Analysis of Uterine Contraction: A Review

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Abstract - *Labor is another word used for natural process of childbirth. To understand the start of true labor is important for the expert for helping mother to have safe delivery. Thus, the signs associated with labor have been reviewed in the beginning of this chapter. The common diagnostic techniques for identification of True Labor are discussed with their advantages and limitations. Significant studies and major research work for these techniques have been briefly reviewed. Various papers and articles from national and international journals, conferences, books, and websites were used as the resource for this review. A comparative analysis has been carried out based on this study to identify simple and accurate non-invasive, cost effective diagnosis technique for true labor determination. The result from this analysis shows that the identification of true labor through EMG signal is effective one. Hence it is a better option for the development of simple, and non-invasive true labor identification system.*

Key Words: Tocodynamometry (TOCO), intrauterine pressure catheter (IUPC), Electromyography (EMG)

1. INTRODUCTION

The objective of this research work is to develop a simple, non-invasive, cost-effective and accurate system for true labor identification and to differentiate it from false labor during the third trimester. The statistics of the World Health Organization (WHO) show that the Women die as a result of complications during and following pregnancy and childbirth. Most of these complications develop during pregnancy and most are preventable or treatable. In order to develop an investigating tool for differentiating true labor and false labor it is essential to understand the electrical activity generated by uterus and the anatomy and physiology of the uterus, mechanical and electrical activity generated by uterus, the existing diagnostic techniques used for identification of the true labor. For these purpose, various papers and articles from national and international journals and conferences, books, and relevant articles from different websites were used as the resources. Discussions have been done by physicians also to understand the physiology of the uterus and diagnosis techniques. The common monitoring techniques being used for identification of true labor in terms of uterine contraction are classical palpation, Tocodynamometry (TOCO), intrauterine pressure catheter (IUPC) and Electromyography (EMG). These techniques are studied with their brief principle of operation; the advantages and limitations to these techniques are identified. Significant studies and major research work for these techniques have been briefly reviewed in this chapter.

A comparative analysis has been carried out based on this study to identify simple and accurate non-invasive, cost effective diagnosis technique for distinguish true labor during pregnancy.

2. ANATOMY AND PHYSIOLOGY OF UTERUS

To understand activity of the uterus during pregnancy and delivery, it is necessary to be familiar with the anatomy and physiology of Uterus. The Uterus is a hollow thick-walled important organ of female reproductive system. It is positioned in the pelvic cavity between the bladder and the rectum. It has flexible size with four major regions and three tissue layers [22]

2.1 Major Regions of Uterus

- Fundus: The broad curved upper area in which the fallopian tubes connect to the uterus.

- Body: The main part of the uterus, starts directly below the level of the fallopian tubes and continues downward until the uterine walls and cavity begin to narrow.

- Isthmus: The lower part of the uterus. The cervix extends from the Lower narrow neck region; isthmus until it opens into the vagina.

- Cervix: The lowest tubular shape section of the uterus. It extends from the Lower isthmus until it opens into the vagina.

- Endometrium: The inner lining that builds up over the course of a month and is consists of glandular cells that produce secretions. This membrane thickens to prepare the uterus for implantation of a fertilized egg.

- Myometrium: The middle layer made of smooth muscle tissue forms the larger part of the uterine wall. This layer plays an active role during pregnancy. It increases both by hypertrophy of the existing cells and by multiplication of the cell number. During the last stage of gestation, the smooth cells reach a maximum length of 300 μm and a maximum width of 10 μm.

- Perimetrium: The perimetrium is the outer layer enveloping the body of the uterus and part of the cervix. It protects the uterus from friction by

forming a smooth layer of simple squamous epithelium along its surface and by secreting watery serous fluid to lubricate its surface.
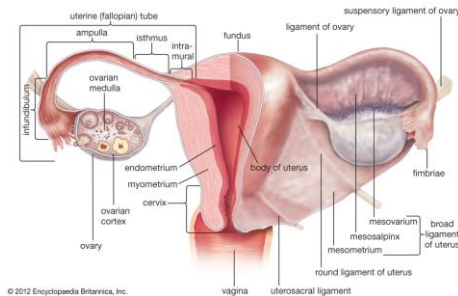

Fig - 1: Female reproductive system

2.2 Function of Uterus

When an egg pops out from an ovary, it enters the fallopian tube. Once, the egg reaches in the fallopian tube, tiny hairs in the tube's lining help to push it down the narrow passageway toward the uterus. During normal menstrual cycle, the egg leaves the body about 2 weeks later through the uterus. Now when a female and male have sex within several days of the female's ovulation, the conception may take place. Millions of sperms from the ejaculated semen swim up from the vagina through the cervix and uterus to meet the egg in the fallopian tube. It takes only one sperm to fertilize the egg. Once fertilization takes place, this newly fertilized cell (zygote) moves down through the fallopian tube into the uterus to get implant. The uterus lining nurtures the implanted zygote, which eventually grows into a fetus. The Uterus grows with size of baby and provides the protection.

The very important fact to consider uterine contraction as a source for true labor identification is that during delivery, the uterine contractions generally begin at the top of the uterine fundus and spread down toward the cervix. With time it increased the strength of the uterine muscle. Oxytocin hormone dramatically increases the strength and frequency of uterine contractions which helps to initiate labor if labor does not begin spontaneously.

2.3 Mechanical activity of the uterus

The uterus does lots of contraction activity right from conception to delivery of child. During the active phase, the Intra Uterine Pressure (IUP) permitted to evidence two types of pregnancy contractions:

- Low Amplitude High Frequency (LAHF) contractions: It is a contraction of low IUP amplitude, which has a very local influence. They occur during the first trimester of pregnancy and appear with a frequency about 1/min.

- High Amplitude Low Frequency (HALF) contractions: It is a Contraction of higher IUP

amplitude but of lower frequency of appearance. They Occurs from 1/day at the beginning to 1/hour that appear at mid-pregnancy. These contractions are called Braxton Hicks contractions. Their influence extends to a larger portion of the uterus. Braxton Hicks contractions become stronger and more frequent during the last weeks of pregnancy.

- Finally, at the time of delivery when the cervix starts to soften and dilate and contractions gradually reflects in terms of high amplitude and high frequency.

2.4 Electrical activity of the uterus

Each uterine contraction is the results of generation and propagation of many electrical activities in the myometrium cells [23]. Several authors have studied the changes in the electrical activity of the uterus during pregnancy to understand the changes in the characteristics of the myometrial contraction occurring before delivery. There is indication that useful information regarding electrical activity of uterine bursts lies in the frequency band 0.1-4.7 Hz divided into two frequency bands: 0.1-1.2 Hz, Fast Wave Low (FWL), and 1.2-4.7 Hz, Fast Wave High (FWH) [24]. The FWL is assumed to be related to the propagation of the electrical activity along the uterus, while the FWH is assumed to be related to the excitability of the uterus. The shift of the spectrum of uterine bursts towards higher frequencies as labor approaches was reported [25]. Therefore, many other methods used a wider frequency band expanding above 1.0 Hz, 0.3-8.0 Hz [26].

3. EXISTING TECHNIQUES FOR IDENTIFICATION OF TRUE LABOR

In this section, an attempt has been made to review and analyses the performance of currently used techniques for identification of true labor through literature study. This study is based on research papers, publications, web-sources, product manuals, interviews, formal discussions and other available literature on the subject. The outcome of these studies is further helped to conclude in selection of cost-effective non-invasive and effective technique in our research. The most popular diagnostic techniques used for identification of true labor during the pregnancy are Palpation, External Tocodynamometry (TOCO), Intrauterine pressure catheter (IUPC), and Electromyography (EMG).

3.1 Palpation Technique:

Since the late 19th century, examination of the fetus through palpation of the gravid uterus has been used in routine obstetric practice worldwide [27]. In this technique the expert examines the pregnant women with the fingers or hands. It is used to define the position, presentation, and engagement of the fetus in utero.

In Palpation technique, the patient is asked to have an empty bladder and suggest lying comfortably on positioned supine with head and knees supported. The expert fingers and hands with the body of the woman or child and apply pressure to sense the development of fetus as shown in figure 2. It helps to collect the data about uterine contractions, the size of the pregnant uterus, any uterine masses, with position of fetus. This technique is very old, non-invasive, inexpensive and harmless but requires the constant bedside presence of a trained observer.

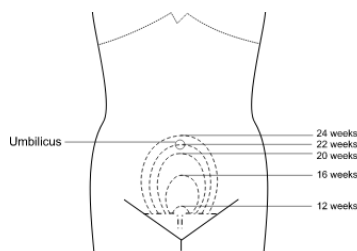
Fig – 2 Palpation examination

Fig – 3 Determination of gestational age using palpation

3.1.1 Overview of Significant Research Work on Palpation Technique:

Physical palpation has been the traditional method to monitor maternal uterine contractions. In a study [14] this technique was studied in 236 patients and concluded that this technique is an inaccurate means of determining contraction strength. They also concluded that contraction frequency is the only parameter that can be correctly assessed by manual palpation. They could predict the contraction strength 49% of the time. The position, attitude and size help to direct the exact mechanism as the fetus responds to the uterine forces. Also in 2008, Antenatal Care guideline, the National Institute for Health and Clinical Excellence (NICE) recommend: Fetal presentation should be assessed by abdominal palpation at 36 weeks or later, when demonstration is likely to influence the plans for the birth. Routine valuation through abdominal palpation should not be offered before 36 weeks because it is not always accurate and may be uncomfortable [28].

3.1.2 Advantages of Palpation Technique:

This is the classic technique of examination of fetus development and identification of true labor. The advantages of technique are summarized as under

- It is non-invasive technique.

- It is inexpensive as no expensive instruments required.

- It is harmless as non-invasive.

- The accuracy is not influenced by BMI.

3.1.3 Limitation of Palpation Technique:

There are a few limitations of Palpation discussed as under

- It predicts only contraction frequency and not the contraction strength.

- All carried by the expert to interpret the progress accurately.

- Inaccurate before 36 weeks of pregnancy.

3.2 Tocodynamometry (TOCO) Technique:

Tocodynamometry technique is a non-invasive technique and is most widely used method for monitoring uterine contractions during pregnancy. This is a harmless technique, in which a force sensor placed on the mother's abdomen, generally over the uterine fundus as shown in figure 4 with sensor. This sensor measures the deformation of the abdomen as a result of a contraction [29].

Fig – 4 Pressor sensor

Though external tocodynamometry offers an objective record of the frequency and duration of contractions without requiring the physical presence of a clinician, the tracing can be interrupted by maternal movement, and contraction strength cannot be quantified [30]. The sample signal of Tocodynamometry signal is shown in figure 5.
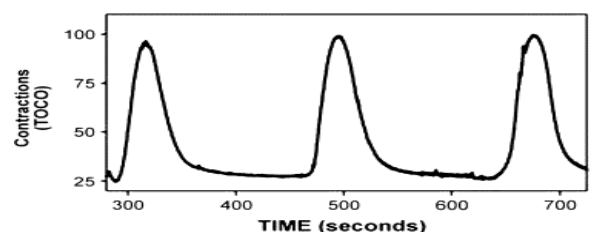

Fig - 5 The Tocodynamometry waveform

3.2.1 Overview of Significant Research Works on TOCO Technique:

Moni SS et al., [31] in their study of monitoring uterine electrical activity through non –invasive technique from February 2017 to April 2018 of patients with obesity, applied TOCO technique in 65 patient concluded that TOCO can identify the frequency and duration of uterine contractions, it cannot precisely quantify the contraction intensity, which is particularly important for the clinical management of patients with a protracted active phase of labor. Euliano TY et al. [32] Observed that accuracy depends on the correct positioning of the sensor on the abdominal wall relative to the uterus. Sangeeta Jain et al. [5] the tocodynamometer (TOCO) has poor sensitivity and specificity in monitoring uterine contractions, especially in obese patients. Although the external tocodynamometry provides an objective record of the frequency and duration of contractions without requiring the physical presence of a clinician, the tracing can be interrupted by maternal movement, and contraction strength cannot be quantified.

3.2.2 Advantages of TOCO Technique:

The advantages of TOCO Technique are discussed as under

- It is non-invasive and harmless technique.
- It provides accurate information about the frequency and duration of contractions.
- TOCO can be wireless.

3.2.3 Limitation of TOCO Technique:

The limitations of TOCO Technique are discussed as under

- The TOCO has poor sensitivity and specificity in monitoring uterine contractions, especially in obese patients.
- As it is used to measure tension across the abdominal wall, it provides information about the frequency and duration of contractions, but not their amplitude.
- Maternal movement affects the accuracy of techniques.

3.3 Intrauterine pressure catheter (IUPC) Technique:

Intrauterine pressure catheter (IUPC), Technique is invasive technique in which a flexible tube is placed into the amniotic space during labor in order to measure the strength of uterine contractions. During labor, a woman's uterus contracts to dilate, or open the cervix and push the fetus into the birth canal. The catheter provides the information about the pressure within the amniotic space during contractions. This and allows the physicians to assess the strength, frequency, and duration of contractions. These measurements allow the experts to evaluate the development of labor and intervene when contractions are too weak to properly dilate a laboring woman's cervix to successfully deliver a fetus. The catheter is shown in figure 6. The sample waveform of EMG is shown in figure 7.
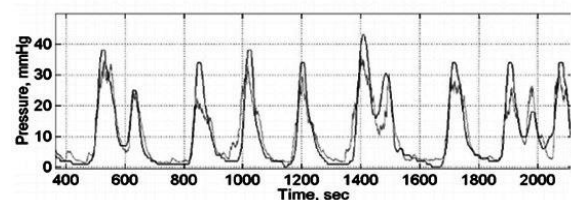

Fig – 6 IUPC sensor

Fig – 7 The IUPC waveform

3.3.1 Overview of Significant Research Work on EMG Technique:

American College of Obstetricians and Gynecologists suggested IUPC to be used when external methods do not provide a clear tracing of contractions, such as, in cases of maternal obesity or when response to oxytocin is limited [33]. They do not recommend routine use of IUPCs. Song X. et al., accomplished that IUPC directly measures the intrauterine pressure changes caused by UCs but is limited by its invasiveness which can cause ruptured membranes and infection [34]. Harper et al. identified the risk of insertion of catheter and concluded that routine use of an IUPC in laboring patients should be avoided [35].

3.3.2 Advantages of IUPC Technique:

The advantages of the NT technique for cardiac abnormality detection are

- It directly measures the intrauterine pressure changes caused by UCs.
- It provides exact measurements of contractions, unlike external monitors.

3.3.3 Limitation of IUPC Technique:

The limitation of NT technique is highlighted below

- It is invasive technique.
- It is recommended to be done by well-trained and experienced hands.

- Invasiveness can cause ruptured membranes and infection in uterus.

- Mobility of women is seriously hampered as these women are confined to bed.

3.4 Electromyography (EMG) Technique:

Electromyography (EMG) is another non-invasive technique used for identification of true labor through the action of myometrial electrical activity. These electrical activities are responsible for uterine smooth muscle contraction and relaxation. A burst of electric activity is generated whenever a muscle contract. These bursts are recorded using electrodes placed on the maternal abdomen surface to sense the electrical activity of the uterus and is able to monitor the frequency, duration, and intensity of uterine contractions without the obstetrical risks. The needle electrodes are placed near the navel closed to the midline. The surface is cleaned by alcohol to remove the excess oils and conductive gel is applied for proper interaction of electrode with myometrial tissues. The electrodes are connected to lead wires and cables which pass the uterine EMG signals on to an amplifier/filter. The uterine EMG signals are then displayed on a monitor and stored in a computer for later analysis. The electrode and the technique is shown in figure 8a and 8b respectively.
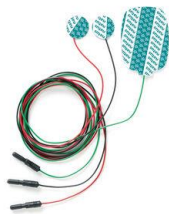

Fig - 8a EMG muscle sensor
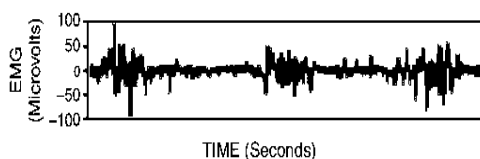

Fig - 7b EMG Monitoring Technique

Fig - 8 The Electromyography waveform

3.4.1 Overview of Significant Research Work on EMG Technique:

Many researchers used EMG signal as a source for assessment of true labor and concluded as one of the best techniques. Saila et al., 2021 [9] in comparison to TOCO and IUPC device is a recorded EMG of 110 patient and concluded that noninvasive are equally effective to the invasive IUPC technique and superior to the traditionally noninvasive TOCO technique. Song et al., 2021 evaluated EHG signals with conventional TOCO signal with the sensitivity, positive predictive value (PPV), and UC parameters. They observed the sensitivity and PPV are 87.8% and 93.18% for EHG, and 84.04% and 90.89% for TOCO and also concluded that EHG detected a larger number of UCs than TOCO [34]. Khalil et al. [35] used neural networks and wavelet analysis to perform contraction detection and classification. They observed overall accuracy of 80% for four event classes: Alvarez, Contractions, Foetal Movements and LDBF.

3.4.2 Advantages of EMG Technique:

- It is a promising non-invasive technique.

- It contains valuable information about uterine contraction.

- It is most comfortable for the pregnant woman during recording in comparison to TOCO and IUPC technique.

- No expert is required; a simple training can be given to the operator.

3.4.3 Limitation of EMG Technique:

- Most real-time EHG systems do not (yet) provide wireless connections.

- This noise and artifacts in the signal is a serious issue to be considered, as this adversely effects the quality of the signal.

4. COMPARATIVE ANALYSIS OF UTERINE CONTRACTION DETECTION TECHNIQUES:

In the previous sections, an attempted was made to describe and elaborate review of various techniques for identification of true labor through uterine contraction. A comparative analysis of these techniques is done in this section to find out a simple, non-invasive yet efficient diagnostic tool for detection of true labor during pregnancy. The analysis was carried out using different parameters such as simplicity, safety, economy, etc. From the above findings and literature review following conclusions has been drawn.

Manual palpation, which is used to identifies uterine contraction by palpating the abdomen over the uterine, needs expertise and routine assessment of this technique not suggested by expert before 36 weeks of pregnancy.

External tocodynamometry (TOCO) is the most widely used technique to monitor uterine activity during pregnancy and delivery. However, TOCO is most uncomfortable by the tightness of the belt and transducer position on the maternal abdomen. Additionally, it is prone to motion artifacts and inaccurate in obese women. Intrauterine pressure catheter (IUPC) directly measures the intrauterine pressure changes caused by uterine contraction but is limited by its invasiveness which can cause ruptured membranes and infection. It is only suggested when external techniques do not provide satisfaction information.

The result of comparative analysis of diagnostic techniques is summarized in Table 1.

Table -1: Result of Comparative Analysis of Diagnostic Techniques

Techniques → Parameters ↓	Palpation	TOCO	IUPC	EMG
Simplicity/ Minimal expertise	Expert is required	Simple	Expert is required	**Simplest**
Invasiveness	**Non-Invasive**	**Non-Invasive**	Invasive	**Non-Invasive**
Safety	Safe	Safe	Risky	**Safest**
Economy	No cost	**Economical as sensor can be reused**	Expensive	Moderate cost
Accuracy in identifying CHD	Not Accurate	**Accurate**	**Accurate**	**Accurate**
Comfortability of patient	Not Comfortable	Not Comfortable	Not Comfortable	**Comfortable**
Long term monitoring	**Possible**	**Possible**	Not preferred	**Possible**
Handling of diagnosis unit	No instruments	Difficult to handle	Most difficult to handle	**Moderate**

5. CONCLUSIONS

Half of the babies born at or below 32 weeks (2 months early) i.e. pre-maturely die due to a lack of feasible, cost-effective care. In order to minimize these deaths uterine contraction which is the result of the electrical activity within the myometrium should be monitored regularly through cost effective and safe technique. In the previous sections, we have attempted to describe and elaborate review of various techniques used for monitoring uterine contraction which gives valuable information of true labor. These techniques are palpation, TOCO, IUPC and EMGG. Their effectiveness, advantages and limitations were reviewed. From the descriptions and findings, concluded as under:

EMG is a promising noninvasive technology effective in external uterine monitoring. With electrodes placed on the maternal abdomen, EMG can provide a useful information of the myometrium activity. EMG is more reliable and similar in accuracy to TOCO in detecting uterine contraction compared to IUPC. It is applicable for long-term monitoring uterine activity throughout pregnancy and delivery.

The EMG technique is the simplest of all techniques, where as other techniques require special training and can only be performed in a clinical environment under the supervision of an experienced physician for recording the signals. The risk involved in IUPC technique is highest among these techniques as it is an invasive process.

Compactness, handling and portability of instrument in EMG are most convenient in all the techniques.

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