Device for Intrapartum Materno-Fetal care (IMFC device)

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Abstract— Maternal and fetal care during labor is of utmost importance, lack of which is the major cause of neonatal and maternal mortality. Partograph is a graphical record of important data measured during labor. The main parameters that are to be recorded in the partograph are many. But the ones that can be electronically measured and recorded are the number and duration of uterine contractions, fetal heart rate, maternal pulse rate and body temperature of the mother. This project involves the design of a wearable device which can continuously monitor these parameters, display them continuously and alarm in the case of any abnormalities.

Index Terms— Body temperature, Fetal, Maternal, Partograph, Pulse rate, Uterine contractions, Tocodynamometer

1 INTRODUCTION

Each year 904,000 intrapartum-related fetal deaths and close to 536,000 maternal deaths occur all over the world [1]. During labor, there can be many complications that may be fatal to the mother or baby. If the mother already has a heart condition or any other abnormal health conditions, then the monitoring during labor should be carefully done when compared to when the mother is otherwise healthy. Monitoring the mother's heart rate is very important. Contractions can become very high or very low going above and below the normal values. The contractions occurring during labor to push the baby out of the uterus can be stressful on the baby. This can be determined by monitoring the heart rate of the fetus. Any infections during labor and childbirth will cause a rise in body temperature of the mother. So monitoring the temperature of the mother will help in identifying any infections. All these parameters are measured and graphically recorded on a sheet of paper and it is called a partograph.

There can be abnormalities in the above measured parameters and can be fatal to both mother and fetus. This can be avoided by using this IMFC wearable device to continuously monitor the uterine contractions, FHR, pulse and temperature during labor and an alarm system can be included which notifies any abnormalities so that immediate attention is imparted. This can reduce the mortality rate during labor and childbirth to a large extent by imparting proper care at the proper time.

2 LITERATURE SURVEY

Hadar E et al. conducted a comparison between Electrical Uterine Monitor(EUM), tocodynamometer and Intra Uterine Pressure(IUP) catheter for uterine activity in labor by continuously and simultaneously monitoring the uterine contraction in pregnant women using EUM, tocodynamometer and IUP and found that the sensitivity, positive predictive value and false positive rate for individual contraction identification by tocodynamometer and EUM are 54.0%, 84.4%, 15.6% and 94.2%, 87.6%, 12.4%, respectively. They concluded that EUM is efficient as IUPC for uterine activity assessment hence supporting the use of non-invasive technology to monitor uterine activity [3].

Graeme John Clare et al. came up with a more reliable, accurate and sensitive measurements of uterine contractions. They improved transducer for and the circuitry associated with converting linear deflections of a sensing element of the tocodynamometer into electrical signals and amplifying the signals sufficiently to activate a suitable display. External devices have also been used to measure intra- uterine pressure as an alternative for or as a complement to the internal methods. However, external uterine activity monitors are large, bulky machines primarily designed for use in hospitals under controlled conditions. Also, many external devices are regarded as inaccurate and have not always been entirely successful, since the information obtained by their use could only be used in semi-quantitative assessments. External devices measure the tension in the uterine wall during contractions or monitor the internal pressure through recording the pressure required to render the uterus flat [4].

A signal processor isolates a uterine electromyogram signal from fetal and maternal heart rate signals and filter through motion artifacts from the electromyogram with the help of the movement signals. An output presents electrohysterogram (EHG) information from the uterine electromyogram signal. FHR was measured using the Doppler Effect. This is a method suitable for long term monitoring and detection of the health of a human fetus and the mother during pregnancy, during both of the antenatal and intrapartum periods [6].

2.1 Existing device

A tocodynamometer is a medical device used to measure the frequency and duration of uterine contractions. A fetal heart rate monitor is a medical device used to monitor the heart rate of the fetus. These two devices are used to monitor the health of the mother and fetus. Due to high cost, this device suffers affordability issues in Government hospitals and Primary Health Centers [4]. There is no existing device which measures all these important parameters continuously during labor and aims on plotting it on a partograph. Also the alarm for any abnormal reading alerts the nurses and doctors regarding any problems and demands immediate care and attention. Currently all these parameters are measured separately. Uterine contractions are measured using tocodynamometer and fetal heart is measured using stethoscope or Doppler ultrasound. But these do not help in continuous monitoring. In most of the hospitals, these measurements are taken whenever there is free nursing staffs available which does not give the required attention at the required time.

2.2 Field survey

Hospitals visited to survey the current methods practiced to obtain the various parameters during labor and to also see the frequency of usage of partograph are listed below,

- Victoria hospital, Bangalore.
- Kempegowda Institute of Medical Sciences (KIMS), Bangalore.
- Narayana Hrudayalaya, Bangalore.

The need for this project was concluded after meeting several gynecologists from the above mentioned hospitals. Victoria and KIMS are government hospitals. The intake of pregnant women into the labor ward is in large numbers. This creates a shortage of nursing staff and doctors to attend them and monitor them on a regular basis. This deprives the mother and fetus of immediate care and attention whenever there is an abnormality. This leads to further complications in childbirth. This is where this device for Intrapartum Materno-Fetal care (IMFC device) becomes very useful in continuously monitoring the mother and fetus during labor and aims at giving immediate attention so that the patient can be taken for caesarean section.

3 METHODOLOGY

The block diagram representing the methodology involved in developing this device is as shown in Fig. 1.

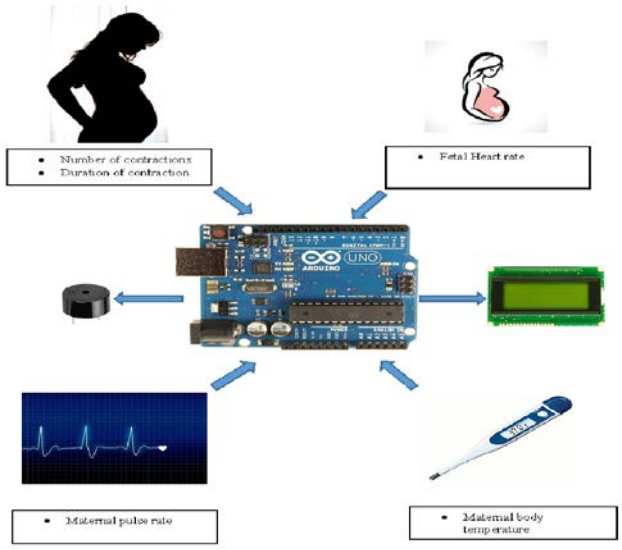

Fig. 1. Block diagram representing the methodology

- Uterine contraction measurements uses two sensors force and flex sensors to measure the compliance of the abdomen which in turn determines the presence or absence of contraction. The number of contractions in every 10 minute interval is measured and also the duration of each contraction is also measured and given as input to Arduino.
- The Fetal heart rate is measured using ECG. The signals from the electrodes are amplified using an instrumentation amplifier and then filtered to the required band of frequency. The output signal is given as input to the Arduino.
- Pulse rate sensor is used for maternal pulse rate measurement. This is also given as input to the Arduino.
- Temperature sensor is used for temperature measurement of the mother and sends it to Arduino.
- Arduino is a microcontroller which will take these signals as inputs and is programmed using Arduino software to get the desired output.
- 16 by 4 LCD displays the output values of these blocks which are given from Arduino.
- A piezoelectric buzzer gets input from the Arduino and it alarms every time any value exceeds a particular threshold.

4 IMPLEMENTATION

4.1 Uterine contraction measurement

This is one of the most important parameter to be measured during labor. The number of contractions for every 10 minute interval and the duration of each contraction are crucial. These two are measured using two electrical sensors, force and flex sensor. Both these sensors are interfaced to the Arduino and the values of force and displacement are noted. The sensors have to be calibrated before integrating to find the compliance [20].

Measuring uterine contractions with this sensor integrated

device cannot be validated by testing on a pregnant woman; a mock-up of the uterus has been designed using a funnel and an elastic balloon like material which is used to cover the broader end of the funnel. A balloon inflator is used to inflate the elastic material which gives a similar effect of a contraction happening and its effect on the wall of the abdomen. Block diagram of the mock up model shown in Fig. 2. The funnel covered with an elastic layer is used to measure the compliance of the material on which it is placed. The pump is used to apply the force which resembles the force that is applied on the elastic membrane during a uterine contraction.

The compliance values measured during a single contraction gives a waveform with peak value. These values are plotted in a graph to get the compliance plot and also to obtain thresholds as seen in Fig. 3. Since the measurement of number and duration of contractions is a qualitative measure, the thresholds are derived for the material for which the compliance is being measured. The duration of contraction is measured using the threshold value. The time duration in which the compliance value stays above a certain threshold is considered to be the duration of that particular contraction.

Force and flex sensors are placed on the stretchable membrane of the funnel perpendicular to each other. When the membrane is inflated by using a balloon inflator, both the force and flex resistance values changes which in turn causes a change in the output voltage from these sensors.

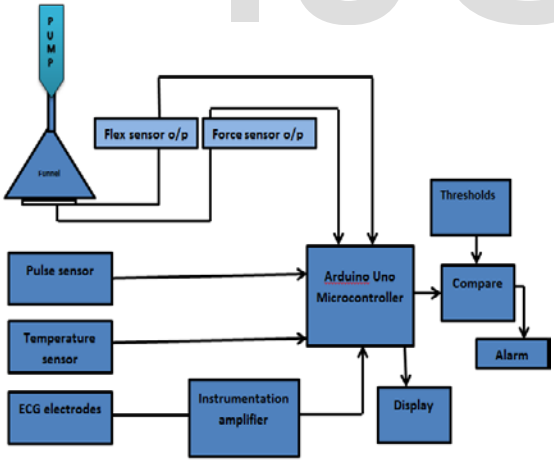

Fig. 2. Block diagram of mock-up model

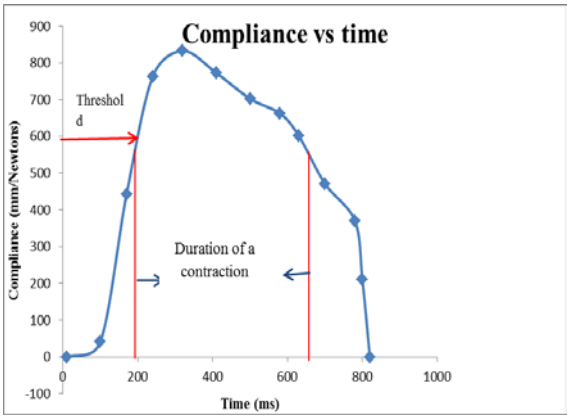

Fig. 3. Compliance plot with thresholds for magnitude and duration

4.2 Fetal heart rate measurement

Fetal heart rate measurement is done using ECG. Electrocardiogram (ECG) to obtain the electrical signals generated by the heart by placing electrodes in the sites where these electrical signals can be easily captured and measure the heart rate. In this case where the fetal ECG needs to be measured, the electrodes are placed on the abdomen to obtain the fetal heart rate. All biomedical signals including the ECG signals are very low amplitude signals. The voltage range of ECG signals is 1mV to 5mV. Hence we need an instrumentation amplifier with a high gain in order to measure those signals. The instrumentation amplifier gives an amplified signal which is then passed through a band pass filter which gives the heart rate. Further processing of these signals for fetal heart rate measurement is considered in the future scope.

4.3 Pulse rate measurement

The pulse rate is a direct measurement of the heart rate, or the number of times the heart beats per minute. The NSK22 pulse sensor is used for heartbeat measurement. TCRT1000 reflective optical sensor is used. It uses the principle of photoplethysmography. A high pass filter is used to eliminate the DC component from the signal. We can obtain the pulse rate by using the frequency of the signal using,

$$BPM = 60*\text{frequency of the pulses}$$

An LED is connected to the output which blinks synchronous to the heart beat or pulse rate.

4.4 Maternal body temperature measurement

Body temperature of the mother is an important parameter. Elevated body temperature indicates presence of infection of the vagina or can also be flu. LM35 temperature sensor is used for this purpose. Output of the sensor is given to the analog input of the Arduino board. The ADC gives digital values corresponding to the sensor values and temperature value in degree Celsius is calculated in the Arduino software.

4.5 Hardware setup

The entire hardware setup showing all the sensors used for the measurement of these four parameters is shown in Fig. 4.

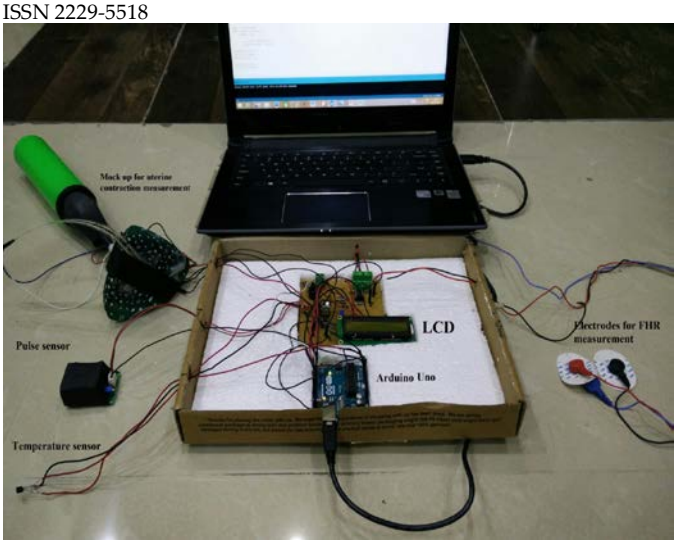

Fig. 4. Hardware setup

5 Results and Validation

5.1 Results

All the four vital parameters are displayed on an LCD screen as seen in fig. 5. The values are compared with the predefined thresholds and whenever there is an abnormality in any of these parameters an alarm will turn on. NC represents the number of uterine contractions. DUR stands for the duration of contractions. FHR and MHR represent fetal heart rate and maternal heart rate respectively. TEMP is for temperature measure.

Fig. 5. Four parameters displayed on the LCD

5.2 Validation

- Uterine contractions

The contractions are manually induced using an inflator. So, validation was done by considering 13 trials for the actual number of contractions that are induced and the number of contractions that are being displayed on the device. The graph showing the variation of the measured value from the actual value is shown in Fig. 6. The efficiency of the device in calculating the number of contractions is 79.6%.

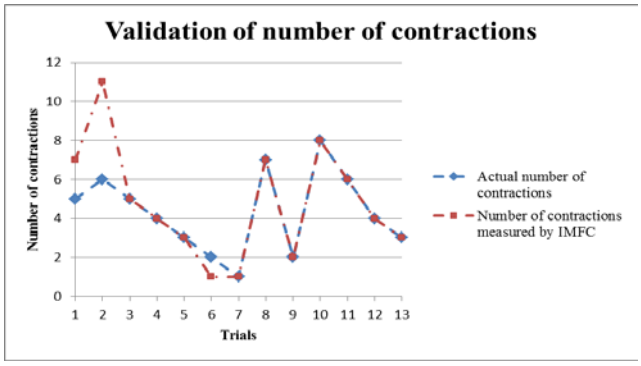

Fig. 6. Validation graph for number of contractions

- Fetal heart rate

Since using this device on a pregnant woman is not possible, the electrodes were placed on the chest and the heart rate was measured. These values for 10 subjects were compared with the values obtained using Schiller patient monitoring device. Graphically the variations between the values measured by this device and the standard one is shown in Fig. 7. The individual efficiency of the heart rate values are calculated in comparison to the standard device values for each subject. Then the average of all these values is taken and the efficiency of heart rate measure using this device is 96.2%.

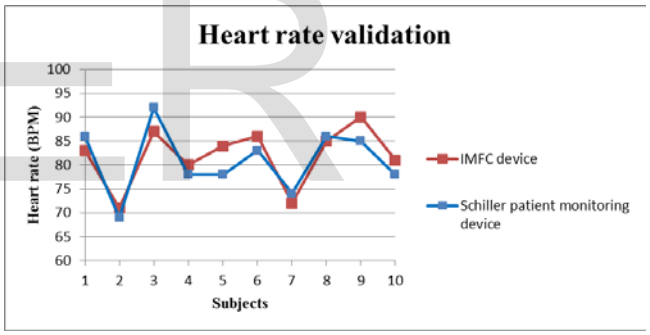

Fig. 7. Validation curve for heart rate

- Maternal Pulse rate

The heart rate of 10 subjects was measured for duration of 30 seconds for every subject using the device and also using standard Schiller patient monitoring system. Graphically the variations between the values measured by this device and the standard one is shown in Fig. 8. The individual efficiency of the pulse rate values are calculated in comparison to the standard device values for each subject. Then the average of all these values is taken and the efficiency for measuring the pulse rate measurement using this device is 96.33%.

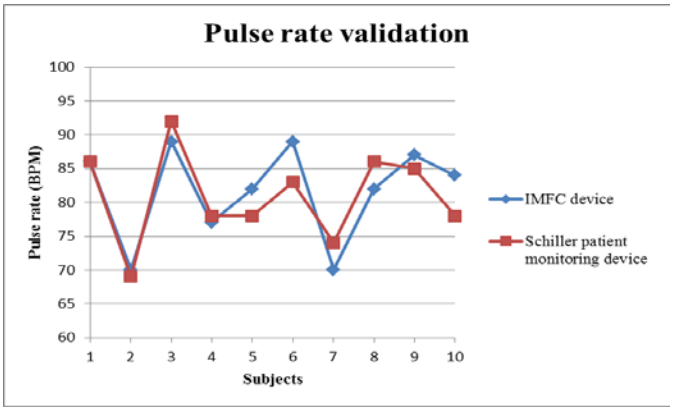

Fig. 8. Validation curve for maternal pulse rate

- Maternal body temperature

The temperature values of different subjects were made to hold the temperature sensor in the IMFC device and also the same subject was asked to hold the temperature sensor in the Schiller patient monitoring device. Graphically the variations between the values measured by this device and the standard one is shown in Fig. 9. The efficiency of the IMFC device in the measurement of temperature is 98.15%.

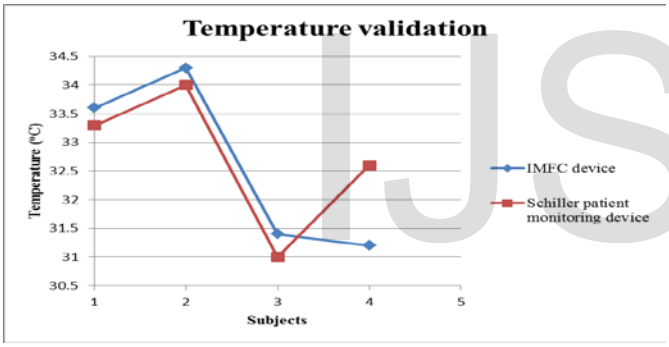

Fig. 9. Validation curve for temperature

6 Conclusion and Futurescope

A wearable, compact and affordable device which measures the number and duration of uterine contractions, fetal heart rate, maternal pulse rate and maternal body temperature continuously during labor. Without this device the mother or fetus might get into complications and it might be too late by the time the mid wives or doctor become aware of it. The device is less expensive and easy to use. So even untrained personnel can wrap this device around the pregnant women's abdomen and monitor the mother and baby.

The applications of the device are the following

- The device is low cost and hence can be used in Primary health centers and Government hospitals where the number of patients is more and the staffs are comparatively less.
- This device targets rural India where there are no hospitals and only midwives take care of the labor and delivery. Since it is a simple device, there is no need of any sort of expertise to handle the device.
- Useful even in multispecialty hospitals for continuous monitoring instead of intermittent analysis done by the nurses and midwives.

The future development of this device is to use it as a part of an android application for digital partograph which automatically plots the partograph given all the desired readings to it [7]. A motor could be used to give a gentle force externally to the elastic surface on the funnel. The compliance during presence and absence of inflation of the surface when the continuous force is being applied is measured.

Also a TENS (transcutaneous electrical nerve stimulation) can be included in the device such that it will help the mother with the intense pain occurring during the labor process.

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