men has been reported [57]. In rectal cancer, a decreased rate of local recurrences following refined surgery and preoperative radiotherapy has been shown to come at a price of more frequent bowel movements, increased rates of urinary and fecal incontinence, a negatively influenced sexual function and worse scores for global quality of life and social function [58,59]. In gastroesophageal cancer, major postoperative complications such as dyspnea, fatigue and nutritional problems have been documented in one-third of the patients 5 years after treatment [60]. In men with prostate cancer a significantly elevated risk of serious adverse effects after curative treatment has been demonstrated up to 12 years after treatment [61]. Also risks of other late effects such as second primary cancers and loss of working years have been reported based on clinical registry data [62,63].

Data from the clinical registries may also be used to study clinical parameters and outcome in tumor subsets and select populations, e.g., the elderly, where evidence is limited. In prostate cancer, clinical registry data from more than 19,000 men with high-risk tumors have shown that among men in their 70's, only 10% in the age group 75–80 years received radical treatment despite greater than 50% probability of 10-

year remaining life expectancy [64]. Based on more than 15,000 patients with colon cancer above age 70, this patient group was less often adequately staged prior to surgery, were less likely to be discussed at a multidisciplinary team conference, showed higher rates of emergency surgery and lower rates of curative resections [65]. Clinical registries are also highly relevant to study the impact of and effects from geographical and socio-economic inequalities, e.g., related to differences in cancer incidence and outcomes [66–69]. Such studies have revealed geographical and socioeconomic disparities in stage distribution and excess mortality in malignant melanoma and suggest that highly educated patients with gastroesophageal cancer patients are 1.5–3 times more likely to be discussed at a multidisciplinary conference and receive treatment with curative intention [70,71].

Clinical registries may also provide data that support and motivate political initiatives. In Denmark, data from the clinical registry for prostate cancer revealed unmotivated differences in treatment strategies despite national standards of care and case discussion at multidisciplinary treatment conferences. Based on these data, the Danish National Board of Health revised the directives for risk assessment and patient information with the aim to ensure correct case management. In Norway the Colorectal Cancer Registry was used to evaluate outcome after transanal total mesorectal excision for rectal cancer with identification of higher anastomotic leak rates and unfavorable local recurrence rates, which led to a national recommendation against this surgical technique [72]. In Sweden and in Norway, clinical registries have been used to verify low case volumes for e.g., penile cancer and sarcoma, which has supported treatment centralized to national expert centers [73]. In e.g., penile cancer these initiatives have been shown positive effects e.g., on surgical competences at the specialist centers, reduced waiting times and adherence to clinical guidelines.

Clinical registries may also be used to support precision medicine approaches. In Sweden, an ongoing project develops a generic model for how registry data can support individualized clinical decision-making through ‘patient overviews’ [74]. Pilot projects have been run in the clinical registries for kidney cancer, lung cancer and prostate cancer where such modules have been implemented and provide real-time data with a dashboard visualization of key clinical data, an overview of the treatment history and patient-reported outcome measures (PROMs) in graph format. The clinical registries may also provide relevant for initiation of individualized treatment initiatives [75]. The registries may also support identification, inclusion and randomization of patients in clinical trials. In Sweden, the ALASCCA trial on adjuvant Non-Steroidal Anti-Inflammatory drugs uses a randomization platform in the registries for colon cancer and rectal cancer for study inclusion.

Benchmark studies

The clinical registries are also used to investigate differences in outcome between regions or care providers, benchmark hospitals and promote data-driven investigations of observed

variations [18,76–78]. Studies of risk profiles, diagnostic strategies, treatment patterns and principles for follow-up between different geographical regions and countries, however, require alignment of variables and indicators, which is only partly possibly at present. We have collected examples of comparable indicators and target levels in the clinical registries for breast cancer, lung cancer and colorectal cancer to demonstrate limited overlap and variable target levels for many parameters (Table 4). In ovarian cancer comorbidity has been suggested to explain differences in survival between Danish and Swedish patients with better outcome in the latter country [79]. To test this hypothesis, more than 3,100 patients from the Danish and Swedish Gynecologic clinical registries were studied with demonstration of comparable comorbidities. Though concomitant diseases negatively influence survival, this parameter could not explain the observed survival differences between the countries [80].

The RKKP in Denmark, the CRN in Norway and the RCCs in Sweden contribute to benchmarking studies with in-depth analyses aimed at investigating and explaining differences in patient outcome between subsets of patients and between different regions and countries. Some registries have aligned their process indicators with international guidelines, e.g., the Swedish and the Norwegian breast cancer registries that aligns several variables and target levels with the EUSOMA guidelines [81,82]. In Denmark, clinical registry data also contribute to European benchmarking initiatives such as EURECCA, EU-MELACARE and EPID and have documented treatment variability, survival patterns and outcome in specific subsets such as elderly patients [83,84].

Rare cancers

Collaborative initiatives are particularly important and relevant in rare cancers, but despite a Scandinavian tradition for clinical collaborative initiatives, the countries have taken different and non-coordinated approaches to the establishment of clinical registries in this area (Table 3) [85–89]. This can be exemplified by the clinical registries for penile cancer, anal cancer, eye tumors, mesothelioma and sarcoma. In Sweden and Norway, anal cancer is registered in a sub-registry of the colorectal cancer registry, but this diagnosis is not registered in Denmark. Sweden is the only of these countries that register mesothelioma as part of the lung cancer registry. The penile cancer registries are free-standing clinical registries in Sweden and Denmark, with the Danish registry discontinued from 2020, whereas this diagnosis is not covered by a clinical registry in Norway [90]. Eye tumors are registered in a specially dedicated registry in Denmark, whereas these diagnoses are not registered separately in Norway and Sweden.

All three countries have sarcoma registries based on a long-standing collaboration on clinical studies and research initiative within the Scandinavian Sarcoma Group [87]. Yet, the development of clinical registries for these tumor types has not been coordinated, which implies a missed

Table 4. Comparison between quality parameters and target levels for breast cancer, colon cancer and lung cancer in clinical registers in Denmark, Norway and Sweden. Fraction discussed at a multidisciplinary meeting

Denmark		Norway		Sweden	
Quality indicator	Target	Quality indicator	Target	Quality indicator	Target
Breast cancer					
No re-operation due to post-operative complications	95%	Fraction undergoing a sole surgery for a primary tumor	90%	No re-operation due to tumor data	High (low) 90% (80%)
Adjuvant radiotherapy according to guidelines; lumpectomy/mastectomy	92%/95%	Postoperative radiotherapy after breast-conserving surgery	95%	Immediate reconstruction following mastectomy (patients without distant metastases)	20% (15%)
		Immediate reconstruction, patients below age 69	40%	Breast-sparing surgery for invasive cancer ≤30 mm or noninvasive cancer ≤20 mm (patients without distant metastases)	80% (70%)
		Breast-conserving surgery, tumors ≤30 mm	85%	Screening-detected breast cancer in women aged 40–74 years	70% (60%)
Node positive breast cancer patients where axillary resection is indicated, minimum 10 nodes extracted	95%	Fraction with diagnosis confirmed with biopsy/cytology, among patients operated on	90%		
Data completeness of reported patients	95%	Fraction of patients evaluated with MRI	10%	Individual care plan established with participation from the patient	99% (95%)
High-risk patients allocated to adjuvant treatment according to guidelines	90%	Fraction of patients evaluated with MRI, neoadjuvantly treated patients	60%	Patient has been presented with a contact nurse	99% (95%)
Patients that fulfill follow-up program	95%	Breast-conserving surgery, DCIS ≤20 mm	90%	Multidisciplinary team conference prior to start of treatment	99% (90%)
Local recurrence after breast-conserving therapy	2.5%	Fraction of patients that initiate chemotherapy within 6 weeks of surgery	80%	Diagnosis verified prior to surgery (patients without distant metastases)	90% (85%)
Late sentinel node positivity	97%	5-year relative survival	80%	Time from suspicion of cancer to primary surgery, maximum 28 days	80%
Follow-up mammography	95%			Chemotherapy according to national guideline	90% (80%)
Macro-metastases detected without sentinel node biopsy	NA			Radiotherapy following mastectomy according to national guideline	85% (70%)
				Endocrine treatment, ER-positive patients who have undergone surgery and have no distant metastases	90% (85%)
				Treatment with antibodies, HER2 positive tumors following surgery and chemotherapy (patients without distant metastases)	95% (90%)
Colorectal cancer					
30-day mortality after elective surgery	≤2%			30-day mortality, acute/elective	<4%<1%
90-day mortality after elective surgery	≤3%	Mortality 100 days after surgery	<5%	Preoperative multidisciplinary team conference	≥90%
Multidisciplinary treatment conference, newly diagnosed colon cancer	>90%			Postoperative multidisciplinary treatment conference	≥90%
Multidisciplinary treatment conference, newly diagnosed rectal cancer	>90%			Circumferential margin ≥1 mm	≥90%
Distance from tumor to resection margin >1 mm, elective resection	≥97%	Structured pathology reports	>90%	Radically operated	≥90%
Specialist consultation in pathological diagnostics of polypectomy specimen with adenocarcinoma		Laparoscopic surgery	>60%	3-year relative survival, acute/elective surgery	≥80%/95%
Anastomotic leakage after colon cancer surgery	≤3%	Pre-operative radiotherapy, rectum	20–40%	Local recurrences within 3 years	<5%
Anastomotic leakage after rectal cancer surgery	≤10%	No metastases, 5 years after surgery	>85%	Peroperative perforation	0%
No postoperative medical complications within 30 days	≥90%				

(continued)

Table 4. Continued.

Denmark Quality indicator	Target	Norway Quality indicator	Target	Sweden Quality indicator	Target
No postoperative surgical complications within 30 days	≥90%	No local recurrence, 5 years after surgery, rectum	>95%	Lead time, diagnosis to start of treatment within 4 weeks	≥80%
Specialist surgery, acute, acute intervention	≥90%	5-year relative survival after surgery	>80% (colon)/ >85% (rectal)	Lead time, surgery to pathology report within 2 weeks	≥80%
Referral for adjuvant treatment, colon/rectum, stage III	≥95%	5-year relative survival after diagnosis	>68%	Lead time, surgery to start of adjuvant treatment within 8 weeks	≥80%
Initiated adjuvant treatment, colon/rectum, stage III	≥85%	Permanent stoma, rectum	20–40%	Completeness, registry inclusion	100%
				Complete staging	≥90%
				Accredited colorectal surgeon	≥95%
				Number of investigated lymph nodes ≥12	≥95%
				Referral to oncology (resected, stage III, ≤75 years	≥80%
				Included in clinical trial	≥30%
				Coverage, 3/5-year follow-up	100%
Lung cancer					
				Multidisciplinary treatment conference	95% (70%)
Fraction curative resection		Multidisciplinary treatment conference	95%	PET-CT prior to curative treatment	100% (90%)
30-day survival from first registered surgery	30%	Fraction curatively treated	35%	Curative treatment for localized disease	90% (79%)
90-day survival from first registered surgery	97%	Death within 30 days or surgery	≤1.5%		
	95%	Death within 90 days or surgery	≤3%		
1-year survival from diagnosis	42%			1-year survival from diagnosis	NA
5-year survival from first resection	40%	Relative 5-year survival	≥25%	5-year survival from diagnosis	NA
2-year survival from diagnosis	25%	Fraction reported within 60 days of treatment decision	≥70%	Timeliness, report within 3 months	100% (40%)
		Median survival, months	≥14		
5-year survival from diagnosis	12%			Fraction stage IV EGFR tested, NSCLC	95% (60%)
1-year survival from first resection	85%			Planned palliative chemotherapy (stage IV)	90% (78%)
2-year survival from first resection	75%			Planned curative radiochemotherapy for advanced localized disease	75% (50%)
Agreement between cTNM and pTNM	90%			Treated in structured treatment study	NA
Fraction resected, NSCLC	20%			3-year survival from diagnosis	NA
Fraction curative treatment, NSCLC	40%				

opportunity for collaborative studies. In Denmark, sarcomas at different locations are collected within one registry. Norway has a sarcoma registry that has not yet been included in the national registry initiative. Sweden has separate registries for bone and soft tissue sarcoma and for visceral sarcomas, whereas gynecologic sarcomas are registered within the endometrial cancer registry. In Sweden and Norway development of the sarcoma registries is hampered by lack of funding from the national registry initiatives. The possibility of collecting, studying and reporting patterns of disease, treatment and outcome for rare cancers in a truly population-based setting has a particularly strong potential in the Nordic setting with a joint population of 27 million and similar environments for registry-based research. However, this requires joint action and coordinated design and selection of quality indicators.

In Scandinavia, long-term professional collaborations in pediatric oncology, largely coordinated by the Nordic Society of Pediatric Oncology and Hematology (NOPHO), serve as a model for how coordinated efforts to develop and compatible registries, design and run clinical trials, define treatment standards and study late side effects have had positive effects on survival and quality of life [91–94]. In Denmark and Norway, the childhood cancer registry is part of the national clinical registries and in Sweden work is ongoing to migrate 8 separate childhood cancer registries into the Swedish national platform for clinical registry work [95].

Patient-reported measures

The introduction of PROM and patient-reported experience measures (PREM) currently receives much attention in cancer care and may contribute to identification of risk factors and protective factors for long-term outcome and increase our understanding of quality of life aspects. Although a multitude of instruments to capture quality-of-life and patient experiences have been developed, only a few clinical registries have implemented PROM and PREM measures, e.g., the non-melanoma skin cancer registry in Denmark, the Norwegian clinical registry for prostate cancer and the Swedish registries for brain tumors, acute leukemia, pancreatic cancer and prostate cancer. In Norway, a pilot study collects PROM data from in three cancer types in a separate health registry with inclusion of data also from age-matched controls. PROM should be designed in response to defined purposes to collect relevant and timely data [96,97]. In prostate cancer, such measures have revealed frequent adverse effects, which most commonly relate to erectile dysfunction and sexual inactivity, but also negatively influence urinary incontinence, bowel disturbances and overall quality of life in 14% that may provide an important basis for choice of therapy and further refinement of future treatment principles [98,99]. In the Swedish prostate cancer registry PREM data have demonstrated a high degree (74%) of satisfaction with care with participatory care, high-quality information, and access to a nurse navigator defined as success factors [100].

Patient involvement

Patient involvement is a cornerstone in the work of the Scandinavian clinical registries, but has been implemented in various ways in the countries and the in registries. Patient participation in the clinical registry steering groups is focused at obtaining input on relevant measures, sharing and communicating data and discuss quality reports. In Denmark, patient representation is in the process of implementation with patient representation in a growing number of registry steering groups. In Norway, patient involvement is organized through annual meetings with patient organizations. The registry center organizations also include patient representatives in their advisory boards and arrange annual patient panel meetings. National patient organizations are notified about annual reports through targeted communication initiatives. In Sweden, patient representation in registry steering groups has been established since several years. The development of instruments for open and easy access to real-time quality data can positively contribute to the public debate, but also underscores needs for presentation formats designed for laymen. In order to facilitate interpretation of data, all stakeholders and end-user needs should be considered and in this regard training is relevant for all parties; for patient representatives related to data interpretation and benchmarking and for health professionals related to patient-centeredness [101].

Challenges and future developments

The clinical registries in Denmark, Norway and Sweden have provided cancer care with an extensive and comprehensive set of quality indicators that allows surveillance of quality and equity in care. The registries are at a point in their development where high completeness rates and data maturity allow for population-based assessment of patterns of care and long-term outcomes. However, maximized return on investment for quality assurance, health care development and research purposes depends on further developments related to data quality and harmonization of variables and indicators, efficient data links, data sharing and comprehensive and attractive reporting formats.

Harmonized variables and common standards

In the clinical cancer registries, data completeness is good to excellent for variables related to inclusion, diagnostics and surgery, whereas several registries need to improve the inclusion and quality data on variables related to oncology, rehabilitation and patient-reported parameters. Lack of standardization and definition of relevant variables represent barriers for collaborative and comparative studies. This can be exemplified by similar, but non-identical, variables in the registries for breast cancer, colorectal cancer and lung cancer (Table 4). To monitor the provision of cancer care, the registries need to be enriched by updated information on socioeconomic indicators, include quality indicators that cover the entire patient trajectory

as well as patient-reported outcomes [102]. The clinical registries would also benefit from harmonization of definitions and reporting standards with the national cancer registries to ensure comparable results and efficient management of both types of registries.

Research and data sharing

To utilize the full potential of the clinical registries, steering groups, researchers and decision-makers in health care need to accelerate registry initiatives, not least related to simplified and expedited data sharing and intensified research ambitions. Generation of new evidence typically requires record linkages between registries and data sharing not only to address key questions, but also to evaluate quality development initiatives. In reality, such record linkage is increasingly complex and time-consuming due to long handling times, variable requirements for documentation and divergent interpretations of the General Data Protection Regulation (GDPR) for data sharing and data transfer [97]. Another obstacle is long handling times in registry steering groups, at the responsible Registry Centers or at the National authorities that oversee and administer linkage to national health population databases.

Data sharing remains complex between the Nordic countries, partly because of challenges in the interpretation of EU standard contract on part of countries' or institutions' legal representatives. This has led to registry copies in research database format enriched with data on e.g., comorbidity, socioeconomic factors, treatment, side-effects, migration and causes of death from other relevant registries. Though feasible for research purposes this development requires relatively large resources and intermittent data updates with a risk of generating parallel systems for clinical improvement initiatives and research purposes. Initiatives that map registry variables and provide overviews in toolbox format are underway in Sweden and Denmark. Further, NordForsk under the Nordic Council of Ministers supports Nordic collaborative research, research infrastructures and also investigates possibilities for a fellow Nordic IT infrastructure to share health data.

With a common basis in publicly funded health care systems, the clinical registries can provide unique insights into the determinants and effects on health disparities and underserved populations. In these areas, the clinical registries could provide highly relevant information and insights provided data linkage to information on education and income, currently available through the national bureaus of statistics, is possible.

Another obstacle to achieve the full potential of the clinical registries is limited funding for clinical and epidemiologic research, which restricts efficiency e.g., through lack of support for data managers and statisticians. To stimulate research in this area and to introduce a new generation of scientists the Association of the Nordic Cancer Registries has initiated a research school in epidemiology, which integrates education in epidemiologic research methods and cancer surveillance with individual project work.

Comprehensive cancer care quality reports

An important aspect to stimulate interest in and usage of the clinical registries as a means to develop quality of cancer care is easy access to close to real-time, user-designated and comprehensive out-data formats aimed at various target groups such as decision-makers, health care leaders, health professionals and patient representatives.

Recommendations to accelerate registry-based health care improvements

To support and stimulate usage of the clinical registries for evidence-based health care improvements, we suggest that

Responsible authorities:

- Promote and disseminate registry-based data through real-time data and comprehensive overviews of quality performance
- Request data validation and harmonization of variables and ensure relevant interaction between the cancer registries and the clinical registers in cancer
- Engage in solutions for efficient administrative processes for data extraction and reduce barriers for data sharing and transfer between the Nordic countries
- Actively involve patients and public in the registry initiatives
- Contribute to educate a new generation of scientists in registry-based research, epidemiology, data management and biostatistics

Health care leaders and quality managers:

- Regularly monitor clinical registry parameters, request data on data validity, provide regular feed-back on achievements, follow improvement initiatives and link these to transparent structures for responsibilities to implement relevant changes
- Support registry-based research and contribute to dissemination of relevant findings

Registry steering groups and registry organizations:

- Actively promote the potential of the clinical registries for health-care improvement and lead by good example through establishment of comprehensive registry overviews
- Develop principles for validation and continuous quality assurance, including provision of variable definitions and information on data quality in the various registries
- Secure transparent processes for data access and efficient processes for data extraction and transfer
- Work to harmonize quality variables between diagnoses and countries to allow comparison and collaborative studies and facilitate benchmarking, e.g., related to variables for rehabilitation and patient-reported outcomes
- Ensure inclusion of variables that reflect the entire patient trajectory, including performance in diagnostics, data on various treatment types and new medicines, rehabilitation and patient-reported outcomes

- Prioritize development of real-time, user-designated, interactive registry reports
- Consider how key socioeconomic parameters can be captured to provide data on equity of care
- Establish research plans for all clinical registries

Patient organizations:

- Demand open, real-time and accessible quality data and engage in reviewing and discussing results based on these to contribute to a strengthened focus on quality of care
- Request inclusion of relevant patient-reported outcome variables

Conclusions

The clinical registries related to cancer in Denmark, Norway and Sweden are receiving increasing attention based on broad coverage, high completeness and levels of maturity that allow for comprehensive analyses and impactful studies. Over the years, key performance indicators have been optimized, report formats improved and the registries have been used to answer clinically relevant questions, document improvements in care and define areas for targeted intervention. At the same time, the potential to use of registry data for strategic decisions, quality improvement and research is not fully utilized. Further work is needed to ensure validity, harmonize variables, ensure parameters throughout the patient trajectory and allow for more efficient access and sharing of data. The many recent development in the cancer-related registries related to at-glance overviews of the quality landscape and user-friendly, personalized real-time data access will likely increase interest in as well as outcome of the Nordic registry initiatives for different stakeholders – from health professionals and leaders to patient advocates and decision-makers. The clinical registries have contributed to better quality of cancer care in the Nordic countries, but need further nursing to continue to fill important knowledge gaps and meet future needs.

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References

- [1] Bray F, Parkin DM. Evaluation of data quality in the cancer registry: principles and methods. part i: comparability, validity and timeliness. *Eur J Cancer*. 2009;45(5):747–755.
- [2] Pukkala E, Engholm G, Hojsgaard-Schmidt LK, et al. Nordic cancer registries – an overview of their procedures and data comparability. *Acta Oncol*. 2018;57(4):440–455.
- [3] Danckert B, Ferlay J, Engholm G, et al. NORDCAN: Cancer Incidence, Mortality, Prevalence and Survival in the Nordic Countries, Version 8.2 (26.03.2019).
- [4] Sorensen HT, Pedersen L, Jorgensen J, et al. Danish clinical quality databases – an important and untapped resource for clinical research. *Clin Epidemiol*. 2016;8:425–427.
- [5] Parkin DM. The role of cancer registries in cancer control. *Int J Clin Oncol*. 2008;13(2):102–111.
- [6] Juliusson G, Lazarevic V, Hörstedt A-S, et al. Acute myeloid leukemia in the real world: why population-based registries are needed. *Blood*. 2012;119(17):3890–3899.
- [7] Cazzaniga W, Ventimiglia E, Alfano M, et al. Mini review on the use of clinical cancer registers for prostate cancer: The National Prostate Cancer Register (NPCR) of Sweden. *Front Med*. 2019a;6: 51.
- [8] Schmidt M, Schmidt SAJ, Adelborg K, et al. The Danish health care system and epidemiological research: from health care contacts to database records. *Clin Epidemiol*. 2019;11: 563–591.
- [9] Lassen K, Høye A, Myrmet T. Randomised trials in surgery: the burden of evidence. *Rev Recent Clin Trials*. 2012;7(3):244–248.
- [10] Frank L. Epidemiology. When an entire country is a cohort. *Science*. 2000;287(5462):2398–2399.
- [11] Nilssen Y, Brustugun OT, Eriksen MT, et al. Patient and tumour characteristics associated with inclusion in cancer patient pathways in Norway in 2015–2016. *BMC Cancer*. 2020;20(1):488.
- [12] Wilkens J, Thulesius H, Schmidt I, et al. The 2015 national cancer program in Sweden: introducing standardized care pathways in a decentralized system. *Health Policy*. 2016;120(12): 1378–1382.
- [13] Nyholm T, Olsson C, Agrup M, et al. A national approach for automated collection of standardized and population-based radiation therapy data in Sweden. *Radiother Oncol*. 2016;119(2): 344–350.
- [14] Sakkerstad ST, Olsen BC, Karliczek A, Dahl O, et al. Validity of Norwegian Rectal Cancer Registry data at major university hospital 1997–2005. *Acta Oncol*. 2014;23:1–6.
- [15] Arboe B, El-Galaly TC, Clausen MR, et al. The Danish national lymphoma registry: coverage and data quality. *PLoS One*. 2016; 11(6):e0157999
- [16] Christiansen P, Ejlertsen B, Jensen M-B, et al. Danish breast cancer cooperative group. *Clin Epidemiol*. 2016;8:445–449.
- [17] Hansen S, Nielsen J, Laursen RJ, et al. The Danish neuro-oncology registry: establishment, completeness and validity. *BMC Res Notes*. 2016;9(1):425
- [18] Rosenkrantz Holmich L, Klausen S, Spaun E, et al. The Danish melanoma database. *Clin Epidemiol*. 2016; 8:543–548.
- [19] Ingeholm P, Gögenur I, Iversen LH. Danish colorectal cancer group database. *Clin Epidemiol*. 2016;8:465–468.
- [20] Linder G, Lindblad M, Djerf P, et al. Validation of data quality in the Swedish National Register for Oesophageal and Gastric Cancer. *Br J Surg*. 2016;103(10):1326–1335.
- [21] Overgaard J, Jovanovic A, Godballe C, et al. The Danish Head and Neck Cancer database. *Clin Epidemiol*. 2016;8:491–496.
- [22] Thorstenson A, Harmenberg U, Lindblad P, et al. Cancer characteristics and current treatments of patients with renal cell carcinoma in Sweden. *Biomed Res Int*. 2015;2015:456040.
- [23] Häggström C, Liedberg F, Hagberg O, et al. Cohort profile: The Swedish National Register of Urinary Bladder Cancer (SNRUBC) and the Bladder Cancer Data Base Sweden (BladderBaSe). *BMJ Open*. 2017;7(9):e016606.

- [24] Rosenberg P, Kjølhede P, Staf C, et al. Data quality in the Swedish Quality Register of Gynecologic Cancer – a Swedish Gynecologic Cancer Group (SweGCG) study. *Acta Oncol.* 2018; 57(3):346–353.
- [25] Löfgren L, Eloranta S, Krawiec K, et al. Validation of data quality in the Swedish National Register for Breast Cancer. *BMC Public Health.* 2019;19(1):495.
- [26] Tomic K, Sandin F, Wigertz A, et al. Evaluation of data quality in the National Prostate Cancer Register of Sweden. *Eur J Cancer.* 2015;51(1):101–111.
- [27] Stattin P, Sandin F, Sandbäck T, et al. Dashboard report on performance on select quality indicators to cancer care providers. *Scand J Urol.* 2016;50(1):21–28.
- [28] Loeb S, Folkvaljon Y, Curnyn C, et al. Uptake of active surveillance for very-low-risk prostate cancer in Sweden. *JAMA Oncol.* 2017;3(10):1393–1398.
- [29] Robsahm TE, Helsing PE, Nilssen Y, et al. High mortality due to cutaneous melanoma in norway: a study of prognostic factors in a nationwide cancer registry. *Clin Epidemiol.* 2018;10:537–548.
- [30] Guren MG, Kørner H, Pfeffer F, et al. Nationwide improvement of rectal cancer treatment outcomes in Norway, 1993–2010. *Acta Oncol.* 2015;54(10):1714–1722.
- [31] Hofvind S, Holen Å, Aas T, et al. Women treated with breast conserving surgery do better than those with mastectomy independent of detection mode, prognostic and predictive tumor characteristics. *Eur J Surg Oncol.* 2015;41(10):1417–1422.
- [32] Hartmann-Johnsen OJ, Kåresen R, Schlichting E, et al. Survival is better after breast conserving therapy than mastectomy for early stage breast cancer: a registry-based follow-up study of Norwegian women primary operated between 1998 and 2008. *Ann Surg Oncol.* 2015;22(12):3836–3845.
- [33] Åsli LM, Johannesen TB, Myklebust TÅ, et al. Preoperative chemoradiotherapy for rectal cancer and impact on outcomes – a population-based study. *Radiother Oncol.* 2017;123(3):446–453. Jun;
- [34] Bernstein TE, Endreseth BH, Romundstad P, et al. Norwegian Colorectal Cancer Registry. Improved local control of rectal cancer reduces distant metastases. *Colorectal Dis.* 2012;14(10):e668–e678.
- [35] Nedrebø BS, Søreide K, Eriksen MT, et al. Excess mortality after curative surgery for colorectal cancer changes over time and differs for patients with colon versus rectal cancer. *Acta Oncol.* 2013;52(5):933–940.
- [36] Jeremiasen M, Linder G, Hedberg J, et al. Improvements in esophageal and gastric cancer care in Sweden-population-based results 2007–2016 from a national quality register. *Dis Esophagus.* 2019;33(3):doz070.
- [37] Helsing P, Robsahm TE, Vos L, et al. Cutaneous head and neck melanoma: a population-based study of the prognostic impact of tumor location. *J Am Acad Dermatol.* 2016;75(5):975–982.
- [38] Veierod MB, Page CM, Aaserud S, et al. Melanoma staging: varying precision and terminal digit clustering in breslow thickness data is evident in a population-based study. *J Am Acad Dermatol.* 2018;79(1):118–125.
- [39] Holmes AC, Riis AH, Erichsen R, et al. Descriptive characteristics of colon and rectal cancer recurrence in a Danish population-based study. *Acta Oncol.* 2017;56(8):1111–1119.
- [40] Jakobsen E, Rasmussen TR, Green A. Mortality and survival of lung cancer in Denmark: results from the Danish Lung Cancer Group 2000–2012. *Acta Oncol.* 2016;55 Suppl 2:2–9.
- [41] Solberg S, Nilssen Y, Brustugun OT, et al. Increase in curative treatment and survival of lung cancer in Norway 2001–2006. *Eur J Epidemiol.* 2019;34(10):951–955.
- [42] Malmström PU, Gårdmark T, Sherif A, et al. Incidence, survival and mortality trends of bladder cancer in Sweden 1997–2016. *Scand J Urol.* 2019;2:1–7.
- [43] Petersen AC, Sogaard M, Mehnert F, et al. The database of the Danish Renal Cancer Group. *Clin Epidemiol.* 2016; 8:725–729.
- [44] Liedberg F, Holmberg E, Holmang S, et al. Long-term follow-up after radical cystectomy with emphasis on complications and reoperations: a Swedish population-based survey. *Scand J Urol Nephrol.* 2012;46(1):14–18.
- [45] Stormark K, Søreide K, Søreide JA, et al. Nationwide implementation of laparoscopic surgery for colon cancer: short-term outcomes and long-term survival in a population-based cohort. *Surg Endosc.* 2016;30(11):4853–4864.
- [46] Alfonzo E, Wallin E, Ek Dahl L, et al. survival difference between robotic and open radical hysterectomy for women with early-stage cervical cancer: results from a nationwide population-based cohort study. *Eur J Cancer.* 2019;116:169–177.
- [47] Johansen G, Dahm-Kähler P, Staf C, et al. Fertility-sparing surgery for treatment of non-epithelial ovarian cancer: oncological and reproductive outcomes in a prospective nationwide population-based cohort study. *Gynecol Oncol.* 2019;155(2):287–293. Nov
- [48] Stornes T, Wibe A, Nesbakken A, et al. National early rectal cancer treatment revisited. *Dis Colon Rectum.* 2016;59:623–629.
- [49] Mortensen MS, Lauritsen J, Gundgaard MG, et al. A nationwide cohort study of stage I seminoma patients followed on a surveillance program. *Eur Urol.* 2014;66(6):1172–1178.
- [50] Daugaard G, Gundgaard MG, Mortensen MS, et al. Surveillance for stage I nonseminoma testicular cancer: outcomes and long-term follow-up in a population-based cohort. *J Clin Oncol.* 2014; 32(34):3817–3823.
- [51] GuldbRANDT LM, Møller H, Jakobsen E, et al. General practice consultations, diagnostic investigations, and prescriptions in the year preceding a lung cancer diagnosis. *Cancer Med.* 2017;6(1): 79–88.
- [52] Song H, Fang F, Valdimarsdóttir U, et al. Waiting time for cancer treatment and mental health among patients with newly diagnosed esophageal or gastric cancer: a nationwide cohort study. *BMC Cancer.* 2017;17(1):2.
- [53] Vatne K, Stensvold A, Myklebust TÅ, et al. Pre- and post-prostatectomy variables associated with pelvic post-operative radiotherapy in prostate cancer patients: a national registry-based study. *Acta Oncol.* 2017;56(10):1295–1301.
- [54] Aagaard Rasmussen L, Jensen H, Virgilsen LF, et al. A validated algorithm to identify recurrence of bladder cancer: a register-based study in Denmark. *Clin Epidemiol.* 2018;10:1755–1763.
- [55] Thomsen FB, Westerberg M, Garmo H, et al. Prediction of metastatic prostate cancer by prostate-specific antigen in combination with T stage and Gleason Grade: nationwide, population-based register study. *PLoS One.* 2020;15(1):e0228447.
- [56] Stormark K, Krarup P-M, Sjøvall A, et al. Anastomotic leak after surgery for colon cancer and effect on long-term survival. *Colorectal Dis.* 2020. DOI:10.1111/codi.14999
- [57] Christensen NL, Kejs AMT, Jakobsen E, et al. Early death in Danish stage I lung cancer patients: a population-based case study. *Acta Oncol.* 2018;57(11):1561–1566.
- [58] Bruheim K, Guren MG, Skovlund E, et al. Late side effects and quality of life after radiotherapy for rectal cancer. *Int J Radiat Oncol Biol Phys.* 2010;76(4):1005–1011.
- [59] Bruheim K, Guren MG, Dahl AA, et al. Sexual function in males after radiotherapy for rectal cancer. *Int J Radiat Oncol Biol Phys.* 2010;76(4):1012–1017.
- [60] Derogar M, Orsini N, Sadr-Azodi O, et al. Influence of major postoperative complications on health-related quality of life among long-term survivors of esophageal cancer surgery. *J Clin Oncol.* 2012;30(14):1615–1619.
- [61] Fridriksson JO, Folkvaljon Y, Nilsson P, et al. Long-term adverse effects after curative radiotherapy and radical prostatectomy: population-based nationwide register study. *Scand J Urol.* 2016; 50(5):338–345.
- [62] Praestegaard C, Kjaer SK, Andersson M, et al. Risk of skin cancer following tamoxifen treatment in more than 16,000 breast cancer patients: a cohort study. *Breast Cancer.* 2016;23(6):908–916.
- [63] Plym A, Bower H, Fredriksson I, et al. Loss in working years after a breast cancer diagnosis. *Br J Cancer.* 2018;118(5):738–743.

- [64] Bratt O, Folkvaljon Y, Hjälm Eriksson M, et al. Undertreatment of men in their seventies with high-risk nonmetastatic prostate cancer. *Eur Urol.* 2015;68(1):53–58.
- [65] Egenvall M, Schubert Samuelsson K, Klarin I, et al. Management of colon cancer in the elderly: a population-based study. *Colorectal Dis.* 2014;16(6):433–441.
- [66] Dalton SO, Frederiksen BL, Jacobsen E, et al. Socioeconomic position, stage of lung cancer and time between referral and diagnosis in Denmark, 2001–2008. *Br J Cancer.* 2011;105(7):1042–1048.
- [67] Tomic K, Ventimiglia E, Robinson D, et al. Socioeconomic status and diagnosis, treatment and mortality in men with prostate cancer. Nationwide population-based study. *Int J Cancer.* 2018;142(12):2478–2484.
- [68] Willén L, Berglund A, Bergström S, et al. Educational level and management and outcomes in non-small cell lung cancer. A nationwide population-based study. *Lung Cancer.* 2019;131:40–46.
- [69] Thogersen H, Moller B, Åsli LM, et al. Waiting times and treatment following cancer diagnosis: comparison between immigrants and the Norwegian host population. *Acta Oncol.* 2020;59(4):376–383.
- [70] Strömberg U, Peterson S, Holmberg E, et al. Cutaneous malignant melanoma show geographic and socioeconomic disparities in stage at diagnosis and excess mortality. *Acta Oncol.* 2016;55(8):993–1000.
- [71] Linder G, Sandin F, Johansson J, et al. Patient education-level affects treatment allocation and prognosis in esophageal- and gastroesophageal junctional cancer in Sweden. *Cancer Epidemiol.* 2018;52:91–98. Feb
- [72] Wasmuth HH, Faerden AE, Myklebust TÅ, et al. Transanal total mesorectal excision for rectal cancer has been suspended in Norway. *Br J Surg.* 2020;107(1):121–130.
- [73] Rosell L, Wihl J, Hagberg O, et al. Function, information, and contributions: an evaluation of national multidisciplinary team meetings for rare cancers. *Rare Tumors.* 2019;11:2036361319841696.
- [74] Franck Lissbrant I, Hjälm Eriksson M, Lambe M, et al. Set-up and preliminary results from the patient-overview prostate Cancer. Longitudinal registration of treatment of advanced prostate cancer in the National Prostate Cancer Register of Sweden. *Scand J Urol.* 2020;54(3):227–234.
- [75] Rosen AW, Degett TH, Gorgenur I. Individualized treatment of colon cancer. *Danish Med J.* 2016;178:V11150916.
- [76] Blomqvist P, Ekbohm A, Nyren O, et al. Survival after rectal cancer: differences between hospital catchment areas. A nationwide study in Sweden. *Gut.* 1999;45(1):39–44.
- [77] Cazzaniga W, Godtman RA, Carlsson S, et al. Population-based, nationwide registration of prostatectomies in Sweden. *J Surg Oncol.* 2019;120:803–812.
- [78] Glimelius B, Myklebust TÅ, Lundqvist K, et al. Two Countries – two treatment strategies for rectal cancer. *Radiother Oncol.* 2016;121(3):357–363.
- [79] Sperling C, Noer MC, Christensen IJ, et al. Comorbidity is an independent prognostic factor for the survival of ovarian cancer: a Danish register-based cohort study from a clinical database. *Gynecol Oncol.* 2013;129(1):97–102.
- [80] Noer MC, Leandersson P, Paulsen T, et al. Confounders other than comorbidity explain survival differences in Danish and Swedish ovarian cancer patients – a comparative cohort study. *Acta Oncol.* 2018;57(8):1100–1108.
- [81] Biganzoli L, Marotti L, Hart CD, et al. Quality indicators in breast cancer care: an update from the eusoma working group. *Eur J Cancer.* 2017;86:59–81.
- [82] Hartmann-Johnsen OJ, Kåresen R, Schlichting E, et al. Using clinical cancer registry data for estimation of quality indicators: results from the Norwegian Breast Cancer Registry. *Int J Med Inform.* 2019;125:102–109.
- [83] Vermeer NCA, Claassen YHM, Derks MGM, et al. Treatment and survival of patients with Colon Cancer Aged 80 Years and Older: a EURECCA International Comparison. *Oncologist.* 2018;23(8):982–990.
- [84] Claassen YHM, Vermeer NCA, Iversen LH, et al. Treatment and survival of rectal cancer patients over the age of 80 years: a EURECCA international comparison. *Br J Cancer.* 2018;119(4):517–522.
- [85] Toft N, Birgens H, Abrahamsson J, et al. Risk group assignment differs for children and adults 1–45 yr with acute lymphoblastic leukemia treated by the NOPHO ALL-2008 protocol. *Eur J Haematol.* 2013;90(5):404–412.
- [86] Tandstad T, Stahl O, Hakansson U, et al. The SWENOTECA group: a good example of continuous binational and multidisciplinary collaboration for patients with testicular cancer in Sweden and Norway. *Scand J Urol.* 2016;50(1):9–13.
- [87] Trovik C, Bauer HVCF, Styring E, et al. The Scandinavian Sarcoma Group central Register: 6,000 patients after 25 years of monitoring of referral and treatment of extremity and trunk wall soft-tissue sarcoma. *Acta Orthop.* 2017;88(3):341–347.
- [88] Berner K, Zaikova O, Johannesen TB, et al. Validity and completeness of the Scandinavian Sarcoma Group central register by comparison with a nationwide cohort of patients with osteosarcoma in Norway. *J Surg Oncol.* 2018;118(1):246–247.
- [89] Biccler JL, Eloranta S, de Nully Brown P, et al. Optimizing outcome prediction in diffuse large B-cell lymphoma by use of machine learning and nationwide Lymphoma Registries: a nordic lymphoma group study. *JCO Clin Cancer Inform.* 2018;2:1–13.
- [90] Kirrander P, Sherif A, Friedrich B, et al. Swedish National Penile Cancer Register: incidence, tumour characteristics, management and survival. *BJU Int.* 2016;117(2):287–292. Feb
- [91] Gunnes MW, Lie RT, Børge T, et al. Suicide and violent deaths in survivors of cancer in childhood, adolescence and young adulthood—a national cohort study. *Int J Cancer.* 2017;140(3):575–580.
- [92] Stensvold E, Kronen Krossnes B, Lundar T, et al. Outcome for children treated for medulloblastoma and supratentorial primitive neuroectodermal tumor (CNS-PNET) – a retrospective analysis spanning 40 years of treatment. *Acta Oncol.* 2017;56(5):698–705.
- [93] Pritchard-Jones K, Pieters R, Reaman GH, et al. Sustaining innovation and improvement in the treatment of childhood cancer: lessons from high-income countries. *Lancet Oncol.* 2013;14(3):e95–e103.
- [94] de Fine Licht S, Rugbjerg K, Gudmundsdottir T, et al. Long-term inpatient disease burden in the adult life after childhood cancer in Scandinavia (Aliccs) study: a cohort study of 21,297 childhood cancer survivors. *PLoS Med.* 2017;14(5):e1002296.
- [95] Schroder H, Rechnitzer C, Wehner PS, et al. Danish childhood cancer registry. *Clin Epidemiol.* 2016;8:461–464.
- [96] Aaronson NK, Ahmedzai S, Bergman B, et al. The European Organization for Research and Treatment of Cancer qlq-c30: a quality-of-life instrument for use in international clinical trials in oncology. *J Natl Cancer Inst.* 1993;85(5):365–376.
- [97] Van Der Wel KA, Östergren O, Lundberg O, et al. A gold mine, but still no Klondike: Nordic register data in health inequalities research. *Scand J Public Health.* 2019;47(6):618–630.
- [98] Carlsson S, Drevin L, Loeb S, et al. Population-based study of long-term functional outcomes after prostate cancer treatment. *BJU Int.* 2016;117(6B):E36–45.
- [99] Nguyen-Nielsen M, Møller H, Tjønneland A, et al. Patient-reported outcome measures after treatment for prostate cancer: results from the Danish Prostate Cancer Registry (DAPROCAdata). *Cancer Epidemiol.* 2020;64:101623.
- [100] Bergengren O, Garmo H, Bratt O, et al. Satisfaction with care among men with localised prostate cancer: a nationwide population-based study. *Eur Urol Oncol.* 2018;1(1):37–45.
- [101] Sparring V, Granström E, Andreen Sachs M, et al. One size fits none – a qualitative study investigating nine national quality registries’ conditions for use in quality improvement, research and interaction with patients. *BMC Health Serv Res.* 2018;18(1):202.
- [102] Feltelius N, Gedeberg R, Holm L, et al. Utility of registries for post-marketing evaluation of medicines. A survey of Swedish health care quality registries from a regulatory perspective. *Ups J Med Sci.* 2017;122(2):136–147.