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Development of the Internet of Things (IoT) in early detection of emergencies using postpartum alert

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ABSTRACT

Background: IoT-based postpartum alert is the development of a vital sign-checking tool using obstetric early warning system indicators. This is an effort to prevent maternal death during the postpartum period. Monitoring is carried out manually without interpretation and recommendations and is not connected to the Internet. Adding interpretations and recommendations and connecting to the Internet can help mothers and families with self-examination and remote monitoring by midwives or health workers because, generally, mothers are at home during the postpartum period.

Purpose: This research aims to create and test an IoT-based Postpartum alert detection tool that has been developed.

Methods: This research is R&D, divided into five stages: collecting information through literature study, product/model design, design validation, design revision, and small-scale product/model testing.

Results: An IoT-based early postpartum detection tool with a portable design has been created. The test results are based on the Receiver Operating Characteristic (ROC) classification in the area under the ROC curve, which shows that the tool has an outstanding category with an accuracy level of 90%.

Conclusion: The IoT-based postpartum emergency detection alarm is a vital sign measuring tool that can interpret and recommend signs and connect to health workers using internet features. The measurement and interpretation results are sent to the cloud system to provide recommendations, data storage, and notification alarms to health workers.

INTRODUCTION

Half of maternal deaths (51.8%) occur during the postpartum period, more than during pregnancy and childbirth, so this period needs attention. Generally, after giving birth, the mother will be sent home and spend her postpartum period outside the health service building, so follow-up midwifery care is provided through home visits. Home visits during the postpartum period are generally carried out by health workers only around four times within 42 days after giving birth. Emergency conditions can occur for up to a year, so continuous monitoring is required. The results of the study showed that Postpartum death occurred around 18.6% on days 1-6 postpartum, 21.4% on days 7-42 postpartum, and 11.7% on days 43-365 postpartum.[1,2]

Vital signs can be benchmarks for early detection of emergencies that identify postpartum morbidity. Oxygen saturation (SpO2) <93% is significantly associated with postpartum sepsis.[3] High blood pressure or hypertension can be a benchmark for postpartum preeclampsia.[4] This clinical observation is based on pulse, temperature, blood pressure, and level of consciousness in obstetrics, known as the Early Warning System (EWS) in obstetrics, which has a very high accuracy of 89% and specificity of 85%. Obstetric EWS has very high accuracy in predicting mortality (AUROC >0.80) in critically ill obstetric patients.[5] Systolic and diastolic blood pressure and heart rate are the most muscular physiological parameters for predicting morbidity.[6]

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Innovation is needed to continuously monitor the health of postpartum mothers, at least by using indicators to measure vital signs. The Internet of Things (IoT) can fulfill the need to continuously monitor postpartum mothers' health without staying overnight at a health facility. IoT refers to a network of interconnected physical devices that can communicate with each other over the Internet. IoT devices can collect and transmit health data in postnatal maternal health monitoring in real-time.[7,8] Previous research examined emergencies in the postpartum period using vital signs, namely pulse rate and oxygen saturation. However, this research was still limited to assessing the risk of postpartum hemorrhage, did not assess other emergency conditions such as preeclampsia, and was not connected to the Internet to facilitate real-time data transmission to health services.[9] Further action is needed to research and develop these tools to fill the existing gaps.

This research aims to create and test an IoT-based Postpartum alert detection tool. It is hoped that the tool can answer the need for measuring instruments that can detect emergency conditions during the postpartum period, such as preeclampsia, and the addition of internet features so that health workers can continue remotely monitoring postpartum mothers who have been cared for at home. It allows mothers to be more aware and involved in monitoring their health so that early preventive measures can be taken if any abnormal changes occur.

METHOD

This is a Research and Development (R&D) outlined in five steps: literature study, product/model creation, design validation, design revision, and small-scale product/model testing.[10]

Stage 1 Literature Study

At this stage, a literature review is carried out in an effort to obtain information for collecting supporting data. The potential and problems that exist in the community are explored through interviews about maternal mortality rates with policymakers at the Pemalang District Health Service and field observations regarding vital examination tools that currently exist.

Stage 2 Tool Development

Researchers assisted by Electrical Engineering made model designs and carried out technical and technological feasibility tests, accompanied by making a development schedule for the devices to be built. Then, the stage of analyzing possible problems in making the sensor is continued, supported by data from measurements on a digital sphygmomanometer to be used as recommendations and displayed on the sensor.

Stage 3 Expert Validation

This sensor design was validated by experts to determine the validity of determining postnatal emergency status and recommendations using a vital sign measuring instrument consisting of systolic pressure, diastolic pressure, pulse rate, and oxygen saturation. Testing is carried out by experts with basic knowledge in electrical engineering, information technology, obstetricians, and midwives.

Stage 4 Product Revision

After carrying out expert validation and obtaining recommendations from the results of the application design created, the researcher's next step is to carry out revisions based on the expert's recommendations.

Stage 5 Small Scale Trial

The design used in this research is observational research with a one-approach shot case study approach. This design was used to assess the effectiveness of sensors in measuring pulse rate, blood pressure, and oxygen saturation to detect postpartum maternal emergencies in one group. This study uses a vital sign measuring tool to detect early postnatal emergencies.

The stages carried out in observational research with a one-shot case study design provide treatment to the observation group. Checking vital signs in postpartum mothers, namely blood pressure, pulse, and oxygen saturation, using a tool designed, namely IoT-based Postpartum Alert with manual measurement results using Omron HEM-8712, which has calibrated PT. Indocal with number S/N: 20200404465VG dated 13/12/2022-13/12/2023 and oxygen saturation using the Jumper brand. Then, the results of observations of design tools and manual tools that have been calibrated will be compared with the results of midwife/doctor examinations listed on the medical record sheet. Data from observations or treatments are compared, and accuracy calculations are carried out, which are used to test the established hypotheses.

The trial was carried out in the city of Pemalang in March-April 2023. The population used in this study was mothers >6 hours postpartum, with a sample size of 40 respondents. Inclusion criteria consisted of postpartum mothers (>6 hours – 42 days), normal or cesarean delivery, mothers with a history of high risk during pregnancy and childbirth, and those willing to be respondents. The exclusion criterion was not being willing to take part in this research. Samples were taken using a purposive sampling technique. This research has received of ethical approval from the Health Research Ethics Committee of the Ministry of Health, number 0163/EA/KEPK/2023, Semarang Health Polytechnic. Clinical Trial Registration System (UMIN-CTR) ID UMIN000050274.

RESULTS

Result in Literature Study

Conducting a study of data on the causes of maternal death in Pemalang Regency over the last five years using data on the health profile of Pemalang Regency in 2018, there were 11 cases (64.70%) of deaths that occurred during the postpartum period. In 2019, there were 10 cases of maternal death during the postpartum period (76.92%). In 2020, there were 12 cases of maternal death during the postpartum period (80%). Moreover, in 2021, there were 16 cases of maternal death during the postpartum period (50%). Measuring instruments for detecting pulse rate, blood pressure, and oxygen saturation are available on the market and used by health workers and the general public, but in their form and do not provide recommendations for results, mainly when used as monitoring for early postpartum detection emergency state.

Results of Application Development

Postpartum Alert uses a digital blood pressure monitor and MAX30102 sensor to measure blood pressure, pulse rate, and oxygen saturation. Several components, including Arduino Nano, SIM 900A, and buzzer assist the performance of this tool. This tool consists of 2 devices. Device I measures vital signs and then sends the data to device II and the cloud system (Figure 1). The tool has an LCD to display measurement results and emergency status. The push button, which acts as an on and off button, is installed on the monitor's side, making it easier for users to read measurement results. The wireless communication system uses Global System for Mobile Communications (GSM) module communication to control devices using a remote monitoring system to send sensor data from device I to device II (alarm) and connect the device (device I) to the Internet.

Furthermore, the measurement results will be stored in the Cloud, which can be connected to a computer, laptop, or cellphone database, making it easier for users to analyze the health status of postpartum mothers. And as a communication suggestion in the form of notification to midwives or obstetricians in the form of alarm notifications as early notification of the emergency status of postpartum mothers. This tool is designed with a minimalist design, portable, easy to use, and practical so that the primary goal of making a postpartum monitoring tool at home can be achieved. Initially, device 1 of the postpartum alert measures systolic pressure, diastolic pressure, pulse rate, and oxygen saturation. After measuring vital signs, the device will provide an interpretation. Then, the measurement results will be sent to the alarm (device II) to sound an alarm as a notification for health workers. At the same time as sending notifications, tool one will also send data to the cloud system for data storage and finding recommendations.

Result of Validity and Product Revision

Product revisions are based on expert recommendations, namely wiring improvements, tool calibration using linear regression, and better testing of tools on postpartum mothers to detect preeclampsia. Expert recommendations regarding the development of tools used in all types of obstetric emergencies can be made after knowing the effectiveness of existing tools for postpartum mothers.

Result of Trial

Based on Table 1, emergency status is based on age; in the 20-35 year age range, the majority have emergency status within normal limits at 47.5%, alert and danger status at 30%. Based on parity, most multiparous mothers have normal emergency status at 42.5%. Meanwhile, primiparous mothers had the highest emergency alert and danger status at 27.5%. Based on the postpartum period, normal emergency status, alertness, and danger most often occur in the period >6 hours days, respectively, 52.5% and 30.0%. Moreover, based on birth history, the emergency status of normal, alert, and danger is highest in mothers with normal delivery at 40.0% and 25.0%, respectively.

Table 1. Characteristics of Respondent (n=40)

Characteristics	Emergency Status	
	Normal	Warning
Age		
< 20 years	0 (0.0%)	1 (2.5%)
20-35 years	19 (47.5%)	21 (30.0%)
>35 years	4 (10.0%)	4 (10.0%)
Parity		
Primipara	6 (15.0%)	11 (27.5%)
Multiparous	17 (42.5%)	6 (15.0%)
Postpartum period		
>6 hours-2 days	21 (52.5%)	12 (30.0%)
3-7 days	2 (5.0%)	3 (7.5%)
8-28 days	0 (0%)	1 (2.5%)
29-42 days	0 (0%)	1 (2.5%)
Types of Childbirth		
Normal Delivery	16 (40.0%)	10 (25.0%)
Cesarean Section	7 (17.5%)	7 (17.5%)

Table 2 shows that the accuracy of the four vital sign components measured is the highest in measuring oxygen saturation at 99.49%, and the lowest in measuring systolic pressure at 91.92%. Of the 40 measured postpartum mothers, 57.5% of the results were normal, while 42.5% were alert and dangerous. Overall, the tool provides accuracy results of 90%. Based on Table 3, calculating the tool's effectiveness shows a precision value of 76%, a recall/sensitivity value of 100%, a specificity value of 85%, and an F1 Score value of 88%. Meanwhile, the accuracy value of the tool in providing interpretation is 90%. This shows that the device is practical and performs well in providing interpretation.

Table 2. Postpartum Alert Measurement Accuracy

Variable	Accuracy
Systolic pressure	91.92%
Diastolic Pressure	92.21%
Pulse	92.26%
Oxygen Saturation	99.49%
Enforcement of Emergency Status	
Normal	57.5%
Alert and Danger	42.5%
Accuracy level in interpreting emergency status and recommendations	
In accordance	90%
Not exactly	10%

Table 3. Postnatal Emergency Detection

Precision	Recall	F1-score	Specificity	Accuracy
0.76	1.00	0.88	0.85	0.90

DISCUSSION

Postnatal emergency detection is designed to measure vital signs guided by obstetric EWS. The vital sign parameters used in obstetric EWS assessment are pulse, blood pressure (systolic and diastolic), oxygen saturation, respiratory frequency, and level of consciousness. It is hoped that this detection tool can later be used at home as a monitoring tool during the postpartum period so that only three indicators are used, namely, blood pressure (systolic and diastolic), pulse rate, and oxygen saturation, considering that this tool is easy and is starting to be commonly used by mothers or families. The selection of these three vital signs indicators was also based on their application as indicators for assessing postpartum emergencies in other types of EWS and were proven to have good performance in predicting morbidity and mortality.[11–13]

In developing this tool, researchers were assisted by experts with basic knowledge of electrical engineering, information technology, obstetricians, and midwives. Based on the advice of the expert team, the initial design of the tool by a team of electrical and information systems experts carried out several product revisions, namely wiring improvements and tool calibration using linear regression. Meanwhile, the expert team of obstetricians, obstetricians, and midwives recommended that testing of the device should be carried out on postpartum mothers to detect preeclampsia because most maternal deaths occur after birth and the need for blood pressure monitoring within seven days after birth, especially for mothers with a history of hypertension in pregnancy.[14] Then, expert recommendations regarding the development of tools used in all types of obstetric emergencies can be made after knowing the effectiveness of existing tools for postpartum mothers.

Self-monitoring of blood pressure for postpartum mothers with a history of hypertension in pregnancy or preeclampsia who received continued therapy during the postpartum period resulted in better control of diastolic blood pressure for up to 6 months, even after stopping treatment.[15] est results of the device in postpartum women treated at RSUD Of the four postpartum periods in Pemalang, period I, namely 6 hours – 2 days, had the most emergency status of alert and danger. In the period >7 days postpartum, there were still postpartum mothers being treated at the Pemalang District Hospital with emergency status of danger. This data shows that the mother's postpartum period still requires monitoring because this period contributes the most to maternal morbidity and mortality.[16] It is recommended that all women contact midwifery services within three weeks postpartum, receive further care as needed, and then end with comprehensive care within 12 weeks postpartum.[17] So, it is necessary to understand the importance of self-monitoring of postpartum mothers so that preventive or immediate action can be taken if necessary.

Based on test accuracy, systolic pressure has an accuracy rate of 91.92%, diastolic pressure has an accuracy rate of 92.21%, pulse rate has an accuracy rate of 92.26%, and oxygen saturation is 99.49%. Accuracy results of >90% based on the AUC alarm can be declared to have a classification suitable for use.[18] Even though the measurement accuracy results for these variables have different ranges, these four variables still contribute to monitoring postnatal maternal health. However, in this case, the alarm still needs to be improved through technological development and further testing so that the four variables can function properly because the existing variables have error values that are not yet allowed by the Health Equipment and Facilities Safety Agency (BPAFK), namely <5%.

The determining factor for sensor performance in a digital sphygmomanometer that produces <95% accuracy can be influenced by several factors. In general, there should be sufficient rest time before starting measurements. Differences in arm position can cause differences in 5 to 10 mmHg values. The influence of arm position on the measured blood pressure is due to hydrostatic pressure: raising the arm (or wrist) 1 cm lower can cause blood pressure-

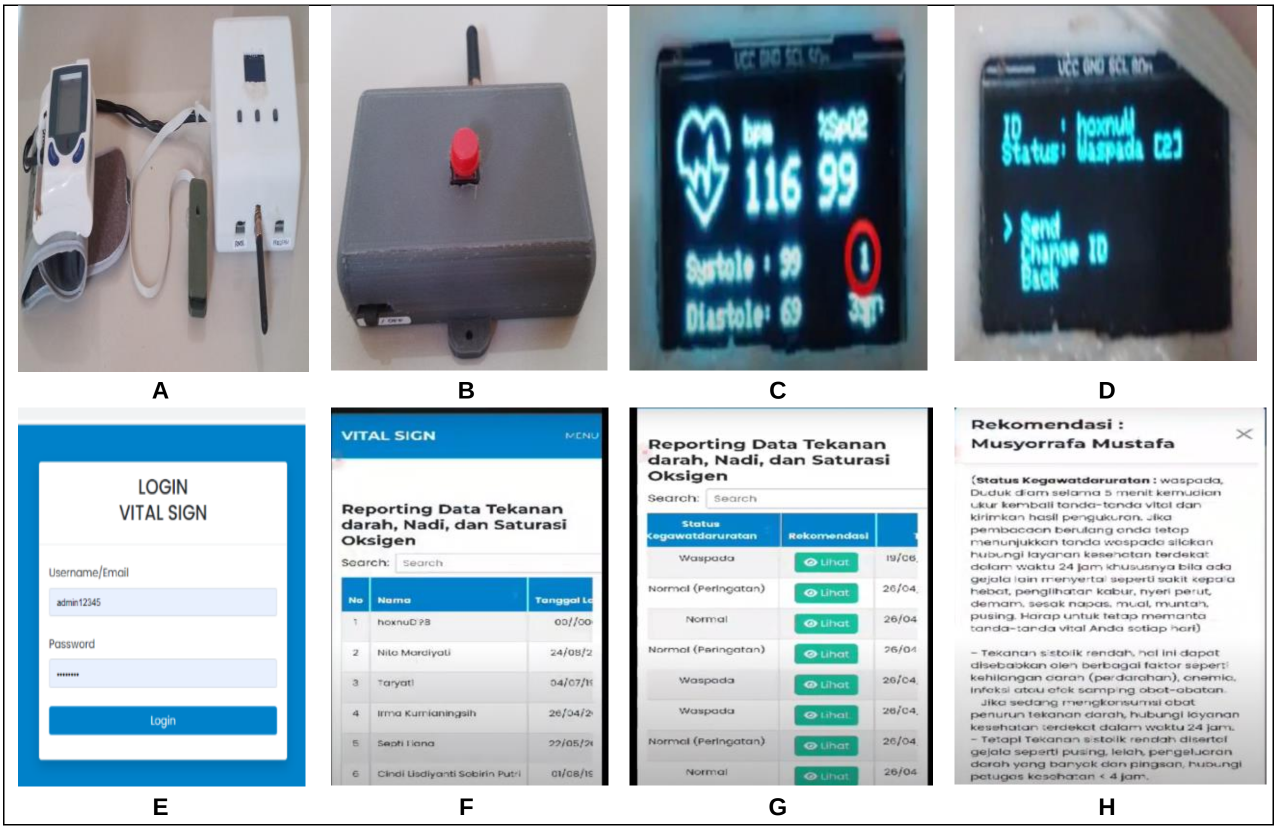

Figure 1. Postpartum Alert. A: Device 1; B: Device 2 (Alarm Notification); C: Vital signs measuring; D: Interpretation device. E: Login menu; F: List of patient; G: Emergency status and recommendations; H: Recommendation display on the web page.

to be 0.7 mmHg lower or vice versa. The cuff should be held at heart level, that is, at the right atrium level, which is generally midway between the jugular vein and the xiphoid process. It can be equipped with a tilt sensor to help keep the wrist in the same position for each measurement or subsequent devices using an upper arm cuff. Blood pressure is physiologically different at the wrist than at the upper arm. Moving further from the ascending aorta to the radial artery, systolic blood pressure increases, and diastolic blood pressure decreases, increasing pulse pressure. Blood pressure difference tests using oscillometry on the wrist and upper arm provide measurements that often differ significantly by around 5 mmHg.[19]

The choice of the MAX30102 sensor in the design tool is correct because it has an accuracy of 99.59%. The sensor measures oxygen saturation by shining light on the skin and measuring changes in the light absorption of oxygen (oxyhemoglobin). Deoxygenated blood (reduced hemoglobin) using two wavelengths of light, 660 nm (red) and 940 nm (infrared). Conventional pulse oximeters use transmission sensors in which the light emitter and detector are placed on opposite surfaces of the tissue layer. This sensor is suitable for use on fingers, toes, or earlobes; when tested under low perfusion conditions, the finger probe performed better than other probes.[20]

The results of evaluating the tool's performance in interpreting measurement results show that the tool has good performance in general. The accuracy of the alarm in interpreting and providing recommendations is around 90%, precision 76%, recall/sensitivity 100%, specificity 85%, and F1 score value 88%. Overall, the tool performance evaluation results show that the tool performs well in classifying data and can be used as a consideration for monitoring the health of postpartum mothers who are generally at home. Having recommendations can help postpartum mothers know their emergency conditions and the right time to contact health workers.

The advantage of this monitoring tool is its ability to send measurement results in real-time to the cloud system, allowing health workers to monitor the mother's health condition and immediately respond if danger signs are detected. It is essential to ensure the safety and health of mothers after giving birth by taking preventive measures through remote monitoring.[21] Early treatment starting in the postpartum period with a peripartum screening approach can identify women at risk of developing hypertension with intensive blood pressure monitoring and immediate pharmacological therapy. They are carried out to prevent cardiovascular disease.[22] Postnatal blood pressure monitoring programs carried out by the patients themselves are appropriate for closer supervision of all patients, especially those who have risk factors or are in conditions of limited health services.[23]

This research utilizes IoT technology, using the internet network and GSM as the central infrastructure. IoT has shown its application potential in connecting various medical devices, sensors, and health professionals to provide quality medical services in remote locations.[24] In this research, a postpartum mother's vital sign monitoring tool was designed to collect vital sign data through sensors and then transmit the data. To the cloud system via the internet network. The cloud system can then analyze and process vital signs data in real time and provide notifications or alarms if significant changes exist. In other words, the use of internet networks and cloud systems in this research allows for sending data automatically, without human intervention, which is the basic concept of IoT.

Self-monitoring of blood pressure has benefits related to convenience (no need to visit a health facility), convenience (performed in an environment where they feel comfortable, reduces the likelihood of white coat hypertension), increased self-empowerment, reduced anxiety, and a cost-effective approach to expanding health services.[25] Thus, it is hoped that this research can significantly contribute to the world of health because it has the innovation potential that is very relevant to the health problems of postpartum mothers.

CONCLUSIONS AND RECOMMENDATION

The Postpartum Alert tool has been created, which is an innovative tool for monitoring vital signs that is connected to health workers using internet features, measurement results can be sent in real-time to the cloud system to provide recommendations that allow data storage, and an alarm will sound to provide notification to health workers if postpartum mothers monitor their vital signs independently and send the measurement results so that if danger signs are detected, preventive action can be taken. The results of the accuracy of measuring certain variables still need to be improved as input for developing better tools in the future. The currently designed tool still needs to improve in that there is varying accuracy for each vital sign measurement component and does not meet the standard for the type of medical device as recommended at least 95%.

REFERENCES

1. Petersen EE, Davis NL, Goodman D, et al. Vital Signs: Pregnancy-Related Deaths, United States, 2011-2015, and Strategies for Prevention, 13 States, 2013-2017. *Morbidity and Mortality Weekly Report*. 2019;68(18):423-429. doi:10.15585/mmwr.mm6818e1
2. Schrey-Petersen S, Tauscher A, Dathan-Stumpf A, Stepan H. Diseases and Complications of the Puerperium. *Dtsch Arztebl Int*. 2021;118(Forthcoming):436-446. doi:10.3238/arztebl.m2021.0168
3. Bakhtawar S, Sheikh S, Qureshi R, et al. Risk factors for postpartum sepsis: a nested case-control study. *BMC Pregnancy Childbirth*. 2020;20(1):297. doi:10.1186/s12884-020-02991-z
4. Filipek A, Jurewicz E. Preeclampsia - a Disease of Pregnant Women. *Postepy Biochem*. 2018;64(4):232-229. doi:10.18388/pb.2018_146
5. Umar A, Ameh CA, Muriithi F, Mathai M. Early warning systems in obstetrics: A systematic literature review. *PLoS One*. 2019;14(5):e0217864. doi:10.1371/journal.pone.0217864
6. Hannola K, Hoppu S, Mennander S, Huhtala H, Laivuori H, Tihtonen K. Obstetric early warning system to predict maternal morbidity of pre-eclampsia, postpartum hemorrhage and infection after birth in high-risk women: a prospective cohort study. *Midwifery*. 2021;99:103015. doi:10.1016/j.midw.2021.103015
7. Abdulmalek S, Nasir A, Jabbar WA, et al. IoT-Based Healthcare-Monitoring System towards Improving Quality of Life: A Review. *Healthcare (Basel)*. 2022;10(10):1993. doi:10.3390/healthcare10101993
8. Al-Atawi AA, Khan F, Kim CG. Application and Challenges of IoT Healthcare System in COVID-19. *Sensors (Basel)*. 2022;22(19):7304. doi:10.3390/s22197304
9. Angraini MJ, Hidayat ST, Ramlan D, Hadisaputro S, Sumarni S. Pengembangan dan EfektivitasPulse Oximeter Terhadap Pemantauan Risiko Perdarahan Postpartum. 2020.
10. Sugiyono. *Metode Penelitian Kuantitatif Kualitatif Dan R&D*. Cetakan ke. Bandung: Alfabeta; 2020.
11. Ibáñez-Lorente C, Casans-Francés R, Bellas-Cotán S, Muñoz-Alameda LE. Implementation of a maternal early warning system during early postpartum. A prospective observational study. *PLoS One*. 2021;16(6 June). doi:10.1371/journal.pone.0252446
12. Agarwal V, Suri J, Agarwal P, Gupta S, Mishra PK, Mittal P. Shock index as a predictor of maternal outcome in postpartum hemorrhage. *Journal of SAFOG*. 2021;13(3):127-132. doi:10.5005/jp-journals-10006-1894
13. Aarvold ABR, Ryan HM, Magee LA, Von Dadelszen P, Fjell C, Walley KR. Multiple Organ Dysfunction Score Is Superior to the Obstetric-Specific Sepsis in Obstetrics Score in Predicting Mortality in Septic Obstetric Patients. *Crit Care Med*. 2017;45(1):e49-e57. doi:10.1097/CCM.0000000000002018

14. Paladine HL, Blenning CE, Strangas Y. Postpartum Care: An Approach to the Fourth Trimester. *Am Fam Physician*. 2019;100(8):485-491.
15. Cairns AE, Tucker KL, Leeson P, et al. Self-Management of Postnatal Hypertension: The SNAP-HT Trial. *Hypertension*. 2018;72(2):425-432. doi:10.1161/HYPERTENSIONAHA.118.10911
16. Dol J, Hughes B, Bonet M, et al. Timing of maternal mortality and severe morbidity during the postpartum period: a systematic review. *JBI Evid Synth*. 2022;20(9):2119-2194. doi:10.11124/JBIES-20-00578
17. McKinney J, Keyser L, Clinton S, Pagliano C. ACOG Committee Opinion No. 736: Optimizing Postpartum Care. *Obstetrics and gynecology*. 2018;132(3):784-785. doi:10.1097/AOG.0000000000002849
18. Hoyer A, Zapf A. Studies for the Evaluation of Diagnostic Tests–Part 28 of a Series on Evaluation of Scientific Publications. *Dtsch Arztebl Int*. 2021;118(33-34):555-560. doi:10.3238/arztebl.m2021.0224
19. Kallioinen N, Hill A, Horswill MS, Ward HE, Watson MO. Sources of inaccuracy in the measurement of adult patients' resting blood pressure in clinical settings: a systematic review. *J Hypertens*. 2017;35(3):421-441. doi:10.1097/HJH.0000000000001197
20. Jubran A. Pulse oximetry. *Crit Care*. 2015;19(1):1-7. doi:10.1186/s13054-015-0984-8
21. Al-Kahtani MS, Khan F, Taekeun W. Application of Internet of Things and Sensors in Healthcare. *Sensors (Basel)*. 2022;22(15). doi:10.3390/s22155738
22. Giorgione V, Khalil A, O'Driscoll J, Thilaganathan B. Peripartum Screening for Postpartum Hypertension in Women with Hypertensive Disorders of Pregnancy. *J Am Coll Cardiol*. 2022;80(15):1465-1476. doi:10.1016/j.jacc.2022.07.028
23. Hacker FM, Jeyabalan A, Quinn B, Hauspurg A. Implementation of a universal postpartum blood pressure monitoring program: feasibility and outcomes. *Am J Obstet Gynecol MFM*. 2022;4(3):1-14. doi:10.1016/j.ajogmf.2022.100613
24. Pradhan B, Bhattacharyya S, Pal K. IoT-Based Applications in Healthcare Devices. *J Healthc Eng*. 2021;2021:6632599. doi:10.1155/2021/6632599
25. Yeh PT, Rhee DK, Kennedy CE, et al. Self-monitoring of blood pressure among women with hypertensive disorders of pregnancy: a systematic review. *BMC Pregnancy Childbirth*. 2022;22(1):454. doi:10.1186/s12884-022-04751-7