

Invasive and Non Invasive Fetal Heart Rate measurement techniques: A Review

Shivani Saxena¹, Shruti Pathak², Divyanshi Sharma²

¹Department of Electronics, Banasthali Vidyapith, Tonk (India), Pincode 304022

^{2,3}M.Tech (VLSI Design), Banasthali Vidyapith, Tonk (India), Pincode 304022

Abstract- Fetal heart rate (FHR) monitoring is a routine for obtaining significant information about the fetal condition during pregnancy and labor. Monitoring the fetal heart condition in order to evaluate health status and diagnosis of possible diseases is one of the most important concern during pregnancy to determine fetal well-being, development of fetal nervous system and the presence or absence of any congenital heart diseases. Various techniques are used for this purpose. Therefore, a comparative study is done on various fetal heart rate monitoring techniques with discussions on performance indices, where Fetal electrocardiogram (FECG) comes out to be the best available techniques among all.

Index Terms- Fetal, Invasive, Non Invasive, gestation age, FHR.

I. INTRODUCTION

The most common method for fetal monitoring is recording of Fetal Heart Rate (FHR) and analysis of fetal heart rate variability (fHRV). The fHRV analysis has a physiological significance as the changes in FHR are coupled to fetal well-being. The importance of this subject has been felt as every year about one out of 125 babies are born with some form of congenital heart defects. The medical reports show about 12.8% of babies is born prematurely due to improper growth of their nervous system [1]. In addition, fetal, maternal and placental are other causes of fetal death. But such conditions can be detected if we measure the heart rate of the fetus during its growth. It was reported by the department of pathology, India in 2014 that the cause of fetal death due to placental causes were seen in majority of cases (48.57%) followed by fetal(35.72%) and then maternal(21.42%). Most prevalent cause of death was congenital anomalies(28.6%) followed by placental Insufficiency(21.4%) and chorioamnionitis (14.2%) [2].

Fetal heart rate (FHR) was first introduced in the 17th century. It is an important parameter that can be monitored during pregnancy and/or labor and in some cases the only available source of information to illustrate fetal development cycle. Fetal heart starts pulsating at around 250 beats per minutes (bpm) at 12th weeks of gestation period. It decreases down to around 120 to 150 bpm at 36 weeks (9th month). This paper presents a survey on fetal heart rate variation measuring system and the fetal heart rate data to define the diagnostic indices. These diagnostic indices can be utilized to predict the fetal feature life growth and can be utilized for preventive measure.

Table 1: Fetal heart rate variations and its development

Fetal age / size of fetus	Normal fetal heart rate	Development
5 weeks (beginning)	80-85 bpm	-
5 weeks	Starts at 80 bpm and ends at 103 bpm	-
6 weeks	Starts at 103 bpm and ends at 126 bpm	Baby's nose, mouth and ears are beginning to take shape
7 weeks	Starts at 126 bpm and ends at 149 bpm	Baby- still an embryo with a small tail- is forming hand and feet Uterus has doubled in size
8 weeks	Starts at 149 bpm and ends at 172 bpm	Baby is constantly moving, though can't be felt
9 weeks	155-195 bpm (average 175 bpm)	Nearly 1 inch long, baby is starting to look more human
12 weeks	120-180 bpm (average 150 bpm)	Toes can curl Brain is growing furiously Kidneys starting to excrete urine

After 12 weeks	120-180 (average bpm)	bpm 140	13th week is the last of 1 st trimester. In this week, baby now has exquisite fingerprints and almost 3 inch long
----------------	-----------------------	---------	--

II. FETAL HEART RATE MONITORING TECHNIQUES

There are various techniques that can be used to measure the fetal heart rate in gestational period i.e fetal development period from the time of conception until birth. They can be categorized as Invasive techniques, i.e insertion of instruments or other objects into the body to measure heart rate using various methods and non-invasive where heart rate can be monitor on the body surface of fetal.

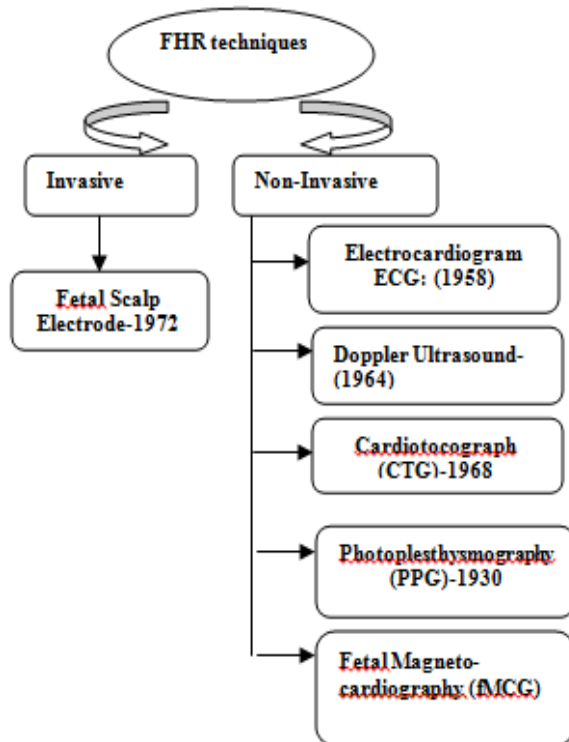


Fig 1: Fetal heart rate monitoring techniques

In ECG, heart rate is monitored by placing electrodes on fetal body surface, as shown in fig 2. Source and gestational age: Electrical energy and 20-40 weeks

Drawbacks:

- This method needs clinical practitioners and not suited in long term monitoring.
- Complex system.
- Depend on fetal movements and orientation.

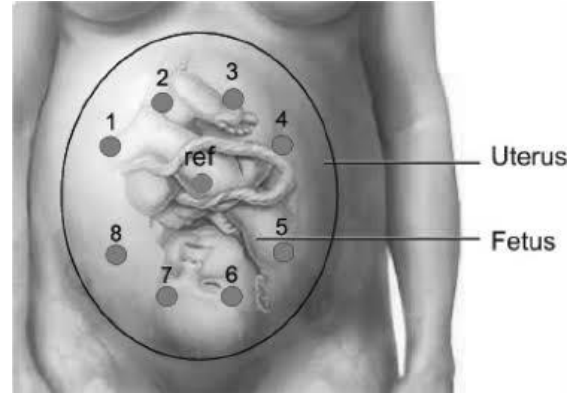


Fig 2. ECG measurement using electrode [6]

In Doppler Ultrasound, fetal heart pulses typically consisting of several cycles of 1–2-MHz sinusoids, is transmitted toward the fetal heart. The reflected pulse, slightly shifted in frequency, called Doppler shift by contractions of the fetal heart, and is compared with the transmitted pulse, as shown in fig 3. It is not suitable for continuous monitoring [3].

Source and gestational age: Ultrasonic waves and 20-40 weeks.

Drawbacks:

- Doppler monitor uses probes for a signal using ultrasound techniques.
- Not suitable for long term monitoring.

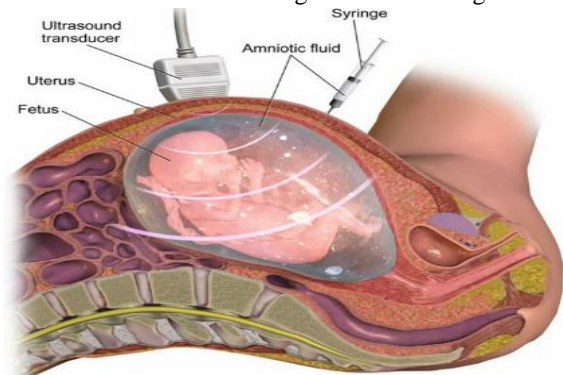


Fig 3: Doppler technique [7]

CTG involves the placement of two transducers onto the abdomen of pregnant women; one transducer records the FHR using ultrasound, whereas other transducers monitors the contraction of the uterus, by measuring the tension of the maternal abdominal wall, providing an indirect indication of intrauterine pressure, as shown in fig 4. The main drawback of the CTG monitors is that they are subjective and difficult to interpret results due to complexity which sometimes leads to unnecessary surgery [4].

Sources type: Ultrasonic wave

Drawbacks:

- Affordability and Portability.
- Difficulty in interpretation.

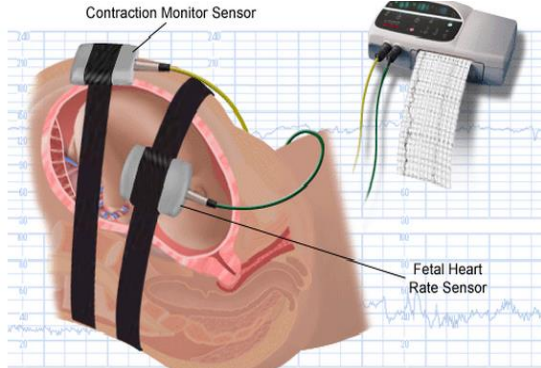


Fig 4: CTG technique [4]

FSE uses an electronic transducer connected directly to the fetal scalp. A wire electrode is attached to the fetal scalp through the cervical opening and is connected to the monitor, shown in fig 4.

Drawback:

- It is a dangerous technique as it may cause injuries in the fetal scalp and/or uterine infection.

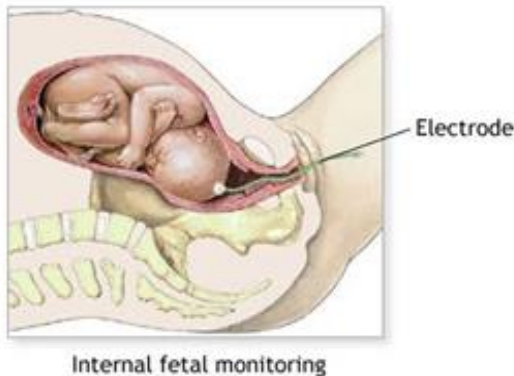


Fig 5: FSE technique [6]

PPG uses a light source and a photo detector to measure blood volume changes in small blood vessels in order to measure FHR. PPG has the advantage of non-invasiveness and can be used for continuous real-time monitoring [4].

Source type: Optical

Drawback:

- Motion artifacts affects accuracy.
- Dependency in fetal orientation.



Fig 5: PPG Device [7]

FMCG makes use of magnetic fields produced by the electrical activity of the heart. Unlike fetal MRI, FMCG does not emit magnetic fields making it safe. FMCG is highly reliable and can record beat-to-beat data [4]. It provides high-quality cardiac signals that enable diagnosis of previously unrecognized fetal pathologies. Although fMCG and fECG are similar in many respects, fMCG achieves much higher quality recordings and less affected by the poor electrical conductivity of fetal skin, and surrounding maternal tissues. fMCG can be performed after 20 weeks' gestation, but is less reliable before this gestational age and have much complex hardware [3]. Source type and gestational age: Magnetic and 20-40 weeks.

Drawback:

- This technique is very complex.
- Large size.

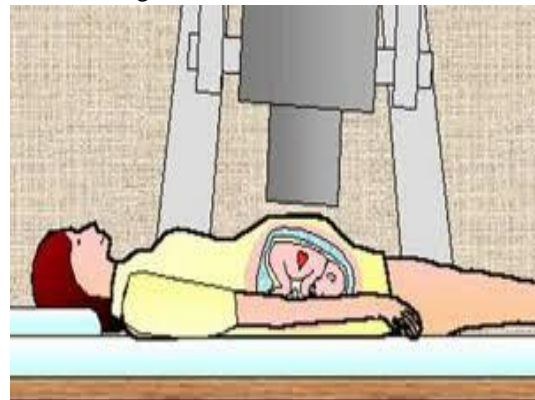


Fig 7: fMCG technique [8]

III. PERFORMANCE MEASURES OF FETAL HEART RATE MONITORING SYSTEM

To evaluate quality and reliability of all available fetal monitoring systems, some performance

parameters need to be calculated, summarized as follows:

1. Accuracy: It can be calculated by comparing the experimentally collected data with some standard simulated data using software. ECG and PPG use such methodology to determine accuracy.
2. Sensitivity: It is the ability of the system to detect the smallest absolute amount of change while measurement. The system should be sensitive enough to each and every change in heartbeat. It should be free from noise of surroundings and mother's psychological parameters like stress and depression. The signals should not movements of fetal and mother both.
3. Signal to Noise ratio (SNR): It define the quality of system in measuring of fetal data. The high value of SNR should be desirable.
4. Safe: Harmless system should be designed for the safety of mother and fetal.

All invasive and non-invasive techniques, discussed in section II, will compared on these performance parameters, as shown in table 2.

Table 2: Comparison of different fetal heart monitoring systems [4], [5]

Method	Accuracy	Sensitivity	Cost	Noise
ECG	Accurate method. Reliability depends on positioning of electrodes	Highly sensitive	High	Less
Doppler Ultrasound	Less accurate for beat to beat analysis but harmless)	Less Sensitivity to movement is less	Less than ECG	
CTG	Limited accuracy	High sensitivity but requires repositioning of electrodes	High	-
FSE	Accurate	-	Less	Less
PPG	Accuracy depends on type of source and detector. Motion artifacts also affects accuracy	Less	Less	High
FMCG	Accurate but very complex design	Sensitive (requires minimum subject movement)	High	Low

IV. CONCLUSION

The comparison shown above shows the FECG can be considered as most preferable method for measurement for fetal heart rate. The system is also used for continuous measurement of heartbeat having high sensitivity and high SNR. But there also exists several limitations in using of ECG systems. It includes presence of noises, requirement of expert, susceptibility of motion artifacts of fetal, preparation of skin before applying, etc.

REFERENCES

- [1] K.D. Desai, et.al, "A Comparison and Quantification of Fetal Heart Rate Variability using Doppler Ultrasound and Direct Electrocardiography Acquisition Techniques", ICATE 2013.
- [2] Uroos Fatima et.al, "Foetal Autopsy-Categories and Causes of Death", Journal of Clinical and Diagonistic Research.2014 ,Vol-8, pp 5-8.
- [3] Janette F. Strasburger et.al, "Fetal cardiac arrhythmia detection and in utero therapy", Nat Rev Cardiol. 2010 , pp-277-290.
- [4] Enas W. Abdulhay, Rami J. et.al,"Review Article: Non-Invasive Fetal Heart Rate Monitoring Techniques", Biomedical Science and Engineering, 2014, pp- 53-67.
- [5] Maria G. Signorini³, Giovanni Magenes, "Linear and Nonlinear Parameters for the Analysis of Fetal Heart Rate Signal from Carditocographic Recordings" Biomedical Engineering transaction, March 2003 , pp-365-374.
- [6] <http://goo.gl/images/4twdBv>
- [7] <http://goo.gl/images/rwEShP>
- [8] <http://goo.gl/images/nrqBYb>