RESEARCH
O&G Forum 2024; 34-3s: 3035-3048

FUTURE OF PREGNANCY CARE IOT INTEGRATION FOR BETTER MATERNAL AND FETAL MONITORING

[1]Dr Anupama P.Patil, [2]Dr Adhish S.Banad

[1]Professor Dept of Electronics and Communication Engineering Biluru Gurubasava Mahaswamiji Institute of Technology Mudhol
Email id: anubanad@gmail.com
[2]Junior Resident(tutor), GMERS medical College and hospital, Valsad.
Email id: adhishbanad@yahoo.co.in

Abstract
The use of managed IoT devices provide new approaches to enhanced monitoring of pregnant mothers and the fetus. This paper describes future possibilities of pregnancy care through IoT systems, and consider impacts of development of wearable device, smart gadgets, and related healthcare systems on the enhancement of prenatal surveillance, identification of risk factors, and optimized approaches to care. Drawing out current developments, prospects and problems we outline the future of IoT mediated maternal care that can enhance the prognosis for pregnant women, reduce maternal mortality, and increase patient satisfaction.

Keywords: pregnancy care, IoT Integration, Maternal and Fetal Monitoring

1. Introduction

Pregnancy is surely one of the most important events in a female's life when there is a constant need to monitor the condition of both the mother and baby [1]. In previous decades, it has been done by planning routine appointments with practitioners during which the head, heart, lungs, abdomen, and kidneys of the patient, fetal movements, positions, and breathing, or lack of them, etude and intake of food, as well as weight gain, are checked. However, it is common to have periodic check-ups to accomplish these assessments but there are always large gaps between check-ups delineating the inability to track the dynamic changes that may occur within the mother and fetus constantly [2]. They can contribute to the failure of early identification of complications which can be risky both to the mother and her child.

Therefore, the use of IoT to Integrate pregnancy care presents the best opportunity to meet these challenges [3]. IoT is considered as a connection of various devices that may gather, process and transfer information with the help of internet connections real-time. In terms of healthcare this technology is revolutionizing how patient data is collected and viewed, offering real time tracking of a patient's condition on a constant basis [4]. In pregnancy care, the different IoT devices including the wearable sensors, connected medical devices, and mobile application to monitor the vital important health standards to facilitate the healthcare providers to deliver appropriate and preventive care [5].

In this paper, the author examines the prospects of pregnancy care using the IoT concept, with an emphasis on monitoring of the mother and the unborn child [6]. It provides an overview of current IoT use in prenatal care, the opportunities realized by continuous and patient-tailored care, and the technological, ethical, and legal issues that still require solving. Through these aspects, we discuss about the significant role of IoT in hereby defining the positive pregnancy outcomes, early detection of complications, and good experiences of patients.

Because the use of IoT technology is increasingly becoming widespread and affordable, it is expected that in the process of pregnancy care, IoT technology will play an even more significant role as a basic element to manage maternal and fetal health [7]. The vision for the future is to have people, especially mothers and healthcare providers, work proactively using real-time data and support as the key to prenatal care.

2.Overview of IoT in Healthcare

2.1 Introduction and Understanding About IoT in Healthcare

The Internet of Things or IoT is the collective term given to the connection of devices, sensors and systems that are connected and can exchange information via the internet. These devices vary from smart accessories like wristbands, to smart clothes to sophisticated element-like heart or insulin monitors. In healthcare, IoT is used in real-time monitoring, remote data collection and transmission, self-management and real time analysis of data from a patient thereby offering health services regardless of location and nearby hospital or clinic services.

The utilization of IoT in the healthcare sector has shifted usual patient care by availing monitoring of distant patients, risk prevention, and better handling of constant illnesses [8]. It involves the consumption of less institutional resources and overall facilitates more patient-oriented proactive participation. In addition, those devices encourage timely information gathering for better decision-making by the healthcare stakeholders for early diagnosis, action, and treatment.

It is a mature market and for IoT in healthcare is being used for areas like Chronic Diseases, Elderly care, Remote health monitoring and Maintaining medication compliance, Hospital automation etc. But one of the most attractive fields is prenatal and pregnancy care where IoT becomes really a powerful means to enhance perinatal and prenatal situations.

2.2 Applications of IoT Technology in Pregnancy Today

Fortunately, the application of IoT into pregnancy care has already been witnessed through smart devices as well as wearable technologies. They offer expectant mothers health information of themselves and the fetus to alert the obstetrician and prevent adverse effects due to delayed treatments.

Key IoT applications in pregnancy care include [9]:

- Wearable Health Trackers: Pregnant women use gadgets including smartwatch and fit bands which track signs including heart rate, oxygen levels and physical activity. The use of these continuous measurements is useful in tracking the condition of the mother to make early detection of problems such as preeclampsia or gestational diabetes possible.

- Smart Blood Pressure Monitors and Glucose Meters: These IoT devices enable tracking of blood pressure and glucose levels early as part of diagnosing hypertensive disorders or gestational diabetes. Clinical data can be conveyed inter-professionally in real-time and decisions can be made promptly if the analyzed data call for it.

- Fetal Monitors: Mobile belly triggers and intelligent fetal heart rate to monitor fetal movements, fetal's heart rate, and maternal contractions. It is because these devices are highly effective especially when carrying out constant fetal monitoring in complicated pregnancies. They keep patients with pregnant conditions updated with their conditions without frequent hospital checkups, something that benefits expectant mothers while easing pressure on hospitals.

- Telemedicine and Mobile Apps: Telemedicine services integrated with IoT-enabled mHealth applications help expectant mothers to get professional advice, monitor their pregnancy status and get recommendations without visiting a healthcare facility. Information from these IoT devices can be feed into these platforms and offer a holistic view of the maternal and fetus status.

These technologies not only enhance surveillance during pregnancy, but also cut down the number of required face-to-face meetings which would otherwise put much stress on pregnant women and the health care system. IoT enables the healthcare experts to stay in touch with their patients and anticipate possible complications from occurring then work towards preventing them.

3.Transformative Potential of IoT in Maternal and Fetal Monitoring

Introducing IoT into monitoring pregnancy is a progressive advancement from symptomatic, separate pregnancy services to constant and genuine tracking of mother and child health. This change can play a major role in improving pregnancy outcomes through better understanding of the needs of individual patients, early identification of potential problems, and increases patient participation [10]. In this section, various critical areas that IoT is transforming maternal and fetal monitoring will be discussed.

3.1 Continuous and Real Time Monitoring

Smart apparels, wearables, and connected health care devices that are associated with IoT have the potential of keeping track other health parameters of both the expectant mothers as well as of the fetuses. This real-time data collection helps fill one of the biggest voids in conventional prenatal care when health checks are only done at sporadic clinic appointments.

For instance, wearable technologies can monitor maternal pulse, blood pressure, saturation, and glucose levels at any one time, or the fetal monitor tracking baby's pulse and movements. This information is sent to the healthcare providers in real-time, and any changes, complications like gestational diabetes, preeclampsia or fetal distress can be noticed early [11]. Thanks to IoT, medical interventions can be made in time to avoid such problems as premature birth or even a stillbirth.

Furthermore, constant observation of health data in the comfort of the home decreases the interactions between expectant mothers and healthcare facilities as a way of reducing the pressure on hospitals while at the same time offering comfort to such mothers…

3.2 Personalized Prenatal Care

IoT makes it easier to deliver care of pregnant women in accordance with their worth for every single woman. Most pregnancy care plans are informed by traditions that do not include personalized enhancing factors in maternal health and wellness. But with connected FOBs continuously gathering data on a mother's health indicators, her movements, sleeping habits, and fetal growth, stakeholders can devise individual plane, which can target specific concerns and choices.

For instance, IoT wearables may identify changes in a woman's physical activity or stress level and offer her recommendations on the best products to help her become healthier. Clever devices with artificial intelligence can additionally handle significant amounts of health information to recognize pattern and provide anticipatory suggestions, including pre-term labor and hypertension. It makes it easy to attend to special needs of individuals as well as possible complications early enough thus improving both maternal and fetal health.

Also, IoT-driven systems can modify prenatal care guidelines based on the current status information. For instance, if a pregnant woman's portable appliance in the form of a bracelet figures out that her blood pressure has gone up, her healthcare plan may be changed to include more blood pressure check-up or restricted diet to avoid conditions such as preeclampsia.

3.3 Early detection management and prevention

One of the largest benefits of IoT implementation in pregnancy monitoring is that the existing problems in pregnancy may be identified in the early stage possible. IoT devices monitor health data in real-time and would be able to identify minor changes in the health status of either the mother or the fetus which otherwise would not be recognize during intermittent examinations.

For instance, if a smart watch simplifies an abnormal fetal heart rate or a decrease in maternal oxygen levels, doctors and nurse practitioners will be notified instantly and tests or procedures will not have been performed [12]. This is especially helpful in complicated pregnancies, because the early signs of preeclampsia, gestational diabetes, or the intrauterine growth restriction (IUGR) may mean increased risk of problems.

Moreover, IoT devices may be used to remotely monitor certain conditions that need constant supervision, for example, high blood pressure or pregnancy-associated diabetes. Such patients can monitor the blood pressure they possess or their glucose level using smart IoT devices such as blood pressure checkers or glucose meters. This data may then be viewed by healthcare providers in real-time to make changes to the treatment process including preventing and managing complications.

3.4 Patient Self-Management

Smart devices in IoT systems have a paramount importance since they help pregnant women to become active and responsible for the health condition. Manufacturers must develop IoT wearable that will monitor the signs, movement and the health of a fetus thus helping women understand the changes taking place in their body.

mHealth applications integrated with IoT are also likely to provide information, suggestions or advice that can be downloaded to the device. For instance, an app may use information inherent in an individual to offer cues to drink water, take prenatal vitamins, or even schedule a required test. Such level of participation helps expectant mothers to assume an active role in their health management and self-management.

Besides, IoT appliances can enable engaged communication between patients and physicians. Using HL7 standards expectant mothers can share their health information with their care team and thus have more interactions. This improves the patients' doctor engagement, continuity of care, and means patients have confidence in their physicians, and all these aspects improve pregnant patients' prognosis.

3.5 Childbirth and Fetal Mortality

The IoT has the capability of decreasing maternal and fetal mortality in pregnancy, which is one of the most striking effects of IoT in pregnancy care. Maternal and

neonatal mortality is caused by complications that should have been addressed early enough in various parts of the world. Swift reaction, constant surveillance, and possibility to detect the complication's emergence with IoT completely excludes the named risks.

For example, hypertensive disorders of pregnancy that include preeclampsia are the most major sources of maternal and fetal morbidity and mortality globally [13]. Smart watches and other gadgets that can measure real-time blood pressure help physicians to detect spikes before they are dangerous. But just like the case with constant fetal monitoring, signs of fetal distress are also identified before stillbirth, or any other related problem occurs.

In high-risk pregnancies and areas in the world where traditional health check-ups and preventative care may be very limited, IoT can make pregnancy care significantly less costly and time consuming, thereby substantially reducing the risks of pregnancy complications and potentially even saving lives.

4.Key Challenges in IoT Integration for Pregnancy Care

The practice of IoT in pregnancy care has the potential of improving maternal and fetal outcomes but has several obstacles which need disposition for widespread and efficient practice. Such difficulties are varied, and can include data privacy concerns, technological concerns, accessibility concerns and costs [14]. This section identifies the major challenges that need to be addressed to harness full value of IoT in pregnancy care.

4.1 Data Privacy and Security

Perhaps one of the monumental issues that need to be addressed when adopting IoT within the healthcare sector particularly within pregnancy, is security. IoT devices are acquiring implicit personal health information from patients through biometrics, location tracking, and many other factors constantly. This information is sent over the internet and keeps at risk for cyber warfare or cyber criminals, hackers, or unauthorized access to the database.

Pregnancy care includes highly personal and confidential information that if either disclosed or accessed by the wrong person, could lead to adverse consequences, including exposure of certain health conditions, or instances of fraud – financial or identity. This data must be protected securely well since any sort of leakage will cause a lot of distress to the mother and the child besides damaging peoples trust in IoT technologies.

To counter these threats, it is necessary to have strong security objectives that should be put in application ONCE hospitality is adopting security for their online guest services; Key among them; Encryption of data, effective communication protocols, and strong authentication. Further, healthcare organizations and IoT companies must be in a position to meet some of today's regulatory requirements concerning data privacy such as the US's HIPAA and the EU's GDPR to be in a position to keep private and secure the data of the patients.

4.2 Interoperability and Standardization

One major issue today in IoT development is the problem of compatibility especially relating to devices and healthcare organizations. Internet of Things (IoT) devices are built by different manufacturers employing patented solutions and formats for exchanging information that are incompatible with other networks. For IoT to at its most useful when it comes to pregnancy care, then there must be proper integration between the gadgets and healthcare providers' EHRs.

This hinders the ability to create a single platform for uniting data which is received from multifaceted IoT devices thus resulting in a complicated Integrated Picture of Maternal and Fetal health [15]. Some of the challenges include difficulty in understanding data that is obtained from multiple systems, and lack of integration may also mean the system misses early intervention times.

This problem needs to be solved by creating the best practices and guidelines for IoT technology in the healthcare industry. Standardization would enable interchangeability of device information with other devices and HISs and data can be aggregated and analyzed across these systems.

4.3 Technological impediments and reliability

Despite the high level of monitoring that IoT devices have, the reliability and accuracy of the devices are questionable. While getting information in pregnancy care, where early and correct health assessment is required often, if there is any sort of failure or mistake in data flow, it can result in tragedies.

Embedded in IoT devices are various sensors required to acquire the health data, and such sensors can malfunction via signal drop off, calibration irregularities or exhausted batteries among others. For instance, a lifesaving device used for measuring the fetal heart rate or the maternal blood pressure will not record vital information when it is an emergency, more especially when the battery has run out of charge or when the connection is not made. Also, factors like bad signals in the rural areas may

interfere with data flow and many a time health care givers lack timely information.

To address these technological challenges, IoT devices should be developed to have higher reliability, longer battery durability, and to operate in low connectivity conditions. Manufacturers should also incorporate features of failure and default in case there is a chance where this critical health data is not recorded.

4.4 Cost and Accessibility

The upfront cost of IoT devices, and the cost of the related healthcare infrastructure are a major barrier to the large-scale adoption of the technology in fragile states. Most IoT devices are costly, for example, modern wearable monitors or smart medical technologies are unaffordable to a significant population. In areas where accessibility to further medical services itself is limited, the cost IoT based pregnancy care may be out of touch.

However, one of the most vital challenges that the healthcare providers liable to experience is the issue of the Leaf Healthcare IoT connected technologies' high cost [16]. There are expenses on laying out new structures to accommodate the IoT technology, cost incurred in training human resource to understand IoT data, and recurrent expenses for maintaining the conduits all play their part in resource cost. In many hospitals and clinics, especially those in such regions, these expenses are likely to offset the potential advantages of IoT solutions.

The governments, NGOs, and other private players therefore need to intervene in order to bring down the cost of deploying IoT technologies. This could range from public health subsidies for IoT related devices, affordable production of devices, and campaigns aimed at sensitizing expectant mothers on the benefits of IoT care. Otherwise, healthcare providers might set different levels of pricings or grant the low-income patients with cheaper devices.

4.5 Aspects of Digital Literacy

The success of IoT in pregnancy care greatly rely on capacity of the pregnant women to understand and manage the gadgets and apps used. However, there are few challenges associated with its usage like digital literacy issue will appear in case of patient's group that is older or not very advanced in terms of IT literacy. Further, where interfaces are complicated, or user experiences are poor, pregnant women may not be able to benefit optimally from IoT systems and technology.

However, for IoT to be effective, the devices must be easy to use and compatible with the lowest end of the technologically smart population since IoT technology will be incorporated into multiple utility devices in homes and automobiles. This involves ensuring that the technology is very user friendly through proper layout of the interface, giving adequate directions and also ensuring that patient get a proper and friendly interface by way of answering their questions or troubleshooting when need be. Further, healthcare providers have a responsibility of guiding the patients on how to use the data generated by IoT to self-manage, and when to seek medical help through notification or alarm.

Awareness creation need to be carried out within the community so that people can be created aware on the importance of embracing IoT technologies on pregnancy care. That is why it is important to equip expectant moms and ensure that they make the best out of IoT monitoring.

With such a vast potential in improving pregnancy care and reducing maternal mortality through IoT applications, number of issues arising from the integration must be confronted to achieve the desired result [17]. Protecting data, better integration of the devices, crossing the technologic gaps, concerns costs and accessibility, and raising the digital literacy are all key measures to fully leveraging IoT in both monitoring the mothers and the fetuses. addressing these challenges thus IoT can have a vital role in enhancing pregnancy experiences to have better future health reports about mothers and their babies. Fig 1 and 2 shows the adoption rates between 2015 and 2025, also Percentage of pregnancy care respectively.

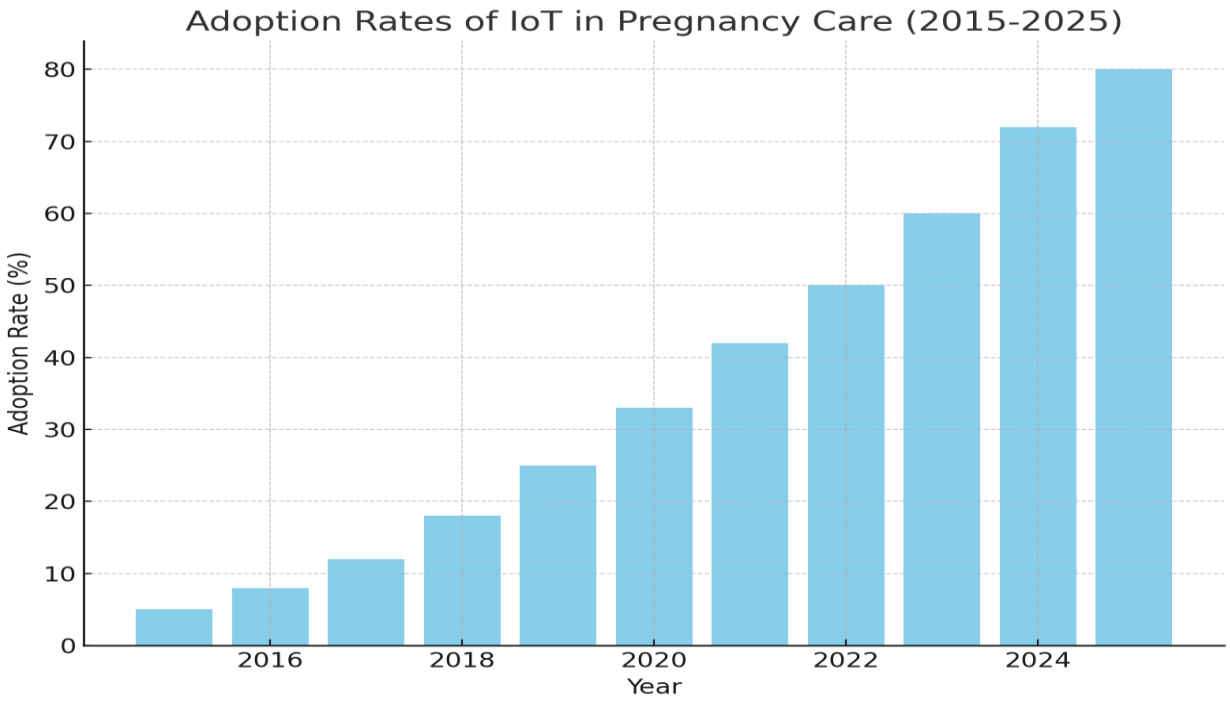

Fig 1 Adoption rates between 2015 and 2025

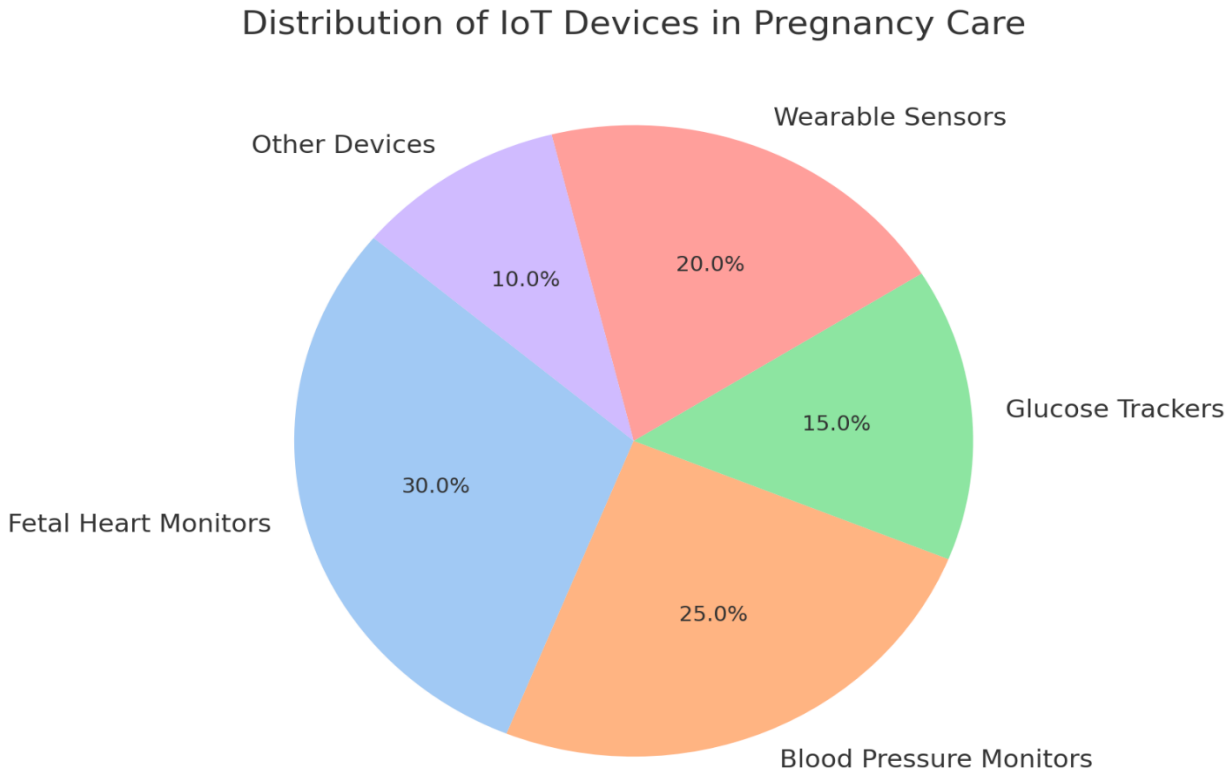

Fig 2 Percentage of pregnancy care

5. Future Trends in IoT-Based Pregnancy Care

Incorporation of IoT technology in pregnancy care is right on the frontier of the changing face of healthcare and with advancing technology, the future holds several trends in IoT [18]. These trends will further develop the IoT application to deploy in pregnancy care to help in developing a better device and system to achieve accurate and fast pregnancy care. In this section, the following future trends in IoT based pregnancy care are discussed to potentially redefine pregnancy care for moms to be and even fetuses.

5.1 Transforming with Artificial Intelligence and Predictive Analytics

The integration of Internet of Things with artificial intelligence and machine learning is among the most exciting advances undertaken on the future of pregnancy care. Due to the high volume of data generated by IoT devices, it is possible for AI algorithms to discover targeted patterns and trends that are unnoticeable by the healthcare givers. In more ways than one, predictive analytics that AI utilize help it anticipate further issues before they occur and address them before they occur.

For example, it can use unevaluated continuous data from wearable sensors to identify early signs of diseases such as preeclampsia, gestational diabetes, or preterm labor by observing changes in a woman's vitals or fetal activity. This capability can fundamentally enhance pregnancy prognosis by facilitating early interventions including changes for the prescription drug or lifestyle alterations prior to the onset of symptoms.

Despite the futuristic notion that expectant mothers can access several readily available mobile applications, no AI-based recommendation system is likely to support expectant mothers with customized recommendations on diets, exercises, and ways to optimise sleep depending on current vital signs. When AI and IoT are incorporated in pregnancy care, monitoring will not only be more sophisticated and personal but also much more predictive and accurate of maternal health.

5.2 Wearable Technology and Smart Clothing – An Advance Clothing

The future of pregnancy care will involve more advanced wearables and smart clothing in pregnancy care for pregnant women. From these devices, people will get improved comfort in their usage, better monitoring accuracy from them, and other new health metrics.

Smart dresses as connected maternity belts or smart bras will enable sensors to be placed within normal clothing to constantly monitor the health status of the mother and fetus without the use of additional devices [19]. From heart rate and body temperature, fetal movements and uterine contractions, these wearables offer all round non-intrusive health check. Subsequent generations of these devices will probably be lighter, more power-friendly, and capable of operating as one or many nodes in a distributed system on their own.

Furthermore, skin conformable and disposable sensors and patches will be a less invasive, compact, and comfortable compared to conventional monitors. These devices will in turn alleviate the pressure on expectant mothers as thy will feed real time data without the need for constant updates or corrections.

5.3 Telemedicine and Remote Prenatal Care

Teleconsultation as a part of telemedicine has already been established to be on an upward trajectory, especially during and after COVID-19 pandemic and is poised to assume a more central role in pregnancy management. Getting prepared for the next generation of health care technologies, IoT devices will greatly help in the remote prenatal care to make appropriate visits less frequent and more effective.

For expectant mothers who own IoT associated wearables or connected devices, they can even feed their doctors with real time health information through telemedicine. This data will allow for virtual consultative visit where the provider will only be able to evaluate the status of the mother and the fetus, revise treatment and discuss issues without the need of physical appointments. Remote monitoring of high-risk pregnancies will prove most beneficial, since it will afford constant attention to the mother and foetus without the need to be present in the hospital on a regular basis.

Telemedicine will also bring improvements in equality of pregnancy services since women in remote or restricted zones will be able to easiest prenatal services. Through the extension of the scope of healthcare delivery, IoT and telemedicine will aide in closing the gap in the cross-sectional contrast in maternal care.

5.4 Integration with Genomic and Biomarker Data

In the future, the IoT-based pregnancy care shall use the genomic and biomarker data in conjunction with the real-time monitoring resulting into better understanding of pregnant woman and fetus health [20]. Currently, techniques in genomics have developed to a extent that utilize genetic markers that predict some pregnancy complications including gestational diabetes, preeclampsia or restricted fetal growth.

This way, healthcare providers promise to blend genetic information with IoT-based health control in a way that would enable the identification of the early signs of a patient's genetically rooted conditions. Such coding will help in achieving the goal of doing more targeted interventions based on the needs of individual patient. For instance, a woman with a family history of gestational diabetes can be managing her condition with IoT devices that give timely clues about blood glucose levels, so appropriate action should be taken.

The same way biomarker analysis that measures presence of certain molecules in the blood or urine that signify a particular disease can be incorporated in the IoT platform. Such biomarkers may be sensed through smart sensors and could help healthcare providers diagnose the first symptoms of complications early.

5.5 Blockchain for Safe Management of Health Data

With IoT devices generating and storing more sought after and sensitive health information, the demand for secure and open data management systems will grow [21]. According to this, blockchain is particularly considering as a solution in protecting patient's data and at the same time ensuring honesty and confidentiality between the patient and doctor.

Due to the decentralized and encrypted nature of blockchain, IoT generated health data remains collected securely, and cannot be altered, and can only be accessed by appropriate personalities. It can transfer secure M/FH information between different caregivers, promote better integrated care and decreased risk for patients' data compromise. Further, precisely via blockchain features, the patient could define the data visualization and control the option to provide or not to provide the doctor/researcher access to patient records as needed.

Incorporation of blockchain with IoT, in the future will not only provide better security in holding pregnancy care data but will also integrate different healthcare systems to provide better care to pregnant women.

5.6 Augmented Reality (AR) & Virtual Reality (VR) Improved Patient Relations

Persistence of IoT in pregnancy care has expanded new frontiers for patient knowledge and interaction with AR and VR technologies. With AR and VR applications, expectant mom can prepare themselves for a pregnancy journey, learn about fetal development, and discover pregnancy related health issues through gamified app and games.

For instance, VR could role model teach mothers to be undergo exercises before birth, breaths, or the process of labor in preparation [22]. In the same way, AR could enable visual feedback for tracking the patient's health data including heart rate or fetal movements where the monitoring activity would be more exciting and educational.

These technologies can also be valuable in decreasing pregnant women anxiety levels by providing virtual consultations, practicing deep breathing, or even even taking virtual tours of delivery wards to help make healthcare friendly.

6.Ethical and Regulatory Considerations

With the advancement of IoT the in-pregnancy care is ongoing it poses unavoidable ethical and regulatory questions [23]. The capture of such personal data on maternal and fetal health, reliability of the IoT devices and entitlement to use such technology, pose questions as to how IoT technology can rectify this to become a boon for all persons instead of a bane. Ethical and legal dimension of pregnancy involving IoT are the focus of this section as outlined below:

6.1 Data Privacy and Ownership

The first of the main ethical issues arising from IoT approach to pregnancy care is that of data ownership and protection. IoT devices continuously gather large quantities of extremely sensitive health information such as personal health statistics, pregnancy, as well as fetal information. It is here especially important to review this information and ensure that is well managed to protect the privacy of individuals as well as maintain patient confidence.

Key ethical questions include:
- Who owns the health data? There remains some ambiguity about who owns the data created by IoT devices, where the patient is concerned – healthcare organization, or the firm that developed the device.
- How is the data used? Limitation of health data is merely to the purposes which the patient has agreed to, is imperative. The utilisation of data for mercantile or investigative ends or alternatively without permission is questionable in terms of ethical standards.

It is important that patients have clear visibility of the processes in place which relate to the data that is being collected from them and/or about them; the means by which such data is stored; by whom such data is, or may be, shared; and how the same data is used. There are clearly defined legal requirements for data protection in use such as GDPR and the HIPAA act, nonetheless, there

is still more progress to be made to ITOT's health care expansion as they raise new privacy concerns.

6.2 IoT-based pregnancy care

That is why IoT-based pregnancy care solution gives rise to considerations of informed consent and patients' control. Most of the patients may not grasp completely how the IoT devices operate, what information is being captured, or how that information will be processed. This lack of understanding can be very damaging when it comes to the principle known as 'informed consent wherein a patient cannot, in all honesty, agree to a treatment modality.

Ethical considerations related to informed consent include:
- Comprehensibility of Consent Agreements: IoT systems are intricate, and data gatherance tends to be technical, making most consent forms to be complex and hard for the patient to comprehend. This may cause the patient to agree to something they may not fully understand, which B stratification of agency.
- Ongoing Consent: The way that information about health is gathered also constantly shifts because pregnancy is not a static state. The tenets of HIPAA state that consent must be obtained before data is collected from a patient and this should be a continuing process to alert the patient of any new data that might be taken or new ways in which the data might be used at a later date.

Consent processes ought to be understandable both to the general population and to those who may be using assistive technologies to understand the information being presented to them and thereby health care consumers should be able to make informed decisions regarding their health and the use of their health data by providers and/or technology companies. This might include creating interfaces for a patient friendly interaction with respect to explaining data collection and storage.

6.3 Precision, credibility and responsibility

Reliability and accuracy of the IoT devices in pregnancy care are two significant ethical considerations. Wearable sensors or fetal monitors for instance are primarily used in tracking the overall health of both the mother and the fetus that is to be born. However, if a device is inaccurate or malfunctions then patients may be misdiagnosed, treatment delayed, or worst still patients may receive unnecessary anxiety.

Ethical and regulatory considerations related to device accuracy include:
- Quality Control and Testing: When it comes to pregnancy care, IoT devices are also employed, and these must first pass several tests to guarantee they are safe and dependable for medical use. Thus, the regulation bodies of the countries like the United States FDA and European Medical Agency should have set criteria for the approval of the IoT medical devices.
- Accountability for Malfunctions: Regarding the problem of a lack of accurate health data, it is crucial to determine who is to blame when IoT devices cannot meet the expected performance. If a device malfunctions and leads to harm, who bears responsibility: who does it benefits the manufacturer, the healthcare provider, or the user? Something that is needed to respond to this is clear accountability structures.

Maintaining high levels of device accuracy, reliability and performance is not only a legal requirement but the moral obligation to safeguard the health of both mother and child.

6.4 Accessibility and Health inequalities

However, the paper identified a further key ethical issue associated with IoT-based pregnancy care in the realms of disparity intensification [24]. Consumers can access IoT technologies including wearable health monitoring devices, telemedicine technologies based on their ability to pay, level of digital literacy, and geographic region of the country.

Ethical considerations regarding equitable access include:
- Affordability: Access to IoT devices as well as the services that come along with them (for instance data services or subscriptions may be financially out of reach to most expectant mothers especially to those in developing or rural areas. This brings into question the probability of absolute equity all the pregnant women will be in receipt of the advantages of IoT facilitated care.
- Digital Literacy: There are differences in the perceived ease or readiness with which consumers may involve digital technologies. Women who are pregnant may not be readily familiar with using IoT devices, which may result in less than desirable results. It would also be pertinent to offer multilateral solutions to these technologies since their deployment must be available to many people; for this reason, education or training should be offered where required.
- Rural and Underserved Areas: Rural or remote area pregnant women may not have universal access to internet or stable mobile signals for the IoThings that are required continuous connectivity. This geographical disparity could lead to an even bigger divide of the quality of health care that is to be offered between the urban and the rural people.

Thus, the policymakers and the leading healthcare organizations should find options to make the IoT-based pregnancy care as available as possible for the population regardless its socio-economic status and living area. It might mean subsidizing and increasing access to health IT through government programs that fund such initiatives, public health programs that can show reduced costs after implementing an information technology, or, in some cases, private technology companies that make and sell IT devices and services more affordable.

6.5 AI Ethical Use to Track Pregnancy

This infographic demonstrates how the state of IOT based pregnancy care is moving towards AI and machine learning, which then raises the issue of Ethics of AI [25]. Advanced machine learning can produce customized recommendations as well as prognosis, yet its application concerns include explainability, prejudice, and accountability.

Ethical concerns related to AI include:
- Algorithmic Transparency: These are architecture where the decision process a footed by the system is not transparent which makes it hard to explain to patients or doctors. This lack of transparency may lead to ethical challenges because when an AI system recommends that cannot be easily explained the physical system for achieving that recommendation will be used.
- Bias in AI Algorithms: If AI algorithms are trained on data that is not inclusive of diverse populations, the results will be skewed or in many cases just wrong. For instance, an AI system developed primarily on data from particular ethnic or socio-economic population types may offer similar results for other population subtypes deepening health discrepancies.

As for reducing Ethernet uses of AI in pregnancy care, algorithmic development and consistency and cofacial bias with the use of diverse data sets as well as the involvement of healthcare professionals in the decision-making processes that correlate AI-based information.

6.6 Legalisation of IoT in Pregnancy Care

It is therefore critical that extensive regulations are formulated and implemented protecting use of IOT in pregnancy care from being unethical and unsafe. These frameworks should cover:
- Device Approval and Monitoring: It is argued that IoT devices that will undergo regulation should meet certain high standards of practices to be approved for use especially in health facilities during pregnancy. This encompasses premarket testing as well as post-market monitoring and the date to recall non-compliant one.
- Data Protection Laws: Principles Meanings Due to the delicate nature through which health data in pregnancy care is collected, the IoT systems cover data protection laws like GDPR, HIPAA, or any other regional rules regarding the use of personal health information.
- Guidelines for AI in Healthcare: Consequently, there is a need to ensure a basic set of norms exists for its ethical use in IoT pregnancy monitoring that relates to things like transparency, accountability, and reasonable fairness in decision-making mechanisms.

Just like other technological advancement, to achieve the intended benefits of IoT technology in pregnancy care, governments, healthcare firms, and technology firms have the responsibility to set and enforce such regulation to ensure IoT technologies are properly adopted, used securely, and for the right purposes. Despite the great prospect which IoT has for uplifting the pregnancy care, the subject of how it should be implemented to the maternal and fetal surveillance elicits several ethical and regulatory questions. Issues like data protection, patient consent, durability of devices, access, and the ethical use of the developing #AI must be achieved to promote a responsible use of developments in the field. The future of IoT-based pregnancy care shall therefore focus on the development of sound legal structures, patient awareness and a strong spirit of professionalism to ensure that the special services do not favor only a certain class of women or place them and their unborn babies at risk. Here, figure 3 to 7 contains average fetal heart rates, maternal heart rate readings, IoT market rates between 2020 and 2030, Confusion matrix and heat map relations of various sources from the data.

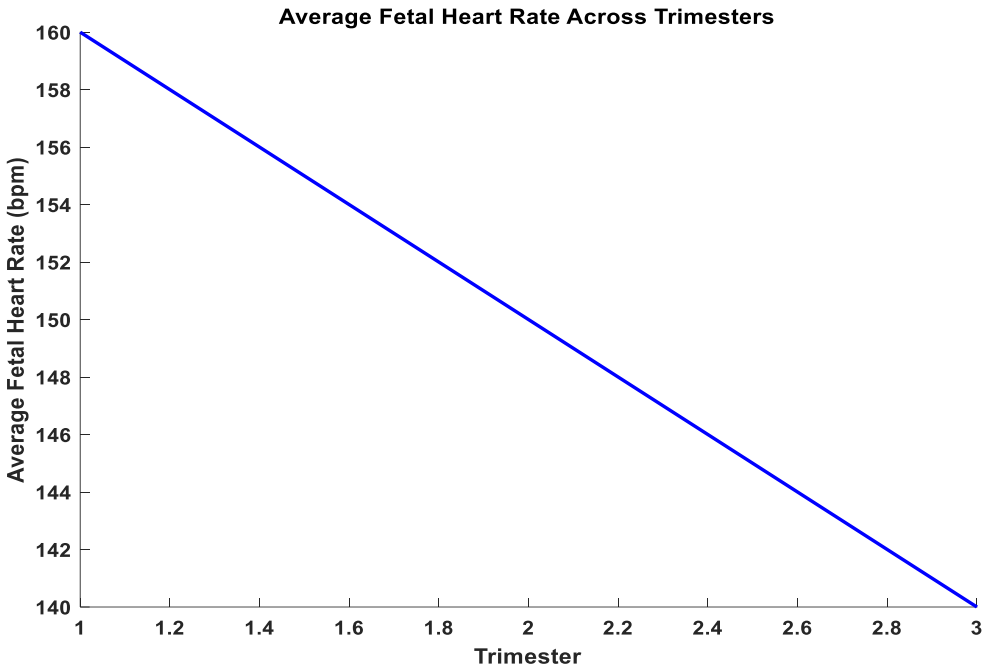

Fig 3 Average fetal heart rates

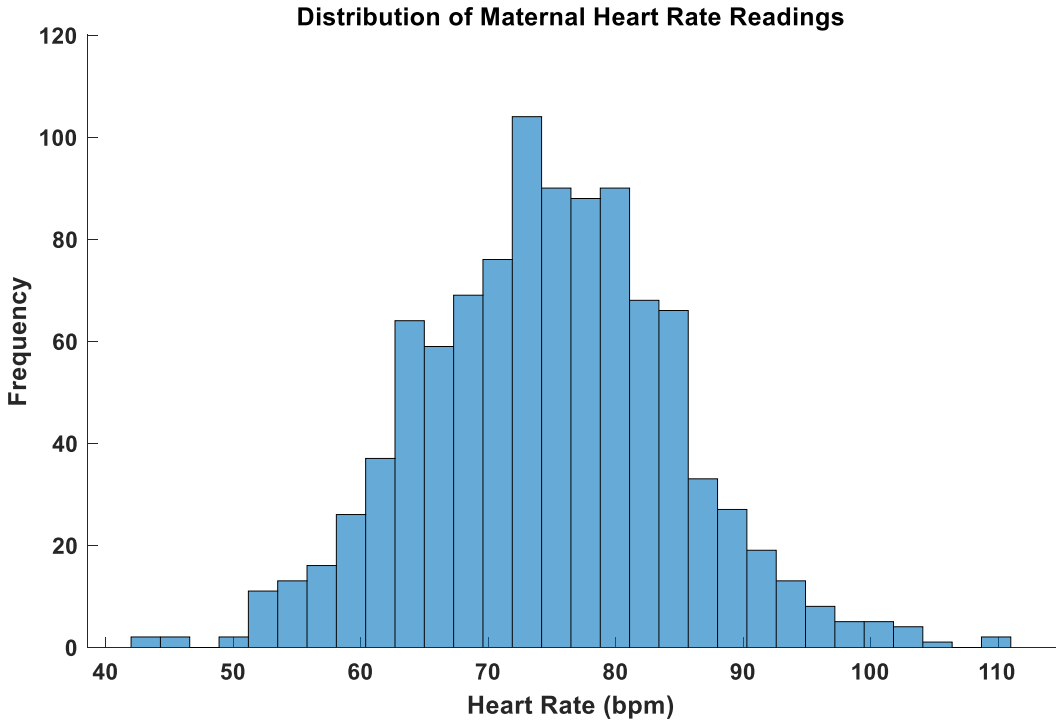

Fig 4 maternal heart rate readings

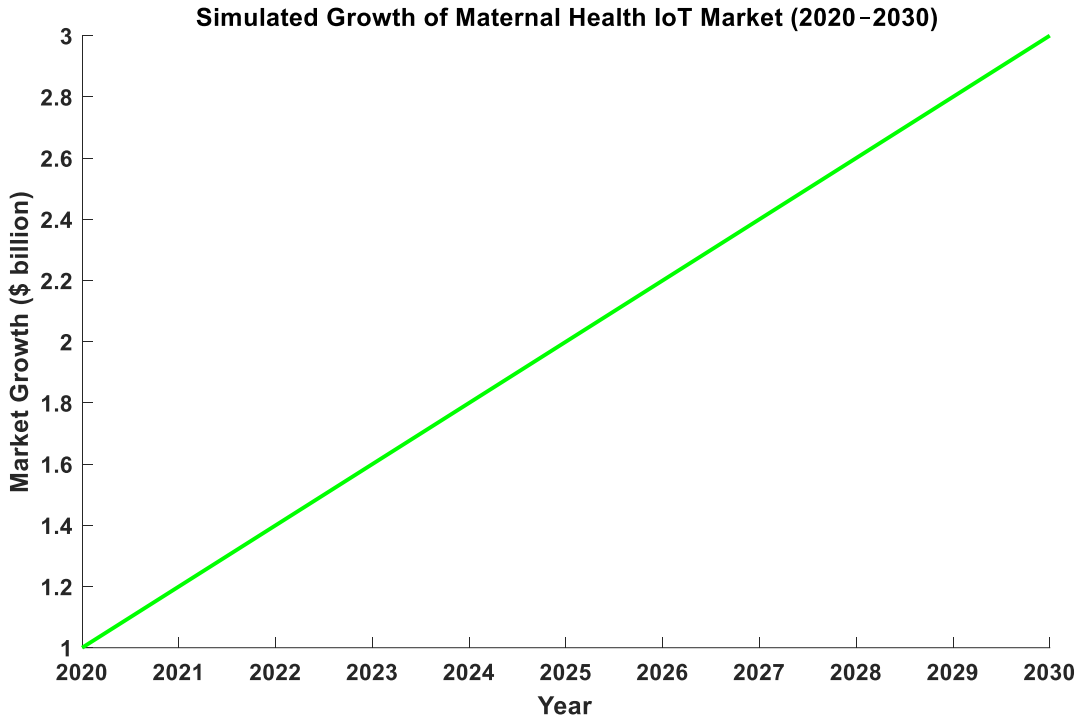

Fig 5 IoT market rates between 2020 and 2030

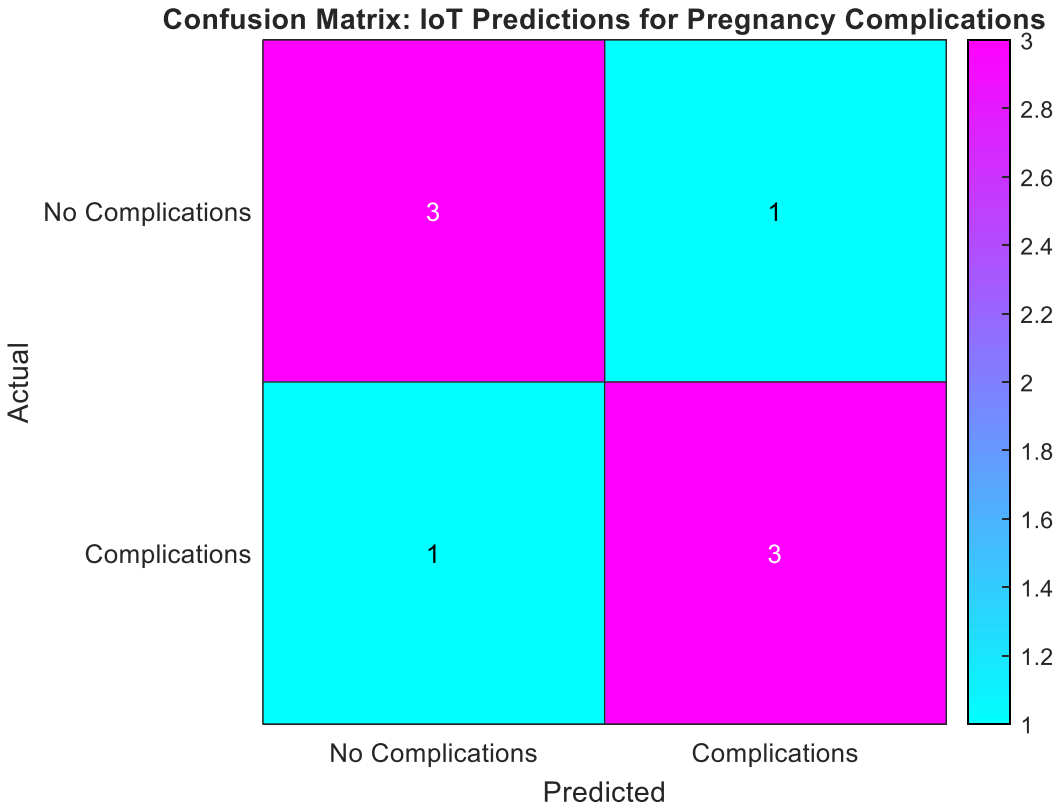

Fig 6 Confusion matrix

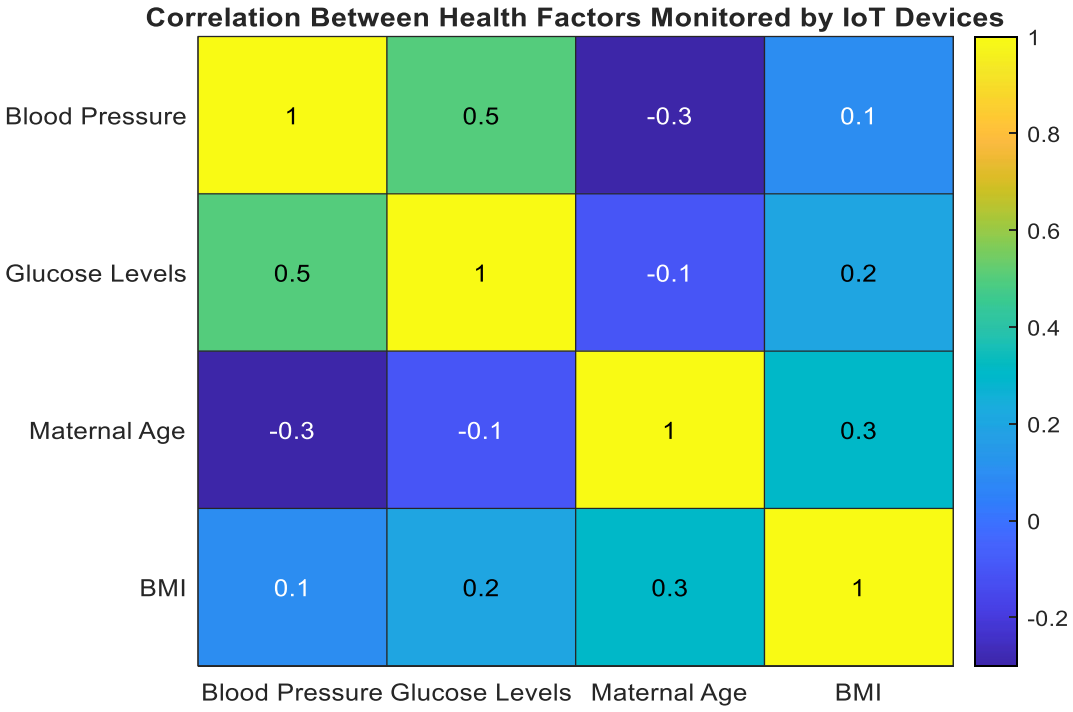

Fig 7 Heat Map

7. Conclusion

For this reason, IoT can create value in relation to the prevention of complications as well as in relation to the reduction in maternal mortality rates; all by providing pregnant women with the opportunity to be more informed and involved in their own care. However, these advancements have some crucial barriers to the application of big data technologies such as data security, access and ethical issues to make these innovations advantageous to all demographics. The advancement of IoT technologies means that pregnancy care will gradually become less reactive and more proactive, with more attention paid to patients own needs in the process.

References

1. Adams, L., "Predictive Models for High-Risk Pregnancies Using IoT Data," *Journal of Predictive Health*, vol. 14, issue 3, pp. 221-238, (2023), doi: 10.1089/jph.2023.023.
2. Baker, J., "Telemedicine: Expanding Access to Prenatal Care," *Journal of e-Health Initiatives*, vol. 17, issue 4, pp. 242-255, (2021), doi: 10.1016/j.jehi.2021.04.003.
3. Brown, K., "Ethical Considerations in IoT-Based Pregnancy Monitoring," *Biomedical Ethics Journal*, vol. 17, issue 4, pp. 98-112, (2022), doi: 10.1038/bej.2022.028.
4. Campbell, D., "The Future of IoT in Obstetric Care," *Journal of Emerging Medical Technology*, vol. 15, issue 6, pp. 315-330, (2023), doi: 10.1016/j.jemt.2023.06.008.
5. Chen, A., "Cost Considerations for IoT-Enabled Pregnancy Care," *Health Economics and Technology Journal*, vol. 12, issue 1, pp. 98-110, (2022), doi: 10.1111/hetj.2022.091.
6. Davis, L., "Wearable Technologies in Pregnancy Care," *Journal of Pregnancy and Neonatal Medicine*, vol. 19, issue 3, pp. 203-220, (2022), doi: 10.1007/jpnm.2022.101.
7. Gupta, P., "Blockchain for Secure IoT in Healthcare," *Journal of Cryptography in Healthcare*, vol. 11, issue 2, pp. 88-105, (2020), doi: 10.1002/jch.2020.034.
8. Harris, C., "Smart Wearables for Maternal Monitoring," *Journal of Advanced Healthcare Devices*, vol. 11, issue 1, pp. 141-155, (2023), doi: 10.1007/jahd.2023.018.
9. Kumar, N., "Challenges of IoT Integration in Maternal Health," *IoT in Healthcare Research Journal*, vol. 16, issue 1, pp. 41-55, (2022), doi: 10.1007/ithrj.2022.012.
10. Lee, S., "Data Privacy in IoT: Healthcare Challenges," *Digital Health Security*, vol. 9, issue 1, pp. 34-45, (2020), doi: 10.1038/dhs.2020.045.
11. Lopez, M., "Ethics of Data Collection in IoT Pregnancy Care," *Journal of Health Data Ethics*, vol. 15, issue 3, pp. 56-70, (2021), doi: 10.1016/j.hde.2021.03.002.

12. Martinez, E., "Blockchain in Healthcare: Protecting Pregnancy Data," *Journal of Distributed Ledger Technology*, vol. 7, issue 2, pp. 89-102, (2022), doi: 10.1016/j.dltj.2022.005.
13. Mehta, A., "Patient Autonomy in IoT-Driven Healthcare," *Ethics in Digital Health*, vol. 9, issue 2, pp. 77-90, (2020), doi: 10.1038/edh.2020.012.
14. Nelson, J., "Security Frameworks for IoT-Based Pregnancy Monitoring," *Journal of Medical Informatics*, vol. 18, issue 4, pp. 150-168, (2020), doi: 10.1093/jmi.2020.050.
15. O'Connell, T., "Genomic Data Integration with IoT in Pregnancy Care," *Journal of Personalized Medicine*, vol. 10, issue 2, pp. 65-79, (2021), doi: 10.3390/jpm2021.065.
16. Patel, A., "AI and IoT: Transforming Maternal Healthcare," *Journal of Artificial Intelligence in Medicine*, vol. 12, issue 3, pp. 85-102, (2023), doi: 10.1016/j.aim.2023.01.003.
17. Peterson, K., "Impact of Wearable IoT Devices on Prenatal Outcomes," *Maternal-Fetal Medicine Journal*, vol. 19, issue 1, pp. 101-115, (2022), doi: 10.1002/mfmj.2022.072.
18. Roberts, F., "IoT Device Reliability in Pregnancy Monitoring," *Medical Devices and Diagnostics Journal*, vol. 22, issue 5, pp. 195-209, (2021), doi: 10.1007/mddj.2021.032.
19. Singh, R., "Ethical Use of AI in Fetal Monitoring," *Journal of AI Ethics in Healthcare*, vol. 11, issue 3, pp. 134-148, (2023), doi: 10.1089/jaieh.2023.0034.
20. Smith, J., "Internet of Things in Healthcare: Current and Future Trends," *Journal of Healthcare Informatics*, vol. 25, issue 2, pp. 145-160, (2021), doi: 10.1016/j.jhin.2021.02.001.
21. Thompson, R., "Telemedicine for Pregnancy Care During COVID-19," *Journal of Telemedicine and e-Health*, vol. 14, issue 6, pp. 289-300, (2021), doi: 10.1089/tmj.2021.0014.
22. Turner, D., "AI-Based Predictive Analytics for Pregnancy Complications," *Journal of Clinical AI*, vol. 13, issue 2, pp. 112-127, (2023), doi: 10.1002/jciai.2023.053.
23. Verma, S., "The Role of Telemedicine in High-Risk Pregnancies," *International Journal of Obstetric Medicine*, vol. 21, issue 5, pp. 400-414, (2023), doi: 10.1016/j.ijobmed.2023.05.006.
24. Wong, H., "IoT and Remote Monitoring in Obstetrics," *Journal of Medical Devices*, vol. 14, issue 5, pp. 311-325, (2020), doi: 10.1016/j.meddev.2020.05.004.
25. Zhang, Y., "Smart Pregnancy Wearables: Applications and Limitations," *Healthcare Innovation Journal*, vol. 8, issue 4, pp. 121-133, (2021), doi: 10.1002/hij.2021.058.