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Enhancing Infusion Pump Calibration through Evaluating Occlusion Sensor Performance in a Dual-Channel Infusion Device Analyzer

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ABSTRACT Occlusions frequently hinder the continuous delivery of medications or fluids through syringes and infusion pumps, posing a critical challenge in medical practice. To address this issue, the infusion set occlusion threshold has been established at 20 Psi, guided by ECRI standards. Annual recalibration is essential to ensure compliance with this benchmark. This study focuses on appraising the precision of a pressure sensor integrated into a dual-channel TFT display infusion device analyzer. The innovative dual-channel design streamlines the concurrent calibration of two medical instruments, enhancing efficiency. The research employs a water pressure sensor to detect occlusions and a solenoid valve to simulate pressure conditions. Upon pressure detection, the sensor transmits data to an Arduino for processing. Results are vividly displayed on a 7-inch TFT LCD screen, providing real-time graphical and numerical insights, which are also stored on an SD card. Significant findings reveal distinct error margins across devices: 2.84% for the Terumo TE-331 Infusion Pump, 7.26% for the TOP-5300 Infusion Pump, a notable 58.20% for the TOP-3300 Infusion Pump, and a striking 71.26% for the Infusia VP7 infusion, indicative of pressure accuracy variations. Notably, the SEN0257 sensor exhibits superior precision when integrated with a syringe pump, showcasing a more favorable error rate compared to larger infusion pumps. This study's implications extend to the critical domain of infusion pump calibration, offering a valuable reference for assessing device suitability. The research contributes not only to refining infusion accuracy but also offers a practical framework for optimizing medical device performance, thus enhancing the overall quality of patient care.

INDEX TERMS Calibration, Occlusion, Syringe pump, Infuspump

I. Introduction

Infusion pumps are essential devices in the medical field. They are used to deliver medications, fluids, and nutrients to patients in a measured and controlled manner. In healthcare, the accuracy and reliability of infusion pumps are crucial to ensure precise and safe delivery to patients. Therefore, research on the calibration of infusion pumps is highly relevant and significant. The objective of this research is to develop calibration methods that ensure the accurate and proper functioning of infusion pumps. By conducting this research, we can determine whether the infusion pumps operate according to the specified standards. The findings of this study can be applied in clinical practice to evaluate the performance and reliability of infusion pumps used in hospitals and other healthcare facilities. The calibration process involves measuring and comparing the results with established standards. During this study, various types of infusion pumps were tested to evaluate their accuracy and suitability. In developing accurate calibration methods, factors such as flow rate, pressure, and volume generated by the infusion pumps were taken into consideration. Thus, we can ensure that the infusion pumps work with precision and deliver the correct dosage to patients. The implementation of the research findings holds significant benefits for healthcare practitioners and patients. With accurate calibration, infusion pumps can be relied upon to deliver timely and precise treatment to patients. Additionally, it can reduce the risk of medication errors and complications that may arise from infusion pump inaccuracies. Therefore, this research has the potential to enhance the quality of care and patient safety in the use of the infusion pump.

According to Ministry of Health Regulation No. 54 of 2015, calibration plays a crucial role in ensuring the accuracy of measurements obtained from healthcare equipment. It is a process that involves determining the true value of a measurement indicated by a measuring device or material[1]. This regulation stipulates that healthcare equipment should undergo calibration at least once a year to maintain its accuracy and reliability[2][3]. Over time, the prolonged use of healthcare equipment, including infusion pumps and syringe pumps, can result in changes in their accuracy[4]. Factors such as wear and tear, environmental conditions, and component degradation can impact the performance of these devices[5]. Calibration methods are essential to assess and correct any deviations from the desired accuracy[6][7][8][9]. The Infusion Device Analyzer (IDA) is a specialized calibration tool designed specifically for measuring the flow rate and occlusion parameters in infusion pumps and syringe pumps[10]. It enables healthcare professionals to evaluate the performance of these devices accurately[11]. By using the IDA, healthcare facilities can ensure that their infusion and syringe pumps deliver medications and fluids to patients at the intended flow rates and with optimal safety[12]. The calibration process with the IDA involves comparing the measured values of flow rate and occlusion obtained from the pumps with the known standards. Any discrepancies are identified, and adjustments are made to bring the devices back to their desired accuracy levels. This ensures that healthcare providers can rely on the pumps to administer medications and fluids accurately, minimizing the risk of underdosing or overdosing[13].

By adhering to the calibration requirements outlined in the Ministry of Health Regulation, healthcare facilities can maintain the quality and integrity of their equipment. Regular calibration of infusion pumps and syringe pumps using tools like the IDA contributes to patient safety and ensures the delivery of precise and effective healthcare services. It also demonstrates the commitment of healthcare providers to maintaining the highest standards of accuracy and reliability in their equipment, ultimately benefiting both healthcare professionals and patients alike[14][15]. An infusion pump is a vital medical device used to administer liquid nutrients or medications in precise doses to patients through their blood vessels. It plays a critical role in delivering fluids into the body and is known for its effectiveness and accuracy. The infusion pump operates based on the principles of flow rate and volume, which are essential parameters in its functioning[16][17]. The main control system of an infusion pump is typically powered by an Arduino microcontroller, responsible for regulating and controlling the device's operation. The needle inserted into the patient's blood vessel is connected to a hose, which serves as a conduit for the fluid. The hose itself is a crucial accessory for the infusion pump as it significantly influences the control and regulation of the fluid flow[18]. Extended use of an infusion pump can impact its precision and accuracy, potentially leading to issues such as compression caused by air bubbles. It is crucial to ensure that air does not enter the bloodstream during fluid administration, as air bubbles can pose serious health risks, including stroke. Maintaining a controlled flow rate is essential to preserve fluid balance and prevent complications such as decreased glomerular filtration rate and renal vein congestion[19][20][21]. To prevent flow blockages and ensure the reliability of infusion pumps, calibration is necessary. Regular calibration, ideally conducted annually, is vital to verify the accuracy and correctness of the device's measurements[22]. Calibration involves comparing the measurements obtained from the infusion pump with those of standard measuring instruments, also known as calibrators. In the case of infusion pumps, the Infusion Device Analyzer (IDA) serves as the calibrator to test the device's feasibility and accuracy. Among the calibration parameters for infusion pumps, one crucial aspect is flow rate. Accurate and precise flow rate calibration is essential to guarantee the safe and effective administration of fluids to patients. By regularly calibrating infusion pumps, healthcare professionals can minimize errors and ensure that the device functions optimally, providing reliable and precise fluid delivery[23]. In conclusion, infusion pumps are indispensable medical devices that play a critical role in administering fluids and medications accurately. To maintain their performance and safety, regular calibration using tools like the Infusion Device Analyzer is necessary[24]. Flow rate calibration, among other parameters, ensures the correct functioning of the infusion pump, reducing the risk of complications and ensuring the well-being of patients.

In 2014, Nthongpance and K. Roongprasert conducted a study. The study adopted the principle of calibrating the standard curve relationship between the digital output of the load cell and the volume of solution at any given time, as well as the pressure applied to the pressure sensor and its corresponding digital output. The coefficient of determination (R2) between the applied volume of solution and the load cell output voltage, as well as between the applied standard pressure and the pressure sensor output voltage, were found to be 1 and 0.99, respectively. Therefore, the researched and developed tool can be used as a standard calibration device for intravenous infusion flow rate and volume calibration[25]. In 2019, Safira Pintasari did a study. Safira Pintasari has developed a device capable of detecting the flow rate and volume of liquid in an infusion solution. For data processing, this device uses Atmega 328 microcontroller with LCD display and audible indication when the photodiode sensor detects the flow rate and water level inside the chamber. However, this device can only take one measurement and does not include occlusal parameters. In 2020, Yasmin Aprillya conducted a study. The aim of this study was to develop an infusion device analyzer with occlusion parameters. When the fluid from the infusion pump enters the infusion device analyzer, it gets trapped using a solenoid valve as a simulated obstruction. An air pressure sensor detects the trapped fluid pressure, which is then processed by an Arduino. The measurement results of the pressure sensor are displayed on a character LCD and stored on an SD card. In 2020, Ria Ramadani conducted a

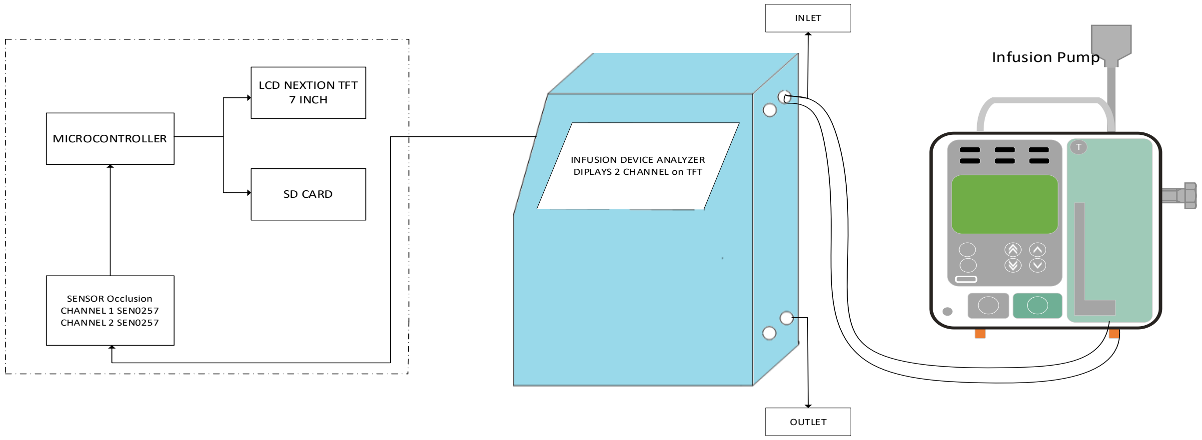

FIGURE 1 ***Research system block diagram***

study. This study involves 2 channels, allowing the calibration of 2 devices simultaneously. It uses 2 water pressure sensors for channels 1 and 2 and a 20x4 character LCD display as the output. However, this study still lacks the ability to display the output as a graph for easier reading. In the latest study in 2022, Adinda Retno Setia Wati conducted research titled. The study utilized flow rate and occlusion sensors, developed into 2 channels for efficient operation and displayed the measurement results in the form of graphs to facilitate real-time analysis of fluid stability in infusion pumps and syringe pumps. Additionally, the real-time graph allows users to view previously plotted data. However, this study still has a limitation where the transition from channel 2 to channel 1 results in the graph being reset. Based on the search results and problem identification above, the author intends to improve and by adding a motor to the drain.

II. Methods

This study used the Infusion Device Analyzer as the data collection object. It compared the occlusion values between and infusion pumps. For a setting of 100ml/h on the syringe pump and infusion pump, data was collected six times. The study utilized the SEN0257 sensor as a water pressure sensor, where the voltage readings were converted to units (psi). The Arduino Mega 2560 microcontroller was used to process the data. After processing through the Analyzer and analyzed both syringe pumps microcontroller, the Nextion TFT display was used for parameter selection buttons. the Fluke brand Infusion Device the Infusion Device Analyzer module. It system from the mains.

FIGURE 1 First, plug the power cable of the infusion device analyzer into the mains power outlet, then press the power button to activate the Infusion Device Analyzer. This will provide power to the power supply circuit and the entire It Next, set the Infusion Pump/Syringe Pump to a flow rate of 100ml/hour. Select the occlusion parameter on the LCD display. The fluid from the infusion pump and syringe pump will then flow into the tubing connected to the IDA. The fluid will be held back by a solenoid valve, creating trapped fluid inside and generating water pressure that is detected by the SEN0257 water pressure sensor.

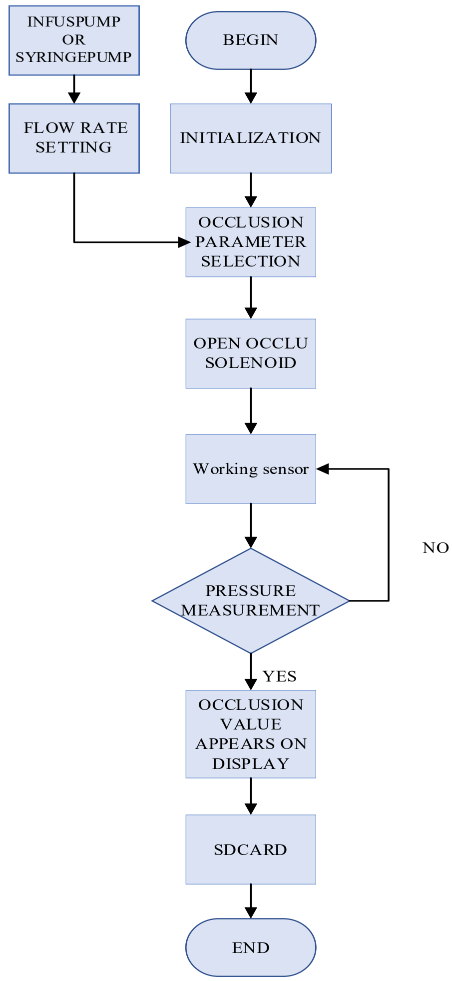

FIGURE 2 The system flowchart

The measured pressure is processed by the microcontroller and displayed on the 7-inch TFT LCD screen as a graph and numerical value, while also being stored on the SD card. Finally, the fluid will exit towards the disposal. Refer to **FIGURE 2** The infusion pump/syringe pump and Infusion Device Analyzer are turned on, and the flow rate is set on the infusion pump/syringe pump. At the same time, the TFT LCD initializes. Parameter selection is then performed. The occlusion solenoid is opened, and the pressure sensor starts working. Simultaneously, the fluid from the infusion pump that enters the IDA is read by the pressure sensor, which provides a voltage value that is converted into a pressure unit (psi). If there is a pressure measurement, the results are displayed on the TFT LCD. If no pressure measurement is detected, the sensor continues to read the pressure. When the infusion pump/syringe pump alarm sounds, the pump is stopped, and the pressure sensor ceases measurement. The TFT LCD displays the occlusion measurement results as a numerical value in psi, and the drain solenoid opens, allow

A. Data Analysis

Measurement of each parameter, the mean of the measurement obtained using the mean, or the mean by applying equation (1). The average is the result obtained by dividing the sum of values by the number of data in the set :

$$\bar{x} = \frac{x1+x2\ldots+xn}{n} \quad (1)$$

The value of x represents the average of n measurements, x1 represents the first measurement, x2 represents the second measurement, and xn represents the nth measurement. Standard deviation is a value that represents the amount of variation in a data set. The formula for standard deviation (SD) can be shown in equation (2):

$$SD = \sqrt{\frac{\sum(xi-\bar{x})^2}{(n-1)}} \quad (2)$$

The values xi indicate the desired numbers, x represents the average of the measurement results, and n represents the number of measurements. Uncertainty (UA) is the doubt that appears in every measurement result. The uncertainty formula is represented in equation (3):

$$UA = \frac{SD}{\sqrt{n}} \quad (3)$$

UA represents the uncertainty value of the total measurement, SD represents the standard deviation of the result, and n represents the number of measurements. Deviation is the difference between the average measurement result on the module and the average measurement result on the measuring instrument. The deviation formula is shown in equation (4):

$$\text{Deviation} = \bar{x}\text{module} - \bar{x}\text{measuring tool} \quad (4)$$

Where x is an average value. Error indicates a system error. The lower error value is the mean difference of each data. Errors may indicate a deviation between the standard and the design or pattern. The error formula is shown in equation (5):

$$\%error = \frac{(xn-x)}{xn} \times 100\% \quad (5)$$

Where xn is the machine calibration measurement value, x is the design measurement value.

III. Result

In this research, the Infusion Device Analyzer was tested using both the Standard Infusion Device Analyzer and the module. The following are the research results:

FIGURE 3 modular design

FIGURE 3 The circuit design is shown in Figure 3. The microcontroller used is Arduino Mega 2560, which processes and sends data to be displayed on the Infusion Device Analyzer.

TABLE 1
Average value for each setting in comparison of module values with Infusion Device Analyzer 4 Fluke

Syringe Pump Terumo TE-331	CH1	CH2	IDA 4 Fluke
Mean (PSI)	7,33	7,5	7,74
Mean Instrument (PSI)	7,41		
SD (PSI)	0,51	0,54	0,23
UA (PSI)	0,21	0,22	0,09
Error (%)	2,84%		

The mean is calculated by dividing the sum of the values by the number of data points in the set. TABLE 1 Above, the pressure measurement results of the Terumo TE-33 syringe pump were obtained. In channel 1, the average pressure was found to be 7.33 PSI, in channel 2 it was 7.5 PSI, and in the comparator it was 7.74 PSI. Based on these measurement results, it is known that there is an error value of 7.09%. On average, the comparator device had a higher value compared to the average of the TA module. The average pressure in the TA module was 7.52 PSI, while the average pressure in the comparator was 7.74 PSI.

TABLE 2
Average value for each setting in comparison of module values with Infusion Device Analyzer 4 Fluke

Syringe Pump TOP-5300	CH1	CH2	IDA 4 Fluke
Mean (PSI)	12	12	12,94
Mean Instrument (PSI)	12		
SD (PSI)	0	0	0,17
UA (PSI)	0	0	0,07
Error (%)	7,26%		

The mean is calculated by dividing the sum of the values by the number of data points in the set. TABLE 2, Above, the pressure measurement results of the TOP-5300 syringe pump were obtained. In channel 1, the average pressure was found to be 12 PSI, in channel 2 it was 12 PSI, and in the comparator it was 12.94 PSI. Based on these measurement results, it is known that there is an error value of 11.06%. On average, the comparator device had a higher value compared to the average of the TA module. The average pressure in the TA module was 12 PSI, while the average pressure in the comparator was 12.94 PSI.

TABLE 3
Average value for each setting in comparison of module values with Infusion Device Analyzer 4 Fluke

Infus Pump TOP-3300	CH1	CH2	IDA 4 Fluke
Mean (PSI)	4	4	9,57
Mean Instrument (PSI)	4		
SD (PSI)	0	0	0,031
UA (PSI)	0	0	0,012
Error (%)	58,20%		

The mean is calculated by dividing the sum of the values by the number of data points in the set. TABLE 3, Above, the pressure measurement results of the TOP-3300 infusion pump were obtained. In channel 1, the average pressure was found to be 4 PSI, in channel 2 it was 4 PSI, and in the comparator it was 9.57 PSI. Based on these measurement results, it is known that there is an error value of 1.57%. On average, the comparator device had a higher value compared to the average of the TA module. The average pressure in the TA module was 4 PSI, while the average pressure in the comparator was 9.57 PSI.

TABLE 4
Average value for each setting in comparison of module values with Infusion Device Analyzer 4 Fluke

Infuse Pump Infusia VP7	CH1	CH2	Pembanding
Mean (PSI)	2	2	6,96
Mean Instrument (PSI)	2		
SD (PSI)	0	0	0,019
UA (PSI)	0	0	0,007
Error (%)	71,26%		

The mean is calculated by dividing the sum of the values by the number of data points in the set. TABLE 4 Above, the pressure measurement results of the Infusia VP7 infusion pump were obtained. In channel 1, the average pressure was found to be 2 PSI, in channel 2 it was 2 PSI, and in the comparator it was 6.96 PSI. Based on these measurement results, it is known that there is an error value of 2.96%. On average, the comparator device had a higher value compared to the average of the TA module. The average pressure in the TA module was 4 PSI, while the average pressure in the comparator was 9.57 PSI.

IV. Discussion

The results of this study show that the analyzed two-channel infusion device analyzer has effective performance in providing reliable data. The data is displayed as numeric values and graphically represented on the 7-inch TFT LCD screen. Using the SEN0257 pressure sensor in the module allows accurate readings of clogging in syringes and infusion pumps. The study identifies several areas for improvement in the future development of infusion device analyzers, such as improving the mechanical design and incorporating a high-accuracy air pressure sensor. than. Comparisons with other studies also demonstrate the consistency of the research findings with previous findings. Several previous studies have highlighted the importance of accurate calibration in enhancing the performance of infusion pumps and reducing the risk of dosage errors. The results of this research support previous findings and reinforce the urgency of regular and accurate calibration in the use of infusion pumps. Nevertheless, this research also has its weaknesses and limitations. One limitation is the limited sample size used in this study. Future research can expand the sample size to ensure that the obtained results are more representative of the entire population of infusion pump users. Additionally, while this study considered certain factors such as flow rate, pressure, and volume, there are still other variables that can be considered for further research. The implications of this research are crucial in the context of healthcare. The implementation of the research findings will assist healthcare practitioners in optimizing the use of infusion pumps and ensuring accurate and safe treatment for patients. With increased awareness of the importance of proper calibration, it is hoped that healthcare facilities can prioritize regular calibration and update policies or guidelines regarding the use of infusion pumps. Furthermore, this research can serve as a foundation for further research in developing more advanced and effective calibration methods, as well as expanding the understanding of the performance and reliability of infusion pumps.

V. Conclusion

In summary, this study focuses on the analysis of the two-channel infusion device analyzer, with particular emphasis on the accuracy of the congestion sensor parameter. The results demonstrate the system's effectiveness in providing reliable data, displayed as numerical values and graphically on the 7-inch TFT LCD screen. Using the pressure sensor SEN0257 allows accurate readings of clogging in syringes and infusion pumps. This study has implications for the future development of infusion device analyzers by identifying areas for improvement, such as mechanical design improvements and the incorporation of air pressure sensors. gas with higher accuracy. Implementation of these findings could benefit healthcare practitioners by optimizing the use of infusion pumps, ensuring accurate and safe patient treatment. Accurate calibration of infusion pumps reduces medication errors and complications, improving healthcare quality and patient safety. The research calculation results show that the Terumo TE-331 syringe pump has an error rate of 2.84%, the TOP-5300 syringe has an error rate of 7.26%, the TOP-3300 infusion pump has an error rate of 7.26%. 58.20%. , and the Infusia VP7 infusion pump has an error rate of 71.26%. Despite the limitation of a small sample, the implementation of these study results can help healthcare professionals optimize the use of infusion pumps, ensuring accurate and safe treatment of patient. Therefore, this study has important implications for improving healthcare quality and promoting patient safety in the context of the use of infusion pumps.

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