Original Article

Survey On Different Methods Used to Track Maternal and Fetal Health During Pregnancy

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Abstract

Health of the mother and child is of great concern to all. Many mothers become extremely cautious of their health and are ready to make a lot of changes in their lifestyle as they become aware of the impact of a good lifestyle on the fetus. They also want to be assured of the proper growth of the fetus and want to be monitored medically for the same. The tests and the scans done during pregnancy can reveal a lot of information that can be used to identify possible threats for the mother and her child. A lot of wearable devices are there in the market which aid the monitoring of pregnancy. Some wearable devices track the lifestyle and others track measurable biological parameters. Identification of possible complications during pregnancy and thus enabling appropriate healthcare to the mother and her unborn baby can be achieved by combining ML and IOT based technologies. This paper talks about the various medical parameters that can be used and the technological approaches used for monitoring maternal health during pregnancy to possibly identify the risks associated with it.

Keywords: Internet of Things, Machine Learning, Pregnancy monitoring, Wearable solutions.

1. INTRODUCTION

Gynecologists and obstetrics consider Preterm Birth (PTB)as a very serious condition, especially in rural India. Care should be taken of the pregnant lady and her fetus during pregnancy for the well-being of both [1]. The unborn child's health gets greatly affected by the way the mother leads her life and her health also is impacted post pregnancy. In addition, if there are health issues for the mother then that leads to complications during pregnancy. Pregnancy with disorders like hypertension, hormonal imbalance or gestational diabetes affect the health of the pregnant woman later in life. Hence, care during pregnancy is very essential. Timely check-ups during pregnancy are necessary to detect and prevent abnormalities and other complications which could be fatal. Traditionally, blood pressure, blood glucose, hormones and urine tests are done regularly to monitor pregnancy.

Also, growth of the baby in the uterus and mother's weight gain is monitored regularly.

Leading a healthy lifestyle is important so caretakers do counsel and offer lifestyle and self-management suggestions for physical activity, sleep, nutrition etc. To ensure all this, continuous monitoring of different health parameters can provide great insight to obtain quantitative data that could be helpful in monitoring pregnancy [2].

A lot of end user wearable options are present in the market today that measure physical activity and other changes in lifestyle. Smart watches, baby's kicks monitoring devices and Internet of Things based smart devices are examples.

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Some of these devices monitor physiologic parameters (e.g., blood pressure), stress, heart rate etc. but none of the above-mentioned ones target pregnant women.

A lot of innovations in health monitoring such as wearable devices and smart textiles have shown to enhance the diagnosis, clinical monitoring, and management of health.

If lifestyle behaviors are monitored continuously the occurrences of early risk factors can be detected and hence complications related to pregnancy can be avoided. Very few studies have examined the implementation and use of wearable sensors in the daily routine of pregnant ladies or for high-risk pregnancy care. Wearable sensors and other smart technologies can help in the detection of risks to the mother and her baby associated with pregnancy.

2. PARAMETERS USED TO MONITOR PREGNANCY

Doppler studies primarily were used in estimating the gestational age at the time of delivery and secondarily for studying prenatal and neonatal complications. The authors further state that those patients whose doppler reports were normal rarely needed an emergency cesarean section than the ones whose doppler reports were abnormal. They also stated that high-risk pregnancies can be managed efficiently through Doppler studies.[2]

After studying 100 cases of pregnant women in gestation week 24 it was predicted that the the risk of preterm delivery for women having cervical length <2.5 cm is high. For such cases the measures of sensitivity, specificity, PPV and NPV were 33.3%, 68.2%, 63.2%, and 64.1% respectively [13]. Many parameters can be used to keep a track of the progress in pregnancy. Also, these parameters provide insight into the well-being of the fetus and the pregnant woman.

The table below summarizes the most commonly used parameters found during this survey that can be used to identify and predict problems in pregnancy. Parameters and their values from ECG reports, doppler readings, values of the lactic acid sensors, baby kick and movement count, readings from the MRI scan and values form the sensors used to measure muscle contractions and a few more indicators, along with their normal ranges are tabulated below.

Table 1 Parameters to measure severity of problems in pregnancy and their normal range

Parameters / Indicators	**Normal range**
PR, QRS, QTc	(0.14 + 0.01, 0.08 + 0.008, and 407.83 + 11.98, respectively) [12]
Doppler	OR 0.1, 95% CI 0.03-0.4 [13]
lactic acid	25 or 30 mM [14]
Baby kicks	Ten movements (such as kicks, flutters, or rolls) in 1 hour or less are considered normal. If baby is not asleep [15]
Biometric parameters of baby of 28 weeks of gestation with the standard deviation (SD)	Biparietal diameter (in mm):70.1±05.0 Femur length (in mm):52.2±03.9 Head circumference (in mm):255.7±18.9 Abdominal circumference (in mm):225.7±17.6 [16]
Muscle contraction sensor use of uterine EMG (electromyography) using machines such as a tocodynamometer.	In normal labor, less than five contractions in a 10-minute period is ideal. If Uterine EMG with PV and PS peak frequency exceeds the value of 84.48, then there is a high chance of the baby getting delivered within 7 days. [17]
BP-Sphygmomanometer	110.4 (108.5, 112.3) mmHg, increasing till 40 weeks to 116.0 (113.6, 118.4) mmHg [18]
Cervical length	Above 26 mm [11]
Maximum Heartbeat of a pregnant woman	>100 bpm [19]
Minimum Heartbeat of a pregnant woman	<80 bpm [19]
Body temperature	Up to 37.8 °C [19]

3. WEARABLE SOLUTIONS OF PREGNANCY MONITORING

Evolving technology has changed the nature of Prenatal care. Smartphone and digital technology can now be used effectively. Also, Wearable sensors and other smart technology if used, remote monitoring of subclinical changes in pregnancy health status is possible. Patients have become open to adapt to the changes in the technology knowing the usability of mobile sensors during pregnancy and are open to share their experiences [13].

A study where blood pressure, weight and blood glucose, to monitor hypertension and diabetes was done where mothers who developed hypertension during pregnancy were to use home blood pressure monitoring systems. Whenever values noted were above the fixed specified threshold, mothers would be advised to seek doctor's advice [5].

High Risk mothers could be notified using smartphone applications. A system was developed where a mobile application collected recorded values of blood pressure and weight from mothers and were given notification when the parameters were abnormal. A framework to notify pregnant ladies on their mobile phone who had uterine contractions above some personalized threshold aimed to reduce preterm birth. Authors used a smartphone-based system which used a Naive Bayes Classifier, which enabled real-time decision-making [2].

A model to monitor hypertension during pregnancy was implemented which used a wristband to self-monitor heart rate, sleep, stress and step count. This proposed model was tested in a hospital and was found to have satisfying results and that too using a noninvasive way [6]. Necessary adaptations that need to be done can be understood with the help of the system based collected health data.

The drawbacks of the existing systems are that it could only address specific health issues in a short time span or be performed with a limited number of methods for data collection [7]. Mothers' health can be one major reason for the same, such health issues of the mother could be monitored, analyzed and notified [8]. Lifestyle changes that need to be incorporated to reduce the risk of pregnancy complications like miscarriage, stillbirth, and preterm birth were suggested. Wearable sensors can come to aid this and can motivate pregnant ladies to lead a healthier lifestyle. Hormones, mental state and psychological adaptations play a massive role in the health of pregnant women. These factors need to be taken into account when quantifying the lifestyle of the pregnant woman. No solution has addressed this wholly. The authors have developed algorithms for the systems that deal with lifestyle changes, and enable remote and continuous monitoring throughout pregnancy. This is done using sensor data [20].

A novel wearable system consisting of four accelerometers for capturing the movement of a baby in the uterus was proposed. The mother is constantly provided with information related to the movement of the baby in the uterus using ML techniques through an android device. They claim that their proposed system can deliver reliable time series signal classification results with a specificity of 0.99 and a sensitivity of 0.77 [21].

There is a risk of infant mortality due to preterm birth. Uterine electromyography (EMG) may be used predicting risk of preterm delivery which can be promising [9].

A new analytical approach for assessing the risk of preterm delivery using EMG recordings is proposed. Analysis of the positions of three different electrodes was done to find out which uterine EMG recording location gives optimal signal data. It was noticed that if the electrode was positioned below the navel maximum accuracy could be achieved [9].

4. MACHINE LEARNING FOR PREGNANCY MONITORING

Most models so far for detecting preterm birth have the drawback of not being able to select the most accurate features from the medical dataset in linear time. An attempt to design a smart system for the prediction of PTB was done. They named it the Risk Prediction Conceptual Model [5]. The authors have used a feature selection approach based on entropy to find the most suitable medical parameters for the pregnant lady that are responsible for PTB from the obstetrical dataset. They aimed to have high accuracy using classifier. They worked on obstetrical data from the Community Health Center of rural areas (Kamdara, Jharkhand) and suggested an approach to identify the excellent maternal features (text-based symptoms) present in pregnant women in order to classify all birth cases into term birth and PTB. They used logistic regression (LR), support vector machine (SVM) and decision tree (DT) classifiers for PTB prediction and claim the accuracy of 90.9% measured in terms of accuracy, specificity, and sensitivity [5].

Classification of depressed patients from normal subjects by using EEG signals can be done [22]. The authors here showed how machine learning can be used along with an EEG signal and FFT (Fast Fourier Transform) for classifying a person's mental state into either normal or depressed. They used SVM for this. The use of ECG signals for doing depression analysis was emphasized [23].

A real-time data analysis model using wearable technology to control and track hypertension during pregnancy was proposed [8]. The authors improved on the previous models by using more health parameters to prevent and correct hypertension disorders in pregnancy. They used cloud storage to store the data collected from the wearable devices. The model was in a public hospital in Lima, Peru. Their preliminary results proved to be effective as they found an 11% increase in patients that could be controlled and 7% decrease in maternal deaths. They used other relevant health factors that allowed healthcare providers to take actions to deal with the issues [24].

A noninvasive way to track fetal heart function is by using a Fetal electrocardiogram (FECG) The authors used the decomposed FECG signal from maternal ECG (MECG) which was quite challenging due to the low amplitude of

FECG. They proposed a modified Cycle Generative Adversarial Network (CycleGAN) to map signal domains efficiently. They believe that their results show the potential of their proposed method as a new algorithm for FECG extraction [25].

To improve the accuracy in predicting and assessing preterm delivery risk, inductive machine learning techniques on data records of pregnant patients were done. It provided production rules to predict preterm delivery [14].

A model that predicts preterm birth based on excellent features which are available in obstetrical data is proposed [20]. Another model has used the SVM, DT and LR classifiers for the classification of birth cases into preterm and term births. They claim to have achieved 90.9% accuracy with SVM. Their model aids in the making decisions by identifying risks and alerting the pregnant women at risk of preterm delivery. This also helps in preventing complications and cutting down the cost of diagnosis [26].

Depression detection can be done using EEG signal data. Classification of the patient is done based rule-based classifier.[27]

5. INTERNET OF THINGS BASED SOLUTIONS FOR PREGNANCY MONITORING

The advancements of the Internet of things and its applications in domains like healthcare have made it possible for doctors to diagnose their patients early and avoid complications by suggesting further modifications if needed. Internet of Things has the capability of collecting patient data incessantly which surely helps in preventive care.

As the whole process is automated, risk of errors is reduced. Administrative paperwork and data entry tasks will be automated due to tracking and connectivity. Tracking patient's vitals, activities and fitness with the aid of connected devices now is possible and unfortunate occurrences can be avoided. Several methods, practices and prototypes are described regarding the Internet of Things in the field of healthcare for women and children [28]. Different solutions proposed for maternal health monitoring systems are designed for specific health problems. Some solutions use questionnaires and short-term data collection methods. For maternal health monitoring to be done properly a comprehensive framework is needed which uses data by continuous monitoring of pregnant women [29].

Different techniques for analyzing exhaled breath can be used along with tests like X-rays, CT scans, MRI, ECG, a standard eye examination, and urine tests to determine the health of any individual and hence of pregnant women as well[30].

A full IOT based system has been implemented and a real study on pregnant women has been carried out in Southwestern Finland. The system's feasibility, energy efficiency, and data reliability were also evaluated. Their results show feasibility of the systems use during nine months. They suggest wearing a smartwatch to collect reliable photoplethysmography data [29].

Use of cervix dilation sensors can also be used to do pregnancy monitoring [27].

6. GENERIC ARCHITECTURE FOR IOT AND ML BASED SYSTEM

Risks determining parameters factors and false alarm conditions can be considered along with deep convolutional neural networks and other machine learning algorithms to do pregnancy monitoring. [22]

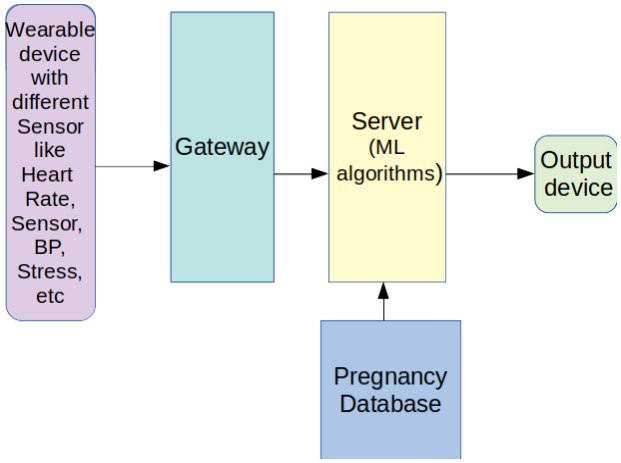

Figure 1 Generic block diagram of system architecture for Internet of Things and Machine Learning based pregnancy monitoring systems.

7. COMPARISON AND SUMMARY OF THE STUDY DONE.

Table 2 Summarizes the study done and gives a clear comparison of the existing methods for pregnancy monitoring on the basis of accuracy, usability and continuous monitoring capability. It also talks about the limitations of the existing methods and the medical parameters that have been considered to make the predictions after monitoring.

Table 2. Comparison and summary table.

References	Method	Technology	Accuracy	Prediction made	Medical parameters	Usability	Continuous monitoring	Monitoring pregnant lady's health	Monitoring fetal health	Limitations

					measured					
[13],[16], [17].	Instruments at the hospital	ECG, Doppler (Sonography), EMG,	High	Preterm labor, abnormalities in pregnancy.	Muscle contractions, heart rate.	Only at the hospital	Only if regular visit to hospital is possible	Yes (ECG)	Yes	Available only at the doctor's clinic or at the hospital and costly
[3]	Baby kick monitoring device	Accelerometer based	Adequate	Baby in distress	Baby kicks	Limited and cannot be worn continuously	Can be done at regular intervals	No	No	Bulky to use and costly.
[5]	Smart watches	Sensor based	Moderate	Health of mother	Heart rate, BP, step count, sleep	Can be worn continuously	Yes	Yes	No	Does not detect most risks associated with pregnancy.
[2]	Smart phone apps	Body sensor and ML	Adequate	Preterm birth	Uterine contractions, BP, weight	Can be worn continuously	Yes	Yes	No	Detection of abnormality based on threshold parameters accuracy can be improved by taking better medical parameters
[6],[9],[13], [20],[21], [30]	Pregnancy related Wearab	Sensors and ML	Satisfactory	Mothers' health	Hypertension, sleep rate, heart rate, step	Can be worn continuously	Yes	Yes	No	Detection of abnormality based on threshold

	le device/ IOT based solutions				count					parameters, accuracy can be improved by taking better medical parameters
[28], [29],[30]	IOT based solutions	sensors	Satisfactory. 90% approximately	Specific characteristic such as preterm birth	Cervical length, EMG, ECG	Can be worn continuously	Yes	Yes	Yes	Monitoring and alarm generation done using Specific parameters and their threshold values.
[5],[8],[14,][22],[23], [24],[25], [26],[27]	ML based Solutions	Predictions done on medical reports	Satisfactory. 90% approximately	Specific characteristics such as risk of diabetes, preterm birth etc.	Can use database and personal medical report	-	No	No	No	Prediction For specific heath parameter
[14],[24], [25],,[26], [27],[28], [29]	IOT and ML based solutions	Sensors	Satisfactory	Lifestyle and physiological adaptations	Hormonal, physiological, and psychological , fetal movement, preterm birth	Can be worn with ease	Yes	Yes	Can be done	Detection of abnormality based on threshold parameters, accuracy can be improved by taking better medical parameters

										like EMG, cervical length

8. CONCLUSION

Wearable systems may be good to aid doctors and hospital resources. These could also be used for home-care applications in the field of e-Health. Besides this, the signals capturing fetal movement can help to build databases which could be used for medical analysis of sensor-recorded fetal behaviors with the help of volunteers. A lot of development regarding the use of Machine Learning has been documented until now by different authors. And hence Machine Learning can be used effectively to predict complications that may occur during pregnancy. Different parameters can be considered for making predictions such as lactic acid, blood serum values, cervical length, baby kicks and more. Algorithms such as SVM, Linear regression, random forest etc. are used and have shown good results with higher accuracy [31]. The Internet of Things can be used effectively to monitor pregnancy.

However, the acceptance of such wearables is a challenge. Therefore, there is a need for having a simple and less disadvantageous system for pregnancy monitoring.

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