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RESEARCH

A Prospective Evaluation of Arrhythmias in a Large Tertiary Neonatal Intensive Care Unit

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Abstract

Arrhythmias in the neonatal period are common and can be classified as bradyarhythmias and tachyarrhythmias and as benign or non-benign. Neonatal arrhythmias are further differentiated between those with abnormalities in generation (non-sinus) and those with abnormalities in propagation. Because the neonatal myocardium is immature and operates at the peak of the Starling curve, significant changes in heart rate can result in a decline in cardiac output and compromise end-organ perfusion. This is especially true for premature neonates, those critically ill, or those with concomitant congenital heart disease. While sustained arrhythmias are frequently witnessed and recorded in tertiary neonatal intensive care units (NICU) very little data exist on the observance of non-sustained brady- or tachyarrhythmias in this cohort. No prospective study has been performed on all neonates admitted to a large tertiary NICU throughout their entire stay. The purpose of this study was to prospectively evaluate the prevalence and type of arrhythmias in a large NICU population from admission to discharge. All neonates admitted to the NICU at Inova Children's Hospital at Inova Fairfax Medical Campus between January 1, 2021 and April 1, 2021 were prospectively evaluated from admission to hospital discharge via continuous bedside monitoring reviewed every 24 h. Concerning telemetry strips were reviewed by two team members as well as the senior electrophysiologist. Two-hundred and one neonates (mean gestational age = $34^{4/7}$ weeks) were enrolled in the study. Admission length ranged from 1 to 195 days (total of 5624 patient days, median 16 days). Overall, 68% ($N = 137$) of admissions had one or more arrhythmias, the most common of which was sinus tachycardia (65%, $N = 130$), followed by sinus bradycardia (30%, $N = 60$). Clinically relevant arrhythmias were diagnosed in 6.5% of neonates. During the study period there were four deaths, none of which were directly attributable to a primary arrhythmia. Approximately 68% of neonates exhibited at least one arrhythmia. Although the vast majority of these arrhythmias were benign, clinically relevant arrhythmias were observed in 6.5%. Patients admitted to the NICU appear to have a relatively high burden of benign arrhythmias, but a relatively low burden of pathologic arrhythmias.

Keywords Neonate · Neonatal intensive care unit · Arrhythmia · Telemetry

Introduction

Neonatal arrhythmias (NAs) may occur as a result of various cardiovascular, systemic, or metabolic problems [1, 2]. Arrhythmias are often classified as those causing tachycardia or bradycardia and may be automatic or re-entrant in nature. In addition, there may be supraventricular or ventricular ectopy, sinus or AV nodal conduction perturbations, and genetic arrhythmias such as long QT syndrome that require ongoing surveillance and possible pharmacologic or device interventions. While tachyarrhythmias in older children are often a result of an accessory pathway, arrhythmias in the neonatal population may be more related to electrolyte imbalances, disturbances in autonomic maturation, central line access, sepsis, pulmonary hypertension, and/or medications [3]. Clinical presentation of such arrhythmias is variable, depending on the type of arrhythmia, ventricular rate, presence and degree of AV dissociation, and the duration of the arrhythmia. If undiagnosed and untreated, such arrhythmias can contribute to infant morbidity and occasionally mortality. [1]

Although the exact prevalence and types of neonatal arrhythmias remain unknown, previous literature has

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estimated a prevalence of 1 to 5% [2, 4–6]. These arrhythmias are classified into two categories: benign and non-benign. Benign arrhythmias are those that are not clinically significant and do not require treatment. Nodal or junctional rhythms, premature atrial contractions (PACs), and premature ventricular contractions (PVCs) generally fall into this category, if the burden is insignificant. Non-benign arrhythmias may result in hemodynamic compromise and have the potential to cause clinical deterioration and thus require timely identification. Supraventricular tachycardia, disorders of AV conduction, ventricular tachycardia, ventricular fibrillation, and long QT syndrome fall into this category. [4, 7]

Multiple retrospective studies have analyzed the prevalence or incidence of both benign and non-benign neonatal arrhythmias in the neonatal intensive care unit (NICU) population. The majority of studies showed that male sex and term or near-term gestational age were associated with an increased risk of neonatal arrhythmia [2, 5, 6, 8–10]. However, other similarly designed studies actually reported opposite trends [1, 5]. All of these studies were limited by the fact that there were long and inconsistent gaps in when and how they collected and reviewed patient arrhythmia data. To date, no prospective study has evaluated a large cohort of neonates admitted to a tertiary NICU.

With advancements in technology, bedside cardiac monitoring now allows practitioners access to real-time data, including respiratory rate, heart rate, and rhythm interpretation. However, along with increased use of monitors comes alarm fatigue and the chance that some events, especially if non-sustained, may be missed. This project aimed to identify the overall prevalence and most common types of neonatal arrhythmias in a large NICU. This is the first large-scale prospective evaluation of all continuous rhythm monitoring on an event-by-event basis in a large-volume Level IV NICU. Historically, the NICU at Inova Children's Hospital admits 3 patients daily and has an average daily census of 83 neonates.

Methods

Patient Population

Approval from the Inova institutional review board (IRB) was obtained prior to patient enrollment or data collection. All patients admitted to the NICU at Inova L.J. Murphy Children's Hospital (ICH) from January 1, 2021 to April 1, 2021 were prospectively enrolled in the study. Inclusion criteria were admission or transfer to the NICU at ICH at less than 24 h of life. Exclusion criteria were neonates admitted or transferred to the NICU beyond 24 h of life or those who were already admitted to the NICU at the start of the study enrollment period. All enrolled patients were followed daily from NICU admission through discharge. If a patient was transferred to the pediatric cardiac ICU, they continued to be followed until the time of cardiovascular surgical repair or discharge without surgery. These patients were subdivided from the non-CHD NICU cohort and were discharged from the study on the day of cardiovascular surgical repair. However, if a patient was transferred to the general pediatric wards or regular nursery (off telemetry), that date was considered discharge (study-end-point).

Data Acquisition

All patients were monitored using full-disclosure bedside monitors (GE CareScape™ D19KT Chicago, Illinois) from the time of their admission until discharge. This system stores information for 72 h or longer depending on the event burden and allows for an event-by-event analysis of each patient. All alarms (sustained or non-sustained), events (sustained or non-sustained), as well as heart rate trends were examined with tracings carefully reviewed for 2 min prior to the alarm and 2-min post-alarm. The recordings were reviewed every 24 h by one of the investigators. All patient information and arrhythmia data were recorded and stored in a RedCap database designed specifically for the purpose of this study. Any unclear rhythm strips were reviewed by the lead resident investigator and all final coding was determined by the senior electrophysiologist. The arrhythmias reviewed included sinus tachycardia (200 bpm or greater for $>/=5$ beats), sinus bradycardia (70 bpm or less for ≥ 5 beats or pauses > 3 s), premature atrial contractions (conducted or non-conducted), premature ventricular contractions, supraventricular tachycardia (narrow complex $>$ 240-bpm lasting ≥ 3 beats), first degree, second -degree atrioventricular block, complete heart block (AV dissociation, atrial rate greater than ventricular rate), ventricular tachycardia (wide complex ≥ 3 beats at a rate $> 20\%$ above the preceding sinus cycle length), ventricular fibrillation, QT prolongation (QTc interval ≥ 440 ms), and other. In addition, all electrocardiograms were reviewed by the senior investigator for any abnormalities. (Table 1).

Patient Characteristics and Medical History

For each patient, a record review was conducted at the time of enrollment and once during each subsequent 24 h period. Demographic and medical history data collected at the time of enrollment included date of birth, gestational age, sex, birth weight, method of delivery, Apgar scores at 1 and 5 min, complications at the time of delivery, significant maternal history, maternal pregnancy and delivery history, presence or absence of congenital heart disease, and maternal COVID testing results. Medical information collected every 24 h included level of respiratory support,

Table 1 Arrhythmia definitions

Arrhythmia type	Definition
Sinus tachycardia	< 70 beats per minute for > / = 5 beats
Sinus bradycardia	> 200 beats per minute for > / = 5 beats
Premature atrial contraction	Any atrial ectopy
Premature ventricular contraction	Any ventricular ectopy
Supraventricular tachycardia	> 240 beats per minute for > 3 beats; sustained if > 30 s
Heart block	AV dissociation; atrial rate > ventricular rate
Ventricular tachycardia	Wide ventricular complex lasting > / = 3 beats
Ventricular fibrillation	Chaotic and irregular ventricular beats
Prolonged QT	QTC interval > / = 440 ms

medications, presence of a central line, and if present, the location of the central line. If a non-benign arrhythmia was recorded, laboratory values and 12-lead EKGs, if obtained, were also reviewed. Laboratory values were reviewed specifically for abnormalities in potassium, calcium, magnesium, glucose, and acidosis. For any patient with a non-benign arrhythmia, the clinical scenario at the time of such event was reviewed by chart review of physician and nursing comments or discussion with either nursing staff caring for the neonate or the rounding attending.

Results

Patient Population

During the study period, 201 babies were enrolled with gestational ages ranging between $22^{5/7}$ weeks and $41^{3/7}$ weeks (median $34^{6/7}$ weeks). The study population consisted of 7.5% ($N = 15$) extremely preterm (< 28-week gestation), 12% ($N = 25$) very pre-erm (28–31 weeks plus 6-day gestation), 49% (N = 99) moderate-to-late preterm (32–36 weeks + 6-day gestation), and 31% ($N = 62$) term (ε 37-week gestation or greater). The total length of stay ranged from 1 to 195 stays, for a total of 5624 patient days reviewed (median: 16 days). During the three-month enrollment period, there were no neonates with pre-natal diagnoses of arrhythmia. Neonates with a pre- or postnatal diagnosis of congenital heart disease were generally brought to the pediatric cardiac intensive care unit within 24 h of birth ($N = 4$). These patients were kept on telemetry and followed until the time of heart surgery.

Prevalence of Arrhythmias

The overall prevalence of arrhythmia in the study population was 68% ($N = 137$). Of the 201 neonates enrolled in the study, 137 had some form of an arrhythmia.

Frequency of Arrhythmias

The most frequently reported arrhythmia was sinus tachycardia. Of the 201 neonates studied, 65% ($N = 130$) experienced sinus tachycardia at some time during the study. The second most common arrhythmia was sinus bradycardia. Of the 201 neonates studied, 30% ($N = 60$) experienced sinus bradycardia. Junctional rhythm was observed in 24 neonates (12%) with junctional rates between 28 and 91 bpm (mean = 67 bpm). One baby had a documented brief, < 20 s and junctional bradycardic rate of 28 bpm. The next lowest documented junctional bradycardic rates were 48 and 51 bpm. The remaining arrhythmia types, including premature atrial contractions, premature ventricular contractions, supraventricular tachycardia, heart block, ventricular tachycardia, and prolonged QT, occurred in less than 5% of the cohort (Table 2). The prevalence of arrhythmia per event is demonstrated in Table 3.

Looking at the arrhythmia burden by linear gestational age, bradycardia was the highest arrhythmia burden at younger gestational ages. At 29–30 weeks' gestation, tachycardia increased in prevalence and had a much higher proclivity than bradycardia as the gestational age increased. (Fig. 1).

Table 2 Prevalence of arrhythmia per study subject

Arrhythmia	Number of neonates	Prevalence (%)
Sinus tachycardia	130	65
Sinus bradycardia	60	30
Premature atrial contraction	5	2
Premature ventricular contraction	7	3
Supraventricular tachycardia	5	2
Heart block	1	0.5
Ventricular tachycardia	7	3
Ventricular fibrillation	0	0
Prolonged QT	2	1
Other (Junctional)	24	12

Table 3 Prevalence of arrhythmia per event

Arrhythmia	Number of events	Prevalence (%)
Sinus tachycardia	767	63
Sinus bradycardia	369	30
Premature atrial contraction	5	0.4
Premature ventricular contraction	7	0.6
Supraventricular tachycardia	5	0.4
Heart block	1	0.08
Ventricular tachycardia	9	0.7
Ventricular fibrillation	0	0
Prolonged QT	3	0.25
Other (Junctional)	45	4

Both male sex and delivery via C-section had a higher prevalence of both benign and non-benign arrhythmias. Moderate-to-late preterm neonates had the highest prevalence of benign arrhythmias, while extremely preterm and moderate-to-late preterm neonates had a similar prevalence of non-benign arrhythmias. Overall, all preterm sub-groups had a higher prevalence of non-benign arrhythmias than term infants. Neonates in the low birth weight category had the highest prevalence of benign arrhythmias and those in the extremely low birth weight category had the highest prevalence of non-benign arrhythmias. (Table 4).

Non-Benign Arrhythmias

A total of five neonates experienced non-sustained supraventricular tachycardia (longest episode 20 beats). One neonate had an ECG that demonstrated extreme right axis deviation but no obvious evidence of pre-excitation. This neonate had a structurally normal heart. Only one of these five neonates had a central line in place at the time of the recorded event. No neonate had an episode of sustained SVT during this time period.

There was one patient who had two recorded episodes of transient heart block, both on the same day, each lasting less than 120 s. This arrhythmia went unrecognized by nursing or physician staff in real time. Based on retrospective chart review, the patient's electrolytes and hemoglobin were within normal limits at the time of the event. A few weeks later, the patient was noted to have an irregular heart rate, and an EKG performed at that time showed only slowed sinus rhythm with conducted and blocked premature atrial contractions. (Fig. 2).

There were five patients who had recorded episodes of non-sustained ventricular tachycardia ranging from 205 to

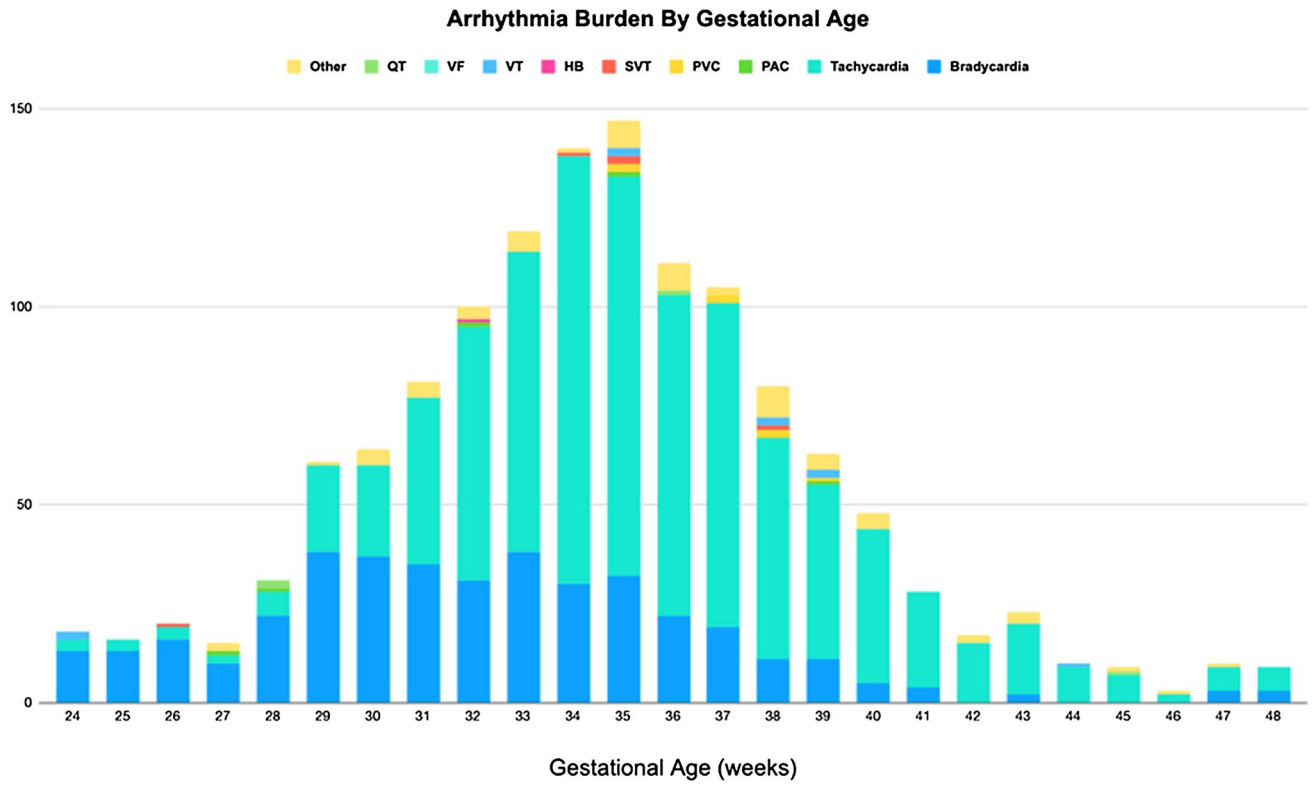

Fig. 1 Arrhythmia Burden by Gestational Age. This graph shows the arrhythmia burden by gestational age. The x-axis indicates the gestational age of the study subjects and the bars represent the frequency of different arrhythmias

Table 4 Demographic risk for benign and non-benign Arrhythmias

	Benign arrhythmias	Non-benign arrhythmias
Total N = 201		
Sex		
Male (*N* = 103)	61.2%	4.5%
Female (*N* = 98)	52.7%	3.0%
Delivery method		
Vaginal (*N* = 61)	26.9%	1.0%
C-Section (*N* = 140)	86.1%	6.5%
Gestational age at birth		
Extreme prematurity (< 28 wks) (*N* = 15)	18.9%	3.0%
Very premature (28 to < 32 wks) (*N* = 25)	28.9%	1.0%
Moderate-to-late preterm (32–< 37 wks) (*N* = 99)	48.8%	3.0%
Term (> / = 37 wks) (N = 62)	16.9%	0.5%
Birth weight		
Extremely low birth weight (< 1000 g) (*N* = 17)	20.9%	3.0%
Very low birth weight (< 1500 g) (*N* = 22)	26.4%	2.0%
Low birth weight (< 2500 g) (*N* = 84)	45.3%	2.0%
Normal birth weight (< 4000 g) (*N* = 70)	19.9%	0.5%
High birth weight (> 4000 g) (*N* = 7)	1.0%	0.0%

288 bpm (average number of beats = 5). One neonate with non-sustained polymoprhic VT at a rate of 206 bpm, who had a structurally normal heart, had significant leukocytosis and bandemia at the time of the recorded event. The other four patients with non-sustained ventricular tachycardia events had no laboratory abnormalities. The clinical team did not appreciate these events, so no 12-lead EKGs were performed. Two of the five neonates had a central line in place at the time of the recorded event.

There were three neonates who had QT prolongation events noted on rhythm strips. Only two of these patients had a 12-lead EKG performed. One patient had a 12-lead ECG which revealed right axis deviation with possible right ventricular hypertrophy, but no prolongation of the QT interval. The other patient did have a 12-lead ECG which demonstrated a borderline prolonged QT interval (451 ms) (Fig. 3). Upon further investigation it was found that this neonate's father had LQT syndrome with a known KCNQ1 mutation. This neonate was started on beta-blockers and genetic testing confirmed a similar pathogenic KCNQ1 mutation. During his stay in the NICU he had no ventricular arrhythmias.

Structural Abnormalities

Echocardiograms were not routinely performed as part of our study design. However, upon chart review, 28% (*N* = 57) of the cohort had at least one echocardiogram performed during their enrollment period. Of those neonates who had an echocardiogram performed, structural abnormalities were identified in 15% (*N* = 9). Five neonates had minor defects, including patent ductus arteriosus or small atrial or ventricular septal defects. The other four had complex congenital heart disease, with more than one defect contributing to the abnormal structure. No association between arrhythmia burden or type and structural abnormalities was identified. (Table 5).

Mortality

During the study period, there were four deaths, none of which were attributable to a primary arrhythmia. One death occurred at 6 days of life due to hypoxic ischemic encephalopathy. One death occurred at 35 days of life secondary to respiratory failure in the setting of restrictive dermopathy, a rare recessive disorder that affects the lungs, vessels, and skin. One death occurred at 50 days of life secondary to compassionate withdrawal of care in the setting of late onset group B Strep sepsis and meningitis with subsequent cystic encephalomalacia. The last death occurred in a 4-month-old male secondary to complications following surgical correction of a bowel obstruction in the setting of a large omphalocele.

Discussion

The NICU population is prone to arrhythmias, which may occur as a result of various cardiovascular, systemic, and/or metabolic problems. Arrhythmias in this population are often related to electrolyte imbalances, disturbances in autonomic maturation, central line access, sepsis, pulmonary hypertension, and/or medications. Clinical

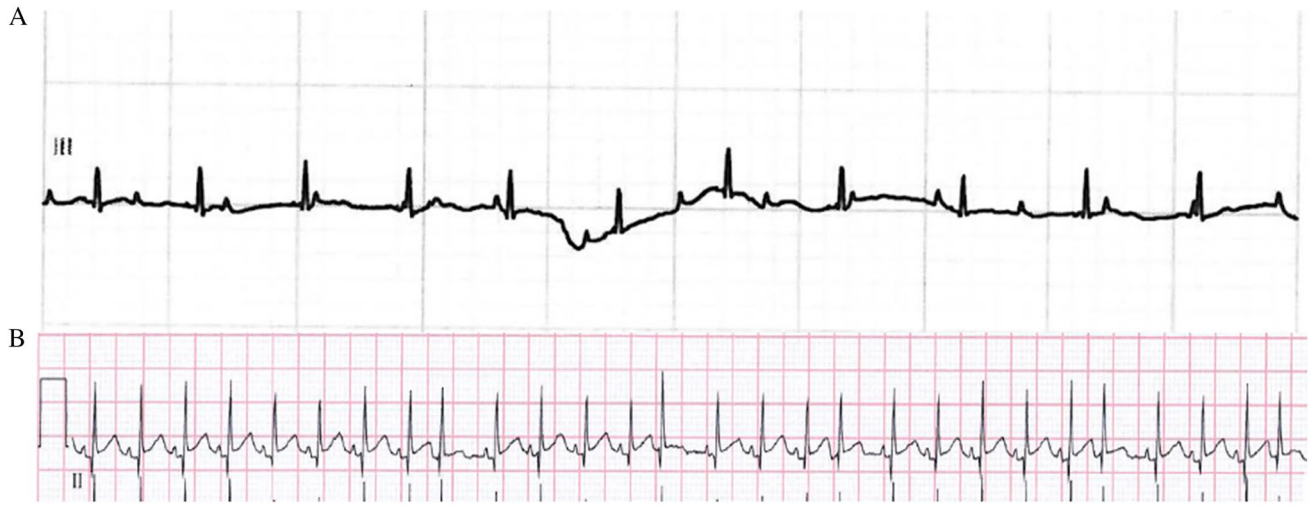

Fig. 2 **A** Transient heart block was noted in one neonate enrolled in the study. There were two recorded episodes, both on the same day, each lasting less than 120 s. The figure shows one such episode displaying clear AV dissociation with an atrial rate of 100 bmp and a ventricular rate of 80 bpm. **B** The same neonate was noted to have an irregular rhythm a few weeks later. A 12-lead EKG performed at that time showed slowed sinus rhythm with conducted and blocked premature atrial contractions but no heart block

Fig. 3 Lead II of the 12-lead electrocardiogram performed on the neonate whose father had a known KCNQ1 mutation showed a borderline prolonged QT interval (451 ms) at one week of life. The neonate was started on beta-blockers and genetic testing confirmed a similar pathogenic LQT1 mutation. During his tenure in the NICU he had no ventricular arrhythmias

presentation of these arrhythmias is variable and depends on the quality, rate, and duration of the arrhythmia. Recognition of these arrhythmic events is often missed due to alarm frequency and fatigue—even when bedside monitors signal, the alarm is often silenced and the neonate presumed to be clinically well unless other metrics support the neonate being unstable or the bedside nurse is concerned about the appearance of the child. Although this study was performed at a 108-bed level IV neonatal ICU, we believe that the breadth and size of our study population makes this data pertinent to all NICUs, regardless of size, acuity, and gestational age dispersion.

Although this is the first prospective study performed in such a detailed, event-by-event manner, previous studies have attempted to retrospectively analyze the prevalence or incidence of neonatal arrhythmias. In a study performed by Bedrawi et al., 12-lead electrocardiograms were performed on 457 neonates admitted to the NICU and Holter studies were performed on every fourth neonate with a normal electrocardiogram and every neonate with an abnormal electrocardiogram. Their analysis of 457 electrocardiograms and 139 Holter recordings estimated an incidence of 8.5% for benign arrhythmias and 1.5% for non-benign arrhythmias in the NICU population. They also demonstrated a significant association between neonatal arrhythmias and male sex, older gestational age, lower glucose levels, maternal smoking, high umbilical artery lines, and use of nebulized beta-2 agonists. They noted that of the 100 infants thought to be arrhythmia free on electrocardiogram, nine demonstrated abnormalities on Holter monitoring, thus demonstrating that the sensitivity of electrocardiogram to Holter monitoring was only 89%. This study was also limited by the fact that they did not include neonates less than or equal to three days of life, premature neonates less than or equal to 28-week gestation, or neonates with multisystem complex congenital anomalies.[6]

Sex Predisposition

Previous retrospective studies performed to analyze the prevalence or incidence of arrhythmias in the NICU population have found varying results regarding sex predisposition.

Table 5 Arrhythmia and structural abnormalities

Arrhythmia	Echocardiograms completed	Structural abnormalities		
		None	Minor	Major
Sinus tachycardia	36% (*N*=47)	85% (*N*=40)	9% (*N*=4)	6% (*N*=3)
Sinus bradycardia	47% (*N*=28)	86% (*N*=24)	14% (*N*=4)	0% (*N*=0)
Premature atrial contraction	80% (*N*=4)	75% (*N*=3)	25% (*N*=1)	0% (*N*=0)
Premature ventricular contraction	29% (*N*=2)	50% (*N*=1)	0% (*N*=0)	50% (*N*=1)
Supraventricular tachycardia	40% (*N*=2)	100% (*N*=2)	0% (*N*=0)	0% (*N*=0)
Heart block	0% (*N*=0)	0% (*N*=0)	0% (*N*=0)	0% (*N*=0)
Ventricular tachycardia	29% (*N*=2)	100% (*N*=2)	0% (*N*=0)	0% (*N*=0)
Ventricular fibrillation	0% (*N*=0)	0% (*N*=0)	0% (*N*=0	0% (*N*=0)
Prolonged QT	100% (*N*=2)	50% (*N*=1)	50% (*N*=1)	0% (*N*=0)
Other (Junctional)	75% (N=18)	72% (*N*=13)	17% (*N*=3)	11% (*N*=2)

The majority of studies have shown that male sex is associated with an increased risk of neonatal arrhythmias [2, 5, 6, 8–10]. However, other studies, similar in design, have shown opposite trends. Our results showed that males had a higher prevalence of both benign and non-benign arrhythmias. (Table 4).

Gestational Age Predisposition

Previous retrospective studies performed to analyze the prevalence or incidence of arrhythmias in the NICU population have found varying results regarding age predilection. The majority of studies have shown that being term or near-term is associated with an increased risk of neonatal arrhythmia [2, 5, 6, 8–10], but other studies have demonstrated disparate trends [1, 5]. Our results showed that of the 137 neonates who experienced any arrhythmia, 70% (*N*=97) were moderate-to-late preterm and 18% were term, supporting the conclusion that the older gestational age is associated with an increased risk of neonatal arrhythmias. Moderate-to-late preterm neonates demonstrated the highest prevalence of benign arrhythmias, predominantly sinus tachycardia. Extremely preterm and moderate-to-late preterm neonates both had a 3% prevalence of non-benign arrhythmias (Table 4). The association between gestational age and arrhythmia burden, especially benign arrhythmia burden, may be due to the effect of having a more developed autonomic nervous systems in infants of older gestational ages. Those infants with less developed sympathetic nervous systems may be more prone to bradycardic episodes, whereas those who are older have a more appropriate sympathetic response to pain at stimuli and other disturbances.

Limitations

This was a prospective descriptive study and was not powered to address arrhythmia burden within specific gestational cohorts. Additionally, while daily respiratory support and medication administration was tracked, pertinent laboratory values, such as electrolyte levels and/or hemoglobin levels, which may have an impact on the frequency of both benign and non-benign arrhythmias in the neonatal population, were not obtained at that moment as the arrhythmia may have not been appreciated or not perceived as being clinically relevant. However, through a retrospective chart review, it was noted that none of the neonates with non-benign arrhythmias had abnormal electrolytes on the day of their recorded arrhythmia and only one had a leukocytosis and bandemia, indicating possible infection.

Not all neonates had 12-lead EKGs performed during their study enrollment. This additional data may have helped identify and further specify some of the arrhythmia events, including subtle pre-excitation or QT prolongation. Future prospective studies should have routine ECGs performed as part of admission criteria. Furthermore, the bedside nurse was not queried daily to comment whether a non-sustained arrhythmia occurred and if so what type was observed on telemetry. The nursing staff may have seen an arrhythmia, but if they did not document it, it would have been missed.

However, despite these limitations, this study highlights the frequency of arrhythmia in a large neonatal ICU population. To date, no similar prospective study has been performed in this detailed, event-by-event manner.

Conclusion

Of the 201 patients admitted to a level IV NICU over 3 months, approximately 68% of neonates exhibited at least one arrhythmia. Although the majority of these arrhythmias proved benign, clinically relevant arrhythmias were observed in 6.5%. Patients admitted to the NICU appear to have a relatively high burden of benign arrhythmias, and a low, but concerning, burden of non-benign arrhythmias. According to our data the subpopulations demonstrating the highest rate of benign arrhythmias include male sex, cesarean-section delivery, being born moderate-to-late preterm, and being low birth weight. Male sex and cesarean-section delivery also demonstrate the highest rates of non-benign arrhythmias. However, extreme prematurity, mid-to-late preterm, and extremely low birth weight show the highest rate of non-benign arrhythmias, not moderate-to-late preterm and low birth weight. This data reiterates the importance of keeping neonates on continuous cardiac monitors and being attentive to alarms that may indicate a clinically significant arrhythmia. Future research is merited regarding the identification of high-risk infants and optimal monitoring for non-benign arrhythmias before hemodynamic effects occur.

Author contributions Nadia Chaudhry-Waterman, Mitchell Cohen, and Robin Baker designed the project and performed the preliminary literature review. Nadia Chaudhry-Waterman, Lydia Nashed, and Mitchell Cohen wrote and submitted the IRB proposal. Nadia Chaudhry-Waterman, Lydia Nashed, Rachel Chidester, Alexandra Nalewanski, David Bastawrous, Hayley Busch, and Hyungjoo Jeong all helped to collected data on a daily basis. Nadia Chaudhry-Waterman wrote the manuscript text with significant editing and guidance from Mitchell Cohen and Kathleen Donnelly. All authors reviewed the manuscript prior to submission.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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