

Incidence of newborn resuscitative interventions at birth and short-term outcomes: a regional population-based study

Peder Aleksander Bjorland ^{1,2}, Knut Øymar,^{1,2} Hege Langli Ersdal,^{3,4} Siren Irene Rettedal¹

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¹Department of Paediatrics, Stavanger University Hospital, Stavanger, Norway

²Department of Clinical Science, University of Bergen, Bergen, Hordaland, Norway

³Critical Care and Anaesthesiology Research Group, Stavanger University Hospital, Stavanger, Norway

⁴Faculty of Health Sciences, University of Stavanger, Stavanger, Norway

Correspondence to

Dr Peder Aleksander Bjorland; peder.aleksander.bjorland@sus.no

ABSTRACT

Objectives To determine the incidence and characteristics of resuscitative interventions at different gestational ages and short-term outcomes after resuscitation.

Design, setting and patients A prospective observational study in an unselected population at Stavanger University Hospital, Norway, from October 2016 until September 2017.

Interventions Using a data collection form and video recordings, we registered and analysed resuscitative interventions.

Main outcome measures Incidence of continuous positive airway pressure (CPAP), positive pressure ventilation (PPV), intubation, chest compressions and intravenous fluid or epinephrine boluses. Short-term outcomes of resuscitated newborns.

Results All 4693 newborns in the study period were included in the study. Two hundred and ninety-one (6.2%) newborns received interventions in the first minutes of life beyond drying and stimulation. PPV was provided in 170 (3.6%) while CPAP (without PPV) was provided in 121 (2.6%) newborns. Duration of PPV was median (IQR) 106 s (54–221). Intubations were performed in 19 (0.4%) newborns, with a mean (SD) intubation time of 47 (21) s. Ten (0.2%) newborns received chest compressions and epinephrine was administered in three (0.1%) newborns. Sixty-three per cent of the treated newborns from 34 weeks' gestational age were returned to parental care without further follow-up.

Conclusions The need for resuscitative interventions after birth was frequent in this unselected population in a high-resource setting, but full cardiopulmonary resuscitation was rare. Short-term outcomes were good, suggesting that most newborns treated with resuscitative interventions were not severely affected.

INTRODUCTION

The transition from intrauterine to extra-uterine life is a critical time for survival and involves considerable changes to the newborn's cardiovascular and respiratory systems.^{1–3} Although most newborns initiate spontaneous breathing within the first 30 s of birth, or respond to drying and stimulation,

What is known about the subject?

- A significant percentage of newborns require some assistance to enable the transition to independent life.
- The incidence of different resuscitation measures is likely to vary between different settings and gestational age (GA) groups.

What this study adds?

- Most compromised newborns respond to airway support alone and full cardiopulmonary resuscitation is rare.
- There is a similar increase in resuscitation measures in near-term (34–37 weeks' GA) and postmature (>42 weeks' GA) deliveries.
- Most newborns treated with resuscitative interventions are not severely affected and short-term outcomes are good.

a significant percentage require some assistance to enable this transition to independent life.⁴ The literature suggests that 3%–8% of newborns receive respiratory support during the first minutes of life, and 0.1%–0.3% require advanced cardiopulmonary resuscitation.^{5–12} However, current estimates are widely based on studies conducted in low or middle-resource settings, and the incidence of resuscitative interventions such as continuous positive airway pressure (CPAP), positive pressure ventilation (PPV), intubation, chest compressions and administration of intravenous fluids or drugs is likely to vary between different settings and countries. Recent studies imply that newborn resuscitation is a frequent concern also in high-resource settings,^{13–16} however most studies are not population based or they are conducted in tertiary referral hospitals accumulating high-risk deliveries. Furthermore, knowledge on

short-term outcomes of near-term or at-term newborns after resuscitation is limited.^{17 18} The aim of this study was (1) to describe the incidence and characteristics of newborn resuscitative interventions during the first minutes of life in an unselected population, and (2) to assess short-term outcomes after resuscitation.

MATERIALS AND METHODS

Study site

This prospective, observational study was conducted at Stavanger University Hospital, Norway, including all newborns born in the region from 1 October 2016 until 30 September 2017. Stavanger University Hospital serves a population of 350 000 with approximately 4600 deliveries annually, and is the only hospital in the region with delivery and newborn services. The hospital has an obstetric and neonatal department, providing care for newborns ≥ 23 weeks' gestational age (GA). Newborns with antenatally diagnosed severe cerebrospinal, cardiac or gastrointestinal malformations requiring surgery immediately after birth are delivered elsewhere, accounting for approximately seven pregnancies each year.

The department of obstetrics includes a midwife-run low-risk delivery unit, a general labour ward and an operating theatre for elective and emergency caesarean sections. Each site has a centrally placed main resuscitation crib with resuscitation and monitoring equipment, and a backup resuscitation crib in case of, for example, twin deliveries. In cases of extreme preterm deliveries (< 28 weeks' GA), a fully equipped mobile resuscitation crib is brought from the neonatal intensive care unit (NICU) for convenient transportation back to the NICU after stabilisation.

The resuscitation cribs are equipped with a radiant heater, suction device, patient monitor (Carescape B450, General Electric, Boston, MA), oxygen blender, self-inflating bag without positive end expiratory pressure (PEEP) (Laerdal Medical, Stavanger, Norway), T-piece resuscitator (NeoPuff, Fisher & Paykel Healthcare, Auckland, New Zealand) and instruments for endotracheal intubation and intravenous access (online supplementary

file 1). CPAP is provided with the NeoPuff T-piece resuscitator with adjustable PEEP, routinely set at 5 cm H₂O.

The primary resuscitation team consists of the midwife and/or nurse assistant responsible for the birth and a paediatric resident. A consultant neonatologist is present in cases of extreme preterm deliveries or risk of severe asphyxia. The primary resuscitation team may also call on a full resuscitation team including a consultant neonatologist (if not already present), a neonatal nurse, an anaesthesiologist and an anaesthetic nurse. All staff undergo regular training. The resuscitation teams follow the Norwegian Resuscitation Council guidelines for newborn resuscitation,¹⁹ based on the International Liaison Committee on Resuscitation (ILCOR)⁴ and European Resuscitation Council²⁰ guidelines.

Data collection

During the study period, an 'observational incidence report form' was completed for every newborn, documenting the time and mode of delivery (vaginal delivery or caesarean section), GA and if the newborn received resuscitative interventions within the first 5 min after birth (online supplementary file 2). We defined resuscitative interventions as one or more of the following: CPAP, PPV, endotracheal intubation, chest compressions and intravenous administration of fluids or drugs. The incidence report forms were continuously cross-checked against the birth record, ensuring that every birth was included.

Video recordings were used to supplement the report forms regarding the resuscitative interventions provided. For this purpose, a video and voice recording camera with motion sensors was mounted above all main resuscitation cribs, and on some of the NICU's mobile resuscitation cribs, during the entire study period. Due to economic and technical limitations, secondary resuscitation cribs and some of the NICU's mobile resuscitation cribs were not equipped with a camera. During the data collection period, study personnel would continuously, at a minimum of twice weekly, collect the 'observational incidence report form' filled out after every birth. Parental consent to analyse the video recordings and to

Table 1 Incidence of resuscitative interventions during 1 year at Stavanger University Hospital

Gestational age group	<28	28–33	34–36	37–41	≥ 42	Total
Total number of newborns	13	61	190	4318	111	4693
Interventions provided in	13 (100%)	47 (77%)	19 (10%)	199 (4.6%)	13 (12.6%)	291 (6.2%)
CPAP only	0	24 (39%)	7 (3.7%)	85 (0.2%)	5 (4.5%)	121 (2.6%)
Positive pressure ventilation	13 (100%)	23 (38%)	12 (6.3%)	114 (2.6%)	8 (7.2%)	170 (3.6%)
Intubation	7 (54%)	2 (3.3%)	1 (0.5%)	9 (0.2%)	0	19 (0.4%)
Chest compression	0	1 (1.6%)	1 (0.5%)	8 (0.2%)	0	10 (0.2%)
Intravenous epinephrine	0	0	0	3 (0.1%)	0	3 (0.1%)
Intravenous fluid bolus	0	1 (1.6%)	2 (1.1%)	12 (0.3%)	0	15 (0.3%)

Incidence is presented as n (percentage of newborns in the same group).
CPAP, continuous positive airway pressure.

Table 2 The characteristics of resuscitated newborns at Stavanger University Hospital by gestational age (GA) and in total

	GA <28		GA 28-33		GA 34-36		GA 37-41		GA ≥42		Total	
	n=12	n=39	n=14	n=177	n=13	n=255						
Characteristics of newborns												
Weight (g)	790	(743-899)	1485	(1325-1804)	2545	(2190-2970)	3566	(3142-3946)	3746	(3654-3924)	3310	(2375-3832)
Male gender	8	(67%)	23	(59%)	10	(71%)	105	(59%)	7	(54%)	153	(60%)
Apgar scores												
1 min Apgar	5	4-7	7	6-8	6	5-8	6	5-7	5	4-7	6	5-7
5 min Apgar	8	7-8	8	7-9	8	7-8	8	7-9	7	7-9	8	7-9
10 min Apgar	8	7-9	9	8-9	8	7-8	9	8-10	9	8-10	9	8-10
Umbilical blood values*												
Arterial pH (n=198)	7.35	(0.05)	7.32	(0.13)	7.25	(0.08)	7.18	(0.14)	7.16	(0.1)	7.20	(0.13)
Arterial BE (n=194)	-2.5	(1.2)	-2.7	(3.5)	-2.6	(1.9)	-5.2	(3.5)	-4.7	(4.9)	-4.7	(3.6)
Venous pH (n=232)	7.34	(0.10)	7.37	(0.13)	7.31	(0.10)	7.28	(0.11)	7.27	(0.1)	7.29	(0.14)
Venous BE (n=229)	-4.3	(1.9)	-1.9	(2.6)	-3.7	(3.0)	-5.8	(3.8)	-4.9	(2.5)	-5.0	(3.4)
Characteristics of births												
Vaginal	5	(42%)	13	(33%)	7	(50%)	115	(65%)	7	(54%)	147	(58%)
Planned caesarean section	2	(17%)	5	(13%)	1	(7%)	4	(2%)	0		12	(5%)
Acute caesarean section	5	(42%)	21	(54%)	6	(43%)	58	(33%)	6	(46%)	96	(38%)
Breech	6	(50%)	10	(26%)	5	(36%)	14	(8%)	1	(8%)	36	(14%)
Vacuum	0		1	(3%)	1	(7%)	60	(34%)	5	(38%)	67	(26%)
Forceps	0		0		1	(7%)	11	(6%)	0		12	(5%)
Induced labour	0		1	(3%)	1	(7%)	59	(33%)	7	(54%)	68	(27%)

The table shows the characteristics of the 255 newborns for which consent was provided to access further details. Weight and Apgar given as median (IQR). Umbilical cord blood values given as mean (SD). All others presented as n (percentage of resuscitated newborns in the same group).

*Umbilical blood samples were not available for all patients.
BE, base excess.

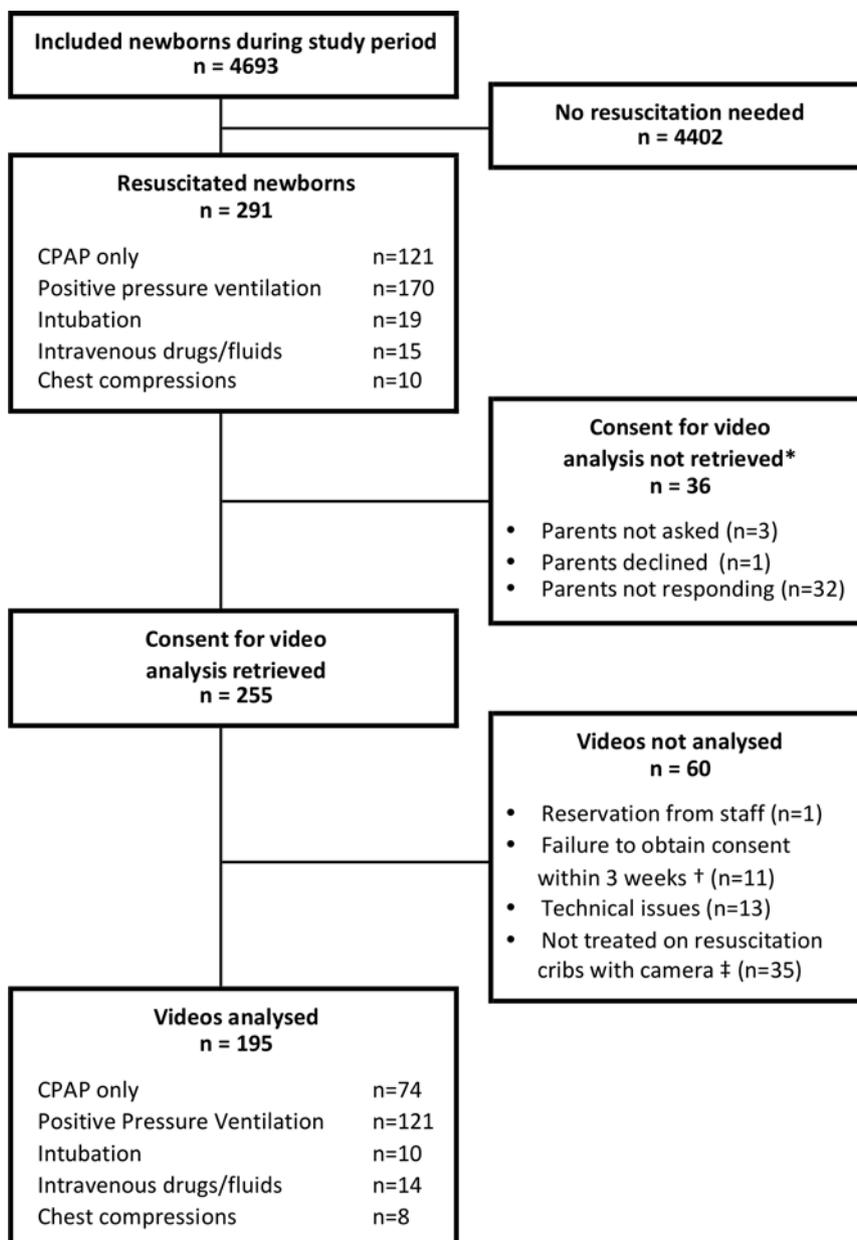


Figure 1 Overview of the studied population *Parental consent was preferably obtained during hospital stay, or else by letter (n=112). Three parents were not asked due to language difficulties. †Videos were automatically deleted after 3 weeks. Consent obtained after 3 weeks resulted in data extraction from patient records alone. ‡Only main resuscitation cribs were equipped with cameras. CPAP, continuous positive airway pressure.

extract patient data from the medical records was asked for all newborns who received resuscitative interventions at birth. If the newborns were already discharged from hospital, parental consent was asked by letter.

During video analysis, the newborn's respiratory effort at placement at the resuscitation cribs was characterised as adequate (eg, crying or showing mild or moderate retractions), inadequate (eg, grunting or severe retractions) or apnoeic. Drying and stimulation was considered adequate if the newborn received tactile truncal stimulation (drying, chest and back rubs) prior to respiratory support.²¹ We recorded mode and duration of PPV, indication for intubation and duration of intubation attempts, and duration of chest compressions.

If established, type of intravenous access and number of fluid/epinephrine boluses were registered. Cord blood samples were taken immediately after birth. We defined short-term outcomes as either death, survival and returned to parents, or survival and admitted to the NICU. Further, we characterised level of intensive care by: length of stay, therapeutic hypothermia, mechanical ventilation, pneumothorax, hypoxic ischaemic encephalopathy (HIE) and death. As all premature newborns <34 weeks of gestation are routinely admitted to the NICU, and the level of intensive care on admission to NICU is strongly related to their prematurity and difficult to part from consequence of resuscitative interventions, we only described short-term outcomes in newborns ≥34 weeks of

gestation. Characteristics of the newborns were retrieved from the medical records.

Analysis

A single investigator (PAB) reviewed all video recordings using the video management software from XProtect Smart Client (Milestone, Copenhagen, Denmark). Statistical calculations were performed in IBM SPSS Statistics V.24 (SPSS). Comparison between groups was done by Mann-Whitney U test for continuous variables and χ^2 test for categorical variables (Fisher's exact test if expected counts were <5). A p value <0.05 was considered statistically significant, all reported p values are two sided. Results are presented as number (%), median (IQR) and mean (SD).

Ethics, patient safety and patient involvement

The study was evaluated as non-interventional by the regional ethical committee and approved by the hospital data protection officer. Waiver of consent was approved for the completion of the incidence reports, ensuring that the registrations were complete and population based. Parental consent was obtained after a resuscitation was videotaped, but prior to video analysis (deferred consent). Video recording is a method increasingly used in clinical research, and its legal and ethical concerns have been debated.^{22,23} The safety of data storage was prioritised, and only the project team members had access to the video recordings. Involved healthcare workers were given the opportunity to demand immediate deletion of the video recording. For privacy purposes, all video recordings were erased after 3 weeks, thus obtaining parental consent and analysing video recordings had to be completed within that period. The local NICU parental user involvement group has been consulted during the project planning regarding ethical aspects, parental information and the process of obtaining parental consent.

RESULTS

Incidence of resuscitative interventions

During the study period, 4610 deliveries took place in our region, resulting in 4697 live born and 13 stillborn newborns. Twenty-six newborns were born outside the hospital (14 home deliveries and 12 deliveries during transport to the hospital, all unplanned). Four newborns were excluded as they were extreme preterm deliveries referred from peripheral hospitals. The remaining 4693 live born newborns were included in the incidence analysis. Of these, 5.6% were born preterm (<37 weeks' GA). There were 85 sets of twins, and one set of triplets. The caesarean section rate was 13.7%; 9.6% was acute and 4.1% elective.

In total, 291 (6.2%) newborns received resuscitative interventions. Respiratory support alone, either by CPAP or PPV, was sufficient in 97% of the resuscitated newborns, whereas the remaining 3% received full cardiopulmonary resuscitation (ie, chest compressions).

Table 3 Level of respiratory support by respiratory effort at arrival on the resuscitation crib

Respiratory effort	Airway support		
	CPAP	PPV	Total
Apnoeic	16	98	114
Inadequate*	34	18	52
Adequate†	24	5	29
Total	74	121	195

*Grunting or severe chest retractions.

†Crying, mild or moderate chest retractions.

CPAP, continuous positive airway pressure; PPV, positive pressure ventilation.

The incidence of different resuscitative interventions for all newborns and in groups by GA is presented in [table 1](#).

The characteristics of the resuscitated newborns for which consent was provided to access further details are shown in [table 2](#).

Characteristics of the resuscitative interventions

We video recorded and analysed 195 of the 291 resuscitations, of which 121 were vaginally delivered newborns and 74 were caesarean sections. The inclusion process and reasons for missed video recordings are shown in [figure 1](#).

On arrival on the resuscitation crib, 160/195 (82%) newborns were adequately dried and stimulated before receiving resuscitative interventions. The respiratory effort of the newborn at arrival at the resuscitation crib, and the level of respiratory support provided, are presented in [table 3](#).

The median duration of CPAP in the group treated with CPAP only was 246 s (113–562). The median duration of PPV was 106 s (54–221), and 87 of 121 (72%) newborns were ventilated for more than 60 s. The T-piece resuscitator was the provider's initial choice in all resuscitations, but in five resuscitations, the provider switched to a self-inflating bag and mask without PEEP during ventilation. Intubation was observed in 10 videos. The intubation was successful at the first (n=4) or second (n=6) attempt. Mean intubation time for each attempt was 47 (21) s. Indications for intubation were failed mask ventilation (n=4), chest compressions (n=3) or need for prolonged respiratory support (n=3).

Eight of the newborns who received chest compressions were video recorded ([table 4](#)).

In three of these, chest compressions were provided for less than 1 min, while three newborns underwent resuscitation with chest compressions exceeding 15 min. In one newborn, return of spontaneous circulation did not occur, and the resuscitation attempt was discontinued after 18 min.

Short-term outcome of newborns ≥ 34 weeks' GA

Resuscitated newborns born ≥ 34 weeks' GA (n=203) were either immediately returned to their parents

Table 4 Overview of newborns receiving chest compressions after birth

Duration of chest compressions	Duration of PPV prior to chest compressions (s)	Gestational age in weeks	Arterial pH/BE*		Intubated	Intravenous access	Epinephrine boluses (n)	Fluid bolus	Immediate outcome	Therapeutic hypothermia	MRI signs of hypoxic ischaemic encephalopathy
			Venous pH/BE*								
0 min/17 s	0	40	7.27/-7.99	7.18/-8.31	No	None	-	-	Parental care	-	-
0 min/36 s	120	37	7.38/0.62	7.35/-1.20	No	None	-	-	Parental care	-	-
0 min/46 s	106	40	7.23/-4.11	7.14/-3.79	No	None	-	-	NICU admission	No	No
1 min/51 s	0 s	35	7.25/-2.38	7.20/-1.59	Yes	None	-	-	NICU admission	No	No
3 min/46 s	140	41	7.31/-4.04	7.26/-3.59	Yes	PVC	0	No	NICU admission	No	No
16 min/41 s	140	39	7.28/-5.65	7.18/-5.76	Yes	PVC	2	Yes	NICU admission	Yes	No
18 min/13 s	62	40	-/-	-/-	Yes	IO needle	1	Yes	Discontinued	-	-
19 min/28 s	44	40	6.51/-20.98	6.88/-16.58	Yes	UVC	2	Yes	NICU admission	Yes	Severe

*Blood values from umbilical cord blood gas taken directly after birth.

BE, base excess; IO, intraosseous; NICU, neonatal intensive care unit; PPV, positive pressure ventilation; PVC, peripheral venous catheter; UVC, umbilical venous catheter.

Table 5 Comparison of newborns ≥ 34 weeks' gestation returned to parental care or admitted to neonatal intensive care unit (NICU)

	Returned to parental care (n=128)	Admitted to NICU (n=75)	P value
General characteristics			
Weight (g)	3629 (3217–3989)	3455 (2865–3870)	0.042*
Gestational age (weeks)	40 (39–41)	40 (38–41)	0.073*
Interventions			
CPAP only	65 (51%)	20 (27%)	0.001†
PPV	63 (49%)	55 (73%)	0.001†
PPV duration (s)	77 (40–112)	202 (90–391)	<0.001*
Intubation	0	8 (11%)	<0.001‡
Chest compressions	2 (2%)	5 (7%)	0.066‡
Intravenous access	0	13 (17%)	<0.001‡
Umbilical blood values			
Arterial pH	7.19 (0.11)	7.17 (0.12)	0.166*
Arterial base excess	-4.6 (3.1)	-5.9 (4.1)	0.073*
Venous pH	7.30 (0.09)	7.26 (0.09)	0.002*
Venous base excess	-5.1 (2.8)	-6.3 (3.5)	0.023*
Apgar scores			
1 min Apgar	6 (6–8)	5 (3–6)	<0.001*
5 min Apgar	9 (8–9)	7 (6–8)	<0.001*
10 min Apgar	9 (9–10)	8 (7–9)	<0.001*

Umbilical cord blood values presented as mean (SD). All others presented as n (%). Weight, gestational age, PPV duration and Apgar presented as median (IQR).

*Mann-Whitney.

† χ^2 .

‡Fisher's exact test.

CPAP, continuous positive airway pressure; PPV, positive pressure ventilation.

(n=128/63%) or admitted to the NICU (n=75/37%). Length of stay on the NICU was median 3 days (2–8), with 70% of the newborns discharged home within 1 week. Twelve newborns needed mechanical ventilation for median 3 (2–5) days. Pneumothorax was diagnosed in three of the resuscitated newborns. Therapeutic hypothermia was provided in five resuscitated newborns, of which two had MRI findings compatible with HIE; one mild/moderate and one severe. Two newborns died during the NICU stay, one due to severe HIE and the second due to severe comorbidity. **Table 5** compares the characteristics of newborns >34 weeks' GA who were returned to their parents and those admitted to the NICU.

DISCUSSION

In this unselected population in a high-resource setting, newborn resuscitation was still a frequent concern, with more than 6% of all newborns requiring resuscitative

interventions at birth. Most newborns responded to respiratory support alone, and the need for full cardiopulmonary resuscitation (ie, chest compressions and epinephrine boluses) was rare. Term newborns had the lowest incidence of interventions with higher incidences among near-term (34–36 weeks' GA) and post-term (>42 weeks' GA) newborns. All extreme preterm newborns (<28 weeks' GA) received PPV, and the intubation rate was 54%.

We defined CPAP as a resuscitation intervention, as it is suggested in the ILCOR guidelines as a means to augment endogenous respiratory effort.⁴ Still, its indication is not clearly defined, and it is not a part of the resuscitation algorithm. In our study, more than 30% of the newborns receiving CPAP were evaluated as adequate breathers by the viewer, highlighting the uncertain necessity of the intervention.

The incidence of PPV in this study was lower than reported in studies conducted in low-resource settings.^{7–9,12} In high-resource settings with modern fetal monitoring and comprehensive obstetric care, the reported incidences vary substantially. Whether these differences represent an unwarranted variation in clinical practice, or different patient characteristics, is unknown. Niles *et al* found that 6% of newborns received PPV in a tertiary-level hospital in Philadelphia, however the caesarean section rate was near 30%, and near 50% received PPV for less than 60s.¹³ A study from a tertiary-level hospital in Iran reported that only 2.8% of the newborns received PPV at birth, despite being a referral centre for high-risk deliveries with a study population including more than 20% premature newborns <37 weeks' GA.¹⁵ This was, however, based on medical records alone and could suffer from under-reporting. Our findings are similar to previous findings from Norway by Skåre *et al*, for both incidence and duration of PPV, in a similar setting with a similar caesarean section rate.^{14,24} Our intubation rates of extreme premature <28 weeks' GA were in line with nationally reported numbers.²⁵

The incidence of full cardiopulmonary resuscitation was low and comparable to findings from other studies.^{5,8,15,26} Still, three of the newborns in our study received chest compressions for less than 1 min, suggesting proper airway handling might have been sufficient. When ILCOR revised their guidelines on newborn resuscitation in 2015, the recommended time of PPV before initiating chest compressions was prolonged, recognising that most compromised newborns will respond to adequate ventilatory support alone.⁴ Our findings may support this recommendation.

When comparing near-term or term newborns admitted to the NICU with those who were returned to their parents after resuscitation, there was a significant difference in Apgar scores, but no difference in arterial umbilical blood gases. Apgar score is used to evaluate the newborn's condition after birth, and to determine the need for, and evaluate the effectiveness of, resuscitation.²⁷ The decision on whether or not to admit a newborn to

the NICU after resuscitation is commonly based on clinical judgement and therefore likely to correlate with the Apgar scores. Furthermore, umbilical cord blood gas, as a predictive value for outcomes, is inconclusive.^{28,29}

The mean umbilical artery base excess (BE) in non-asphyxiated newborns is –4 to –4.8 mmol/L,^{30,31} and asphyxial injury does mostly not occur until fetal BE is ≤ -12 mmol/L.^{32,33} The reported umbilical blood gas values in our study showed low evidence of fetal distress, and the morbidity and mortality were low. This supports the assumption that the majority of newborns in need of resuscitative interventions primarily represent newborns that are not severely affected. Nevertheless, correct and timely management of these newborns is essential for good outcomes,⁷ with a potentially huge impact on socio-economical perspectives.

This study has some limitations. It is a single-centre study with relatively few births, consequently the estimates for the incidences of low frequency interventions such as intubation, chest compressions and intravenous epinephrine are uncertain. We have no information on stimulation attempts in the delivery room prior to arrival at the resuscitation crib. Video cameras were not available at all resuscitation cribs. In particular, many of the NICU mobile resuscitation cribs were without a camera, resulting in a relatively higher missed video recording rate for premature newborns than for near-term and term newborns. This could potentially lead to an underestimation of the characteristics of the resuscitative interventions. There was a poor response rate when consent was asked by letters. This typically included newborns who were discharged early from hospital, and may represent a group where lesser interventions were required. Importantly, the results regarding incidences of resuscitative interventions were not consent or video dependent and therefore not affected by these potential biases.

CONCLUSION

Our study shows a high incidence of newborn resuscitation even in an unselected population in a high-resource setting and supports the recommendations that an adequately trained team must be available in all delivery centres for immediate assistance in the delivery room. Higher level of awareness is appropriate both in near-term and postmature deliveries.

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ORCID ID

Peder Aleksander Bjorland <http://orcid.org/0000-0001-6965-8263>

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