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Heart rate ranges in premature neonates using high resolution physiologic data

Corrie J. Alonzo[1], **Vijay P. Nagraj**[2], **Jenna V. Zschaebitz**[1], **Douglas E. Lake**[3], **J. Randall Moorman**[3], and **Michael C. Spaeder**[1,3]

[1]Department of Pediatrics, University of Virginia, Charlottesville, VA, USA

[2]University of Virginia School of Medicine, Charlottesville, VA, USA

[3]Center for Advanced Medical Analytics, University of Virginia School of Medicine, Charlottesville, VA, USA

Abstract

Objective—There are limited evidence-based published heart rate ranges for premature neonates. We determined heart rate ranges in premature neonates based on gestational and post-menstrual age.

Study Design—Retrospective observational study of premature neonates admitted to the neonatal intensive care unit at the University of Virginia between January 2009 and October 2015. We included gestational ages between 23 0/7 weeks and 34 6/7 weeks. We stratified data by gestational and post-menstrual age groups.

Results—Over two billion heart rate values in 1703 neonates were included in our study. We established percentile-based reference ranges based on gestational and post-menstrual age. Our results demonstrate a slight increase in the initial weeks after birth, followed by a gradual decline with age. The baseline heart rate is lower with advancing gestational age.

Conclusions—Knowing heart rate reference ranges in the premature neonatal population can be helpful in the bedside assessment of the neonate.

Introduction

In 2015, 383,128 premature neonates (< 37 weeks gestation) were born in the United States [1]. Premature neonates often require care in a neonatal intensive care unit (NICU) where routine measurement of heart rate (HR) is performed. Published guidelines exist for normal reference ranges in healthy term neonates [2–4], but not in premature neonates.

Clinical decision-making is often influenced by the presence of abnormal vital signs, so knowing what is truly normal is paramount. Identifying and using accurate, evidenced-based ranges can appropriately guide clinical care decisions and perhaps improve management strategies and avoid unnecessary treatments. We sought to establish HR reference ranges in

Compliance with ethical standards

Conflict of interest Randall Moorman, MD, is the Chief Medical Officer of Advanced Medical Predictive Devices, Diagnostics, and Displays. All other authors declare that they have no conflict of interest.

premature neonates based on gestational age (GA) and post-menstrual age (PMA) in a large cohort of neonates.

Patients and methods

The Institutional Review Board at the University of Virginia School of Medicine approved this study. We performed a retrospective observational cohort study of all neonates admitted to the NICU at the University of Virginia Children's Hospital between January 2009 and October 2015. We included neonates with GAs between 23 0/7 weeks and 34 6/7 weeks. There were no exclusion criteria. We collected HR data on a dedicated computer cluster. HR values were captured every 2 seconds from the bedside monitor, and analyzed in all neonates until a PMA of 38 6/7 weeks.

Values of HR were stratified by both GA and PMA. Average values for each stratum were calculated and used to generate a heat map. We further sub-divided the data into four clinically relevant GA groups: 23 0/7–25 6/7 weeks (group 1), 26 0/7–28 6/7 weeks (group 2), 29 0/7–31 6/7 weeks (group 3), and 32–34 6/7 weeks (group 4). Percentile curves and tables were constructed for each group.

Results

A total of 2,002,756,757 data points from 1703 premature neonates were included in our study. The median GA was 31 weeks (interquartile range 28–33 weeks). Table 1 shows patient demographics including GA, sex, birth weight, size, race/ethnicity, and delivery type.

We plotted average HR values for each GA/PMA strata to create a heat map (Fig. 1). This demonstrates a slight increase in HR after birth followed by a small and gradual decline with PMA. It also demonstrates a lower baseline HR with advancing GA.

Figure 2 shows the HR percentiles for each GA group with the 5th–95th percentiles displayed as a function of PMA, demonstrating an overall HR increase during the initial weeks after birth followed by a gradual decline with age. Table 2 shows a HR reference table with 5th and 95th percentile data points listed.

Discussion

There are limited evidenced-based HR reference ranges available for the premature neonatal population. By providing a heat map, percentile curves, and a reference table for this patient population, clinicians will be more informed of appropriate HR ranges, which can potentially lead to improvement in management strategies and more prompt identification of patients in need of immediate medical attention.

Considerable attention has been placed in recent years on the issue of alarm fatigue. Although determining appropriate lower limits for alarm settings in the neonatal population was outside the scope of this project, our data provides some interesting insights that may inform future study. For example, among neonates with PMA of 38 weeks, irrespective of GA, we found the 1st percentile and 0.1st percentile of HRs to be 95 and 72, respectively.

Efforts to evaluate the impact of different lower limits on alarm fatigue and response to clinically significant events are needed.

This study has substantial strengths. We have included over two billion data points in our analysis and our patient population includes GAs typically seen in NICUs. There are some additional limitations as well. Our patient demographics, such as race, are not representative of all other institutions. It is possible some of these demographic factors unknowingly influence HR values. It is also possible that confounders other than vasoactive use and supplemental oxygen exist in this dataset.

Analysis of HR values from a large cohort of premature neonates has provided a useful heat map, percentile curves, and a reference tables in this vulnerable population. These results can be used at the bedside while assessing the critically ill neonate. Additional research efforts will focus on the development of an interactive website that will be easily accessible to all care providers.

Acknowledgements

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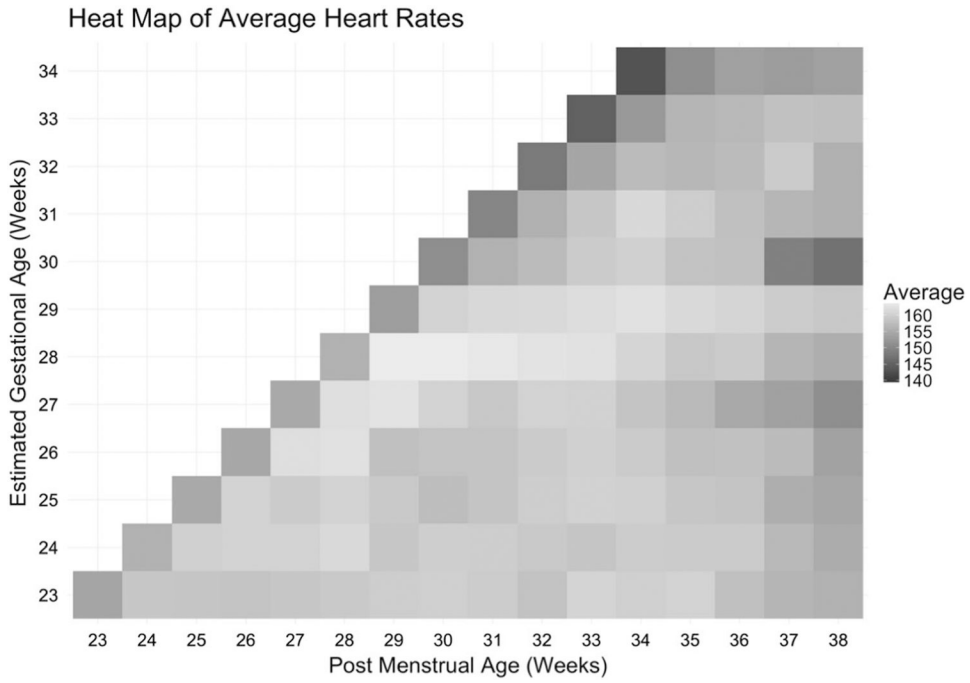

Fig. 1.

Heat map of average heart rates based on gestational age and post-menstrual age

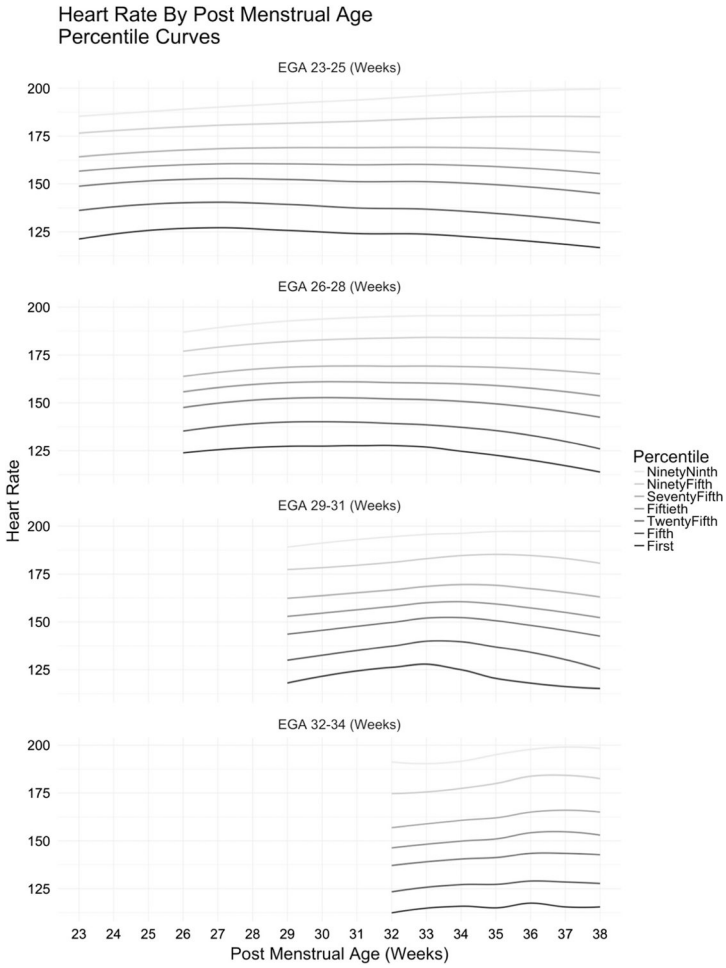

Fig. 2.

Heart rate percentiles for each gestational age group displayed as a function of post-menstrual age

Table 1

Patient demographics are shown

Characteristic	Number (%)
Gestational age	
23 0/7–25 6/7 weeks	212 (12%)
26 0/7–28 6/7 weeks	259 (15%)
29 0/7–31 6/7 weeks	392 (23%)
32–34 6/7 weeks	840 (49%)
Total	1703
Sex	
Male	927 (54%)
Female	776 (46%)
Birth weight	
ELBW (< 1000 g)	349 (20%)
VLBW (< 1500 g)	388 (23%)
LBW (< 2500 g)	849 (50%)
BW> = 2500 g	117 (7%)
Birth size	
AGA	957 (56%)
LGA	36 (2%)
SGA	161 (10%)
Unknown	549 (32%)
Race/ethnicity	
Caucasian	1145 (67%)
African American	348 (21%)
Hispanic	89 (5%)
Asian	18 (1%)
Other	53 (3%)
Unknown	50 (3%)
Delivery type	
Vaginal delivery	670 (39%)
Elective Cesarean Section	114 (7%)
Urgent Cesarean Section	630 (37%)
Emergent Cesarean Section	230 (14%)
Unknown	59 (3%)

SGA defined as birth weight < 10th percentile, AGA defined as birth weight between 10–90th percentile, and LGA defined as birth weight > 10th percentile

Table 2

Heart rate percentile reference table is shown

Post-menstrual age																	
Gestational age	**HR percentile**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**
23	**5th**	135	139	139	140	140	141	141	139	137	137	139	139	136	133	130	129
	95th	177	179	180	180	181	180	181	184	183	182	186	185	187	188	187	189
24	**5th**		139	140	141	141	141	138	138	138	137	135	135	132	133	131	130
	95th		175	181	181	181	183	182	182	184	185	184	184	185	186	184	185
25	**5th**			137	142	141	141	138	136	137	138	135	137	135	132	132	131
	95th			176	180	180	181	181	181	181	182	184	184	184	184	182	182
26	**5th**				134	143	143	137	140	137	137	139	139	135	135	134	127
	95th				176	182	183	181	181	183	184	184	183	182	182	184	182
27	**5th**					134	143	144	141	139	140	138	135	134	131	131	124
	95th					178	182	184	182	183	184	183	184	185	183	184	184
28	**5th**						131	140	141	142	140	140	138	136	133	128	125
	95th						176	184	184	184	185	185	185	186	185	184	183
29	**5th**							130	141	142	141	143	142	139	137	136	134
	95th							177	182	182	183	185	185	186	186	185	185
30	**5th**								126	135	137	139	140	135	134	132	128
	95th								176	179	180	182	184	184	183	176	172
31	**5th**									123	134	137	139	135	130	126	113
	95th									176	180	182	185	186	185	188	185
32	**5th**										123	133	136	135	133	130	127
	95th										175	178	182	183	185	184	178
33	**5th**											119	130	133	133	132	131
	95th											172	179	184	186	185	182
34	**5th**												117	127	128	128	129
	95th												172	179	183	184	185

Gestational age and post-menstrual age are shown in weeks.