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Advancement of Doppler Technique Analysis

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Description

The Doppler shift of echoes from umbilical artery blood flow based on an ultrasound Pulse Wave (PW) Doppler technique is a common method in clinical examination to estimate the FHR. Similarly, a sampling gate at the maternal blood flow can be placed to measure MHR using PW Doppler. One of the most commonly used imaging modes for clinical fetal examinations is ultrasound Color Doppler Flow Imaging (CDFI). Color coding is used to show blood flow velocity and direction in different color grades based on the Doppler shift. Continuous CDF images show dynamic changes in blood flow characteristics. The periodic characteristics can be used to calculate heart rate. The most accurate measurement of periodicity in foetal heart activity is limited to labor; when electrical signals can be acquired using direct Foetal Electrocardiography (FECG) the duration of each cardiac cycle is estimated based on the time interval between successive R-waves in an electrocardiogram.

Cardiotocography (CTG) is the standard method in hospitals for monitoring fetal well-being, and it is based on the recording of FHR with a special device. This methodology is popular and widely used because it is simple to use, non-invasive, has no contraindications, and can be used on a regular basis. The main disadvantage of CTG is its high sensitivity to fetal movement, as the detection of FHR is mostly dependent on the ultrasound probe's proper positioning. In the event of fetal movement, this probe must be adjusted to provide accurate measurements. The advancement of dynamical system analysis has resulted in the introduction of numerous signal processing techniques aimed at extracting parameters from experimental time series. However, in most cases, an accurate model of the generating system is unknown or too complex and the output signal is the only information available about the system itself. A common example is the cardiovascular system, where the analysis of Heart Rate Variability Signals (HRV) is the primary method of investigating heart function. It has been demonstrated that the HRV signal is related to the activity of various physiological control mechanisms.

Their interaction causes changes in the heart rate, ensuring that the system that controls heartbeats responds efficiently to various incoming stimuli. HRV variation is related to changes in heart activity conditions. The frequency domain analysis of the HRV signal provides quantitative and non-invasive measures of Autonomic Nervous System Activity (ANS). Through the measurement of spectral low and high frequency components, a linear modeling approach is used to quantify both sympathetic and parasympathetic control mechanisms and their balance. On a beat-to-beat basis, the same approach can extract parameters related to the heart and cardiovascular control from systolic and diastolic values in Arterial Blood Pressure (ABP). Nonetheless, even if HRV analysis using classical linear methods quantifies the ANS's regulating action in a short period of time, the linear approach cannot explain the entire information carried by beat-to-beat variability. The signal structure appears erratic, but it contains abrupt changes and patterns that indicate a more regular behavior. Nonlinear signal analysis has proven useful in investigating the erratic components of cardiac rhythms and assessing nonlinear deterministic phenomena affecting the HRV signal in both short and long temporal windows.

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