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A Comparative Analysis of Feto-Maternal Monitoring Techniques Utilizing the Bio-Impedance Technique

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Abstract— It is impossible to overestimate the importance of the fetal monitoring approach in the field of obstetrics. The review study illustrates the wide range of fetal monitoring techniques used, from basic feto scope auscultation to more sophisticated electronic fetal monitoring (EFM) technologies in Engineering Society. The survey highlights the significance of constant monitoring throughout labor to identify any indicators of fetal distress and act quickly to ensure that necessary interventions are made in a timely manner. Furthermore, the paper presents an experimental study for Fetal Monitoring, which system is based on the bio impedance principle. The innovative technique described in this work is noninvasive, user-friendly, cost-effective, and suitable for mass health care, and it may be used by the impoverished population and basic health workers. Finally, the review highlights the importance of standardized protocols, continuous research, and healthcare professional training in order to increase the accuracy and effectiveness of fetal monitoring approaches..

Keywords- Feto- maternal monitoring, Electrical Impedance Techniques, Tomography, Imaging, Monitoring

I. INTRODUCTION *(HEADING 1)*

The way healthcare professionals evaluate the fetus's health during pregnancy and labor has changed dramatically as a result of the major breakthroughs made in fetal monitoring technology every year. Simple techniques like intermittent auscultation with a feto scope were widely used in the early 20th century [1]. However, the development of ultrasound technology in the middle of the 20th century made it possible to see the fetus and track its movements, ushering in a new era of prenatal treatment. The Cardiotocography (CTG), which allowed for continuous monitoring of the fetal heart rate and uterine contractions, was developed in the 1960s and improved the ability to recognize signals of distress. In the decades that followed, CTG technology was improved, including the addition of computerized systems and wireless monitoring, making it more effective and precise [2].

Fetal pulse oximetry and cutting-edge computer algorithms were integrated into monitoring systems in the 21st century, providing a more thorough evaluation of fetal health [3]. These developments have improved the ability of healthcare professionals to make knowledgeable judgements about interventions during labor by giving them access to real-time data. Fetal monitoring techniques develop yearly as technology progresses, promising increasingly more precise and individualized care for pregnant mothers and their unborn offspring. These advancements serve as a reminder of the medical profession's continued dedication to ensuring the greatest outcomes in obstetrics [4].

Feto-maternal monitoring is crucial for determining the health of the fetus during pregnancy and labor. Important factors for this assessment include fetal movements, size, head circumference, growth, amniotic fluid volume, and placental position [5]. These physiological and morphological characteristics of the developing fetus can be measured using a variety of monitoring methods. Despite their widespread use and scientific validity, these procedures might cause patients some discomfort and call for an obstetrician's constant supervision [6]. To achieve the best pregnancy outcomes, we contend that the creation of an accessible, non-invasive, ambulatory feto-maternal monitoring system is essential. As mentioned, the use of the Electrical Impedance methodology holds the potential to provide continuous monitoring of both physiological and morphological parameters, giving a more patient-friendly and effective method of fetal assessment during pregnancy and that used for recording and monitoring. Due to fetal movement & related parameters of fetus various changes takes at the surface. And we will done some phantom analysis for electrical impedance technique, based on dynamic and static phantom. Also, we will present the analysis of the dynamic phantom according to the number of electrode and methods of data acquisition of the electrical impedance technique [7]. Electrical impedance technique cannot replace Ultrasound and Magneto-cardiography, Cardiotocography, tocography, but has the potential to be used as a consultation tool [8].

All maternal systems must undergo physiological changes as a result of the particular immunological condition that is associated with pregnancy. The main goal of this complex procedure is to successfully start and maintain a healthy pregnancy. This requires a selective immune tolerance, immune suppression and immune modulation. Pregnant state is a complex dynamic system of acting endocrine and immunological factors that manifest the maternal fetal interface [9]. A more modern theoretical method for studying development is called dynamic systems. The most general definition of the word "dynamic systems" is "systems of elements that change over time." This method of approaching child development takes into account the significant effects that various body systems have on the fetus and the kid's anatomical, physiological, and behavioral characteristic

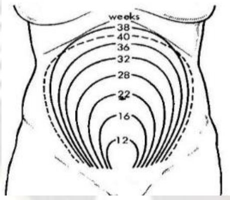

Figure 1: The change of uterus shape according to weeks

In this stage have the anatomical and physiological changes of pregnancy through the gravid period. Like in uterus, the cervix, the vulva, vagina and ovary, such as that, shown in figure of uterus. Physiological values and requirements, as well as normal laboratory assessment parameters, is dynamically changes [3].

A non-invasive technique to evaluate the electrical characteristics of tissues is the electrical impedance technique. Electrical characteristics of the tissue can change as a result of pathological changes to its structure and composition [8]. As a result, it is expected that the disease will cause modifications to tissue impedance. This method, which is frequently used to examine several bodily parameters, may potentially have an impact on the fetus's electrical properties. Electrical impedance measurements on dynamic phantoms can potentially be used to detect detectable changes [10]. Electrical impedance measurements and numerical simulations of phantoms and dynamic phantom models are used to further investigate this theory.

II. Literature Review

As per the literature review, we surmised that something that relates to the advancements in the EIT technique such as giving better Enhanced images using hardware and software algorithm, better Enhanced images using hardware and software algorithms, improvements in number of the electrodes can be used for better resolution of the image and can use for long-term monitoring with the can use for long-term monitoring of the fetus and also Evaluation of the Morphological & Physiological parameters from the images and data acquired from Electrical impedance technique, such as shown in table 1. Of Literature review on fetal Monitoring as per the previous research.

III. Fetal Monitoring Techniques

Modern medical research is committed to the continuous improvement of diagnostic instruments, with an emphasis on the creation of innovative, non-invasive, and long-term patient monitoring strategies [12]. The need to lower healthcare costs is a major driver of these advancements, which has led to the development of more affordable methods such direct bio-signal recording from the body's surface. Due to the fact that non-invasive techniques can be used both throughout pregnancy and labour, they have become the norm in professional practice. Contrarily, due to its sensitivity to maternal and fetal movements, fetal Doppler ultrasound is used during pregnancy but not during labour. Additionally, there are still worries about the potential long-term effects of continuous ultrasound exposure on fetuses and newborns, necessitating caution and restricting its usage for prolonged monitoring [27]. These factors highlight the need for alternate strategies and have led to substantial research into non-invasive recording systems for fetal monitoring. Foetal monitoring is an essential procedure used during the course of pregnancy, labour, and delivery to keep track of the fetus' movements as well as the frequency and intensity of uterine contractions. Examining your baby's motions is a great way to gauge how they are doing and can also reveal any potential problems. Internal monitoring and external monitoring are the two main methods used in fetal monitoring [28].

A. Internal Monitoring

Internal monitoring entails strapping a sensor to the thigh. A thin wire (electrode) is painstakingly pushed into the vagina, through the cervix, and into the uterus from this sensor. The scalp of the infant is firmly fastened with this electrode. The infant's heartbeat can be heard as a series of beeping noises or can be seen visually on a chart [29]. Internal monitoring does not rely on reflected sound waves (ultrasound) for its observations, in contrast to exterior monitoring. Internal fetal monitoring, which uses a scalp fetal ECG to detect, record, and analyze fetal heart activity, is an invasive fetal monitoring technique (IFM) that is frequently used during labour. Both the mother and the fetus may experience discomfort and difficulties as a result. Additionally, once the fetal membranes have broken, this procedure can only be used [10].

B. External Monitoring

Various tools and gadgets can be used to perform external monitoring. One technique, for instance, involves hearing the baby's heartbeat with a special stethoscope. The more typical method of external monitoring, however, involves a pair of flat sensors that are fastened to your belly using elastic belts [27]. The vital signs of your unborn child are monitored by one of these sensors using reflected sound waves (ultrasound), while the other sensor timers the length and force of your contractions. A device that stores and processes this data is connected to these sensors [12]. Ultrasound and magneto-cardiography are a couple of examples of these external monitoring techniques. In Ultrasound, Prenatal ultrasounds use sound waves to provide a visual depiction of the developing child, placenta, uterus, and other pelvic organs. They are a noninvasive diagnostic treatment. High-frequency sound waves are sent through your uterus during the examination by a qualified ultrasound technician, commonly known as a sonographer, who then bounces the waves off the developing fetus. The baby's form, position, and motions are then precisely captured in real-time video images by a computer using these echoing sound waves [30]. However, with Magneto-Cardiography (MCG), the heart's electrical activity creates a voltage difference on the body's surface as well as a magnetic field that extends outside of the body. MCG is a non-invasive electrophysiological mapping technique that provides unmatched insights into how electrical currents in the heart are produced, localized, and behave dynamically [29].

C. Abdominal Recordings

For continuous fetal monitoring, abdominal recording is a non-invasive approach that works well. It involves using surface electrodes to collect electrical signals coming from the mother's abdomen. This technique is preferred since it is inherently safe, boosting both the mother's comfort and the fetus's wellbeing. Furthermore, when combined with a sensor-equipped belly belt, it provides the benefit of continuous monitoring throughout the duration of pregnancy. Like tomography techniques (EIT), it is a bio-impedance measuring method. It helps in monitoring & recording of distributed electric field over a closed object [30].
Ultrasound and Magneto- cardiography, Cardiotocography, tocography, are different methods, which are used during labor for feto-maternal monitoring. These methods have some restriction in real time monitoring & due to which patient as well as fetal face inconvenience [5].
The limitations created by above-used techniques is overcome by a proposed method called non-invasive bio-impedance. Electrical Impedance Tomography is a technique for measuring bio-impedance that is used in this method [31]. It is used to track and keep track of the dispersed electric field within a closed object. Distinct adjustments appear on the surface as a result of fetal movements and dynamic changes in the fetus's numerous physiological and morphological factors. These modifications provide insightful information about the health and status of the fetus. [24]

IV. ELECTRICAL IMPEDANCE TOMOGRAPHY

The theory behind electrical impedance tomography is that by applying a constant current across a material the voltage distribution resulting on the surface will reflect the internal resistivity distribution [32]. However, intuitively one will understand that multiple resistivity distributions can produce the same voltage distribution at the surface. Therefore, the system is stimulated in various manners to constrain the possible resistivity distributions. The figure 2 shows a simple EIT diagram.

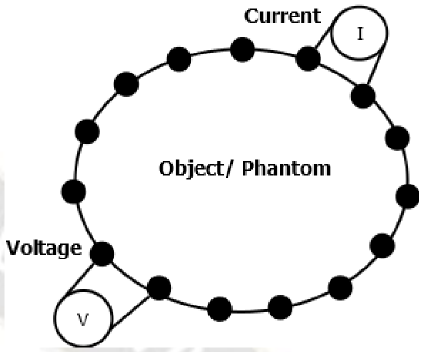

Figure. 2: - EIT Diagram

An innovative method for visualizing an object's interior architecture without interfering with its regular operations is electrical impedance tomography (EIT) [33]. It is used in aqueous-based procedures that include mixing miscible liquids, solid-liquid mixtures, cyclonic separation, and other activities. The advantages of EIT include its non-invasive, economical, non-destructive, radiation-free, and visualization-focused methodology. Using surface electrical measurements, Electrical Impedance Tomography (EIT) is used in the field of medical imaging to produce images that represent the conductivity or permittivity of particular body regions. To make the imaging procedure easier, conductive electrodes are typically attached to the subject's skin and tiny alternating currents are injected through a few electrodes [34].

A. Method of Data Acquisition

In the Bio-impedance have many methods such as the Neighbouring method, In this method the current position is applied on Neighbouring electrodes and measuring voltages from all other adjacent electrode sets. the applied current location is on two Neighbouring electrode and the voltage is measured sequentially with respact to refrance electrode. After that change the current location then determine the voltage measurements from the other electrode pairs. For an EIT system, {N (N-3)} (N= No of electrode) voltage measurements are obtained. In Opposite method, The electrode next to the electrode injecting the current serves as the voltage reference point in the opposite technique, which includes injecting current through two opposing electrodes [35], [36]. Following that, voltage readings are gathered from all other electrodes aside from the reference electrode and the current-injecting electrodes. For each subsequent current electrode, this process is repeated. The opposing strategy generates a significant 104 data points (813) for analysis when using a set of 16 electrodes. The relatively uniform current distribution produced by this method increases its measuring sensitivity. The cross method, on the other hand, produces a more even distribution of current by inserting the current between two electrodes that are farther off from one another [37]. In this method, current injected on crossed manner (manner may be odd and even). After that the voltage is measured successively for all other electrodes with respect to reference electrode. The cross approach delivers higher sensitivity over the entire region, even if it doesn't demonstrate the same level of sensitivity in the periphery as the neighbouring method. And measurements of electric impedance at the body's surface serve as the basis for the analysis in Impedance Plethysmography (IPG), a technique used to evaluate shifting tissue volumes within the body [38].

B. Hardware- Software

The experimental work of Electrical Impedance Tomography (EIT) is the focus of my study. I next used the built system to carry out an experiment involving feto-maternal monitoring in which I collected information on morphological and physiological characteristics [32]. We used this information to reconstruct images using the Electrical Impedance Tomography (EIT) system in the end, and I produced a top-view block schematic of the arrangement. An array of electrodes acting as EIT-sensors, a combination of digital and analogue circuits, and a PC for data processing make up the Electrical Impedance Tomography system. Use of the proper algorithms allows for the successful completion of the image reconstruction. Precision current sources and data capture components are essential elements in the analogue hardware sector. A microcontroller unit is used on the digital front, with the possibility to use a programmable system on chip (PSOC) [33].

A variety of mathematical methods are used using the data gathered from the phantom to recreate the resistivity image. These algorithms start by initializing a conductivity value, and then compute potentials at the locations of the electrodes from that value. The measured potential measurements and the estimated potentials are then compared. The finite element method (FEM) mesh used in this procedure, which consists of triangular elements and nodes, is used to solve both forward and inverse issues [39]. In the forward problem, the potentials are computed using a preset current injection pattern, the magnitude of the current, and the expected conductivity of the homogeneous medium [40-42].

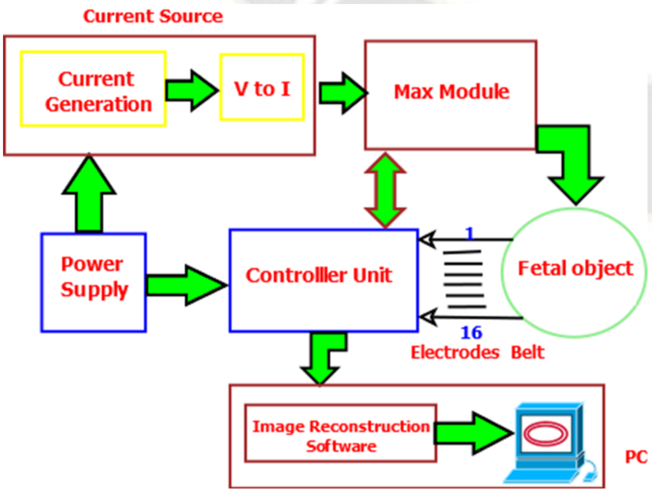

Figure 3: EIT Block diagram for fetal monitoring

C. Experimental Work

The monitoring of fetal well-being is an essential component of prenatal care, serving as a means for healthcare practitioners to evaluate the condition of the fetus during the course of pregnancy and during the process of labour. Different methods are utilized for monitoring the fetus, and the combination of impedance plathysmography (IPG) and electrical impedance tomography (EIT) has demonstrated potential in offering significant information regarding fetal well-being.

Impedance plathysmography (IPG) is a non-invasive methodology utilized to assess respiratory activity by measuring alterations in thoracic impedance. Fetal monitoring employs the use of Impedance plathysmography (IPG) to evaluate fetal breathing movements. This is achieved by detecting alterations in thoracic impedance resulting from the expansion and contraction of the fetal chest during the breathing process. The presence of deviations in fetal breathing patterns might serve as an indication of prospective complications regarding the overall health of the fetus. Consequently, the utilization of intermittent positive pressure ventilation (IPG) proves to be a valuable method for evaluating the respiratory functionality of the fetus.

Electrical Impedance Tomography (EIT) is a medical imaging modality that employs electrical data to generate cross-sectional pictures of the human body. Within the realm of fetal monitoring, electrical impedance tomography (EIT) has the capability to offer instantaneous data regarding the spatial distribution of electrical impedance within the uterus. This enables the observation of alterations in blood circulation, organ performance, and tissue composition. Electrical impedance tomography (EIT) has the capability to detect probable anomalies in fetal circulation and tissue perfusion by monitoring alterations in impedance.

The integration of impedance plathysmography (IPG) and electrical impedance tomography (EIT) has the potential to provide a thorough evaluation of fetal well-being. This combined approach enables the simultaneous measurement of respiratory activity and physiological alterations occurring within the uterus. The utilization of this integrated method facilitates enhanced monitoring of fetal health by healthcare practitioners, leading to the early identification of potential difficulties. Consequently, this enables prompt intervention and enhanced management of pregnancy-related concerns. Although the integration of IPG and EIT (Electrical Impedance Tomography) shows potential in improving fetal monitoring, it is crucial to acknowledge that this methodology may currently be in the experimental phase or undergoing additional research and development. Hence, the extensive utilization of this approach in clinical settings could be constrained until additional investigations substantiate its effectiveness, safety, and feasibility in standard prenatal healthcare. Healthcare professionals and researchers persist in their efforts to investigate novel technologies and approaches in order to better fetal monitoring and optimize outcomes in prenatal care.

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V. Experimental Work for Feto-maternal Monitoring

In experimental work, we will done some phantom analysis for electrical impedance technique, based on dynamic and static system. Firstly we make a dynamic phantom, Created with similar properties of the uterus. After that we will be calculating impedance distribution of phantom using IPG , electrical impedance technique. The phantom analysis will be done according to the number of electrode (may be used 2, 4, 8, 16) and methods of acquisition (Neighbouring, opposite and cross methods) of electrical impedance technique. Finally we will Evaluation the Morphological & Physiological parameters related to fetal from the data acquired from phantom analysis.

A. Impedance Plathysmography based Results

The excitation current is applied to the participants through the E1 and E3 electrodes. Following this, the voltage is quantified by measuring the potential difference between the E2 and E4 electrodes, thereby establishing the first electrode placement. Subsequently, the present location is modified to the E2 and E4 electrodes, and the voltage across the E1 and E3 electrode positions is calculated, so establishing the second position. The impedance measurements obtained are displayed in the table provided below.

Table 2. Experimental on different phantoms through IPG

S. No.	**Experimental Phantoms**	**Impedance of 1st position** (E2 & E4)	**Impedance of 2end position** (E1 & E3)	**Current**
1.	Potato	1.55mv	0.68mv	0.6 mA 10 kHz and 100 kHz
2.	Cabbage	2.31mv	2.34mv	
3.	Onion	1.72mv	2.15mv	
4.	Orange	1.77mv	2.2mv	
5.	Capsicum	3.5mv	3.05mv	
6.	Red chili	0.64mv	2.86mv	
7.	Human body	0.3 mv	0.42 mv	
8.	Papaya	1.15mv	1.05mv	
9.	Plastic box	4.38mv	3.89mv	

B. Electrical Impedance Tomography based Results

In experimental work, we will do some phantom analysis for electrical impedance technique, based on the dynamic and static system. Firstly we make a dynamic phantom, Created with similar properties of the uterus. After that, we will be calculating impedance distribution of phantom using electrical impedance technique. The phantom analysis will be done according to the number of electrodes (may be used 4, 8, 16) and methods of acquisition (Neighbouring, opposite and cross methods) of electrical impedance technique. Finally, we will evaluate the Morphological & Physiological parameters related to fetal from the data acquired from the phantom analysis. In order to recreate images using electrical measurements collected from electrodes attached to the mother's body, the EIT imaging approach relies on the internal conductivity distribution within the body. In this procedure, a pair of input electrodes are used to introduce a low-level, alternating current (usually in the milliampere range) with a frequency between 10 kHz and 100 kHz. The remaining electrodes' output voltages are then measured to determine the results.

Figure 4: Experimental Setup for Fetal with Mother

From the above experimental work to validate the proposed strategy. It was chosen because it can successfully imitate the characteristics of the human uterus. On the mother body, sixteen electrodes were placed in various locations. Following the current patterns recommended by the EIT approach, voltage measurements were then taken at certain locations. For reference, the measurement results are shown in Table 1. of Impedance distribution for one current location.

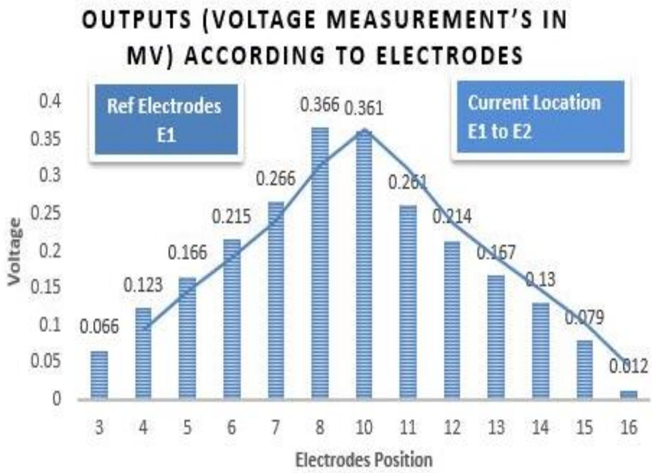

Figure 5: Impedance Distribution for one current location

The graph depicting impedance distribution provides a visual representation of the spatial variability of impedance within a designated area. By subjecting a consistent electrical current to a specific site, the resulting impedance measurements at several locations are utilized to characterize the electrical properties of the tissue and identify any deviations or abnormalities. The presented visualization facilitates the detection of regions exhibiting distinct conductivity or impedance patterns, which may suggest disparities in tissue composition, blood circulation, or physiological functioning. The utilization of impedance distribution graphs in medical diagnostics is highly advantageous, as they provide a more extensive comprehension of the internal dynamics and functional attributes of biological tissues or organs at a designated present place.

As per obtained data from the experimental setup for stomach, have two basic images obtained through the image reconstruction algorithm as shown in the figure below. In this

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figure 6 (A), a 2D image of this experiment and Figure (B) Contour view of this image.

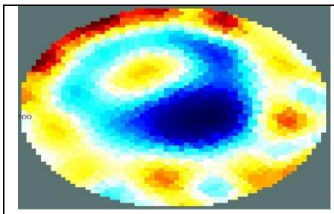	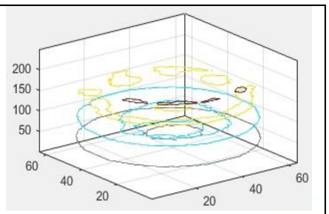
(A) A 2D Image through the Image Algorithm	(B) Contour View Of Image

Figure 6: Final results

Bio impedance monitoring techniques have become more important in the field of fetal monitoring, making a substantial contribution to the thorough evaluation of fetal well-being throughout pregnancy and labour. Impedance IPG and EIT are non-invasive procedures that enable the continuous assessment of different physiological or Morphological parameters in the fetus, including respiratory activity, tissue perfusion, and blood flow dynamics. Bio impedance monitoring offers the advantage of delivering real-time and unbiased data, which aids in the timely identification of any irregularities or indicators of distress. This capability empowers healthcare practitioners to swiftly intervene and effectively address any developing issues. The utilization of bio impedance techniques enables healthcare providers to maintain a consistent and ongoing assessment of the fetal health condition during the various phases of pregnancy. This capability facilitates prompt interventions and individualized healthcare provisions, thereby maximizing the overall health and welfare of both the expectant mother and the developing fetus.

Although bio impedance monitoring techniques provide notable advantages in the field of fetal monitoring, there exist a number of obstacles that must be overcome in order to optimize their efficacy and suitability for use in clinical environments. One significant obstacle lies in the intricacy of interpreting bio impedance data, as impedance fluctuations can be influenced by a multitude of physiological factors. Consequently, healthcare professionals must possess a comprehensive comprehension of the intricate relationship between changes in impedance and the well-being of the fetus. Furthermore, the logistical and cost implications of acquiring modern and specialized equipment for bio impedance measurements can present a significant obstacle in healthcare facilities, hence constraining the general implementation of these methodologies. The paramount importance of safeguarding the well-being of both the maternal and fetal entities during bio impedance monitoring methods remains a matter of utmost significance. Consequently, it is imperative to establish rigorous protocols and guidelines to mitigate any potential hazards that may arise from the administration of electrical currents. In addition, it is imperative to establish standardized techniques and guidelines for the interpretation of bio impedance data in fetal monitoring in order to maintain uniformity and dependability across diverse healthcare environments. The utility of bio impedance monitoring techniques in fetal monitoring can be greatly enhanced by addressing these challenges through ongoing research, advancements in technology, and the development of comprehensive guidelines. This improvement has the potential to positively impact pregnancy outcomes and improve the management of maternal-fetal healthcare

VI. Comparison of Feto-meternal Technique

Many technique have for fetus monitoring technique and also discoursed above literature and others details. Also have choice for patents as per the present clinical scenario, so we shown the comparison table according to below different points such as comprehensive assessment, Continuous monitoring, information etc., such as shown in Table 4.

VII. Discursion

Feto-meternal monitoring during pregnancy can be accomplished through the use of Electrical Impedance Tomography (EIT), a promising and cutting-edge technique. This non-invasive imaging method has demonstrated significant promise in delivering real-time details about both the maternal and fetal states, allowing a thorough assessment of physiological changes throughout pregnancy and labour. The capability of EIT to constantly track variables including lung impedance, heart activity, and uterine contractions can considerably aid in the early identification of potential difficulties and the prompt intervention required to protect the welfare of both the mother and the fetus. It can be especially helpful in situations when typical monitoring techniques may be constrained or ineffective. It's important to recognize that while EIT has a lot of potential, there are still a number of issues that need to be resolved. In order to evaluate its efficacy and safety in many therapeutic contexts, they include performing more extensive clinical trials, optimizing signal processing methods, and enhancing the spatial and temporal resolution of EIT images.

Feto-maternal monitoring is the most important from the initially life and more needs to advancements of this area or applications. Many points to be covered as per the developments or advancements of the feto monitoring system with the make a real portable feto-maternal Monitoring System. This system may be covered the many things such as the identifies the healthy fetus from growth restricted fetus, Low cost, portable instruments, Non-invasive nature

VIII. Concussion

In conclusion, the Electrical Impedance Tomography (EIT) method of feto-meternal monitoring during pregnancy is a promising and cutting-edge approach. This non-invasive imaging method has demonstrated significant promise in delivering real-time details about both the maternal and fetal states, allowing a thorough assessment of physiological changes throughout pregnancy and labour. In conclusion, by offering continuous, non-invasive, and dynamic insights into the mother and fetal physiology, EIT has the potential to completely transform feto-meternal surveillance. EIT may become a crucial component of obstetric care as technology develops and study in this area progresses, ultimately raising the standard of care given to pregnant mothers and their unborn infants. The full potential of EIT in feto-meternal monitoring must be realized through additional research and development work for it to become a useful tool in modern obstetrics

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Table 1: Literature review on fetal Monitoring as per the previous research

Author	Technical Information	No of Electrode and Simulator	Application/ Object
Sarwan kumar, et al. 2013 [11]	A non-invasive EIT monitoring system for fetal.	16 FEM, Matlab	fetal
Maria D. Velazquez, et al. 2002 [12]	The overview of fetal Antenatal Evaluation t Monitoring.	Ultrasound-based	fetus
T Bera, J nagraju 2011 [13]	EIT imaging system for medical appliaction through Labview.	16 (Agcl),Lab view	Human body
K. Aleksanayan Grayr, et al. 2015 [14]	A complete system for EIT of biological objects.	16	Biological objects
V. E. Arpinar, B.M. Eyuboglu, 2001 [15]	Developmental of EIT system through microcontroller controlled with multi-frequency.	16/Labview for data collection	Phantom
Beyhan Kilik, Mehmet Korurek 1997 [16]	An image reconstruction technique using neural network for EIT. (1997)	16 E /FEM/ neural network	phantom
Shuai Zhang, et al. 2012 [17]	A 3-D model for human thorax using finite element method.	16 E in form of 4 rows/ Matlab	Human body
Zhang Cao, et al. 2012 [18]	A 3D ERT by using factorization method.	Analysis of the tool.	phantom
Magdalena Stasiak, et al. 2007 [19]	Analysis through the neural Network for EIT.	16 E, NN network mat lab	Biological objects
S. K. Pahuja, et al 2011 [20]	An image reconstruction and Feto-maternal monitoring.	4/8/ E Matlab	Papaya and plastic box
Sarwan Kumar, et al. 2010 [11]	fetus movement and uterine contractions	Acoustic sensor	fetus
Mascot, B., Gehin et al. 2009 [21]	A health monitoring hardware based on the Programmable system	Hardware based on PSOC	Human
A. Chowdhury et al. 2015 [22]	Review on Impedance variations in banana using EIS.	4 E Ag/Agcl	Banana
Sunjoo Hong et al. 2014 [23]	A real-time lung ventilation monitoring system.	Hardware based on PSOC	Lung Ventilation
Chatziioannidis I. et al. 2011 [24]	A new study for Neonatal Respiratory Distress Syndrome using EIT.	Medical electrode According to body	Child baby
Andrea Fanelli, et al. 2010 [25]	A wearable system for remote fetal monitoring during pregnancy.	8 E (Ag/Agcl)	fetus
R. Harikumar, et al. 2013 [26]	A review of EIT and its medical application. (2013)	8/16 E Matlab	lungs

Table 3. Impedance distribution for one current location

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I (MA) location	Outputs (voltage measurement's in mV) according to electrodes												
1-9 Ref 2	3 .066	4 .123	5 .166	6 .215	7 .266	8 .366	10 .361	11 .261	12 .214	13 .167	14 .130	15 .079	16 .012

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Table 4: Comparison of different Feto-meternal Techniques

Fetal Monitoring Techniques	Type	Parameters	Spatial Resolution	Temporal Resolution	Application	Long-term Monitoring
Ultrasonography	Non-Invasive	FHR, blood flow, umbilical flow	Real-time	Variable	Monitoring, Detecting Abnormalities	No
Cardiotocography	Non-Invasive	Fetal anatomy, growth	Real-time	NA	Monitoring, And Development	No
Doppler Ultrasound	Non-Invasive	Fetal heart rate, blood flow, umbilical flow	Real-time	High	Routine Monitoring, Detecting Abnormalities	No
Fetal Electrocardiography	Non-Invasive	Fetal electrocardiogram	Real-time	N/A	Monitoring Fetal Heart Rate, Rhythm	No
Bio-impedance Monitoring technique	Non-Invasive	Maternal and fetal impedance changes	Real-time	Moderate to High	Monitoring, with Physiological Changes	Yes