



Electromedical Device And Expert System for Early Detection of Hyperemesis Gravidarum

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A B S T R A C T

Hyperemesis Gravidarum (HG) is a pregnancy complication that is often overlooked as it is typically considered normal. If HG is not properly treated, nutrition will not be fulfilled which can negatively affect maternal and fetal health and even maternal and fetal death. The exact cause of HG is not identified, so there are no effective preventive methods. However early detection can help for prompt and appropriate treatment. Therefore, a monitoring system for pregnancy conditions was designed for HG early detection. This system employs the MPX5050 DP pressure sensor for measuring blood pressure, the MAX30100 for assessing maternal heart rate and oxygen saturation, the MAX4466 sensor for monitoring fetal heart rate, and an expert system using the certainty factor method to diagnose the probability of hyperemesis gravidarum. The expert system achieves an accuracy of 93.33%. In comparison to the aneroid sphygmomanometer, the designed sphygmomanometer reveals a mean difference of 3.5 mmHg for diastolic pressure, with a standard deviation below 8 mmHg for both systolic and diastolic pressures. The measurement of heart rate and oxygen saturation has a deviation of 1.8 % and 1.02 % respectively. These deviations align with the standards specified by the Ministry of Health for medical devices. For the fetal heart rate, the mean deviation is 3.4 bpm, and the measurement error is 2.38%. Thus, this system can be utilized to monitor pregnancy conditions, enabling the early detection of hyperemesis gravidarum.

INTRODUCTION

Hyperemesis gravidarum (HG) is a pregnancy complication characterized by persistent nausea and vomiting more than 10 times in 24 hours, making the health of an expectant mother worsen [1][2]. On average, 80-90% of pregnancies progress normally, with only 10-12% of pregnancies manifesting complications or evolving into pathological conditions. HG manifests in the 1st trimester and may persist into the 2nd trimester [3]. The exact cause of hyperemesis gravidarum is unknown [4] According to the World Health Organization (WHO), HG occurs worldwide. In the American continent, the incidence rate is between 0.5 - 2%. while, In Indonesia, the prevalence of HG is between 1–and 3% of all pregnancies.

If not treated properly immediately, HG can cause maternal weight loss (5% of initial body weight), dehydration, experience ketosis, acid-base disorders, aspiration pneumonia, tear of the esophageal mucosa, suffer from liver and kidney damage [5][6]. Another effect of HG can increase the risk of abortion, low birth weight babies (LBW), early birth, and congenital abnormalities. Additionally, pregnant women with HG have a higher incidence of intrauterine growth retardation (IUGR)[7]. If left untreated,

HG can lead to unmet maternal nutritional needs. Hyperemesis gravidarum (HG) can further interfere with maternal and fetal health, leading to fatal consequences and even death [1]. The mother is also at risk of liver, kidney, stomach, intestine, heart, and brain complications, resulting in premature birth[3]. Therefore, early prevention and treatment are essential to avoid dangerous maternal complications [8].

Based on the WHO's 2017 recommendations, expectant mothers are suggested to have eight prenatal care visits, while Indonesia only requires four. Long distances, busyness, pandemics, and other factors can be obstacles for expectant mothers to visit medical facilities as often as recommended. Meanwhile, routine pregnancy checkups are essential to detect pregnancy illnesses and complications, notably hyperemesis gravidarum, so that immediate treatment and therapy can be initiated. Several studies have developed an expert system for early detection of pregnancy disorders and complications. Basiroh [9], Embun F.wati[10], and Abdillah [11] created an expert system to detect pregnancy disorders and complications using the forward chaining method. Maylawati [12] designed an expert system using Artificial Neural Network to diagnose pregnancy complications. The existing research is still limited to designing expert systems. It has not yet been integrated with electromedical equipment. Whereas in data

analysis on expert systems besides requiring data on maternal symptoms and risk factors, it also requires checking the mother's blood pressure and mother's heart rate. An expert system without an electromedical device has limitations for direct use by pregnant women. Fetal heart rate monitoring is needed to know about fetal condition. Oxygen saturation of the pregnant woman must be monitored [13][14]. A $SpO_2 < 900$ constitutes an abnormal value. Some studies of pregnant women have used much higher values (up to $SpO_2 < 95\%$) to classify desaturations and a suggested normal value for SpO_2 in pregnancy is $\geq 97\%$ [13].

Therefore, it is necessary to develop an electromedical device supported by an expert system using factor certainty methods to monitor pregnancy conditions and detect hyperemesis gravidarum early. Electromedical devices include blood pressure, fetal heart rate, maternal heart rate, and oxygen saturation. The monitoring system is Android-based so that pregnant women can carry out self-examinations and detect hyperemesis gravidarum, thereby enabling early risk identification. This approach is expected to make it easier for pregnant women to monitor their pregnancy status. In addition, this technique will be useful for pregnant women who live in remote communities with limited access to health care, as it can support telemedicine applications for monitoring pregnancy conditions remotely. By enabling self-regular checkups for pregnancy conditions and potential hyperemesis gravidarum risks, it is hoped that this pregnancy disorder can be detected and treated early, reducing the risks and preventing total complications for the mother and fetus.

METHOD

Overview of Designed System

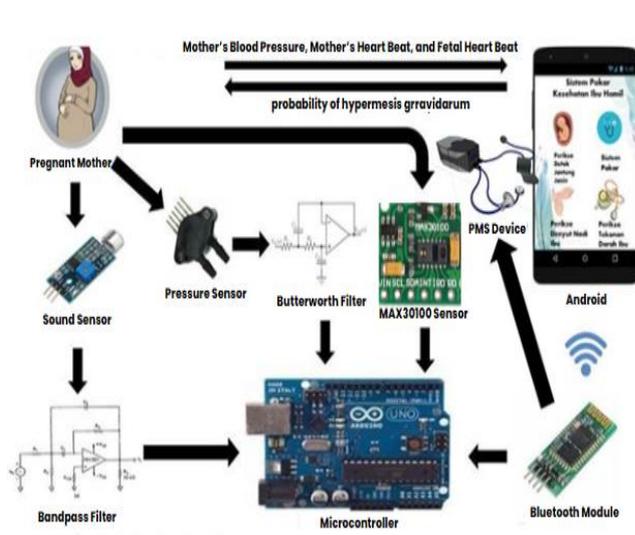


Figure 1. The hyperemesis gravidarum early detection system using the Certainty Factor

Figure 1 depicts the operating system. A blood pressure cuff is placed on the pregnant woman's left arm and then the pressure sensor will receive a signal. This signal is then filtered by the Butterworth High Pass. The filtered signal will be processed to produce systolic and diastolic blood pressure measurements in mmHg units. The MAX30100 sensor is placed on the finger and

relayed to Arduino to determine the mother's heart rate and oxygen saturation (SpO_2). The heart rate (Bpm), SpO_2 , and blood pressure values are displayed on the Android mobile application. Pregnant women place a stethoscope equipped with a MAX4466 sound sensor in their stomachs. The detected sound signal is filtered and processed on Arduino to produce fetal heart rate measurements, which are displayed on the cellphone. Arduino and Android cellphones are connected using Bluetooth. After the data on the mother's blood pressure, her heart rate SpO_2 , and fetal heart rate are obtained, the mother fills out a questionnaire containing symptoms and information related to her condition. The Certainty Factor expert system will process this data and estimate the probability of whether the pregnant woman is experiencing hyperemesis gravidarum or is normal.

Designing a Blood Pressure Measuring Instrument

Measuring Blood Pressure is one of the most common medical procedures performed on thousands of patients every day. Blood pressure is one of the basic vital signs regularly monitored by health professionals [15]. Because 98% of pregnancy tests involve blood pressure checks, the sphygmomanometer is crucial for expectant mothers [16]. The designed digital sphygmomanometer uses an MPX5050DP sensor, a Butterworth high-pass filter, and an Arduino microcontroller. The filter applied is a fourth-order Butterworth high-pass filter with a cutoff frequency of 1 Hz. Figure 2 shows the flowchart of the developed digital sphygmomanometer. The power supply, which has an on/off switch, powers the device. When the switch is turned on, the pump will inflate the cuff until it reaches a pressure of 180 mmHg. The pump then automatically stops operating and the pressure in the cuff is released gradually via a solenoid valve. The escaping air causes a slow change in pressure, which is measured by the MPX5050DP pressure sensor. The sensor signal is processed to determine the patient's systolic and diastolic blood pressure. The systolic pressure position is obtained when the signal magnitude first reaches 80% of the peak magnitude. The position of diastolic pressure is obtained at the last signal magnitude which is still 60% of the peak magnitude. These values are then converted to pressure units (mmHg). The microcontroller processes systolic and diastolic pressure readings which are then displayed on the LCD screen and Android smartphone

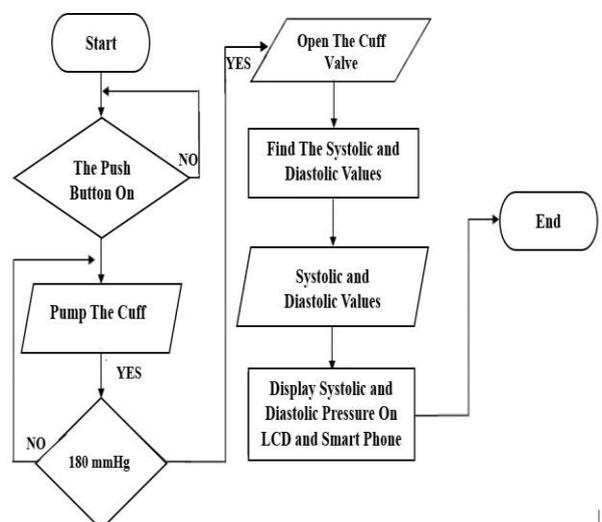


Figure 2. The Flowchart of the Designed Sphygmomanometer

Designing a Fetal Heartbeat Measurement Tool

The expectant mother places a MAX4466 sensor-equipped stethoscope on their abdomen to measure fetal heart rate. The fetal frequencies typically range between 20 Hz and 70 Hz [17]. The sensor output undergoes Butterworth bandpass filtering within this frequency range, followed by conversion to beats per minute (BPM). The data is then displayed on a 16x2 LCD and smartphone. Figure 3 shows the physical layout of the fetal heart rate detection system using a sound sensor.

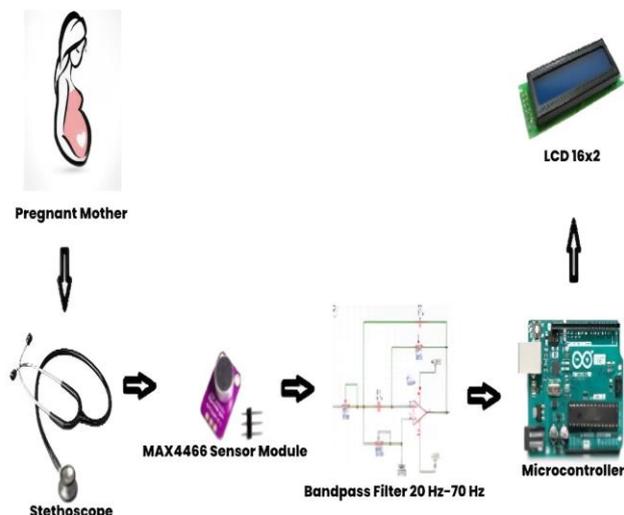


Figure 3. The physical layout of a fetal heart rate detection system using a sound sensor

Expert System Design

The CF value is obtained from the Qualitative Term given by the expert. Qualitative The expert determines the CF value based on Table 1.

Table 1. CF Interpretation Value[18][19]

Qualitative Term	Certainty Factor
Not	- 1.0
Almost definitely not	- 0.8
Mostly not	- 0.6
Probably not	- 0.4
Don't know/not sure	- 0.2 to 0.2
Probably	0.4
Most likely	0.6
Almost definitely	0.8
Definitely	1.0

The combination of Certainty Factor (CF) values satisfies the applicable rules proposed by McAllister, as shown in Table 2.

Table 2. McAllister's rule[18]

No	Rule Conditions	Formula
1	If both CF values are positive (++)	$CF_c(CF_1, CF_2) = CF_1 + CF_2 * (1 - CF_1)$
2	If both CF values are negative (--)	$CF_c(CF_1, CF_2) = CF_1 + CF_2 * (1 + CF_1)$
3	If one of the CF values is negative (+-)	$\frac{CF_1 + CF_2}{1 - \min(CF_1 , CF_2)}$

After conducting interviews with three experts, including obstetricians, a list of risk factors and symptoms of HG with their corresponding CF values was obtained, as shown in Table 3

Table 3. Risk Factors And Symptoms Of Hyperemesis Gravidarum With Their Certainty Factor Values

Parameter	Parameters Selection	CF Value
Age Range	Mother's age ≤ 20 years	0,4
	Mother's age 21-35 years	0,4
	Mother's age > 35 years	-0,6
Pregnancy to-	First pregnancy	0,6
	Second or more pregnancies	-0,6
Pregnancy Distance	Distance pregnant < 24 months	-0,6
	Pregnancy interval ≥ 24 months	0,4
Type of Pregnancy	Single pregnancy	-0,4
	Twin pregnancy	0,6
Disease History	Have a history/heredity of Hyperemesis Gravidarum	0,4
	Have a history/hereditary diabetes	-0,4
	Have a history/hereditary DM	-0,4
	Have a history of immune disorders (systemic lupus erythematosus/SLE)	-0,4
	Body mass index	IMT (Body mass index) > 25
Frequency of Vomiting	IMT (Body mass index) ≤ 25	0,4
	3-5 times/day	0,4
	5-6 times/day	0,6
	6-8 times/day	0,6
	≥ 8 times/day	0,8
Blood pressure	TD ≤ 60/50 mmHg	0,8
	TD 60/50 – 90/60 mmHg	0,4
	TD 90/60 - 120/80 mmHg	0,6
	TD 120/80-140/90 mmHg	0,4
	TD ≥ 140/90 mmHg	0,8
Heart rate	Heart rate ≤ 80 BPM	-0,8
	Heart rate 80 – 100 BPM	-0,6
	Heart rate ≥ 100 BPM	0,8
	Heart rate ≥ 110 BPM	0,4
	Symptom	Dry tongue
Less appetite		0,6
Sunken eyes		0,4
Depression/stress		0,4
Hard to breath		0,6
Fever		0,6
Hard to Poop		0,4
Bad breath		0,4
Pain in the Epigastrium (above the middle of the stomach)		0,6
Decreased skin turgor (skin flexibility)		0,6

The Certainty Factor (CF) method is a systematic process comprising several steps. Initially, CF values for both the expert (CF(H)) and the user (CF(E)) are determined based on Table 1. The CF value is then computed by multiplying the obtained CF(H) and CF(E) values. Subsequent steps involve combining

every two CF values using Mc. Allister's rule, with iterations continuing until the final symptom is selected. Ultimately, the resulting CF value is multiplied by 100% to present the answer in percentage form. This method ensures a thorough and quantifiable assessment of certainty throughout the evaluation process

RESULTS AND DISCUSSION

Blood Pressure Measurement

The performance of the designed sphygmomanometer was compared to a consumer-grade digital sphygmomanometer and a medical-grade aneroid sphygmomanometer. The measurement using an aneroid sphygmomanometer is performed by medical personnel (midwives). The measured results from the designed sphygmomanometer are presented in the Android application. Systematic data collection involved three sphygmomanometers in alternating order: the designed sphygmomanometer (De-S), followed by the digital sphygmomanometer (Di-S), and finally, the aneroid sphygmomanometer (An-S). Figure 4 and 5 presents a comparison of systolic and diastolic blood pressure measurements obtained from these three sphygmomanometers across 10 subjects, respectively.

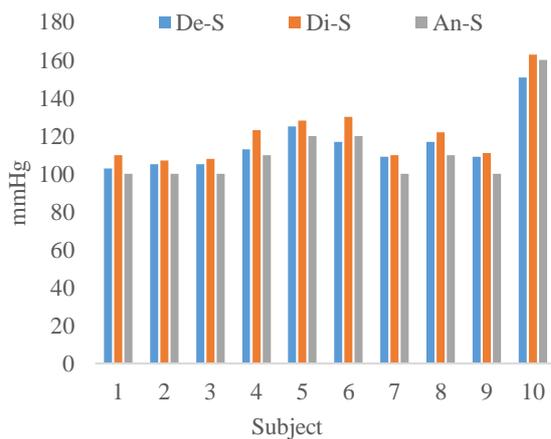


Figure 4. The Comparison of SBP measurement results from three sphygmomanometers

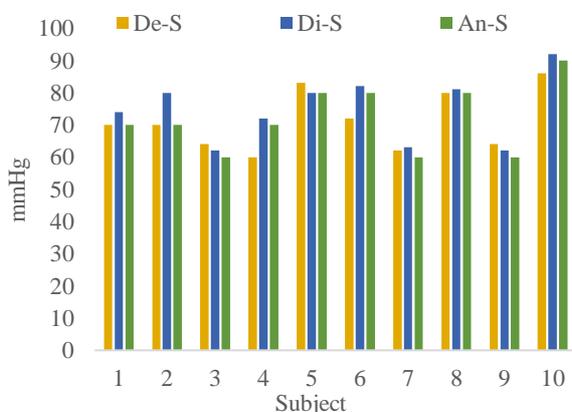


Figure 5. Comparison of DBP measurement results from three sphygmomanometers

Based on the data presented in Figures 4 and 5, we can calculate the variations in sphygmomanometer measurements. It is delineated by the mean difference (mmHg) and standard deviation of the difference (mmHg).

Table 5. The Comparison of 3 Sphygmomanometers

Comparison of	Mean (mmHg)		Standard Deviation (mmHg)	
	SBP	DBP	SBP	DBP
De-S to An-S	5,8	3,5	2,5	3,2
De-S to Di-S	5,8	5,1	4,4	3,9
Di-S to An-S	9,2	2,8	2,9	2,6

Commercial digital sphygmomanometers commonly rely on the oscillometric method for its recognized reliability [20] and the aneroid sphygmomanometers utilize the auscultation method. The aneroid sphygmomanometers which experts perform are more accurate than digital sphygmomanometers [21]. Therefore an aneroid sphygmomanometer served as the reference device in this study.

Figures 1 and 2 show the performance of a sphygmomanometer, which is designed to be closer to an aneroid sphygmomanometer than a digital sphygmomanometer for systolic pressure. In contrast, for diastolic blood pressure, digital sphygmomanometers show better performance.

According to the American National Standard for Electronics or automated sphygmomanometers, the mean difference should be 5 mmHg or less, with a standard deviation of 8 mmHg or less [22]. The designed sphygmomanometer, compared to the aneroid sphygmomanometer, has a mean difference of 3,5 mmHg (less than 5 mmHg) for diastolic pressure and a standard deviation of less than 8 mmHg for both systolic and diastolic pressure. However, the mean difference in systolic pressure still does not meet the standard. Based on the data above, it can be stated that the designed tensimeter has met the standards for measuring diastolic pressure while measuring systolic pressure still needs to be improved.

Measurement of Heart Rate and Oxygen Saturation

The measurement results obtained from the designed oximeter were compared with those from the Ministry of Health's certified oximeter. The disparity in heart rate and oxygen saturation measurements is quantified as a percentage deviation. The results indicate that the developed device exhibits a measurement error of 1.8% for heart rate and 1.02% for oxygen saturation. These findings indicate that the design of this device works well, and the measurement results are almost the same as those of the comparison oximeter. The measurement data can be seen in Figure 6. Based on the manual for testing and calibrating medical equipment in hospitals issued by the Indonesian Ministry of Health in 2001, the allowable deviation of the Pulse Oximeter is $\pm 1\%$ for both pulse rate and SpO₂. Based on the Decree of the Minister of Health of the Republic of Indonesia in 2014 concerning pulse oximetry in defibrillators, the permitted heart rate deviation is $\pm 5\%$ [23].

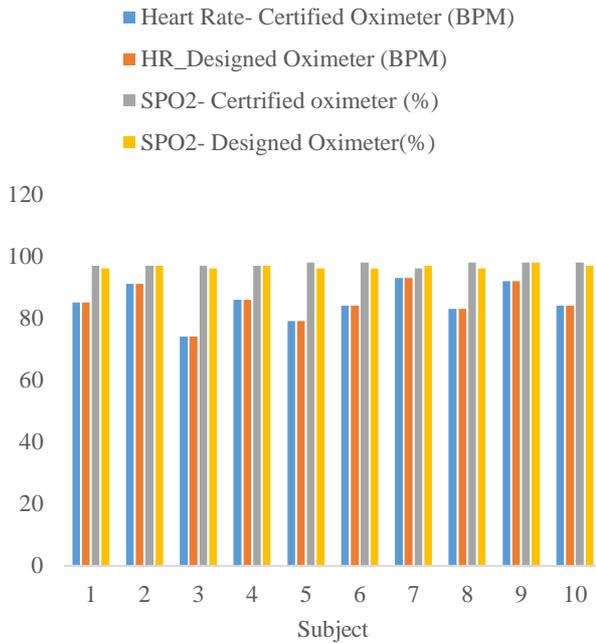


Figure 6. Comparison of Measurement results from Two Oximeter

Fetal heart rate measurement

The designed tool's performance was tested through 15 measurements carried out on pregnant women at various stages of pregnancy. A midwife performs a test using fetal Doppler, followed by a designed tool. The measurement results are presented in Figure 7. The measurements using fetal Doppler serve as a reference. It is known that the average absolute difference measurement is 3.4 bpm, with a measurement error of 2.38%. The accuracy of the device in measuring fetal heart rate is influenced by the carefulness and precision in utilizing the device. If the pregnant woman moves a lot, the measurements will deviate from the fetal Doppler results

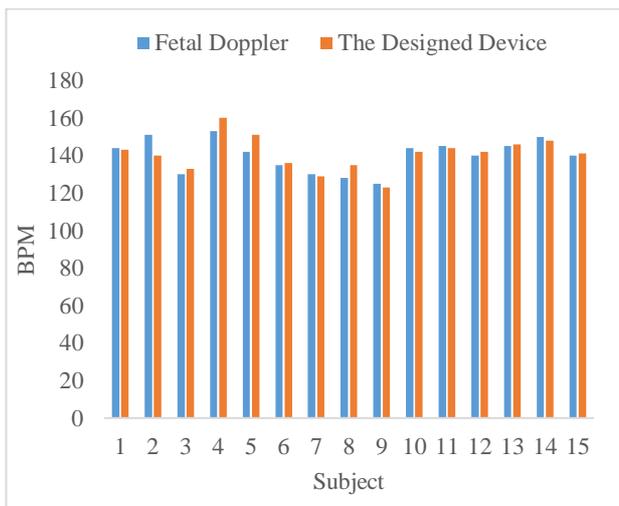


Figure 7. Comparison of Measurement results from fetal Doppler and the designed device

Testing the expert system for Hypermesis Gravidarum

The designed Expert system application was tested in two stages. The first stage is functional testing, where all application functions such as buttons, scrolling, and checkboxes are checked. the second stage focuses on evaluating the accuracy of the system by comparing expert decisions with the results of system decisions. Figure 8 depicts the expert system application interface. Validation of expert system diagnoses was carried out by comparing expert system diagnoses based on diagnoses by doctors. Testing was carried out using 30 Case reports and the results can be seen in table 8.



Figure 8. The Display Of The Expert System Application

The case report that will be used is explained as follows:

Case report 1 :

- 22 Years Old
- First Pregnancy
- Single Pregnancy
- 13 Months of Pregnancy
- Nausea Vomiting 3-5 Times/Day
- Blood Pressure 120/80 Mmhg
- Heart Rate 77 Bpm

Data Case Report 2 :

- Age 25
- Third Pregnancy
- BMI Above 25
- Vomiting More Than 8 Times a Day
- Heart Rate 88
- Blood Pressure 90/80
- Weight Loss And Difficult Defecation
- Sunken Eyes Pain In Epigastrium And Decreased Skin Turgor

Table 8. The Comparison of Diagnosis of Tested Case Report

Case Report	CF Value	System analyse	Doctor's diagnose	Results
1	41,5	Normal	Normal	True
2	95.42	HG	HG	True
3	97.07	HG	HG	True
4	22.95	Normal	Normal	True
5	16.93	Normal	Normal	True
6	8.8	Normal	Normal	True
7	55.53	Normal	Normal	True
8	10.85	Normal	Normal	True
9	50.85	Normal	Normal	True
10	42.59	Normal	Normal	True
11	91.29	HG	HG	True
12	96.21	HG	HG	True
13	96.34	HG	HG	True
14	98.04	HG	HG	True
15	80.17	HG	HG	True
16	99,02	HG	HG	True
17	99,3	HG	HG	True
18	99,54	HG	HG	True
19	99,41	HG	HG	True
20	99,23	HG	HG	True
21	98,12	HG	HG	True
22	74,53	Normal	Normal	True
23	89,65	Normal	HG	False
24	90,52	HG	HG	True
25	81,72	Normal	HG	False
26	80,35	HG	HG	True
27	93,88	HG	HG	True
28	97,34	HG	HG	True
29	98,34	HG	HG	True
29	98,34	HG	HG	True
30	97,93	HG	HG	True

It was seen that 28 cases out of 30 cases tested showed a similar diagnosis. The system accuracy for this data is 93.33%. Therefore, this system can provide early warning by detecting the possible risk of hyperemesis gravidarum in pregnant women. So pregnant women who are suspected of having HG are advised to immediately consult a doctor. The sooner mothers are suspected of having HG receive appropriate treatment and management, it is hoped that it can prevent fatal and detrimental complications for the mother and fetus.

CONCLUSIONS

The design of a pregnancy monitoring system for detecting hyperemesis gravidarum has an expert system accuracy rate of 93.33%. The designed sphygmomanometer compared with the aneroid sphygmomanometer has an average difference of 3.5 mmHg for diastolic pressure and a standard deviation of less than

8 mmHg for systolic and diastolic pressure. Overall it meets the standard deviation permitted by the Ministry of Health for medical devices. Heart rate and oxygen saturation measurements had deviations of 1.8% and 1.02%, respectively. The fetal heart rate has an average deviation of 3.4 bpm and a measurement error of 2.38%. Future work is to connect this system to IoT and use a database system to increase monitoring effectiveness.

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