A comparison of abdominal ECG and Doppler ultrasound for fetal heart rate detection

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Abstract—A fetal monitor has been developed for the measurement of the fetal and maternal heart rates from maternal abdominal electrocardiogram during pregnancy and labor for ambulatory monitoring. Developed algorithm of the fetal monitor is based on digital filtering, adaptive thresholding, statistical properties in the time domain and differencing of local maxima and minima. For these conditions, the status of the fetus can be determined along with the acidosis, premature ventricular

Key words: Fetal heart rate; abdominal ECG; Doppler ultrasound; digital filtering.

1. INTRODUCTION

The electrocardiogram (ECG) is the electrical signal produced by the heart and contains a distinctive shape known as the QRS complex. The time between two successive R peaks of the QRS complex is known as the RR interval and the heart rate (HR) is the reciprocal of the RR interval and expressed in Beats Per Minute (BPM). Fetal heart rate (FHR) variations observed during pregnancy and labor have commonly been used as indirect indication of the condition of the fetus, which may lead to fetal and/or maternal mortality or morbidity. From these conditions, the status of the fetus can be determined along with the acidosis, premature ventricular

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contractions (PVC), cardiac arrhythmia and the activity of the automatic nervous system (ANS) by special heart rate analysis and other clinical conditions that have been correlated with heart rate variability. Usually 20 min of FHR recordings are taken at the clinic as representative of the heart rate variation [1]. However, FHR abnormality may appear at any time and may therefore not be detected during short-term monitoring. The ability to perform long-term (e.g. 24 h) monitoring of the FHR would thus provide more information on the fetal condition [2].

In recent years, Doppler ultrasound has become a popular technique of monitoring the FHR abdominally, but attempts to produce a portable system have not been successful, because of its sensitivity to movements. The expectant mother needs to be in the recumbent position and limit her physical activity during ultrasound FHR monitoring. In addition, changes in the position or orientation of the transducer with respect to the fetus will also affect the signal [3], rendering this technique unsuitable for long-term FHR monitoring. Although there is no significant evidence from clinical data that short-term exposure to low-power ultrasound is harmful to the fetus, complete safety of long-term exposure has yet to be established. To avoid these hazards, some researchers have investigated phonocardiography applied to FHR detection [4].

Methods utilizing the abdominal electrocardiogram (AECG) have a better prospect for long-term monitoring using signal-processing techniques [5]. These methods are non-invasive and allow instantaneous FHR recording. The main difficulties encountered in determining the FHR from the AECG signal are the interference due to the maternal electrocardiogram (MECG), electromyogram (EMG) and motion artifact. To overcome the above problems, some algorithms use the thoracic MECG to cancel the abdominal MECG [6]. These methods require more than three leads, which is inconvenient for the patient during long-term monitoring. Other methods [7] use an average MECG complex formed from previously detected MECG complexes of the AECG signal using peak detection or correlation to cancel the actual MECG complex. As MECG complexes can have different amplitudes and durations, it is not possible to obtain a perfect match between the average MECG complex and the actual MECG complex in all cases. Consequently, MECG subtraction residues lead to errors by producing false fetal peaks. Another single-lead method [8] utilizes the difference in the frequency spectra of the maternal and fetal complexes to separate the maternal signal from the AECG. In this technique, a low pass filter with a cut-off frequency of about 25 Hz attenuates traces of the fetal QRS complexes.

Obtaining a fetal ECG (FECG) with a favorable signal-to-noise ratio (SNR) is dependent on the gestational age of pregnancy. It has been reported that, while during 20 to 26 weeks the FECG seems to be somewhat uniform in amplitude on the abdominal surface area, during the period of 26 to 34 weeks of gestation the FECG is significantly attenuated [9], due to the covering of the fetus with vernix, which is a poor conductor of electricity. From 34 weeks to delivery the amplitudes vary depending on the electrode location on the abdomen [10]. Fetal heart rate monitoring performed weekly from 34 weeks of gestation may identify the need for