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Prevalence of bradycardia in 4876 newborns in the first minute after birth and association with positive pressure ventilation: a population-based cross-sectional study

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ABSTRACT

Objective To determine the prevalence of bradycardia in the first minute after birth and association with positive pressure ventilation (PPV).

Method A population-based cross-sectional study was conducted from June 2019 to December 2021 at Stavanger University Hospital, Norway. Parents consented to participation during pregnancy, and newborns ≥28 weeks' gestation were included at birth. Heart rate (HR) was captured immediately after birth and continuously for the first minute(s). Time of birth was registered on a tablet. Provision of PPV was captured using video.

Results Of 4876 included newborns, 164 (3.4%) did not breathe (two-thirds) or breathed ineffectively (one-third) and received PPV at birth. HR in the first minute had a wide distribution. The prevalence of first measured HR <100 and <60 beats/minute at median 16 s was 16.3% and 0.6%, respectively. HR increased in most cases. At 60 s, 3.7% had HR <100 beats/minute, of which 82% did not require PPV. In total, 25% of newborns had some registered HR <100 beats/minute during the first minute, of which 95% did not require PPV. Among newborns who received PPV, 76% and 62% had HR ≥100 beats/minute at 60 s and at start PPV, respectively.

Conclusion Bradycardia with HR <100 bpm in the first minute of life was frequent, but mostly self-resolved. Among the 4% of newborns that remained bradycardic at 60 s, only 20% received PPV. Two-thirds of resuscitated newborns had HR ≥100 beats/minute at start PPV. None of the ventilated newborns were breathing adequately at start PPV.

Trial registration number NCT03849781.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ According to resuscitation guidelines, heart rate (HR) <100 beats/minute indicate need for positive pressure ventilation (PPV). The prevalence of bradycardia at birth is largely unknown and has been identified as a knowledge gap.

WHAT THIS STUDY ADDS

⇒ Bradycardia was detected in 25% of newborns during the first minute of life, of which 95% did not require resuscitation with PPV. At 60 s, only 4% had HR <100 beats/minute, of which <20% required resuscitation. Two-thirds of resuscitated newborns had HR ≥100 beats/minute at start of PPV.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study provides novel population-based data on bradycardia in newborns the first minute of life, to guide decision-making regarding need for and response to PPV.

INTRODUCTION

The prevalence of bradycardia in an unselected cohort of newborns after the change in recommendations for delayed cord clamping is largely unknown, and has been identified as a knowledge gap by the International Liaison Committee of Resuscitation (ILCOR).[1]

Immediately after birth, assessment of the newborn's heart rate (HR) is used to evaluate the effectiveness of spontaneous breathing, to determine the need for subsequent interventions and as an indicator of successful response to resuscitation.[2] Current resuscitation algorithms recommend positive pressure ventilation (PPV) to be initiated within 1 min after birth if the newborns fails to establish spontaneous and effective breathing following drying and stimulation, HR is <100 beats per minute (bpm) and does not increase, or HR decreases if initially fast.[3] Chest compressions are recommended if HR is <60 bpm despite at least 30–60 s of adequate ventilation.[3–5] The rationale for HR thresholds at <60 and <100 bpm is based on limited scientific knowledge.[6]

Where resources permit, ILCOR suggests the use of ECG for HR assessment of newborns requiring resuscitation, as ECG provide more rapid and accurate feedback on HR compared with alternative methods.[1] However, existing technology has made it difficult to obtain HR measurements in the first minute of life.[4 7 8] Dry-electrode ECG technology was recently developed for HR assessment immediately after birth.[7 9–12] NeoBeat HR metre (Laerdal Global Health, Stavanger, Norway) can rapidly be applied around the newborn's thorax or upper abdomen without prior drying of the skin and digitally display HR from 5 s after birth.[7 9–12]

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HR obtained by NeoBeat correlates well with that of conventional ECG.[7 10 13] This enabled us to study the prevalence of HR <60 and <100 bpm in an unselected cohort of newborns in the first critical minute(s) after birth, when decisions are made on whether to clamp and cut the cord, transfer the newborn to the resuscitation table and initiate PPV.

The objectives were to describe the distribution of first measured HR, prevalence of HR <100 and <60 bpm in the first minute after birth and association between HR<100 bpm and resuscitation with PPV.

METHODS

Study design and setting

This population-based cross-sectional observational study was conducted from 6 June 2019 through 8 December 2021 at Stavanger University Hospital, Norway.[14] Stavanger University Hospital offers tertiary level obstetric and neonatal services for a population of 370 000 with 4300 births/year. The hospital is the only hospital in the region and well suited for population-based studies. The caesarean section rate is 16%. Overall, 3.4% of newborns with gestational age (GA) ≥28 weeks receive PPV at birth.[15] Healthcare providers are trained to perform newborn resuscitation according to national and European guidelines.[3] Late cord clamping (≥60 s) is practiced as standard care,[3 4] but newborns who require resuscitation have the cord clamped and cut and are transferred to separate resuscitation rooms.

Study participants

Informed parental consent was obtained at routine ultrasound screening in pregnancy or on admission for labour. All newborns with GA ≥28 weeks, irrespective of mode of delivery and need for resuscitative interventions at birth or not, were eligible for inclusion. Newborns were included if time of birth was registered in the Liveborn app (Laerdal Global Health) and HR data were captured within the first 120 s of life. Exclusion criteria were congenital malformation interfering with placement of the NeoBeat.

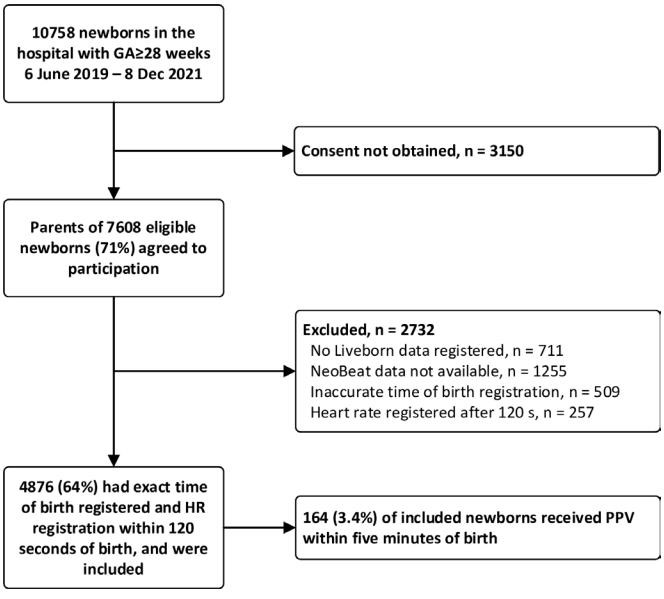

Figure 1 Flowchart of participants. GA, gestational age; HR, heart rate; PPV, positive pressure ventilation.

Data collection and variables

The time of birth and cord clamping was registered in the Liveborn app on a portable tablet by the midwife assistants. NeoBeat was applied to the thorax or upper abdomen of the newborn in the delivery room immediately after birth, and HR was recorded and stored in the Liveborn app.

In apnoeic or ineffectively breathing newborns not responding to drying and stimulation, the umbilical cord was clamped and cut, and the newborn carried to the resuscitation room with the wireless NeoBeat in place. Videos of the resuscitations were recorded using motion sensor cameras placed above the resuscitation tables, capturing images of the newborn and the hands of the healthcare providers. The timestamp in the video server and Liveborn app were synchronised daily. Video recordings of resuscitations were reviewed by two investigators (AK, SR) using XProtect Smart Client software 2016 (Milestone, Copenhagen, Denmark). Breathing efforts at start of PPV (apnoeic/breathing ineffectively/breathing spontaneously), time of initiation and discontinuation of PPV, intubation and chest compressions were registered.

Patient characteristics, treatment and short-term outcomes were electronically extracted from the digital medical records.

Statistical analysis

First HR and last HR were calculated as the median of the first and last 5 HR values, respectively. HR data processing, data point extraction and statistical analysis were done using MATLAB R2021a (MathWorks, Natick, Massachusetts, USA) and R V.4.2.2 (R Core Team).[16] HR data from 10 until 300 s after birth were analysed using centile curves. Continuous data were summarised by median and quartiles, unless otherwise stated. Categorical data were summarised by numbers and proportions. To test for differences between patient groups, the Mann-Whitney test was used for continuous variables and the Fisher exact test for categorical variables. Tests with a p value <0.05 were considered statistically significant.

RESULTS

In total, 4876 newborns of GA ≥28 weeks were included in the study. A flow diagram of participants is presented in figure 1. The umbilical cord was clamped at median (quartiles) 301 (222, 396) s (data available on 4047 newborns). Patient demographics are presented in table 1.

PPV was provided in 164/4876 (3.4%) newborns. Two-thirds (n=86) of ventilated newborns were not breathing or gasping, and one-third (n=45) were breathing ineffectively at start of PPV (video of the resuscitation was available for 131 newborns). PPV started median 72 (52, 148) s after birth (data available from 128 newborns) and was continued for 117 (58, 218) s (data available from 128 newborns).

Distribution of first measured HR

First measured HR had a wide distribution and is presented in figure 2A. First HR was median 150 (113, 174) bpm registered 16 (11, 28) s after birth.

Prevalence of bradycardia in the first minute after birth

The prevalence of bradycardia with first measured HR <100 and <60 bpm was 16.3% (797/4876) and 0.6% (29/4876), respectively. The prevalence of first measured HR ≥180 and ≥200 bpm was 19.0% (927/4876) and 4.0% (196/4876), respectively.

HR increased and the prevalence of bradycardia decreased during the first minute after birth both for newborns not receiving

Table 1 Patient demographics and treatment characteristics

	Total (n=4876)
Gestational age (weeks)	40.3 (39.3, 41.0)
Birth weight (kg)	3.59 (3.25, 3.91)
Gender	
Female	2413 (49.5%)
Male	2463 (50.5%)
Mode of delivery	
Spontaneous vaginal	3648 (74.8%)
Vacuum	605 (12.4%)
Forceps	21 (0.4%)
Elective caesarean	116 (2.4%)
Acute caesarean	405 (8.3%)
Vaginal breech	81 (1.7%)
Apgar	
1 min	9 (9, 10)
5 min	10 (10, 10)
10 min	10 (10, 10)
Umbilical arterial pH	
n=3766	7.24 (7.19, 7.29)
Delivery room PPV	164 (3.4%)
Tracheal intubation	3 (0.1%)
Chest compressions	3 (0.1%)
Admission to the NICU	467 (9.6%)
Therapeutic hypothermia treatment	5 (0.1%)
Hypoxic ischaemic encephalopathy	16 (0.3%)
Death before discharge	1 (<1.0%)

The table shows characteristics of the 4876 newborns. Gender, mode of delivery, PPV, intubation, chest compressions, admission to the NICU, therapeutic hypothermia, hypoxic ischaemic encephalopathy and death before discharge are given as n (%). Gestational age, birth weight, Apgar and umbilical arterial pH are given as median (quartiles).
NICU, neonatal intensive care unit; PPV, positive pressure ventilation.

and receiving PPV, as shown in figure 2B and figure 3A,B. At 30 s after birth (data available for 3716 newborns), median HR was 169 (143, 186) bpm, and 6.3% (235/3716) and 0.13% (5/3716) of newborns had HR <100 and <60 bpm, respectively.

At 60 s (data available for 4372 newborns), median HR was 174 (154, 188) bpm, and 3.7% (162/4372) and 0.06% (3/4372) of newborns had HR<100 and <60 bpm, respectively.

A minimum of 25.1% (1184/4722) of newborns had some registered HR <100 bpm during the first minute after birth (excluding the 154 newborns with first HR measured after 60 s).

Association between bradycardia and resuscitation with PPV at birth

In the 164 newborns receiving PPV, the first measured HR was median 117 (88, 153) bpm measured 28 (14, 46) s after birth, with 32.3% (53/164) and 6.7% (11/164) having a first HR <100 and <60 bpm, respectively. First HR among newborns not breathing or gasping (n=86) was 110 (79, 145) bpm. First HR among those breathing ineffectively (n=45) was 128 (99, 160) bpm.

HR was available in 109 of 128 newborns before time of start PPV. Among these, median first HR was 119 (90, 152) bpm. At start PPV, HR was median 122 (78, 159) bpm, and 37.8% of the newborns had HR <100 bpm (data available from 74 newborns).

PPV was provided in 6.6% (53/797) of newborns with first HR <100 bpm versus 2.7% (111/4079) of newborns with first HR ≥100 bpm, p<0.001. Relative risk (RR) (95% CIs) for PPV if first measured HR was <100 versus ≥100 bpm was 2.4 (1.8, 3.4), p<0.001.

PPV was provided in 5.4% (64/1184) of newborns with some HR <100 bpm registered in the first minute versus 2.6% (92/3538) with all HR ≥100 bpm, p<0.001.

PPV was provided in 17.9% (29/162) of newborns with HR <100 bpm at 60 s versus 2.2% (93/4210) of newborns with HR ≥100 bpm, p<0.001. RR for PPV if HR at 60 s was <100 versus ≥100 bpm was 8.1 (5.5, 11.9), p<0.001.

Associations between bradycardia at 60 s and patient demographics, treatment characteristics and short-term outcomes are shown in table 2.

First measured HR was <100 bpm among 32.3% (53/164) of newborns who received PPV versus 15.8% (744/4712) of newborns who did not receive PPV, p<0.001. In total, 6.7% (11/164) of newborns who received PPV had first HR <60 bpm versus 0.4% (18/4712) who did not receive PPV, p<0.001.

At 60 s, 76.2% (93/122) of newborns who received PPV at birth had HR≥100 bpm.

DISCUSSION

Dry-electrode ECG technology enabled HR measurements immediately after birth in this unselected cohort of almost 5000 newborns. It is surprising that more than 25% of newborns had some HR <100 bpm recorded during the first minute after birth and that 95% of these did not receive PPV. In most cases, HR increased rapidly and only 4% of newborns had HR <100 bpm at 60 s, of which 18% required PPV. Lastly, 76% of newborns who received PPV had HR at 60 s ≥100 bpm.

In this population-based cross-sectional study, we address a knowledge gap identified in the recent ILCOR Consensus on Science with Treatment Recommendations; the prevalence of bradycardia in newborns immediately after birth and after the change in recommendations for delayed cord clamping.[1] Current newborn resuscitation guidelines suggest that HR <100 bpm after birth is a sign of severe distress and a defined threshold for initiating PPV.[3 4] However, 25% of newborns in our study had HR <100 bpm registered at some time during the first minute of life, and 95% of these newborns did not require PPV. Among the 3.7% with persistent HR<100 bpm at 60 s, only 18% needed PPV. Importantly, all ventilated newborns were identified as not breathing adequately at start PPV, as determined by the clinicians and confirmed by review of videos. This indicates that breathing status alone could identify those in need of PPV. However, objective HR measurements supplement the more subjective evaluation of adequacy of respiration. Prolonged bradycardia should alarm healthcare providers of urgency and increased risk of requiring PPV.

Continuous HR feedback provide dynamic information on the newborn's condition and responses to treatment. In a study including 757 apnoeic newborns from a low-resource setting, for every bpm increase in first detected HR after birth the risk of death was reduced by 2%. A rapid increase in HR to >100 bpm in response to PPV reduced the risk of dying by 75%, and a decrease in HR to <100 bpm when ventilation was paused increased the risk of death almost twofold.[17] In our cohort, as many as two-thirds of newborns in need of resuscitation at birth had HR >100 bpm at start PPV. In a recent publication including 98 newborns who received PPV at birth, a wide variation in HR courses from birth to start of PPV was reported.[18] Importantly, among newborns with low HR, HR increased rapidly within 20–30 s of starting effective PPV.[18 19] All these findings support that HR feedback throughout the resuscitation can provide

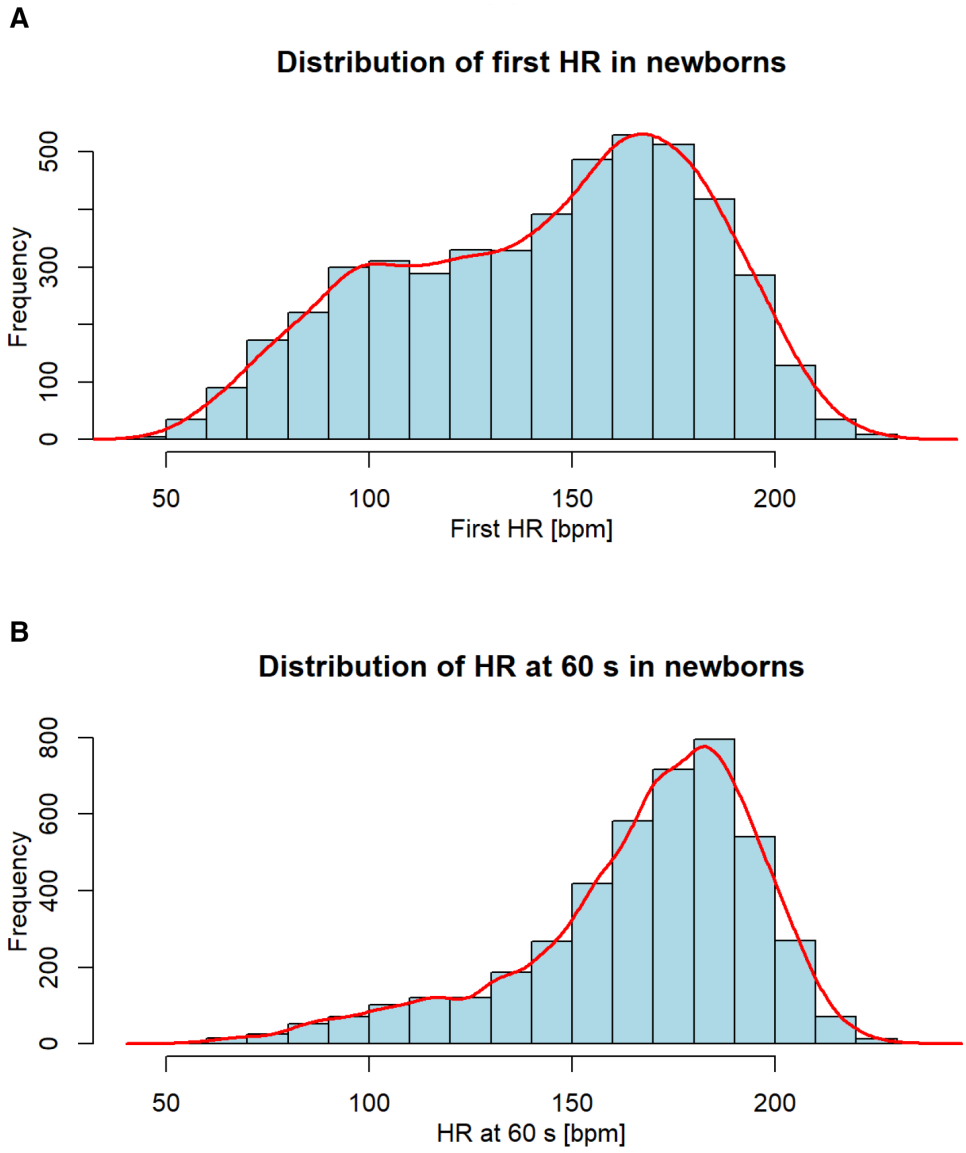

Figure 2 (A) Histogram showing first HR at median 16 (quartiles 11, 28) s after birth among 4876 newborns, and (B) HR 60 s after birth (data available from 4372 newborns). HR, heart rate.

valuable information and prediction on newborn status, guide management and provide feedback in response to PPV.

In the present study, PPV started median 72 s after birth. Several studies have shown a wide variation in compliance with guidelines with regard to time from birth to initiation of PPV.[20–22] This suggests that healthcare providers find it challenging to promptly identify newborns in need of PPV. In the present study, the proportion of newborns who required PPV increased when bradycardia persisted at 1 min after birth. However, 76% of newborns who received PPV had HR at 60 s ≥100 bpm. Assessment of HR should therefore not delay initiation of PPV in newborns not breathing effectively. A previous study described that among newborns not requiring ventilation, 93% will start spontaneous breathing within 30 s and 99% will be breathing within 60 s after birth. In that study, the risk for death or prolonged admission increased 16% for every 30 s delay in starting ventilation among apnoeic newborns.[22] These findings support guideline recommendations of starting PPV within 60 s if newborns are apnoeic.

To summarise, several recent studies from both low-resource and high-resource settings have demonstrated that HR in the first minute of life has a wide distribution from very low to very high, both among newborns in need of PPV and not. An increase in HR during the first minute of life can be expected, also in most newborns that require PPV.[11 12 18 23] Thus, immediate HR distribution and responses are quite similar among newborns in need of PPV and not.

Limitations and generalisability

A limitation to this study was loss of data, predominantly due to technical challenges storing HR recordings. This occurred at random and should not affect the overall results. Time from birth to the start of HR measurements varied between the newborns, and the observed proportion of newborns with some HR <100 bpm during the first minute is likely to represent a minimum. NeoBeat cannot be placed on the newborn in a sterile operation field, and newborns delivered by caesarean section may be under-represented. We did not have video cameras in the

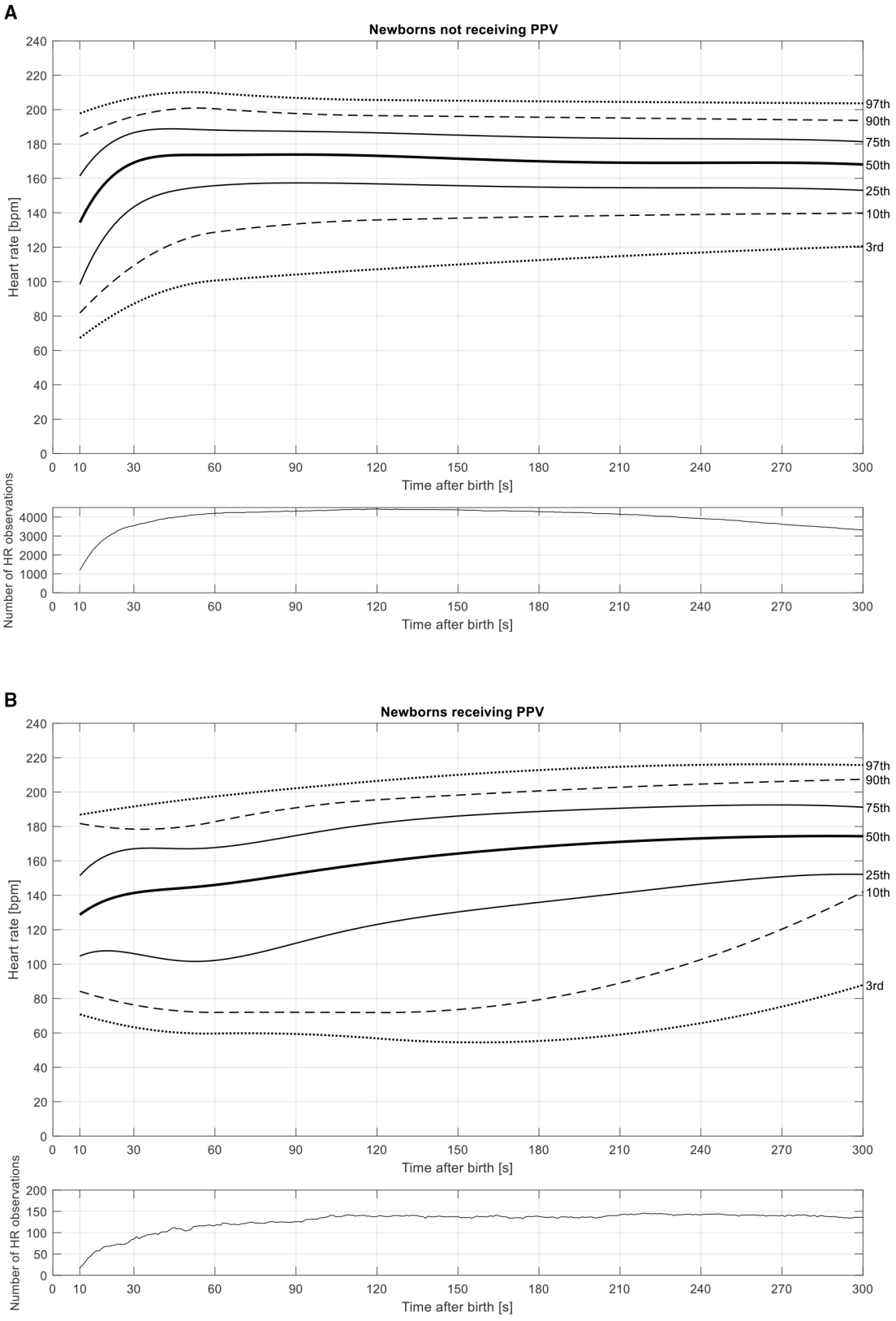

Figure 3 (A) HR nomograms the first 5 min after birth among newborns not receiving PPV (n=4712), and (B) newborns receiving PPV (n=164). HR, heart rate; PPV, positive pressure ventilation; bpm, beats per minute.

delivery rooms and were unable to study HR responses to interventions such as stimulation in the first minute of life. Strengths of the study are the population-based design and large sample size. The incidence of PPV was similar to that previously reports from high-resource settings. The number of severely asphyxiated newborns requiring advanced resuscitation was low. The results may be less generalisable to settings where birth asphyxia is more frequent, where higher prevalence of bradycardia may occur.

Table 2 Associations between HR <100 bpm at 60 s after birth, newborn characteristics, treatment and short-term outcomes

			Total (n=4372)
	HR <100 bpm at 60 s (n=162)	HR ≥100 bpm at 60 s (n=4210)	P value
First HR (bpm)	100 (80, 137)	149 (114, 173)	<0.001
Time to first HR (s)	18 (12, 33)	15 (10, 24)	<0.001
HR at 30 s (bpm)	120 (92, 156)	170 (146, 187)	<0.001
HR at 60 s (bpm)	88 (80, 94)	175 (157, 189)	<0.001
Gestational age (weeks)	40.1 (38.8, 40.9)	40.3 (39.3, 41.0)	0.080
Birth weight (kg)	3.59 (3.25, 3.90)	3.58 (3.24, 3.91)	0.740
Gender			0.998
Female, number (%)	80 (49)	2093 (50)	
Male, number (%)	82 (51)	2117 (50)	
Apgar 1 min	9 (9, 9)	9 (9, 9)	<0.001
Apgar 5 min	10 (9, 10)	10 (10, 10)	<0.001
Apgar 10 min	10 (10, 10)	10 (10, 10)	<0.001
Umbilical arterial pH	7.25 (7.19, 7.29)	7.24 (7.19, 7.29)	0.754
Time to cord clamping (s)	273 (189, 373)	307 (232, 400)	0.004
Mode of delivery			<0.001
Spontaneous vaginal	121 (75%)	3304 (78%)	
Vacuum	7 (4%)	543 (13%)	
Forceps	2 (1%)	17 (<1%)	
Elective caesarean	2 (1%)	42 (1%)	
Acute caesarean	25 (15%)	238 (6%)	
Vaginal breech	5 (3%)	66 (2%)	
Delivery room PPV	29 (18%)	93 (2%)	<0.001
Admission to the NICU	32 (20%)	367 (9%)	<0.001
Tracheal intubation	0 (0%)	2 (<1%)	
Chest compressions	1 (<1%)	0 (0%)	
Hypothermia treatment	0 (0%)	3 (<1%)	
HIE	2 (1%)	9 (<1%)	
Death before discharge	1 (<1%)	0 (0%)	

HR, gestational age, births weight, Apgar and umbilical arterial pH is given as median (quartiles). Delivery room PPV, tracheal intubation, chest compressions, admission to the NICU, hypothermia treatment and HIE as number (%).
HIE, hypoxic ischaemic encephalopathy; HR, heart rate; NICU, neonatal intensive care unit; PPV, positive pressure ventilation.

CONCLUSIONS

Bradycardia with HR <100 bpm in the first minute of life was frequent and observed in 25% of newborns, but was mostly self-resolved with 95% of these not requiring PPV. Among the 4% of newborns that remained bradycardic at 60 s, only 20% received PPV. Two-thirds of ventilated newborns had HR ≥100 bpm at start PPV. None of the resuscitated newborns were breathing adequately at start PPV.

This study provides novel population-based data on bradycardia in newborns in the first minute of life.

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Competing interests JE is a Laerdal Medical employee. SR had an unconditional research grant from Laerdal. The other authors have no conflicts of interest to disclose.

Patient consent for publication Consent obtained from parent(s)/guardian(s)

Ethics approval This study involves human participants and was approved by Norwegian regional ethical committee (ref. 2018/338). Participants gave informed consent to participate in the study before taking part.

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