Techniques for Detection of Fetal Hypoxia from Cardiotocography Signals: A Survey

[1] K. ParvathSuman, [2] Dr.V. Subha

[1] Research Scholar, [2] Assistant Professor

[1], [2] Department of Computer Science and Engineering, [1], [2] Manonmaniam Sundaranar University

[1] parvathavarthine@gmail.com, [2] subha_velappan@msuniv.ac.in

Abstract— The massive growth in Medical Science department is providing a comfort life to human life cycle. New techniques are emerging day by day for the diagnosis of various diseases. Many of the diseases are successfully detected and cured for adults. Apart from these diseases, there is also some issues which causes sudden death. One of such issue is lack of oxygen for fetus during third trimester of pregnancy. As we already know, oxygen is the required gas for the survival of living organisms. Cardiotocography is generated by recording fetal heart rate and uterine contractions signals simultaneously and it is technically obtained from the mother's abdominal wall. Accurate interpretation of the FHR signals is particularly important because FHR signals carry vital information to help an assessment of fetal condition. Most pregnancy period complication leads fetus to a severe drawback that restricts correct growth that causes impairment or death. Predicting pregnancy risk levels before the occasion of complications encourage correct fetal growth. The CTG features that allow the clinician to recognize a fetus who may present with an antenatal insult such as chronic hypoxia, pre-existing non-hypoxic brain injury and fetal growth. This survey will briefly address the techniques leading to intrauterine hypoxia and their impact on the fetal cardiovascular system.

Index Terms—Cardiotocography(CTG), Fetal Heart Rate (FHR), Uterine Contractions (UC), Hypoxia.

I. INTRODUCTION

The intrapartum observation for fetal safety throughout labor and delivery is often performed by a technology referred to as electronic fetal monitoring or a cardiotocography, that provides continuous information on FHR and UC [1]. The CTG could be a straightforward and non-invasive tool which might give to clinician's correct indicators on fetal status. However, the analysis of the CTG involves interpretation of the advanced relationship between the FHR and the UC signals. An honest interpretation of CTG depends on the data, skills and experience of attention user to interpret FHR and UC signals so as to acknowledge the different features and patterns of those signals. This leads to vital intra- and inter- observer variations even though specific guidelines are revealed for its interpretation.

Hypoxia is a fetal and newborn child disease resulting from the lack of oxygen throughout labor may be a major drawback in midwifery. [2] Between one and seven in one thousand fetuses expertise hypoxia that's severe enough to cause fetal death or severe brain injury. sadly, clinicians should consider indirect measures of oxygen delivery and neurological perform so as to assess the fetal state. Contractions cut back fetal oxygen provide by compressing the umbilical cord or by decreasing gas exchange within the utero-placental unit, which may have severe consequences if the placenta is already impaired. In response, the fetal heart rate generally decreases, a feature called FHR deceleration. There's general agreement among clinicians that deceleration depth, frequency and temporal arrangement with relation to contractions are indicators of each the strength of the insult and therefore the ability of the fetus to resist it.

In the scientific research it has an efficient approach to analyse the CTG trace such as DR C BRAVADO' [3], where

- DR: define risk (any risk factors present during labor for that particular patient), C: contractions (defines the number of contractions per 10 min), BR: baseline heart rate, A: accelerations, VA: variability, D: decelerations and O: overall and then concluding with classification of the CTG trace according to the guidelines used.

At the birth time the diagnosis is performed by evaluating the cardio-respiratory depression and the muscle tone. The severity of the hypoxia is commonly quantified using the Apgar Score [4], with a score lower than 7 at five minutes after delivery being considered as pathological, which is usually confirmed with gas analysis of the umbilical cord, low pH values evidence metabolic acidosis. Typical values considered for diagnosis are pH _ 7.05, which are considered pathological in terms of risk of perinatal hypoxia. After the CTG generalization the two signs [5], [6] of suspicious fetal hypoxia namely late deceleration of the FHR and the FHR variability decrease are recognized.

The basic of clinical interpretation is visual pattern recognition and logical thinking, however are inconsistently applied and have low specificity [7]. Vital hypoxia is rare whereas false alarms are common, therefore, physicians typically disregard really abnormal signals [8], [9]. Thus, there are nice motivation to seek out higher strategies that discriminate between healthy and hypoxic conditions. The main goal of antenatal calculation is to recognize fetuses at danger for intrauterine damage and death so that intervention and timely delivery can avoid progression to death of a fetus [10], [11].

In this paper, we briefly focus our attention on the cause of chronic intrauterine hypoxia and how this affects the development and performs of the fetal heart. First, a brief introduction about CTG and Hypoxia. Second, we have given the technical aspects. Third, discussion about the clinical significance of fetal hypoxia. Fourth, hypoxia is categorized

into different types. Fifth, we describe our different general approach in fetal hypoxia. Finally, the conclusion is briefly explained.

II. TECHNICAL ASPECTS

The CTG is recorded using an electrical device placed on the maternal abdomen (external monitoring) or using an electrode placed on the fetal scalp (internal monitoring), and it's printed on a paper in a very similar way to an electrocardiogram. This can be the 'cardiac' a part of the CTG. The external electrical device is an ultrasound device that uses the Doppler principle. There's a second electrical device, the 'toco' part, that is additionally placed on the maternal abdomen below the uterine fundus, and it records the contractions. It's necessary to remember that this electrical device offers us info regarding the frequency and period of the uterine contractions, however not regarding their strength. The amplitude or the 'height' of the recording just reflects a modification within the tension of the anterior abdominal wall. Currently, there are intrauterine pressure catheters that may be placed within the uterus once the membranes are burst, and that they discover the strength of the contractions similarly because the frequency and period [11].
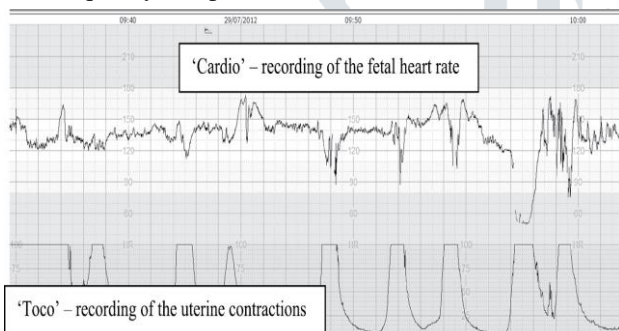

Figure 1. CTG Signal (a) Cardio - FHR signal with deceleration onsets. (b) Toco – UC signal with contraction onsets.

Before beginning CTG recording, it's necessary to see the maternal pulse to avoid incorrect recording of maternal heart rate as fetal [12]. External FHR observation is a smaller amount reliable than internal because it is additional doubtless to possess signal loss, record maternal heart rate or manufacture different signal artefacts, particularly throughout the second stage of labour. If there's a suspicion that the maternal heart rate is being monitored at any purpose in labour, it ought to be checked straight off, and internal observation employing a fetal scalp electrode (FSE) ought to be used, if applicable. There are contraindications for internal observation with the presence of infections like human immunological disorder virus (HIV) and viral hepatitis because of the danger of vertical transmission or fetuses with suspected or confirmed hurt disorders [11].

When beginning the CTG observation, it's necessary to confirm that 'paper speed' is about properly. In most countries, it's set at one cm/min; but, in the USA, it's set at three cm/min, and a few European centres use two cm/min. Failure to line the speed properly can end in errors on the proper interpretation of the FHR variability yet as in distinctive the depth and period of decelerations.

III. CLINICAL SIGNIFICANCE OF FETAL HYPOXIA

Intrauterine hypoxia related with maternal, placental, and fetal conditions may differ in outcomes between the mother and fetus [13]. It will occur in pregnant women living at high altitude and with cardiovascular disease. Low levels of oxygen in the fetus, commonly as a result of diminished placental perfusion, utero-placental insufficiency, or compression of the umbilical cord. The condition is typically accompanied by acidosis and is dangerous unless prompt interventions are undertaken to restore well-oxygenated blood to the fetus. Signs of early fetal hypoxia embrace tachycardia and enhanced variability of the fetal heart rate; deep fetal hypoxia is characterized by bradycardia and a sinusoidal fetal heart rate pattern.

IV. TYPES OF HYPOXIA

- We can classify intrauterine hypoxia into three categories [14]:
  1) Pre-Placental Hypoxia-
     where the mother and fetus are both hypoxic.
  2) Utero-Placental Hypoxia-
     where the mother's oxygenation is normal but the utero-placental circulation is impaired. As a outcome, both maternal and fetal consequences can occur.
  3) Post-Placental Hypoxia-
     Where the fetus becomes hypoxic.
- The descriptive terms are based on the onset and progression of hypoxic stress. During labour a fetus is potentially exposed to another three types of hypoxia is given below [3]:
  1) Acute Hypoxia:
     -Prolonged Deceleration.
     -Sudden drop in baseline heart rate.
  2) Subacute Hypoxia:
     -Fetus spending more time within the deceleration then at the baseline.
     -Recurrent 'atypical' variable or late decelerations, with or without 'Overshoots' and saltatory pattern between decelerations.
  3) Gradually Evolving Hypoxia:
     -First feature is commencement with the onset of decelerations followed by **ABCDE**:
        Accelerations Disappear.
        Baseline heart rate increases.
        Compensated stress.
        Decompensation.
        End stage.

In this paper author has additionally added the fourth type of hypoxia [3].
  4) Chronic Hypoxia:
     -Fetus exposed to long periods of hypoxia during antenatal period.
     -Secondary to chronic utero-placental insufficiency.

V. LITERATURE REVIEW

Fetal hypoxia can be detected using following approaches:

A. Fetal Hypoxia

The oxygen only plays a bit part within the early intrauterine development. When organogenesis has taken place hypoxia becomes additional necessary throughout the second and trimester of physiological condition once foetal growth happens. He [14] shortly mentioned regarding the cause and mechanisms resulting in intrauterine hypoxia and their impact on the foetal vascular system. Additional investigations are required to explore the preventative methods like the first use of antioxidants and selective

vasodilators to limit the consequences of intrauterine hypoxia.

The author has recommended some opinion [10] for the obstetricians with the antenatal tests would decrease fetal death without putting massive numbers of healthy fetuses in danger for premature delivery and therefore the associated morbidity and mortality. Despite widespread use of the many tests, restricted proof exists to demonstrate effectiveness at rising perinatal outcomes with application of those tests.

The clinical pointers created [3] by numerous national and international bodies are helpful in having a scientific approach to CTG interpretation and standardizing the word, understanding fetal physiology, incorporation of antenatal and intrapartum risk factors, use of further tests of fetal well-being, if applicable, are essential to enhance perinatal outcomes and to scale back redundant operative interventions.

The review has suggested that the fetal cerebroplacental ratio (CPR) at term includes a robust association with adverse obstetrical and perinatal outcomes. The prognostic utility [15] of CPR at term is promising but there is inadequate proof to demonstrate its value as a stand-alone test. Inclusion of CPR as a part of clinical care could facilitate higher determine fetuses in danger of adverse outcome, and this could be tested with randomized management trials.

A method was proposed to explore [16] the CTG options that enable the obstetricians to recognize a foetus who could present with an antepartum insult like chronic hypoxia, anemia, infection, fetal arrhythmias and pre-existing non-hypoxic brain injury. it is very important to recollect that "one guideline box doesn't match all babies" and they have planned a 'Foetal observation Checklist' to be performed at the start of each CTG recording to avoid the pitfalls of missing a pre-existing fetal injury.

In spite of several improvements are created within the field of intrapartum fetal observation, rates of cesarean sections stay spuriously high. Moreover, hypoxic-ischemic encephalopathy continues to have an effect on neonates globally. There is horrible necessity of a sufficiently specific test for fetal distress to lower the rate of cesarean sections, and recent advances aren't obtainable to the low-resource populations in dire need of them. Effective IPFM [17] should consider the successive utilization of two or additional observation methods to scale back the incidence of HIE, So the single method is not optimum.

B. Fetal Hypoxia using System Identification Modeling

This paper develops a replacement approach to the current drawback, that uses system identification methods, instead of feature extraction, as a pre-processing step. we tend to model the link between UP (as an input) and FHR (as an output) [18] employing a linear non-parametric model. Then we take special steps to deal with noise and guard against overfitting [19].

The author [20] also used the nonparametric system-identification methodology to evaluate system dynamics in terms of an impulse response function (IRF), that defines the linear, dynamic relation between very LF FHR energy (i.e., <30 mHz) and UP and it provides the robust parameter estimates from noisy CTG collected under clinical circumstances.

After some months he [21] again gone through this approach to make improvements in system modeling. The comparative merits of parameters were calculated from

system identification, baseline and HRV modeling for the early recognition of pathological fetus. The main idea is to absorb models of the fetal response to signals from its situation, using time series data recorded during labor and the parameters of these models as attributes in a binary classification problem [22]. A majority vote over some periods is taken to provide the recent label for the fetus.

C. Autoregressive Model

The author developed automatic techniques to interpret the CTG signal and supply a support system for additional objective physicians choices regarding fetal condition [23]. These approaches involve typically a signal pre-processing step, followed by the extraction of various signal features. Most of them use time domain and frequency domain features connected with FHR variability. The time domain features typically consist of statistical indicators computed from short and long term FHR signal analysis [24]. The frequency-based features are typically computed from operations performed over the energy of various spectral elements computed with FFT-based techniques [25].

The most difficulty of those works is that they do not exploit the pole-based illustration that AR spectral estimation provides. Moreover, within the case of [26], the AR spectral estimation is employed to analyze the reactivity level of the fetus and indirectly targeted on separating pathological fetus cases.

The main objective of this method [27] to extract several AR-based power spectral features from the FHR signal of a CTG recording, and to correlate these features with the fetal welfare in terms of umbilical pH. Hence, two groups of features are analyzed: a primary cluster that is extracted directly from the computed AR-base spectrum and another one is features extracted from the AR poles model. It is applied to real cardiotocographic signals and for various frequency bands, and also the obtained results are terribly promising as they exhibit direct correlations between the extracted features and also the fetal welfare in terms of umbilical pH.

D. FHR Complexity Measures

The concept of this work is tend to study about the FHR complexity modification because of perinatal hypoxia [28]. The complexity of the FHR was assessed by three completely different strategies, namely: SampEn, PE and TI. the two initial estimate the irregularity of a time series, whereas the latter estimates the asymmetry with relation to time reversal. It ought to be note that PE showed focused distributions in each groups.

E. Other Related Works

The infant outcome was analyzed by [29] the developing mechanism of abnormal FHR changes and hypoxia index determined with the total of deceleration length and nadir heart rate. fetal injury develops in cases of continual decelerations in long periods due to the summation of hypoxia in continual decelerations. The hypoxia index may be a helpful objective parameter to predict and stop hypoxic fetal injury in cases of continual decelerations and fetal acute bradycardia. FHR score and hypoxia index are terribly helpful new tools in computerized objective fetal diagnosing.

A replacement approach [30] of CTG analysis was proposed which supports the characterization of FHR decelerations represented by their variability as a signal of the fetal response consistent to a UC event. The core plan

was to review the behavior of those CTG patterns over time, since their growth so as to predict the abnormal condition.

CONCLUSION

In this study, we have briefly discussed about the fetal hypoxia with various detection methods. In the growing international population, and therefore the steady increasing prevalence of medical disorders in gestation that are related to a bigger risk of intrapartum fetal distress, the requirement for higher observation techniques can become additional imperative. There however remains a lot of work to be done by recent developments ought to reassure clinicians that higher tools could shortly become accessible, as analysis continues to advance. It is also clear that many researchers are consequently doing their research in this area with different aspects. There are many different detection techniques and we have discovered some recommendations to researchers such as FHR complexity measures, Hypoxia Index(HI), autoregressive model and so on. In this survey, the discussion is mainly focused on the various Fetal hypoxia detection and recognition techniques. This study can be expanded further by analyzing and various other techniques involved in detection, recognition, and databases. Later we can briefly discuss about the various datasets, feature extraction, classification techniques and feature selection.

REFERENCES

[1] G. Rooth, A. Huch, and R. Huch, "FIGO news: guidelines for the use of fetal monitoring," Int J Gynecol Obstet, vol. 25, pp. 159–67, 1987.

[2] ACOG, "Neonatal encephalopathy and cerebral palsy: Defining the pathogenesis and pathophysiology. ACOG Task force on Neonatal Encephalopathy and Cerebral Palsy," 2003.

[3] Ana Pinas, Edwin Chandraharan, "Continuous Cardiotocography during labour: Analysis, Classification and management," Best Practice & Research Clinical Obstetrics and Gynaecology, Elsevier 1-15, 2015.

[4] Apgar V. "A Proposal for a new method of evaluation of the newborn infant," Anesth Analg 1953; 32:260–267.

[5] Low JA, Victory R, Derrick EJ, "Predictive value of electronic fetal monitoring for intrapartum fetal asphyxia with metabolic acidosis," Obstet Gynecol February 1999; 93(2):285–91. ISSN 0029-7844.

[6] Ayres-de Campos D, Bernardes J, Costa-Pereira A, Pereira-Leite L. "Inconsistencies in classification by experts of cardiotocograms and subsequent clinical decision" Br J Obstet Gynaecol December 1999;106(12):1307–10. ISSN 0306-5456.

[7] J. T. Parer, T. King, S. Flanders, M. Fox, and S. J. Kilpatrick, "Fetal acidemia and electronic fetal heart rate patterns: Is there evidence of an association?" J. Matern.-Fetal Neonatal Med., vol. 19, no. 5, pp. 289–294, May 2006.

[8] E. Draper, J. Kurinczuk, C. Lamming, M. Clarke, D. James, and D. Field, "A confidential enquiry into cases of neonatal encephalopathy," Arch. Dis. Child. Fetal Neonatal Ed., vol. 87, pp. F176–F180, 2002.

[9] S. Ransom, D. Studdert, M. Dombrowski, J. Mello, and T. Brennan, "Reduced medicolegal risk by compliance with obstetric clinical pathways: A case-control study," Obstet. Gynecol., vol. 101, pp. 751–755, 2003.

[10] Erica O'Neill and John Thorp, "Antepartum Evaluation of the Fetus and Fetal Well Being," Clin Obstet Gynecol. 2012 September; 55(3): 722–730.

[11] Murray M, "Antepartal and intrapartal fetal monitoring". 3rd ed. Springer; 2007. ISBN: 0-8261-3262-6.

[12] Nurani R, Chandraharan E, Lowe V, et al "Misidentification of maternal heart rate as fetal on cardiotocography during the second stage of labor: the role of the fetal electrocardiograph," Acta Obstet Gynecol Scan 2012;91(12):1428e32.

[13] Loren P Thompson, Sarah Crimmins, Bhanu P Telugu, Shifa Turan, "Intrauterine hypoxia: clinical consequences and therapeutic perspectives," Research and Reports in Neonatology 79.110.28.53 on 02-Aug-2018.

[14] Damian Hutter, John Kingdom, Edgar Jaeggi, "Causes and Mechanisms of Intrauterine Hypoxia and its Impact on the Fetal Cardiovascular System: A Review", Hindawi Publishing Corporation, International Journal of paediatrics, Vol 2010, Article ID 401323, 9 pages, 2010.

[15] Liam Dunn, Helen Sherrell and Sailesh, "Review: Systematic review of the utility of the fetal cerebroplacental ratio measured at term for the prediction of adverse perinatal outcome", Elseiver, 2017.

[16] Susana Pereira, Edwin Chandraharan, "Recognition of chronic hypoxia and pre-existing foetal injury on the cardiotocograph (CTG): Urgent need to think beyond the guidelines," Porto Biomed. J. 2017;2(4):124–129.

[17] Myron Godinho, Somsubhra De, "Intrapartum fetal monitoring: pathophysiology and evolution of various techniques," Journal of Asian Scientific Research, 2018, 8(1): 30-41.

[18] P. A. Warrick, R. E. Kearney, D. Precup, and E. F. Hamilton, "Systemidentification noise suppression for intra-partum cardiotocography to discriminate normal and hypoxic fetuses," in Proc. Comput. Cardiol. 2006, vol. 33, pp. 937–940.

[19] Warrick, P. A., Hamilton, E. F., Precup, D., & Kearney, R. E. "Identification of the dynamic relationship between intra-partum uterine pressure and fetal heart rate for normal and hypoxic fetuses," (2008).

[20] Warrick, P.; Hamilton, E.; Precup, D.; and Kearney, R. "Identification of the dynamic relationship between intrapartum uterine pressure and fetal heart rate for normal and hypoxic fetuses," IEEE Transactions on Biomedical Engineering 56(6):1587–1597, 2009.

[21] Warrick, P.; Hamilton, E.; Precup, D.; and Kearney, R. "Classification of normal and hypoxic fetuses from systems modelling of intra-partum cardiotocography," IEEE Transactions on Biomedical Engineering, 2010.

[22] Warrick, P.; Hamilton, E.; Precup, D.; and Kearney, R. "A Machine-Learning Approach to the Detection of Fetal Hypoxia during Labor and Delivery," Association for the Advancement of Artificial Intelligence. All rights reserved. ISSN 0738-4602, 2012.

[23] G. Georgoulas, D. Stylios, and P. Groumpos, "Predicting the risk of metabolic acidosis for newborns based on fetal heart rate signal classification using support vector machines," Biomedical Engineering, IEEE Transactions on, vol. 53, no. 5, pp. 875–884, 2006.

[24] M. Cesarelli, M. Romano, and P. Bifulco, "Comparison of short term variability indexes in cardiotocographic foetal monitoring," Computers in biology and medicine, vol. 39, no. 2, pp. 106–118, 2009.

[25] J. Van Laar, M. Porath, C. Peters, and S. Oei, "Spectral analysis of fetal heart rate variability for fetal surveillance: review of the literature," Acta obstetricia et gynecologica Scandinavica, vol. 87, no. 3, pp. 300– 306, 2008.

[26] M. Romano, P. Bifulco, M. Cesarelli, M. Sansone, and M. Bracale, "Foetal heart rate power spectrum response to uterine contraction," Medical and Biological Engineering and Computing, vol. 44, no. 3, pp. 188–201, 2006.

[27] Alfredo Illanes, Michel Haritopoulos, "Fetal Heart Rate Feature Extraction from Cardiotocographic Recordings through Autoregressiv Model's Power Spectral-and Pole-based Analysis," 37th annual international conference of the IEEE Engineering in Medicine and Biology Society - EMBC 2015, Aug 2015, Milan, Italy. 2015. <hal-01203022>

[28] O´ scar Barquero-Pe´rez, Rebeca Goya-Esteban, Antonio Caaman˜o, Carlos Mart´ın-Caballero and Jose´ Luis Rojo-A´ lvarez, "Fetal Heart Rate Complexity Measures to Detect Hypoxia," Computing in Cardiology 2015; 42:133-136.

[29] Kazuo Maeda, "The development of late FHR deceleration and analysis of controversy FHR with hypoxia index," Res Rep Gynaecol Obstet 2017 Volume 1 Issue 3.

[30] Patricio Fuentealba, Alfredo Illanes, Frank Ortmeier, "Progressive Fetal Distress Estimation by Characterization of Fetal Heart Rate Decelerations Response Based on Signal Variability in Cardiotocographic Recordings," 2017.