Monitoring of Fetal Heart Rate via iPhone

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Abstract. Recording of fetal heart rate can be reassuring for the mother about the fetus' wellbeing. Our smart phone application can detect, record and evaluate fetal heart rate at any time. This method is based on sound wave thus free from the effects of ultrasound, and can be used all day without harming the fetus. It does not require medical assistance and easy to use at home. It reduces the queue at outpatient care units, helps pregnant women to relieve stress by listening to their unborn baby's heartbeat. It improves mother-child relationship yet sends an alarming message if further examinations are needed to prevent the consequences of hypoxia.

Keywords: Fetal heart rate · Mobile application · Home monitoring · Phonocardiography

1 Introduction

There are several solutions for the acoustic detection of fetal heart rate (FHR) that can help obstetricians determine whether the fetus is at risk or not [1, 3–5]. From the 38th week (or incase of any complications from the 24th week) cardiotocograph (CTG) is used to monitor the changes and characteristics of fetal pulse and movements. Two transducers are placed on the maternal abdomen; one to detect fetal heart actions (cardio-), the other registers the uterine activity (tocogram). This way the FHR is detected by Doppler ultrasound, while the uterine contractions via a pressure-sensitive contraction transducer, called tocodynamometer. Phonocardiography (PCG) is also proper way to detect fetal heartbeat. The device can record the rhythmic contractions due to the resonance made by the valves.

Brown and Patrick (1981) showed that apart from fetal activity and normal basic FHR the alteration of higher and lower heart rates is also important factor to evaluate the fetal state [2]. They have set up some alternatives for ultrasonographic non-invasive FHR monitoring such as fetal electrocardiography (fECG), fetal magnetocardiography (fMCG), fetal phonocardiography (fPCG). While the fECG requires several electrodes and the form of the recorded waves highly depends on their positions, the fMCG is too

K. Giokas et al. (Eds.): eHealth 2016, LNICST 181, pp. 492–496, 2017.
DOI: 10.1007/978-3-319-49655-9_60

big and expensive for long time home-monitoring, therefore the fPCG has unquestionable advantages for a safe long lasting use at home environment.

2 Materials and Methods

There are numerous electric stethoscopes available (Welch-Allyn, 3 M Littmann, Thinklabs, Cardionics) but the prices go from 200 to 600 EUROs [4]. Our aim was to develop a small, inexpensive, non-invasive device that can easily be used at home to record FHR constantly. The developed measurement device has three main components:

1. Acoustic sensor, which in our case is a modified stethoscope, with a built-in microphone. The sensor transforms the acoustic signal into electric signal and it is sensitive enough in the target frequency range. The acoustic signal can be conveniently captured by placing the stethoscope on mother's abdomen without usage of gel as in CTG monitor. Furthermore, this stethoscope sensor offers a totally passive means, which promises its potential of long term and safe use.
2. A small-sized amplifier and filtering unit, whose main components are pre-amplifier, band filter, amplifier. To separate fetal heart signal from mother's heartbeat and noise, spectral separation method was used, the acceleration sensor or the piezo sensor was not successful [1, 3, 5]. We note that fetal heart signal is lower, by orders of magnitude, than mother's heartbeat and noises (breathing or bowel sound). The filtered signal is transferred to the signal processing and storage medium by frequency modulator. We included the possibility to listen to the filtered fetal heart signal.
3. Signal processing and storage medium, which in our case is an iPhone or iPad, and its software. The software records the fetal heart signal and after the demodulation finds the position of the fetal heartbeats (real-time) with an automatic process, then shows the number of beats per minute and its variability. It plays an alarming sound in case of unsatisfying (badly recorded) signal. Also, it can evaluate the FHR. A healthy FHR is between 120 and 160 beats per minute, a low (bradycardia) or high (tachycardia) FHR indicates the necessity of other examinations or a closer check up by specialists. The indication of fetal movement is also possible.

Figure 1 presents an example of measured signal vs. background noise after filtering, while Fig. 2 shows screenshots of the running application.

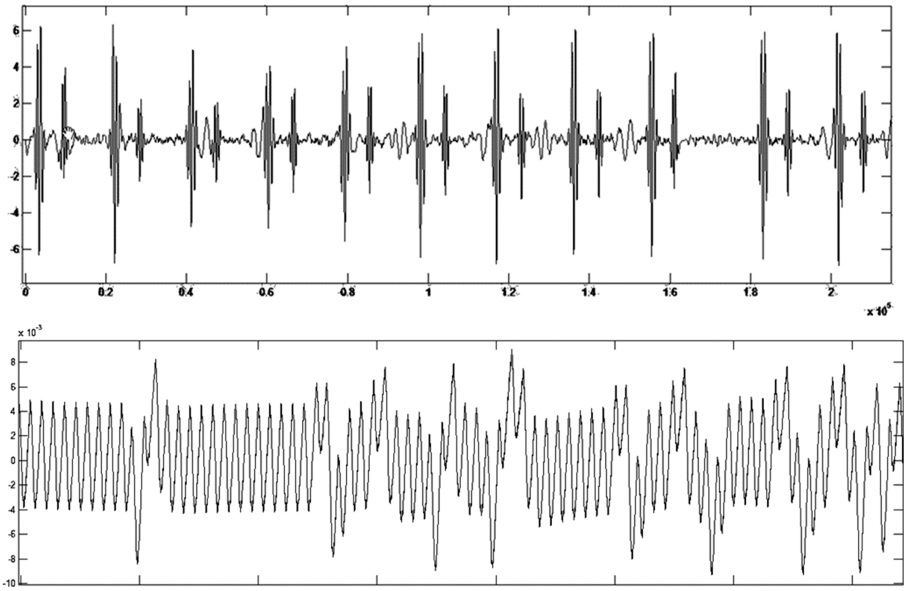

Fig. 1. Measured signal is shown in the top row, where the detected heartbeats S1 and S2 can be clearly seen. Background noise is shown in the bottom row. Signal to noise ratio is 750.

Fig. 2. Menu of the application: Information, Record, Recordings, Settings. the first screen shot is about the information panel. The second screenshot shows the application in work; the recording, the signal, and the fetal movement button. The third screenshot is the statistic evaluation of fetal movements; date, recording, fetal movements (25), evaluation (good), start of the recording.

We compared several stethoscope heads and different recording methods while detecting FHR. Our standard points of auscultation were 3 cm left to the navel and one cm up and down and same points on the right side.

The least accurate method was using the membrane face of stethoscopes used in present clinical practice. This approach is not ideal for FHR detection because stethoscopes are made to detect the maternal heart rate frequency and bowel noises. To get a clarified, noise-free voice file, there are other possible methods. The second best choice is the cone face of a stethoscope. In that case the skin serves as membrane and it reproduces the vibration of fetal heart sound better. The recordings are free from the outer noises (speaking, coughing, traffic). The best approach, however, is to rely on the waveform of the searched sound. We performed several measurements with a 70 mm long and 12 mm wide plastic tube sealed with 5 mm of thread layer. It seems to be optimal for detecting FHR.

We did 60 measurements with 7 patients. The separation of maternal and fetal heart sound was successful in all cases, while the calculation of fetal heart rate and heart rate variability was possible in most of the cases (nearly 70%).

3 Discussion

This PCG recording does not require healthcare assistance and still can provide signals of excellent quality. Although the usability of the FHR recording depends on the relative position of the stethoscope head to the fetal heart, it is sensitive enough to let pregnant women listen to their baby's heart. The method is completely passive, it does not radiates or harms the fetus. Thus it may be used even permanently or only for a shorter time at a family event. It helps women make sure their fetus is healthy, e.g. prevents dysfunctions caused by oxygen deficit. The saved recordings may be sent to doctors, who can immediately provide a diagnosis, hence it is not needed to queue in front of the outpatient care unit. It helps relieve stress, it improves mother-baby relationship, and helps the whole family to prepare to welcome the new member.

To summarize, with this device and application future child's heartbeat & movements may be listened & registered, and medical evaluation may be asked to make sure that the fetus is healthy.

Acknowledgments. This study was supported by "Telemedicine focused Researches on the Fields of Medicine, Mathematics and Informatics" TÁMOP- 4.2.2.A-11/1/KONV-2012-0073 project. The research was financed by the European Union and the European Social Fund.

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