Chapter 4

Fetal Heart Rate Variability Analysis

4.1 Indexes of Heart Rate Variability

The system is designed to measure different linear and nonlinear heart rate variability parameters to show a particular range for identification of autonomic maturation in the normal developed fetus. HRV analysis methods can be divided into time-domain, frequency-domain, and nonlinear methods. HRV parameters were obtained in agreement with the standards of measurements proposed by Task Force committee [6].

4.2 Time Domain Measures of HRV

The simplest time domain measures are the mean and standard deviation of the RR intervals. The standard deviation of RR intervals (SDNN) describes the overall variation in the RR interval signal while the standard deviation of the differences between consecutive RR intervals (SDSD) describes short-term variation. For a stationary time series SDSD equals to the root mean square (RMS) of the differences between consecutive RR intervals (RMSSD). There are also other commonly used parameters like NN50 which is the number of consecutive RR intervals differing by more than 50 ms. The pNN50 is the percentage value of NN50 intervals. The prefix NN stands for normal-to-normal intervals. In practice, RR and NN intervals usually appear to be same [6, 7].

We have taken coefficient of variance (CVRR) of a patient’s normal RR intervals as an index of parasympathetic activity which is defined as ratio of standard deviation of normal RR intervals value to mean of such intervals. Furthermore, there are some geometric measures like the HRV triangular index and TINN that are determined from the histogram of RR intervals.

The fHRV analysis has a physiological significance as the changes in FHR are responsible for fetal well-being. Monitoring of a fetal condition by means of tracking the parameters of heart rate is considered to be one of the promising ways of modern antenatal diagnostics. HRV refers to the beat-to-beat alterations in heart rate stress. Certain cardiac diseases and other pathologic states affect HRV. Here we talk about HRV; we actually mean variability of RR intervals. An RR interval is the time that elapses between two successive R waves. Heart Rate Variability (HRV) measurements analyze how these RR intervals, which show the variation between consecutive heartbeats, change over time. Figure 4.1 shows HRV of a 34 wk of gestation normal fetus. It is
observed that the heart rate variability is much higher in normal fetus. Changes in the HRV patterns provide a sensible and advanced indicator of health impairments. Higher HRV is a signal of good adaptation and characterizes a healthy fetus with efficient autonomic mechanisms, while lower HRV is frequently an indicator of abnormal and insufficient adaptation of the ANS, provoking poor fetus physiological malfunction requiring further investigation in order to find a specific diagnosis.

![Figure 4.1: HRV of a 34 wk of gestation normal fetus.](image1)

Figure 4.1 shows statistics and different time domain parameters of a 34 wk of gestation normal fetus. It is also observed that standard deviation of RR intervals & heart rate standard deviation are much smaller in normal fetus.

![Figure 4.2: Statistics of a 34 wk of gestation normal fetus.](image2)
4.3 Frequency Domain Measures of HRV

The RR interval time series is an irregularly time-sampled signal. This is not an issue in time domain, but in the frequency-domain it has to be taken into account. If the spectrum estimate is calculated from this irregularly time-sampled signal, implicitly assuming it to be evenly sampled, additional harmonic components are generated in the spectrum. Therefore, the RR interval signal is usually interpolated before the spectral analysis to recover an evenly sampled signal from the irregularly sampled event series. In the frequency-domain analysis power spectral density (PSD) of the RR series is calculated. Methods for calculating the PSD estimate may be divided into nonparametric [e.g. fast Fourier transform (FFT) based] and parametric [e.g. based on autoregressive (AR) models] methods. The PSD is analyzed by calculating powers and peak frequencies for different frequency bands. The commonly used frequency bands are very low frequency (VLF, 0-0.04 Hz), low frequency (LF, 0.04-0.15 Hz), and high frequency (HF, 0.15-0.4 Hz). The most common frequency-domain parameters include the powers of VLF, LF, and HF bands in absolute and relative values, the normalized power of LF and HF bands, and the LF to HF ratio. Also the peak frequencies are determined for each frequency band. For the FFT based spectrum powers are calculated by integrating the spectrum over the frequency bands. The parametric spectrum, on the other hand, can be divided into components and the band powers are obtained as powers of these components. This property of parametric spectrum estimation has made it popular in HRV analysis. Figure 4.3 shows Spectral analysis of frequencies [Nonparametric Fast Fourier Transform (FFT) method] of a 34 wk of gestation normal fetus. The total power and high frequency components are smaller in normal fetus. We defined a low frequency/high frequency (LF/HF) ratio as a sympathetic activity is smaller in abnormal mother fetus. The LF/HF ratio reflects the absolute and relative changes between the sympathetic and parasympathetic components of the ANS, by characterizing the sympathetic vagal balance on heart [6, 7].
High-frequency component ranging from 0.15 to 0.4 Hz, which corresponds to the respiratory modulation and is an indicator of the performance of the vagus nerve on the heart. Low frequency component ranging between 0.04 and 0.15 Hz is due to the joint action of the vagal and sympathetic components on the heart, with a predominance of the sympathetic ones. Components of very low frequency and ultra-low frequency indexes is used, since their physiological explanation is not well established and seems to be related to the renin-angiotensin-aldosterone system, thermoregulation and the peripheral vasomotor tone. Figure 4.4 shows Spectral analysis of frequencies [based on autoregressive (AR) models] of a 34 wk of gestation normal fetus. We found the total power and high frequency components are smaller in normal fetus.
4.4 Nonlinear Measures of HRV

It is realistic to presume that HRV also contains nonlinear properties because of the complex regulation mechanisms controlling it. The interpretation and understanding of many nonlinear methods is, however, still insufficient. One simple and easy to comprehend nonlinear method is the so called Poincare plot. It is a graphical presentation of the correlation between consecutive RR intervals. The geometry of the Poincare plot is essential. A common way to describe the geometry is to fit an ellipse to the graph. The ellipse is fitted onto the so called line-of-identity at 45° to the normal axis. The standard deviation of the points perpendicular to the line-of-identity denoted by SD1 describes short-term variability which is mainly caused by respiratory sinus arrhythmia (RSA). The standard deviation along the line-of-identity denoted by SD2 describes long-term variability [6, 7]. The analysis of Poincare plot can be performed in a qualitative manner (visual), by assessing the figure formed by its attractor, which is useful for showing the degree of complexity of RR intervals or quantitative, by adjusting the ellipse of the figure formed by the attractor, from which three indexes can be obtained: SD1, SD2 and SD1/SD2 ratio. SD1 represents the dispersion of points perpendicular to the line of identity and it seems to be an index of instantaneous recording of beat-to-beat variability; the SD2 represents the dispersion of points along the line of identity and represents the HRV in long-term records; the relationship of both (SD1/SD2) shows the ratio between the short- and long-term variations of the RR intervals [11].
Figure 4.5 shows Poincare chart of a 34 wk of gestation normal fetus. The dispersion of both short (SD1) & Long term (SD2) variability is smaller in normal fetus.

Figure 4.5: Poincare chart of a 34 wk of gestation normal fetus.