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Perceptions of Remote Fetal Heart Monitoring: Surveying the Acceptability

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Abstract

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Objective: A survey was developed to act as a guide for fetal monitoring device development. The survey assessed the acceptability levels of a fetal monitoring device among women of reproductive age.

Methods: The survey was administered using the Qualtrics ™ online survey platform. The survey was distributed using snowball recruitment through community and online postering. Compensation was offered to survey respondents. Data was analyzed using SPSS v29.

Results: 163 participants completed the survey, with 103 responses to acceptability questions; older women aged 30-49 showed higher rates of acceptability (70.07%, n=54) than young women aged 18-29 (53.06%, n=49). 70.7% of participants preferred a device of size 1 inch by 3 inches or less (n=149).

Conclusions: Designing a device that incorporates patient preferences increases the likelihood of patient adoption and consistent use. By addressing the needs of underserved and rural communities, this device has the potential to reduce healthcare disparities among mothers and enhance both monitoring and overall health outcomes.

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Abstract

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Trial Registration: N/A

Keywords

Fetal heart monitor; maternal health; fetal health; telehealth; remote monitor; acceptability

Introduction

Background

Although most maternal deaths are preventable, the maternal mortality rate in the United States has been steadily rising since 2000.[1 2] Maternal mortality refers to deaths that occur during pregnancy or within 42 days following childbirth. [1] This concerning trend disproportionately affects pregnant women from racial and ethnic minority groups, who typically experience higher rates of adverse health outcomes compared to non-minority populations.[2]

One significant factor contributing to these disparities is the prevalence of maternity care deserts where limited or no access to obstetrical services or providers are available.[3] Low reimbursement rates, financial issues, and lack of obstetrical and anesthesia providers has forced many hospitals to close their obstetrical units. Those who are pregnant are forced to drive longer distances to access prenatal and birth services which also contributes to poor outcomes.[4] Research indicates that the absence of necessary services at rural hospitals, a shortage of maternal healthcare providers, and long travel times to access care all contribute to the nation's high maternal mortality rate.[1 2]

Additionally, individuals living in rural and underserved communities generally face worse health outcomes than those in urban areas. [5-7] This disparity may be driven by limited access to healthcare, unemployment, financial hardship, and educational inequities.[8]

Not only are maternal health outcomes disparate in rural areas, but fetal outcomes are also affected.[9] Unfortunately, when maternal health outcomes during pregnancy are worsened, this can adversely affect fetal health outcomes during pregnancy and birth. Maternal health issues that are directly related to pregnancy (pre-eclampsia, gestational diabetes, etc.) and underlying chronic health issues are some of the top contributors to maternal and fetal morbidity and mortality.[10]

Importance of Early Detection of Congenital Heart Defects

During the third week of pregnancy, the fetal heart begins to develop. By the seventh week, it has developed into its structure of four chambers. The fetal heart rate can be detected by doppler ultrasound beginning at 10 weeks of pregnancy. Routine monitoring of the fetal heart begins around 18 weeks of pregnancy. [8]

Congenital heart defects (CHDs) are the foremost factor leading to fetal mortality from age 0-1.[11] They often impact the individual in a lifelong manner, and some are more complex than others, needing advanced treatment

techniques and accurate monitoring. Ventricular Septal Defects (VSDs), which cause heart malformation, are the most common type of defect, impacting 1% of babies born per year.[11 12] VSDs cause a hole between the ventricles of the heart; they can exist by themselves, or they can comprise one of multiple CHDs affecting a patient.[13] CHD treatment has improved in recent years, and an important contributing factor to this improvement has been early detection. Early detection is vitally important, as it allows providers to create a treatment plan and monitor the baby before the baby is critically affected by the defect. [14] Early detection can also lower rates of morbidity and mortality during birth. [8]

An undersupply of maternal and perinatal healthcare providers has contributed to the increased maternal mortality rates in the United States.[2] Difficulties accessing care in rural areas can lead to lower detection rates of CHD diagnosis in rural areas compared to urban areas. [15] Inability to access maternal fetal medicine specialists in rural areas can also impede early diagnosis. In order to address this healthcare gap and increase access to maternal and perinatal healthcare, remote monitoring may be a feasible alternative to allow providers to screen earlier for CHD and monitor higher risk patients more frequently.

Telehealth

Telehealth services include any healthcare experience that is aided by telecommunication (video or audio communication). [16] Telehealth is currently used in a variety of ways to enhance obstetrics care through apps that allow for services such as healthcare diary entries, remote blood pressure monitoring, and fertility tracking. Remote monitoring and telehealth virtual visits with providers can help to increase patient access to care and reduce the need for in-person healthcare appointments. [17 18]

During the COVID-19 pandemic, telehealth utilization greatly increased; however, this increase was more profound in urban communities than in rural communities. Barriers such as internet access and less widespread use of telehealth in rural communities have led to people in rural areas not fully benefiting from this technology. [16] In the future, telehealth can be used to bridge the rural healthcare access gap, allowing for increased rates of maternal and perinatal healthcare. [19]

Fetal Monitoring

In the United States, standard prenatal care recommendations include a health care provider visit every 4 weeks until 28 weeks gestational age, every 2 weeks until 36 weeks of gestation, and weekly from 36 weeks until birth. Research shows that telehealth has been used to supplement prenatal care in areas of low healthcare access, and it has been shown that patients who are able to have a combination of virtual and in-person provider visits over the course of their obstetrics care have higher satisfaction levels with their care.[18 20] Patients who require childcare or travel long distances to receive care also benefit from a telehealth model, as it allows them to receive healthcare on a more consistent basis.[21] A fetal heart monitoring device could be an alternative method of

fetal monitoring for those patients who are not able to access a traditional clinic easily or who may need to be monitored more frequently. This could be a more feasible option, bridging the access gap in areas of low maternal and perinatal healthcare access.

Fetal monitoring is utilized throughout pregnancy to assess fetal well-being and oxygenation status. Doppler ultrasound technology, first introduced for clinical fetal monitoring in the 1970s, remains one of the most commonly used tools during both routine prenatal care and labor. The device operates by emitting ultrasound waves through a handheld transducer; differences between the transmitted and reflected wave frequencies (the Doppler shift).[22] This allows clinicians to evaluate the movement of fetal cardiac walls and valves, providing real-time information about fetal heart activity. Over the past several decades, the use of Doppler ultrasound has contributed to earlier detection of fetal compromise and improved perinatal outcomes, particularly when incorporated into standardized antenatal care and intrapartum monitoring protocols. [8 23]

Birth Experiences

Along with medical outcomes, birth experiences can impact maternal health. Labor is a unique and intimate experience, differing for every mother. The labor experience is impacted by many factors, one of which is fetal monitoring. In the hospital, two main forms of fetal heart monitoring are used: intermittent auscultation (IA) and continuous electronic fetal monitoring (EFM). [24] To conduct IA, patients are monitored at regular intervals using a Pinard stethoscope or Doppler ultrasound. EFM is typically used continuously and is conducted using several methods. EFM provides a printout called a cardiotocograph, which provides information on the fetal heart. The EFM can be conducted using an external wired ultrasound transducer placed on the mother’s abdomen or an internal fetal electrode that is placed through the mother’s vagina and attached just under the skin on the fetal head, allowing for direct monitoring of the fetus.[25] The internal monitoring method can provide healthcare professionals with more accurate information, but it can only be used once the membranes have ruptured; it can also increase the risk of infection, fetal injury, and vertical transmission. [26]

Oftentimes, when EFM is used, the mother is connected to monitoring machines by wires, greatly limiting her movement during labor and birth which can reduce positive satisfaction and increase rates of cesarean section. Studies show that freedom of movement in labor can lessen complications, increase rates of spontaneous vaginal birth, rates, decrease labor time and epidural rates. [25] Freedom of movement and a positive birth experience is incredibly beneficial to maternal and fetal outcomes, as well as improved maternal mental health. [27] A negative birth experience can increase maternal risk for postnatal depression (PND). Postnatal depression can impair the bonding between a mother and her baby. It is estimated to affect around 15% of women in their postpartum period. Postnatal depression is associated with a lack of feeling of control during the birth experience. [28] Utilizing wireless fetal monitoring may allow for increased maternal movement and perceived control throughout the labor and birthing process, potentially decreasing maternal PND rates.

While fetal monitoring devices can provide obstetrical providers and mothers with more peace of mind by seeing a real time assessment of fetal wellbeing, they also can cause anxiety when readings are missing or inconsistent due to movement. as the wires and devices need to be in optimal configurations in order to best sense the fetal heart.[29 30] These positioning requirements can cause women to have a disrupted labor experience when utilizing wired fetal monitoring.[31] In some low risk pregnancies, intermittent monitoring is preferred, but in high-risk situations where this is not an option, a wireless device could be considered.[32]

Non-invasive fetal monitoring is now emerging as an option, with capabilities for women to receive wireless monitoring. Wireless fetal monitoring can allow women to be monitored throughout the labor process without being entangled by the limitations of the monitoring devices. This allows for freedom and increased mobility. [24 28]

Study Aim

This study aimed to evaluate the acceptability of using a wireless fetal heart monitor for monitoring the fetal heart rate throughout pregnancy.

A wireless fetal heart monitor could allow mothers to be more comfortable and feel more in control during their prenatal monitoring sessions and during the birthing process. This wireless fetal monitor would be placed on the maternal abdomen. The device would utilize an algorithm to extract the fetal heart data from the maternal heart data and bodily noise. This extracted fECG would be shared with healthcare providers. It would transmit the heart data via an app to healthcare providers, allowing for increased healthcare accessibility and monitoring of the fetal heart. The monitor could also be directly utilized by healthcare providers during the labor process. The wireless fetal monitor would allow women who have low healthcare access to have more consistent care. To best construct the device, a survey of women of reproductive age was created, distributed, and examined.

The questionnaire was developed to address the question “What is the level of acceptability of a fetal monitoring device among women of reproductive age based on survey data?”

The questionnaire complements the concurrent research to develop a wearable fetal monitoring device, to ascertain the best size and specifics of the device. This allows for the development of a device that best serves the target population and will be practical for everyday use.

Methods

Survey Development

Pilot Survey

Before implementing the survey, a pilot survey was created and distributed. The pilot survey allowed for the survey to be tested for readability and flow. Participants were asked to complete the survey

and provide feedback. Participant acceptability levels and opinions on the device were not evaluated; instead, participants were asked at the end of the pilot survey to provide feedback on the survey (length, readability, etc.). All feedback was anonymous. Improvements were made in consideration of participant feedback. Metrics provided by the survey software Qualtrics™ were also examined.
Pilot survey participants indicated that the survey was of a reasonable length. Most completed the survey on a mobile phone; to best accommodate this mode of survey completion, the survey was assessed to ensure readability on mobile phones and laptops. Definitions and clarifications were added to the survey to provide improved readability, accessibility, and ease of participation. After the pilot survey feedback was analyzed and added to the survey, the updated survey was launched.

Survey

The questionnaire was designed in consideration of previous research on acceptability of wearable devices and improvement of the pilot survey.[33-35] It assessed the acceptability (e.g., wearability, comfort, practicality) of a wearable fetal heart monitor (fECG) during pregnancy care.
The Qualtrics™ survey software was used to build an online questionnaire to assess patient acceptability of the device. The questionnaire included 47 questions, implementing the five-point Likert scale, multiple choice questions, and one open-ended question at the end. Scaled questions included the following options: strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, and strongly agree. Participants accessed the survey via a survey link through a QR code. All survey responses were anonymous.

Survey Structure

Consent

Before participants began the survey, informed consent form was provided at the beginning of the survey. Participants were informed of the predicted time length of the survey. This time estimate was based on results from the pilot survey. Question types and topics (including age, gender, educational status, health status, internet access, and technology) were shared, and data security information was communicated with participants.

Background Information

To ensure that participants were informed about the fetal monitoring device that the survey was assessing, an explanation of the device and photo of a monitoring device were provided:
“This survey is about wearable medical devices. These monitoring devices collect data on your heart rate, blood pressure, and if you were pregnant could collect your baby’s heart rate and movement. Below is a picture of the medical device. It is about the same size and weight as a band-aid and could be worn for one week. If used during pregnancy, it would be worn on your abdomen or belly and could send your health data to your doctor/health care provider.”

Conditional Logic

To ensure that participants fit the survey requirements, conditional logic was utilized for several questions. Conditional logic allowed for survey responses that did not fit survey parameters (female, age 18-49) to be discarded. When survey participants gave a response that was outside survey parameters, the survey was automatically ended, and participants did not complete the following survey questions.
Several survey responses were used to determine if participants qualified to take the survey under the provided stipulations: the participant was required to consent to the survey and use of their anonymized information, and they were required to be a female of age 18 to 49. Conditional logic ensured that qualifying participants were included in the survey data.

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Information Technology Information

The definition of the term “information technology” was provided to increase the readability and understandability of the survey:
“Information technology is the use of computers to collect, store and share data.”

Participants were assessed on their information technology experience using a five-point Likert scale. Statements were provided, and participants indicated their level of agreement with the statement. For example, statements such as “I think that information technology has some benefits” or “I think that privacy breaches are a serious issue today” were provided, and participants indicated their level of agreement or disagreement with the provided statements.

Acceptability

Statements were provided to participants concerning acceptability (ie The wearable medical device would limit my daily activities, The wearable medical device could help me during pregnancy), and participants indicated their levels of agreement using a five-point Likert scale.

Recruitment

Responses were collected via snowball recruitment of participants. The aim of the study, along with the QR code that linked to the questionnaire, was presented to the community via postering in public spaces and e-mailed electronic newsletters. Participant inclusion criteria included being a woman of reproductive age (18-49) and the ability to read English. Responses were collected from September 2023 to January 2024.

An incentive of twenty dollars in prepaid gift card form was provided to participants who completed the survey. To maintain anonymity of survey respondents, compensation information was not collected with participant responses. At the end of the survey, a link was provided to all respondents. Instructions were provided to participants, detailing that participants who desired to receive compensation for their survey completion could follow the link to a compensation survey. This survey was separate from the acceptability survey and allowed for participant responses to maintain anonymity. Participants who filled out the compensation survey were provided with compensation, which was a prepaid gift card that was mailed to participants. Follow-up was conducted to ensure that participants received compensation.

Statistical Analysis

Survey responses were analyzed using SPSS (v29) and descriptive statistics. Qualitative methods were used to summarize the main themes of one open-ended question at the end of the questionnaire.
Participant location (urban/rural) was determined using submission IP address. The zip code location of the IP address was determined using an IP Geolocation tool.[36] The urban/rural designation of the zip code was found using the Rural Health Information Hub.
Counties comprised of a population of 5,000 or less inhabitants were considered rural for the purposes of the survey analysis.[37] Responses were individually analyzed to determine the classification of their locations.

Data Exclusion

Incomplete surveys and bot responses were excluded from data analysis.

Results

A total of 163 participants completed the questionnaire. On average, the survey participants completed it in 5.1 minutes. 103 participants provided responses to questions gauging acceptability of the device.

Demographics

The survey was limited to female participants aged 18-49. Participant age, ethnicity, and education level were collected. Participant internet access levels were also assessed.

The median age of survey respondents is over 30 years old.

The race/ethnicity breakdown for the survey participants is as follows: white 49.7%, Black or African American 13.4%, Hispanic or Latino 14.8%, American Indian or Alaskan Native 11.4%, Asian 7.4%, Middle Eastern or North African 1.3%, Two or more 2%. These percentages were similar to the percentage breakdown of the United States Population. The 2020 U.S. Census recorded the following percentages for race and ethnicity: white 57.8%, Black or African American 12.1%, Hispanic or Latino 18.7%, American Indian or Alaskan Native 0.7%, Asian 5.9%, Two or more 4.1%, and 0.6% other.[38] The distributed survey included Middle Eastern or North African as a racial option. This designation was included with white in the 2020 census, but it will be given its own designation in the 2030 census.[39]

The participant education levels are as follows: high school degree or equivalent 2%, some college but no degree 42.6%, associate degree 10.8%, bachelor’s degree 21.6%, and graduate degree 23%. This is slightly higher than the U.S. national average that was recorded in the 2020 Census.[38]

Health Literacy

Health literacy levels were assessed using three questions in the survey. These questions were developed based on the U.S. Centers for Disease Control and Prevention (CDC) guidelines. These three questions allowed respondents to report their difficulty in finding medical information, understanding information communicated by health professionals, and understanding written health information. It is important to assess health literacy, as it can affect patient understanding of their care and quality of care.[40]

The health literacy questions are as follows:

- How difficult is it for you to get advice or information about health or medical topics if you need it?
- How difficult is it for you to understand information that doctors, nurses, and other health professionals tell you?
- How difficult is it for you to understand written health information?[41]

To assess health literacy levels, a median split was utilized to distinguish between high health literacy and less than high health literacy. The answer choices for these statements were as follows: extremely easy (score=4), somewhat easy (score=3), somewhat difficult (score=2), very difficult (score=1), I don't look for health information (score=0), and I don't pay attention to written health information (score=0). As three questions were used to determine health literacy, with a maximum additive score of 12 and minimum score of 0, healthy literacy levels were tabulated using the cumulative score. [42] Participants were separated into two categories: those who have high health literacy and those who have less than high health literacy. This separation was conducted in accordance with the CDC guidelines concerning health literacy tabulation. [41]

Overall Device Acceptability

Participants aged 30-49 demonstrated a higher rate of device acceptability (70.07%, n=54) than younger participants aged 18-29 (53.06%, n=49). Regarding device features, 70.7% of participants demonstrated preference for a device 1 inch by 3 inches or smaller, indicating a preference for a smaller device. 73.6% of participants (n= 120) indicated that they would be comfortable with wearing the device daily. In gauging device convenience, 14.7% (n=24) strongly disagreed and 28.8% (n=47) somewhat disagreed that the monitor would limit their daily activities. Also, 49.7% (n=81) agreed to some degree that the device would be "compatible with most aspects of my activity."

When participants were asked about how they would feel about using the device for the first time, 11% (n=18) somewhat agreed and 2.5% (n=4) strongly agreed that they would feel anxious. However, 21.5% (n=35) strongly disagreed with feeling anxious about using a device they had not previously used. Over half of respondents agreed that learning to use the device seemed easy.

Participant Feedback

Responses to an open-ended question asking participants to voice doubts about the device indicated concern for privacy. Of the 23 participants who provided a written response, six participants voiced concern for data from the monitor being shared with third parties, insurance companies, or any entity outside of their care team. Participants stated concern about the process of learning more about how to use the device, as well as worry about potential side effects. Lastly, concerns were raised about the accuracy of the device.

Discussion

Results

As found in the survey, increasing acceptability levels were positively correlated with increasing age. 163 participants completed the survey, with 103 responses to acceptability questions; older women aged 30-49 showed higher rates of acceptability (70.07%, n=54) than young women aged 18-29 (53.06%, n=49). Participant feedback involving concerns of the target population regarding the wearability, usability, and safety of the device will be considered when developing the fetal monitoring device.

The vast majority of respondents were in urban areas (with a population greater

than 5,000 residents).[37] This may have led to the average health literacy and acceptance rate collected in the survey being higher than it otherwise would have been if more rural-located respondents had participated in the survey. People who live in rural locations have slower medical responses to healthcare emergencies such as stroke. [5] There are less specialists who work in rural areas, leading to a lack of proper healthcare availability.[6] In a study on rural healthcare utilization in the United States, rural patients were generally found to have lower levels of healthcare utilization and worse health statuses than their urban counterparts.[7] All of these factors can contribute to rural health literacy levels, and this can create a reduced average health literacy level among rural patients when compared to urban patients.[43]

When utilizing a monitoring device with patients, it will be vital to fully educate them about the device. As accounted for in survey results, patients who are more educated about health issues, having higher health literacy levels, may be more accepting of a fetal monitoring device.

Limitations

The survey included a highly educated population, and most respondents were in urban areas. This may have impacted the responses that were received, creating a skewed representation of acceptability.

Distribution of the survey provided some challenges, as sharing the link on the internet created a risk of bots creating invalid responses. There was a survey that was implemented before this survey, but it was overwhelmed by bot responses, and the results were discarded in favor of creating a new survey and reimplementing it. Furthermore, the distribution methods used (snowball recruitment, postering, social media) may not have created a fully representative sample of the target population.

Future Research

The questionnaire served as one aspect of an interdisciplinary collaboration to develop a remote fetal monitoring device. Next steps of this project include testing a prototype of the remote monitoring device. Feedback received from the questionnaire will be used in development to create a device that best serves the patient population.

Conclusion

These findings will guide the design and clinical utilization of the monitoring device to ensure effective use for providers and patients alike. Collecting and analyzing this data is crucial in tailoring a product to the intended population’s needs and convenience. Participant feedback aids in creating a product that best serves its intended population.

Use of a fetal monitoring device will allow for increased healthcare access, with the goal of increasing positive health outcomes for mothers and babies alike. It will allow for

More research is required to analyze rural acceptability levels. Future research can aid in the scientific advancement of the understanding of device acceptability and the factors that affect

acceptability. It will also aid in developing a device that best serves the population.

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Conflicts of Interest

None to report

Abbreviations

Fetal echocardiogram: fECG

Congenital Heart Defect: CHD

Ventricular Septal Defect: VSD

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