Smart Newborn: A Tool for Early Prediction of a Severe Preterm Newborn Illness

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Abstract

Sepsis is a major cause of morbidity, mortality and increased healthcare costs among preterm babies. Infants are often diagnosed when seriously ill, which decreases the probability for prompt and complete recovery. To study on sepsis prediction, we developed a medical informatics system prototype, "Smart Newborn" that retains and analyses patient based data. As initial study, we illustrate the evolution of 30 minutes pulse rate (PR) histogram samples of a representative patient within 48 hours before sepsis suspicion, which point out that PR based analysis outcomes are in parallel with previous studies based on heart rate (HR) data obtained from ECG leads. Monitoring based on ECG leads for long time is not the preferred method in many Neonatal Intensive Care Units (NICUs) due to probable skin sensitivity reactions at contact points. Therefore, capturing and visualizing the same disease signs using PR data makes our process more practical and accessible.

Keywords: Medical decision support system, Big data processing, Data visualisation.

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1. Introduction

Earlier prediction of severe preterm newborn illnesses are good examples of many multidisciplinary researches carried out in collaboration of engineering and medicine professionals (Clifton, Niehaus, Charlton, & Colopy, 2015).

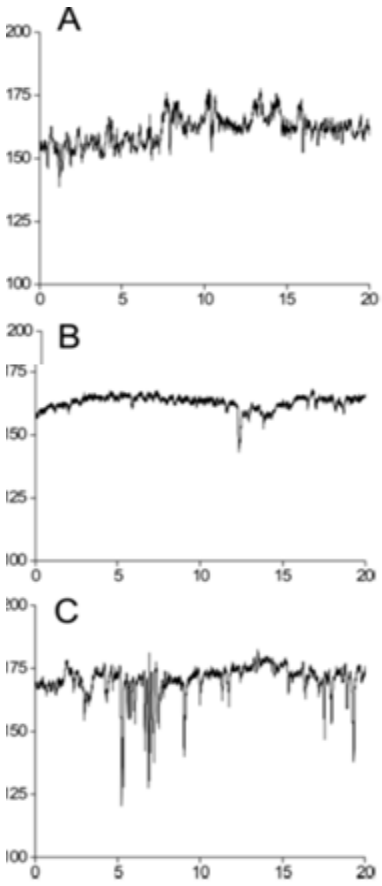
Due to their uncompleted physiological development, preterm newborns have low defence against infectional risks. Late onset neonatal sepsis (LOS) is a bloodstream infection, occurring after the third day of life. Although vital signs are continuously monitored in a NICU, spontaneous values of these parameters are not specific for its diagnosis. Once the baby's condition deteriorates, blood sample for laboratory analysis is taken and treatment is started. Laboratory results can take up to a day before becoming available and are associated with false positive and negative results. Therefore early diagnosis is very valuable, in order to start appropriate and timely treatment to prevent risk of mortality or lifelong neurodisability (Fairchild & O'Shea, 2010).

To study on open research topics, we, Trakya University Computer Engineering and Medical Faculty Pediatrics departments, collected information of babies hospitalised in the NICU of our University Hospital from Feb 2017 to Oct 2017 with the approval of Edirne Clinical Research Ethical Board.

2. Literature Review

Considering the abnormal heart rate characteristics (HRC) during fetal distress and neonatal illness, Griffin and Moorman (2001) hypothesized that abnormal HRC might precede the clinical diagnosis of neonatal sepsis. Using 4096 beats epoch of electrocardiogram voltage signal RR intervals

histogram symmetry, characteristics of normalized heart rate (HR) time series before and after sepsis, sepsis-like illness, or a random time in controls were measured. Sepsis and sepsis-like illness groups had abnormal HRC before clinical deterioration, as reduced baseline variability and short-lived decelerations, represented mainly by positive skewness of their histograms. Studies of Fairchild and O'Shea (2010) were also in parallel. Abnormal patterns were leading to asymmetry, due to the inverse relationship between intervals and frequencies, this time as negative skew of heart rate tracing histograms just before sepsis as depicted at Figures 1 and 2.



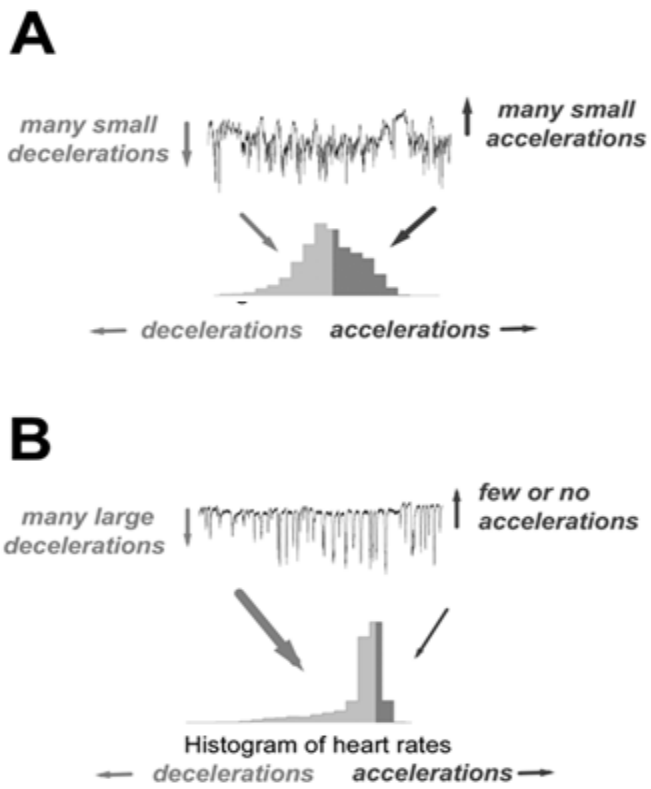


Figure 1: Heart Rate Tracing from a neonate Griffin and Moorman (2001)

A: Normal HRV
B: Decreased HRV with one deceleration
C: Decreased HRV with multiple superimposed trasient decelerations.

Figure 2: Normal and abnormal heart rate histograms Fairchild and O'Shea (2010)

Heart Rate tracing (bpm)
A: From a healthy neonate showing many small HR accelerations and decelerations - symmetric histogram
B: From a septic neonate showing few accelerations and many decelerations - asymmetric histogram

There were several other measures used in these and similar studies (Beuchée, et al., 2009; Bohanon, et al., 2015; Lucchini, Fifer, Sahni, &Signorini, 2016) such as Entropy and Fractal Exponents of RR intervals, which were used as inputs of predictive algorithms to calculate risk scores of an acute clinical deterioration.

3. Smart Newborn

We acquired seconds and minutes based times series vital sign data of infants collected by Mindray iMec Patient Monitors from database of NICU Central Monitoring System and transferred them to Mysql 5.7 Database on Intel Core i5-6200U CPU @ 2.3 GHz PC. Collected data intervals were 2 one hour periods daily (11:00-12:00 and 16:00-17:00), when no care was given to babies. Due to mainly pulse oximeter base monitoring practice of the unit, HR data with 500Hz sampling rate obtained from ECG leads were missing most of the time. Therefore, PR data taken from pulse oximeter with 125Hz sampling rate were taken as surrogate of HR as some of previous researches (Stanculescu, Williams, &Freer, 2014). Collected data were labeled with physicians' patient status comments and diagnosis information over the user interface of Smart Newborn.

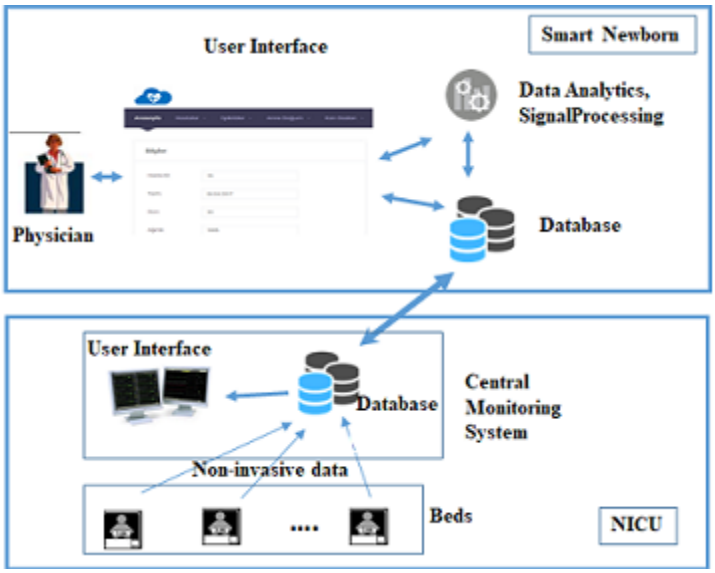


Figure 3: Smart Newborn Infrastructure and its interaction with NICU modules

To be sure of the agreement of PR and HR data, we evaluated the measure of linear dependence by analysing their correlation coefficients with MATLAB *corrcoef* function, where coefficients can range from -1 to 1, with -1 representing a direct negative correlation, 0 representing no correlation, and 1 representing a direct, positive correlation. Mean of the correlation coefficients, for each 154 available 30 minute HR and PR time series pairs were 0,9410; correlation coefficients of their skewness were 0,9651. Due to high correlation values, we started with PR based analysis on our dataset. A few visualisations we obtained with Matlab R2013a are depicted in (Figure 4).

4. Results

Compared to symmetric 30 minutes pulse rate (PR) histogram of the representative patient at Figure 4-A, observed during healthy state, the negative skew of -1.8973 observed after 24 hours in Figure 4-B and absolute value increase of negative skew (to 3.7592) 24 hours later when clinical signs are obvious in Figure 4-C, are clear interpretation of HRV decrease in the course of sepsis. Additionally, presence of spread out and rare lower values in Figure 4-B represents the short-lived decelerations.

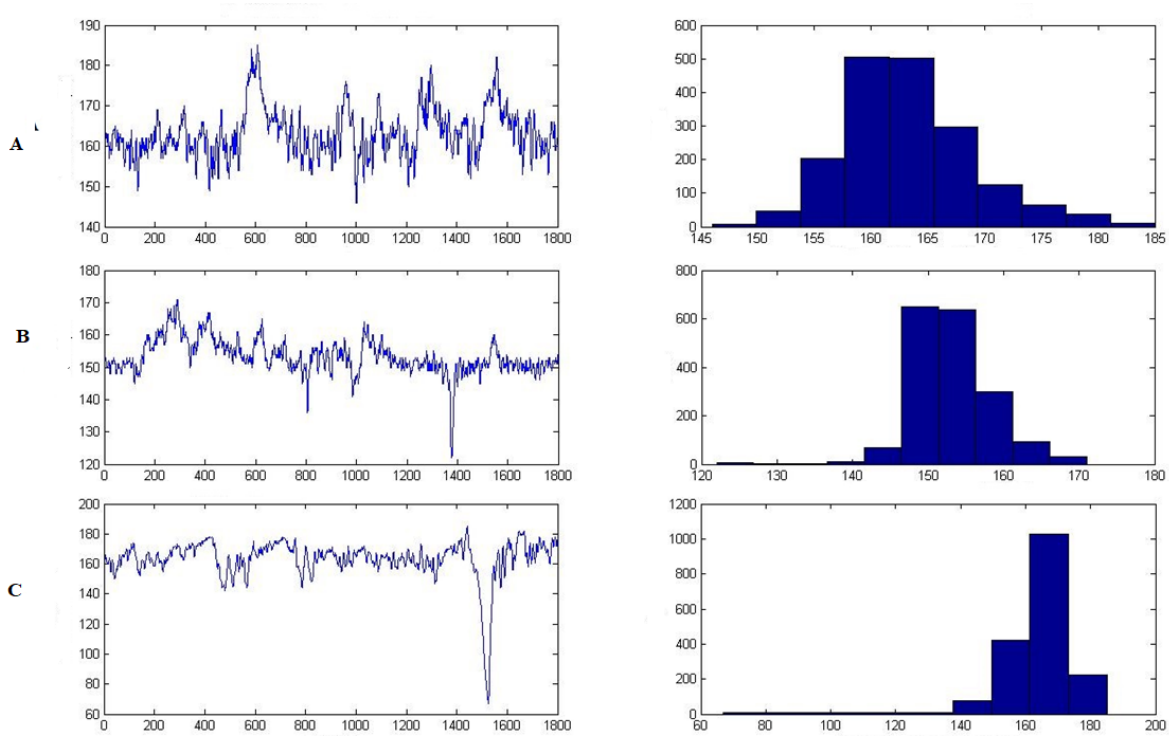


Figure 4: 30 minute Pulse Rate time series of **A-** Healthy; 48 hours before sepsis suspicion. Skewness: 0.70342. **B-**24 hours before sepsis suspicion. Skewness:-1.8973. **C-**Time of sepsis suspicion and blood withdrawal for culture test. Skewness:-3.7592.

Variability decrease and decelerations of HR before clinical deterioration are accepted as evidence based facts and two of the main pillars of many preterm newborn LOS prediction algorithms(Griffin and Moorman 2001; Beuchée, et al., 2009; Fairchild and O'Shea 2010; Stanculescu, et al., 2014 and Bohanon, et al. 2015). Although obtained with lower sampling frequency than HR data, due to its higher availability in NICUs, PR variability evolution analysis is a candidate to be considered as practical tool for pediatricians to evaluate infants' risk of sepsis.

4. Conclusion and Future Studies

Annual newborn infant death ratios have been monitored and considered as an important indicator of national health system quality (Daştan & Çetinkaya, 2015). Estimates show that 10% of all neonates and 25% of very low birth weight babies (VLBW, < 1500 grams birth weight) are affected by sepsis (Stoll et al., 2002; Beck-Sague et al., 1994). This number rises to 50% for extremely preterm infants (Modi, et al., 2009). Practical solutions like ours, which may give warning even before clinical signs of illness, have an important potential to decrease this rate. In order to develop high performing predictive algorithms, our studies on derivatives of alternative non-invasive vital signs and advanced machine learning algorithms are ongoing.

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