

Bayesian analysis for heart rate variability in Hypoplastic Left Heart Syndrome infants

22S:138 Project Report

Divya Kudva

Introduction

Hypoplastic Left Heart Syndrome (HLHS)

Hypoplastic left heart syndrome is a congenital heart disorder that refers to the underdevelopment of cardiac structures on the left side of the heart. HLHS accounts for 7- 9% of all the congenital heart defects occurring in children (1). It occurs in every 1-4 per 10000 live births (2) and in United States alone there are over 1000 cases of HLHS each year (3). One of the treatment options for HLHS is staged cardiac palliation which consists of three surgeries that are performed at different times during the infant's life. Norwood's surgery is the first operation which is typically performed within the first 2 weeks of life. Norwood's is a high risk procedure with a mortality rate of up to 30 %. Causes of mortality following Norwood are largely unknown as most of the infants die suddenly from cardiac failure.

We (the research group I work with) are interested in determining the cause of sudden death in HLHS infants. We believe that an imbalance in the cardiac autonomic tone is responsible for the sudden death of these infants. Our aim is to determine whether the imbalance in autonomic tone is persistent at birth or whether Norwood's surgery is responsible for the disruption of tone. Heart Rate Variability analysis is used in order to assess the cardiac autonomic function.

Heart Rate Variability (HRV)

The heart does not beat at a constant rate but displays periodic variations over time. This beat-to-beat alteration in heart rate or the difference between the R-R peaks in the QRS complex of the ECG signal is known as heart rate variability (Figure 1). The normal variability in heart rate is due to the synergistic action of the two branches of the

autonomic nervous system i.e. the sympathetic and parasympathetic nervous system. Reduced HRV indicates reduction in the variations in the heart rate which may indicate failure of certain regulatory mechanisms in the body.

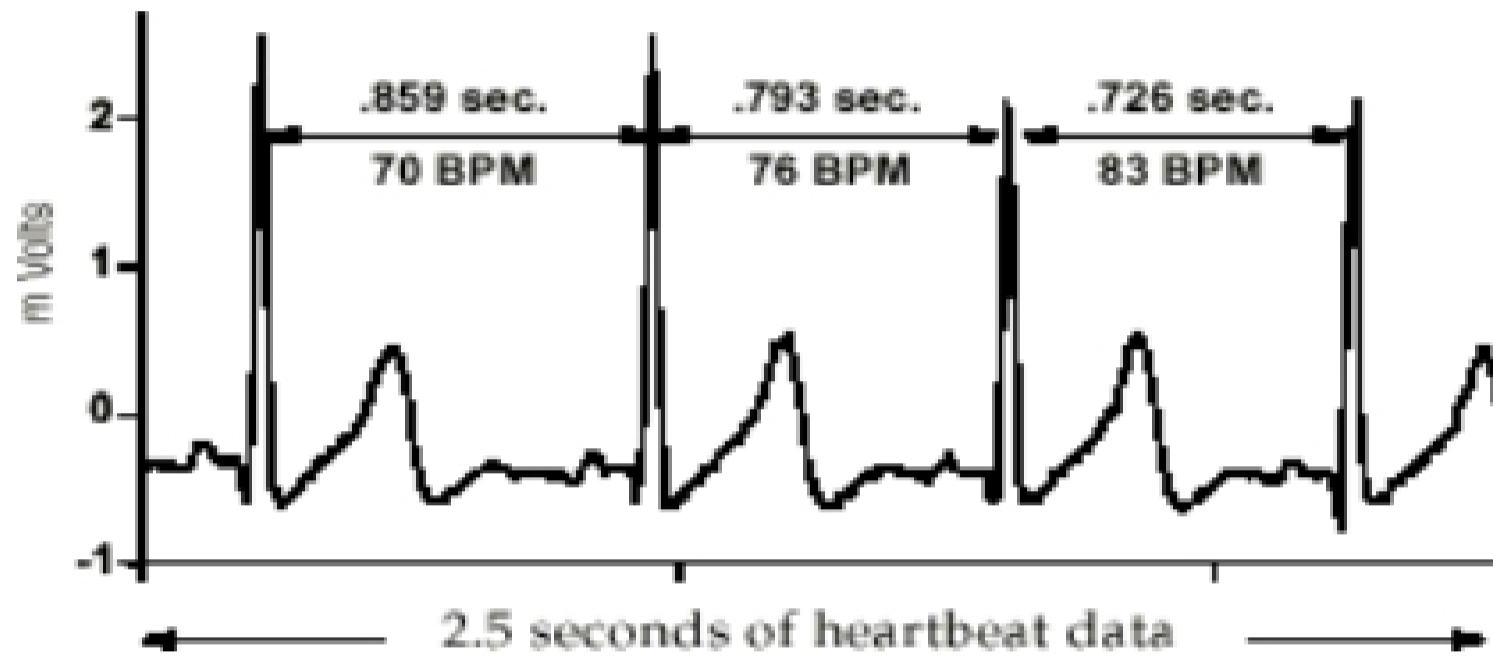


Figure 1: The variations in the R-R intervals (HRV) indicating HRV is a measure of the beat-to-beat changes in heart rate (4).

Depressed HRV is often a cause of concern because it is associated with an increased risk of mortality. Reduced HRV has been observed in adults during myocardial infraction, diabetic neuropathy, cardiac transplantation, etc. (5-7). In infants and neonates reduced HRV has been reported in conditions such as respiratory distress syndrome (RDS), reduced gestational age, and congenital cardiac abnormalities (8-10).

Hypothesis

One of the objectives in this research study is to determine whether there is a difference in the HRV (i.e. difference in the autonomic function) in the HLHS infants as compared to the age matched normal infant population before cardiac surgery. Our hypothesis is that HRV in HLHS infants will be diminished as compared to the normal infants i.e. the variations in HRV within the hypoplast group will be reduced as compared to the control group.

Infant population

For this study, the infant population was divided into two groups. Group I consisted of five normal newborn healthy infants. Group II consisted of five infants diagnosed with HLHS. The electrocardiograph data was recorded using Zymed Philips Digitrak Plus 24-hour Holter monitor. A Holter monitor is a portable device that continuously measures the electrical activity of the heart using electrodes that are attached to the skin. After the collection of Holter data, Philips software was used to determine the exact time of occurrence of the R peak in the QRS complex of the ECG signal. The difference between the R-R peaks was computed and stored which is essentially the HRV data.

Dataset

For this Bayesian analysis project, I am using HRV data for HLHS infants and their age matched normal controls prior to cardiac surgery. Twenty 5-minute segments of heartbeat data are selected for each infant and the mean HRV for each of the 5-minute segments is computed. Thus, the dataset consists of 20 HRV values for each infant in Group I and II.

Method

Bayesian Model

A hierarchical model was implemented with the HRV data considered to be normally distributed,

$$y_{ij} = \text{Normal}(\text{mean}[i], \text{prec}_{\text{within}})$$

where y_{ij} is the HRV for the i th subject and j th sample

$\text{mean}[i]$ is the mean HRV for the i th subject over the entire time duration

$\text{prec}_{\text{within}}$ is the precision (inverse of variance) within the subject

The mean HRV for each subject, $\text{mean}[i]$ is considered to be normally distributed,

$$\text{mean}[i] = \text{Normal}(\theta, \text{prec}_{\text{between}})$$

where θ is the mean HRV for all the subjects

$$\theta \sim \text{Normal}(\mu, \text{variance})$$