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The Performance Analysis of the Infrared Photodiode Sensor to Infusion Set on Infusion Device Analyzer Machine

Anisa Rahma Astuti, Syaifudin[1], Triana Rahmawati[1], and Khongdet Phasinam[2]

[1] Department of Medical Electronics Technology, Poltekkes Kemenkes Surabaya, Indonesia
[2] Pibulsongkram Rajabhat University, Thailand

[#]Corresponding author: syaifudin (email:syaifudin@poltekkesdepkes-sby.ac.id)

ABSTRACT Infusion pumps and syringe pumps are devices used to administer liquid medicine to patients. The frequency of using infusion pumps and syringe pumps for a long time will affect the accuracy of the equipment. Dosage accuracy is very important for patients in critical condition who require intensive care to prevent fluid imbalance in the body. Therefore, it is necessary to periodically calibrate medical devices at least once a year. According to the Regulation of Minister of Health No. 54 of 2015, tera is a calibration activity to determine the accuracy of a tool. Calibrating an infusion pump or syringe pump needs a calibrator, namely an infusion device analyzer. The calibration process for infusion pumps and syringe pumps takes time. Therefore, more than one channel infusion device analyzer is required to make the calibration process more effective. In addition, the accuracy in measuring liquid flow must also be considered when using the sensor. Related to this, current research was carried out, aiming to make an Infusion Device Analyzer (IDA) with a TFT LCD that displays discharge parameter graphs. The method used was analyzing the flowrate value using an infrared photodiode sensor and viewing the flowrate stability graphs on a 7-inch TFT LCD by using 2 brands of syringes and infusion sets. The results obtained can further be stored on the SD Card. The measurement results showed that the performance errors of the syringe and infusion pump read by module on Channel 1 with the Terumo syringe were 1.11 (10 ml/hour), 0.177 (50 ml/hour), and 2.16 (100 ml/hour). Meanwhile, the errors on Channel 2 were 24(10ml/hour), 39.66(50ml/hour), and 39.66(100ml/hour). Furthermore, in terms of using the B-Braun Channel 1 syringe, the errors obtained was 2.4 (10ml/hour), 18.6 (50ml/hour) and 36.94(100ml/hour). Meanwhile, the errors on Channel 2 were 3.9 (10ml/hour), 4.6 (50ml/hour), and 0.88 (100ml/hour). In addition, the use of Terumo brand infusion on Channel 1 obtained error values of 0.07 (10ml/hour), 9.3 (50ml/hour), and 39.66 (100ml/hour), while on Channel 2 was 24 (10ml/hour), 18.6 (50ml/hour) and 36.94 (100 ml/hour). Furthermore, the use of B-Braun Infusion Set on Channel 1, obtained values of 3.5(10ml/hr), 9.5(50ml/hr), and 0.7(100ml/hr). Meanwhile, the values on channel 2 were 8.5 (10ml/hour), 1 (50 ml/hour), and 39.53(100ml/hour). In general, the uncertainty of all is very small, namely the average is below 1, meaning that the modules made are quite precise. The conclusion from this study is that the use of 2 different infusion sets greatly affects readings. Besides that, other factors can also affect readings, including tube position and placement sensors on each channel. Through the making of this tool, it is expected that users can be more efficient in using two-channel Infusion Device analyzer that can be run simultaneously.

INDEX TERMS Calibration, Flowrate, Infusion Pump, Syringe Pump

I. INTRODUCTION

Infusion Pump and Syringe Pump are medical devices that are used to insert liquid medicine into the patient's body with high accuracy and in a certain amount so that there are no errors in giving the dose to the patient [1][2][3]. L. Gurbeta has previously conducted a study on the safety and performance inspections of 325 infusion pumps since January 2015 to January 2016 in public and private healthcare institutions in Bosnia and Herzegovina. The results showed that about 9% of all infusion pumps tested did not meet electrical safety requirements or had out-of-spec performance. The causes of such incorrect performance are environmental conditions, prolonged use of the device, damaged motors and device casings, and lack of systematic maintenance [4]. Furthermore, Tavakoli Golpaygani has also conducted study in the last five years and found that the FDA has received many side effect reports regarding the use of infusion pumps. Reports have stated serious injuries and hundreds of deaths. Therefore, the reliability of infusion pumps is an important issue and both of its performance and safety should be regularly verified at least once a year using adequate analysis by qualified personnel [5]. Bongsu Jung further claimed that the function of the infusion pump must comply with certain international standards. Various safety and efficacy tests must be carried out on the syringe pump, as specified by this standard, and approval must be received from the approving agency based on the results of those tests [6]. Wilton C. Levine wrote about the development of infusion pumps from year to year from manuals to technological developments using wi-fi [7]. E Batista added that infusion pumps, such as syringe pumps and peristaltic pumps, are commonly used for drug delivery, in situations where the delivery dose has strict limits and the impact of risk is high. To ensure metrological traceability of flow and volume, measuring instruments need to use appropriate methods and calibration standards. One of the methods usually used in hospitals is to rely on the Infusion Device Analyzer (IDA) [8]. Flavio Abrantes has evaluated a new method for detecting occlusion in peristaltic infusion pump sets using a non-contact pressure sensor. The proposed method is based on correlation with the reference waveform and synchronized with the infusion cycle [9]. Meanwhile, Elsa Batista performed the conformity test of the IDA calibration method by testing several infusion instruments at different flow rates using the gravimetric method. In addition, comparison of measurements between the Portuguese Accredited Laboratory and the maintenance office of the hospital was carried out under the coordination of the Portuguese Institute of Quality, National Institute of Metrology. The results obtained are directly related to the calibration method used and are presented in this paper. This work has been developed within the framework of the EURAMET EMRP MeDD and EMPIR 15SIP0 projects [10]. The pumping system must be operated accurately and precisely to flow the fluid as predicted [11][12]. In some cases of patients such as hypertension before surgery, heart disease and neurological disease, drug administration must be intensively carried out. For patients in critical condition, intensive care is needed so that there is no fluid imbalance in the body [13][14]. In this case, liquid medicines is inserted into the patient's body by using an infusion set to match the fluid flow given to the patient by intravenous injection in a high degree of accuracy [15][16], with a constant flowrate, and flowrate duration in accordance with the setting and long enough. The frequency of use in the long term will also affect the accuracy of the tool. According to ECRI guidelines, the error tolerance limit of the flowrate for patients in critical condition is ≤ 5%, while for the general patients is ± 10% [17][18]. Therefore, it is necessary to calibrate medical devices periodically [13][19]. In this case, the accuracy of an equipment does not arise from a good design, but is influenced by its performance, stability, reliability, and maintenance [20]. There are two main performance requirements for infusion pumps. The first one is the flow accuracy, which ensures that the actual rate of IV drug delivered is the programmed rate and that the dose delivered can be easily tracked – the latter is especially important for remote infusion systems [21]. The second requirement is the flow uniformity, which ensures that the pump is delivering continuously and with minimal variation in flow rate [22]. According to the Minister of Health, calibration is an activity to verify the indication of a measuring instrument value [23]. Medical device calibration needs to be done at least once a year. Infuse pump and syringe Pump calibration tools are Infusion Device Analyzers used to measure flowrate and occlusion values [11].

Previous references were used to improve the previous research. in the research carried out on the Design and Construction of Infusion Pump Calibrator conducted by Thongpance and Pityeeraphab in 2012, a load cell sensor was used to measure the volume and average flow rate in real time by a 16x2 Character LCD display, but the display of this tool is not yet equipped with graphics and storage [19]. This tool was also equipped with a buzzer warning to know when the infusion is not dripping [24]. In 2017, H. K. Tavokali Golpaygani A, Movahedi MM, et al, conducted a study on the performance and safety tests of infusion pump device. The tests, namely the measurement of flow rate accuracy [25], one of which is by using an inappropriate IV set that will show a smaller value above the standard limit. Furthermore, Kwan Young Hong, You Yeon Kim, et al. conducted a simulation study on the flow rate accuracy of infusion pumps in vibration conditions during emergency patient transport [26]. It shows that the accuracy of the flow rate of the infusion pump is affected by various clinical vibration conditions [27].

In 2020, Dinesh Kumar J.R, Ganesh Babu. C, et al developed a tool through their study entitled a Novel System Design for Intravenous Infusion System Monitoring for Betterment of Health Monitoring System using ML-AI [28]. Furthermore, Bongsu Jung et al, in 2016 conducted an efficacy evaluation of syringe pump developed for continuous drug infusion [6]. In the same year, Destiny F. Chau, MD, Terrie Vasilopoulos, et al have conducted research on Syringe Pump Performance Maintained with IV Filter Use during Low Flow Rate Delivery for Pediatric Patients. Each measurement in the study was displayed graphically after all data has been entered into the database [29]. In 2020, Nuritza Maulidia has conducted research on the Development of Infusion Device Analyzer with Infrared Photodiode Sensor for Drip Conversion of Flowrate. The device was able to detect the velocity of the flow rate in an infusion pump or syringe pump that can be further performed many times or at an unlimited number of times and can store the calibration results on the SD Card [30]. Additionally, in 2021, a Design of Two Channel Infusion Pump Analyzers Using Photo Diode Detector was made by Syaifudin et al, using STM32 with modules in the form of photodiode and infrared sensors installed in the chamber to read flowrate values [31]. Meanwhile, the latest research was done by Nila Nurmala on the design of infusion device analyzer with TFT LCD graphic display (flowrate) that has been able to display data graphically on TFT LCD with SD Card storage.

Based on the identification of the problem above related to the limitations that have been mentioned by previous researchers, among others, the calibration tool that has been made has been equipped with a flowrate graph in real time and data storage of flowrate results [32][33]. In this case, the use of graphs is necessary to show that the needle setting and IDA readings are within the tolerance limits. The graphs are used as monitoring based on data activity [34]. So that the use of graphs is very necessary in this study to see the constant flow rate and time to the specified setting [29]. However, there are still many who have not seen the effectiveness and efficiency of time in calibrating. Therefore, the current author wanted to make a tool for "accuracy analysis of drip sensor on infus set on the infusion device analyzer 2 channel showing TFT". The tool used a flowrate sensor and an occlusion sensor, which were developed with a real time graphic display on a TFT LCD with 2 Channels. The purpose of this tool was to produce calibrator infusion pumps and syringe pumps by using a photodiode sensor as a flow rate sensor for infusion fluids. In this case, the display was in the form of a graph showing the infusion fluid flow rate and its numerical data. Graphs are very useful in analyzing the stability of the flow rate. With the accuracy of this flow rate, when a patient is given a medicinal liquid, the volume and flow rate used will be correct. In addition, the authors also added a drain in this tool which was not available in the previous studies. Furthermore, the tests conducted in this study used an infusion pump and syringe pump by varying the infusion set. The contribution of this study is as follows:

a. It helps to check or calibrate an infusion pump or syringe pump faster because it uses 2 channels
b. The module has a better level of accuracy and precision
c. Graphic display can make it easier to see the stability of blood flow and infusion fluid flow rate.

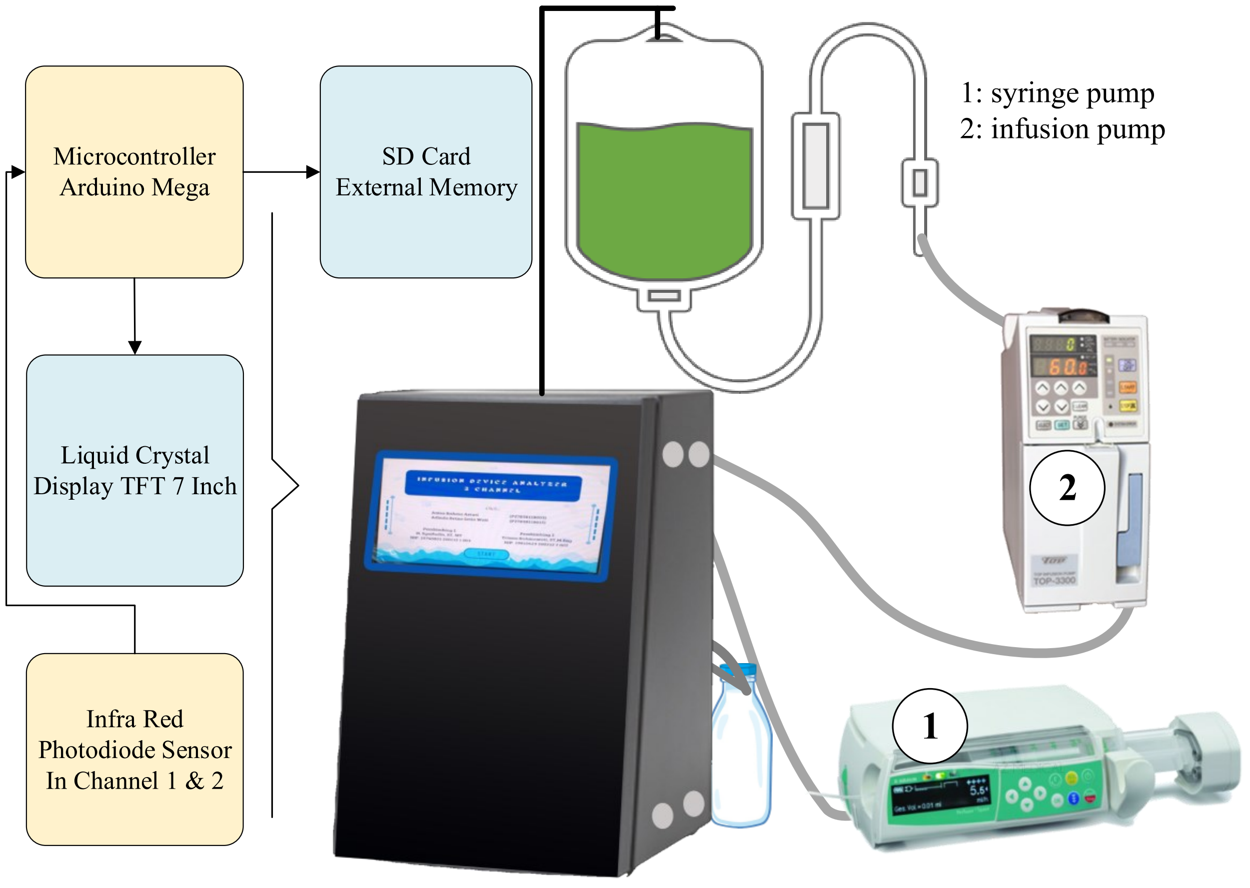

FIGURE 1. Diagram of Infusion Device Analyzer Module Block

II. MATERIALS AND METHODS

This research was conducted as experimental research. The author intended to conduct the research on flow sensors and droplet sensors that would be used in the infusion device analyzer. Materials and methods are explained in the following sections.

A. DATA COLLECTION

The contribution of this research is that this equipment is expected to help the inspection or calibration of infusion pumps or syringe pumps to be faster because it uses 2 channels and is accurate. In addition, the graphical display can make it easier to see the stability of the flow rate of infusion fluids. In this study, the researchers used the TOP-3300 infusion pump unit and the B-BRAUN syringe pump as the units tested to measure the flow rate parameters. This study used an Infrared Photodiode sensor as a droplet sensor and the Arduino Mega component as the microcontroller. The parameters measured in this study were the flow rate of the infusion pump and syringe pump. The initial step of data collection was by preparing an infusion pump and syringe pump that have been connected to the liquid (aquades). Then, the output of the infusion pump and syringe pump were connected to the module, and the liquid output from the module was connected to a container. After the infusion pump and syringe pump were turned on, the module read the flow rate. The logging waited once the flow had stabilized. Measurements were carried out 6 times with flow rate settings of 10, 50, and 100 ml/hour. The results displayed were stable values according to the settings that have been made (ml/h) and the results were further compared to the standard infusion analyzers with the Rigel brand. FIGURE 1 is a block diagram of the entire infusion module system where when the power button is pressed, the power supply circuit and the entire circuit get PLN voltage.

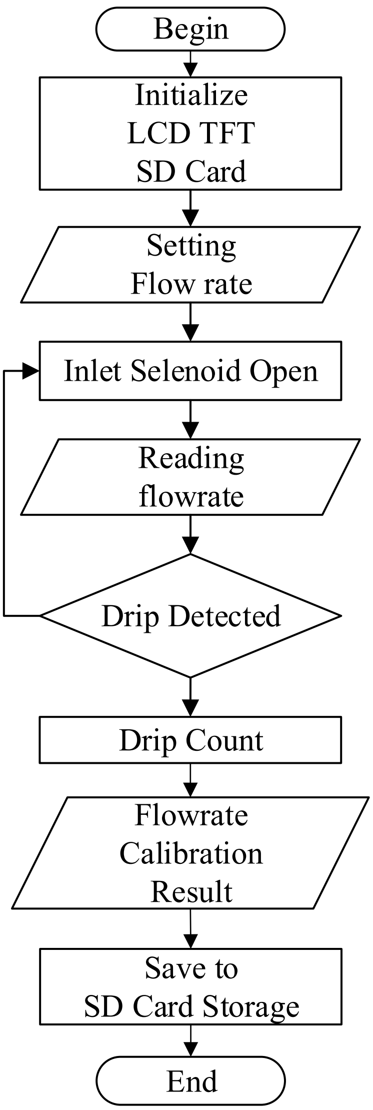

FIGURE 2. Flowchart of Infusion Device Analyzer Module

After that, the Infusion Pump/Syringe pump was set with a flow rate of 10, 50, or 100 ml/hour. The flow rate parameter was selected on the LCD, then the start button was pressed, and the liquid from the infusion pump or syringe pump flowed into the hose located on the IDA. The liquid from the Infusion Pump or Syringe pump flowed and detected by both the photodiode and infrared sensors in the form of droplets. The output from the sensor was further counted by Arduino in the forms of the number of drops that have been set through the program. Arduino calculated the length of time for the number of droplets that have been set so that the flow rate value can be known. The TFT LCD screen displayed the flow rate and a graph of the flow rate with a timer. The flow rate value was then stored in the SD Card. When the measurement of the flow rate was done, the water flowed directly into the outlet.

FIGURE 2 describes when the infusion pump/syringe pump and the infusion device analyzer are turned on, i.e., when setting the flow rate for the infusion pump/syringe pump. At the same time, the TFT LCD initialized, followed by the selection of flowrate parameters. The flowrate solenoid was open and the infrared photodiode sensor worked. At the same time, the liquid from the infusion-pump or Syringe Pump entered the IDA and the sensor carried out a reading when there was a drop and was processed by the microcontroller on the Arduino. The droplets were counted after being detected by the photodiode and infrared sensors until they matched the number of settings, and the time between one drop and the next were calculated. The time was then converted into hours and divided by 20. The number 20 is the specification of the drip chamber where 1 mL equals to 20 drops so that the results that were previously droplets in hours are converted to mL in hours. After the processing, the flowrate value in each drop was displayed in the form of numbers and flowrate graphs on the TFT LCD display. When the stop button was pressed, the sensor stopped working and the drain solenoid opened and water flowed to the outlet to drain the water. The results were then be stored in the SD Card for further analysis.

B. DATA ANALYSIS

The measurements for each setting (10mL/h, 50mL/h, and 100mL/h) on channel 1 and channel 2 were all repeated 6 times. The average measurement value was obtained by using the mean or average value. The average value is the value or the result of dividing the amount of data taken or measured by the number of data collections or the number of measurements. The average value was obtained from the equation (1):

$$(\bar{X}) = \frac{\sum Xi}{n} \tag{1}$$

Where $\bar{X}$ indicates the mean (average) value for n measurement and $\sum Xi$ represents the number of all measurements made. The standard deviation is a value that indicates the level (degree) of variation in a group of data or a standard measure of deviation from its mean. The standard deviation (SD) formula can be shown in equation (2):

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(Xi-\bar{X})^2}{(n-1)}} \tag{2}$$

Where SD indicates the standard Deviation, Xi indicates the amount of the desired values, $\bar{X}$ indicates the average of the measurement results, and n shows the lots of data measurements. Uncertainty (UA) is doubt that appears in each measurement result. It is the result of the calculated value due to the smallest value, calibration error, changes in the measurement value, and the environment so that the measurement can be disturbed, thus it is difficult to get the actual value. The uncertainty formula is shown in equation (3):

$$UA = \frac{SD}{\sqrt{n}} \tag{3}$$

Where UA indicates the uncertainty value from the total measurement, SD shows the resulted standard deviation, and n shows the amount of measurement. The %error shows the error of the system. The lower value Error is the difference between the mean of each data. The error can show the deviation between the standard and the design or model. The error formula is shown in equation (4).

$$\%Error = \frac{(Xn - \bar{X})}{\bar{X}}\ x\ 100\% \tag{4}$$

where Xn is the measured value by the calibrator. The $\bar{X}$ is the average setting value measured from the module.

III. RESULT

The design of the infusion analysis tool module is shown in FIGURE 3. The testing of this module was carried out using a B-Braun brand syringe pump, TOP-3300 brand infusion pump using 2 different brands of infusion sets, and syringes. The results showed that the infusion device analyzer module has worked well and can display numbers and graphics on a 7-inch TFT LCD screen. In addition, the photodiode and infrared sensors on the module can read the flowrate with a predetermined setting value with a stable and quite good graph. Furthermore, the measurement results of this tool can be compared to the standard Infusion Device Analyzer (Rigel Brand).

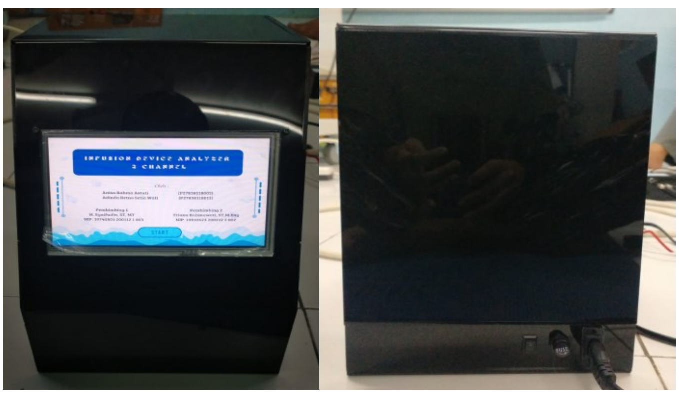

FIGURE 3. Front and Rear Views of Infusion Device Analyzer Module

The testing the performance module of this study was carried out using an infusion pump and syringe pump by varying the infusion set used. The results were also compared to the Rigel Infusion Device Analyzer

TABLE 2.
Measurement of the syringe pump using the terumo spuit

Spuit Terumo						
Flowrate	10 ml/h		50 ml/h		100 ml/h	
	ch1	ch2	ch1	ch2	ch1	ch2
Average	11.11	10.1	49.23	53.8	102.16	101.01
SD	0.075	0.09	0.46	0.16	0.38	0.09
UA	0.03	0.04	0.18	0.06	0.15	0.04
Error	1.11	0.1	-0.77	-3.8	2.16	1.01
Error Relative %	11.1	1	1.54	7.6	2.16	1.01
IDA RIGEL	10.69		48.435		102.091	

TABLE 2 and FIGURE 4 above show the results of flowrate measurements on the B-Braun Syringe pump using a Terumo syringe with a Rigel Infusion Device Analyzer as the data comparison. Data measurements were carried out 6 times for each setting and comparison tool. In this case, the Channel 1 obtained an average of 11.11 ml/hour (10 ml/hour), 49.23 (50 ml/hour), and 102.16 (100 ml/hour). Channel 2 obtained an average of 10.1 (10 ml/hour), 53.8 (50 ml/hour), and 101.01 (100 ml/hour). The error obtained in channel 1 is greater than the error obtained in channel 2. The biggest error was found in the 10 ml/hour setting. When compared to the Rigel Infusion Device Analyzer, the biggest relative error is on channel 2 at a flow rate setting of 50 ml/hour by 11.07%. Based on the data of UA (Type A Uncertainty), the tool has a value below 1 which indicates that this tool has good stability.

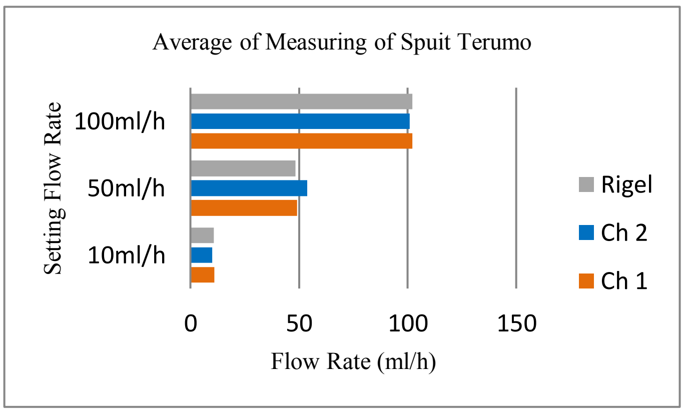

FIGURE 4. Chart the measurement of the syringe pump using the terumo spuit

The TABLE 3 and FIGURE 5 above show the results of the flowrate measurement on the Syringe pump brand B-Brauna using the Terumo brand Infusion with a comparison of the Rigel brand Infusion Device Analyzer. Data measurement was carried out 6 times for each setting and comparison tool. In this case, the Channel 1 obtained an average of 11.11ml/h (10 ml/h), 49.23 (50 ml/h), and 102.16 (100 ml/h). Meanwhile, Channel 2 obtained an average of 10.1 (10 ml/h), 53.8 (50 ml/h), and 101.01 (100 ml/h). The error obtained on channel 1 is greater than the error obtained on channel 1, except for the 10 ml/hour setting on channel 2. When compared to the Rigel Infusion Device Analyzer, the largest relative error is on channel 2 at the 10 ml/hour flowrate setting by 62%. Based on the UA data (Uncertainty type A), the tool has a value below 1 except for channel 2 measurements at a setting of 10 ml/hour. In general, it shows that this tool has good stability.

TABLE 3.
Measurement of the Syringe Pump Using the B-braun Spuit

Spuit B-Braun						
Flowrate	10 ml/h		50 ml/h		100 ml/h	
	ch1	ch2	ch1	ch2	ch1	ch2
Average	10.8	13.9	53.144	52.3	101.63	100.88
SD	0.41	1.2	0.8	0.2	0.6	0.3
UA	0.1	0.5	0.3	0.09	0.2	0.1
Error	-0.8	-3.9	-3.144	-2.3	-1.63	-0.88
Error Relative %	8	39	6.3	4.6	1.63	0.88
IDA RIGEL	8.57		45.9		95.6	

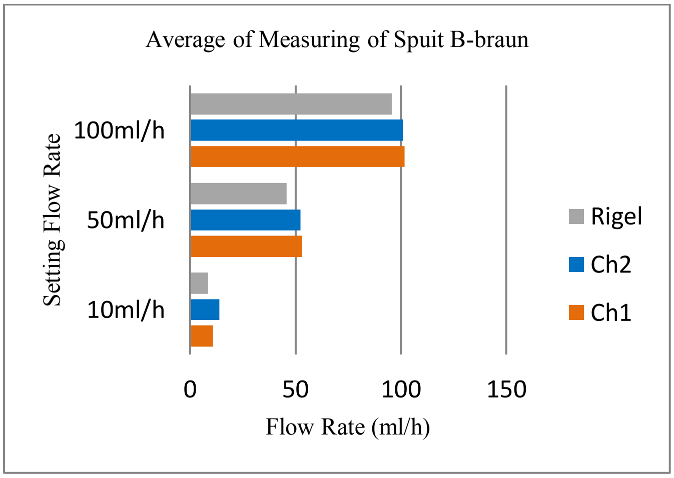

FIGURE 5. Chart of the Measurement of the Syringe Pump using the B-braun Spuit

The TABLE 4 and FIGURE 6 the above show the results of the flowrate measurement on the Infusion Pump using the Terumo brand Infusion with a comparison of the Rigel brand Infusion Device Analyzer. Data measurement was carried out 6 times for each setting and comparison tool. In this case, the Channel 1 obtained an average of 9.93ml/h (10 ml/h), 48.45 (50 ml/h), and 139.66 (100 ml/h). Meanwhile, channel 2 obtained an average of 12.4 (10 ml/h), 59.3 (50 ml/h), and 136.94 (100 ml/h). The biggest error was found in the 100 ml/hour setting on channel 1. Compared to the Rigel Infusion Device Analyzer, the largest relative error is on channel 1 at the 50 ml/hour flow rate setting by 29.17%. Based on the UA data (Uncertainty type A), it has a value below 1 except for measurements at a setting of 100 ml/hour. Therefore, the infusion sets are very influential on flow rate measurements.

Table 4.
Measurement of The Infusion Pump using the Terumo Infusion Set

Infusion Set Terumo						
Flowrate	10		50		100	
	ch1	ch2	ch1	ch2	ch1	ch2
Average	9.93	12.4	48.45	59.3	139.66	136.94
SD	0.05	02	0.7	0.4	5.6	5.7
UA	0.02	0.1	0.2	0.2	2.2	2.3
Error	0.07	-2.4	1.55	-9.3	-39.66	-36.94
Error Relative %	0.7	24	3.1	18.6	39.66	36.94
IDA RIGEL	10.87		68.41		138.5	

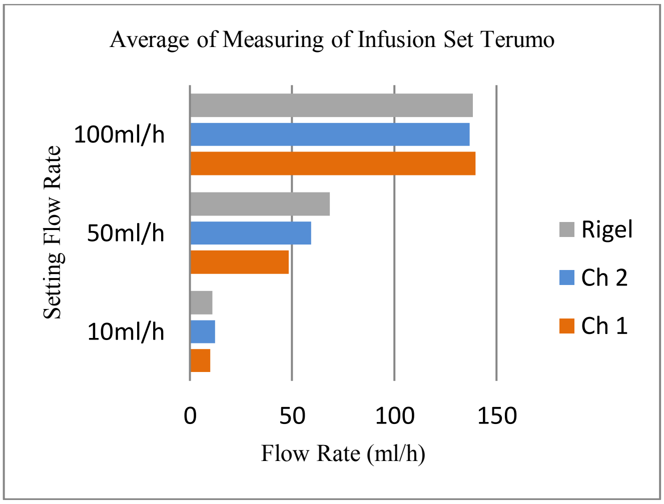

Figure 6. Chart of the Measurement of the Infusion Pump using the infusion Set Terumo

Table 5
Measurement of the infusion pump using the B-braun Infusion Set

Infusion Set B-Braun						
Flowrate	10		50		100	
	ch1	ch2	ch1	ch2	ch1	ch2
Average	10.35	9.15	54.75	50.5	99.3	139.53
SD	0.18	0.13	2.24	0.45	0.68	1.9
UA	0.07	0.05	0.9	0.1	0.2	0.8
Error %	0.35	0.85	4.75	-0.5	-0.7	-39.53
Error Relative	3.5	8.5	9.5	1	0.7	39.53
IDA RIGEL	10.89		49.24		97.49	

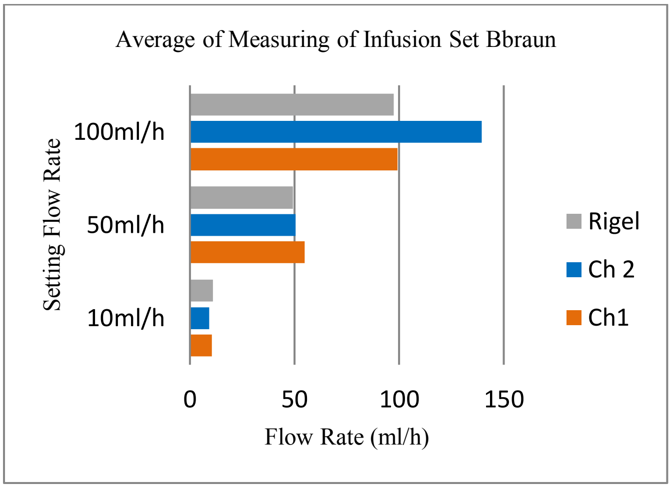

Figure 7. Chart of the Measurement of the Infusion Pump using the Infusion Set B-braun

The TABLE 5 and FIGURE 7 the above show the results of the flowrate measurement on the Infusion Pump using the B-Braun brand Infusion with a comparison to the Rigel brand Infusion Device Analyzer. Data measurement was carried out 6 times for each setting and comparison tool. In this case, the Channel 1 obtained an average of 11.11ml/h (10 ml/h), 49.23 (50 ml/h), and 102.16 (100 ml/h). Meanwhile, channel 2 obtained an average of 10.1 (10 ml/h), 53.8 (50 ml/h), and 101.01 (100 ml/h). The biggest error was found in the 100 ml/hour setting on channel 2. Compared to the Rigel Infusion Device Analyzer, the largest relative error is on channel 2 at the 100 ml/hour flow rate setting by 43.12%. Based on the UA (Uncertainty type A) data, it has a value below 1 except for measurements at 50 ml/hour and 100 ml/hour settings on channel 2.

IV. DISCUSSION

Based on the measurement results using the Syringe Pump that can be seen in TABLE 2 and TABLE 3, the use of Terumo Syringe Pump is better on Channel 1 than Channel 2 because the error value on Channel 1 is smaller than the error value on Channel 2. Meanwhile, the measurement using the B-Braun Spuit on Channel 2 is better than Channel 1. Meanwhile, the measurements using the Infusion Pump can be seen in TABLE 4 and TABLE 5. In this case, the measurements on the Terumo brand Infusion set are better used on Channel 1 than Channel 2. Then, measurements using the B-Braun brand Infusion set are also better used on Channel 1 than Channel 2. This is because the % error value on Channel 1 is lower than the % error value on Channel 2. However, based on the results of the uncertainty calculation, the average value is below 1, indicating that the tool or module worked stably. Discharge measurement was done with the module that has been made. The measurement method was carried out using 2 infusion sets and 2 syringes with different brands. Measurements were made 6 times at each setting of 10mL/hour, 50mL/hour, and 100mL/hour and compared with IDA brand Rigel. This tool could work well and was able to display graphs of discharge measurement results. However, this tool still had some drawbacks, including when using an infusion pump, the graphic results were still in the high range. This is because the measurements using an infusion pump were affected by vibrations caused by peristalsis in the infusion pump. In addition, this tool can also only store measurement data with a duration of 15 minutes. Hence, a laptop/PC may be an additional tool so that it can be used to store measurement data. In this case, the measurement result data are stored on the SD Card in the form of numbers every 0.8 seconds in txt form with the folder name DATA.txt.

V. CONCLUSION

Based on the results of planning, module making, writing, and overall data analysis of this research, it can be concluded that the Infrared Photodiode sensor can read droplets according to the predetermined flowrate setting. The results of the flowrate measurement in each setting that have been compared to the RIGEL brand IDA tool using the Syringe Pump tool, the error values in each setting including on Channel 1 Module using the Terumo brand syringe obtained an average % error of 0.017%, while the average %error value on Channel 2 is 0.056%. Meanwhile, the measurement using the B-Braun syringe on Channel 1 obtained an average % error value of 4.43%, while on Channel 2, the average % error value was 5.6%. Then in the measurement with the Infusion Pump when compared to the Rigel brand IDA comparison tool, the average % error value on the use of the Terumo Channel 1 Infusion set was 0.096% and on channel 2 the average % error value was 0.07%. Meanwhile, the measurement using the Infusion set brand B-Braun Channel 1, the average value of %error is 0.15% and on Channel 2 the average value of %error is 0.49%.

Based on this research, there are still some gaps. Therefore, it is expected that further research development can be done by replacing the sensor with a sensor that is more accurate in reading as well as adding a program in the display on the TFT LCD, and a storage program so that it can store all measurement data.

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