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Internet of Things-Based Infusion Monitoring System in Optimizing Nurse Performance: A Literature Review

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ABSTRACT

Background: monitoring of infusion fluid therapy is carried out continuously as an effort to prevent embolism and nosocomial phlebitis. Nurses who are less than optimal and have inadequate numbers in controlling and monitoring the infusion system mean that the infusion system for each patient cannot be controlled continuously because the workload is high and many patients have to be monitored.
Purpose: this literature review discusses various Internet of Things (IoT)-based infusion monitoring device systems related to accuracy and effectiveness in optimizing nurse work performance.
Methods: several journals search databases were used, such as ProQuest, IEEE Xplore, SAGE Journals, PubMed, and ScienceDirect. Inclusion and exclusion criteria were applied using the Boolean Logic and PICOT methods. Inclusion criteria were original articles discussing IoT-based infusion monitoring, English language, and full-text articles. The exclusion criteria applied were articles in the form of reviews.
Results: this literature review used 10 international journals published in 2014-2024. To assess the quality of the literature, we use the Checklist from JBI Critical Appraisal Tools. The IoT-based infusion monitoring device system is accurate and reliable for monitoring infusions. Accuracy is presented quantitatively and qualitatively. Quantitatively, it shows a range of 88%-100%. Meanwhile, qualitatively stated accuracy means that the device can count infusion drops reliably and accurately. Thus, this IoT-based infusion monitoring system can optimize nurse performance.
Conclusion: accurate and reliable IoT monitoring system devices are able to support the optimization of nurse performance by monitoring and sending signals and information to nurses as users.

Keywords:
Infusion Monitoring; intravenous; Internet of Things

BACKGROUND

Infusion therapy is a procedure that is generally performed to meet the body's immediate needs for fluids, electrolytes, or necessary medication products (Handayani & Lisum, 2020). Infusion therapy is administered intravenously in an invasive way as a first aid for patients experiencing dehydration, bleeding, or hypovolemic shock, so it is expected that this infusion administration has a low error rate (Handayani & Lisum, 2020). Problems in administering intravenous therapy can occur, one of which is the lack of controlling and monitoring of the infusion system. This impacts complications that occur in patients undergoing inpatient care, thus requiring strict monitoring of the fulfillment of fluids and electrolytes for the patients.

Monitoring of infusion fluid therapy should be conducted continuously. This is done as a preventive measure to avoid complications or nosocomial infections such as nosocomial phlebitis and embolism due to infusion fluid therapy. In developing countries, the incidence of nosocomial phlebitis is relatively high. The current cases in India are at 27.91%, Iran at 12.70%, the Philippines at 10.10%, and Indonesia at 9.80% due to phlebitis (Kurniatie, 2019). These indicate that there are still obstacles in administering intravenous fluids, which affects patient safety. In addition, insufficient monitoring of the intravenous fluid therapy system can lead to delays in replacing depleted intravenous fluids or the flow of intravenous fluids not running smoothly, resulting in blockages in blood vessels that ultimately cause embolism (Kurniatie, 2019). Controlling and monitoring intravenous fluid therapy includes the number of intravenous fluid drops, the smoothness of the fluid flow, and the quantity of fluid administered. Patients receiving intravenous fluid therapy have their own fluid needs. Therefore, each patient receiving intravenous fluid therapy is expected to meet their required fluid needs to achieve fluid balance in the patient's body (Yamin et al., 2021). When a patient receives excessive intravenous fluid therapy, there is a possibility of fluid overload in the patient's body or hypervolemia.

Nurses are health professionals who spend 24 hours with patients and have a dominant role in monitoring and controlling intravenous fluid therapy for patients compared to other healthcare workers. Competence in controlling and monitoring infusion systems is mandatory for nurses. However, the issue is the inadequate number of nurses to carry out this monitoring, which results in the infusion systems of each patient not being continuously controlled (Priyandoko et al., 2021). The high workload of nurses, with the many patients that need to be monitored, is one of the factors that leads to suboptimal control and monitoring of patient infusions. Consequences will arise and eventually create an increasingly suboptimal cycle in the provision of nursing practice if this phenomenon persists without any solutions or innovations. The development of technology in the nursing practice is not something foreign, it can be applied in the nursing practice process through caring technology. In nursing practice, it has become one form of innovation to create alternative solutions in addressing issues related to controlling and monitoring intravenous fluid therapy. Control and monitoring of infusion systems have been significantly developed, such as the presence of the Internet of Things (IoT) (Krel et al., 2022). The existing system is designed in such a way, with the help of the Internet of Things (IoT), to send signals related to infusion therapy, such as the volume of drops per minute, the presence of blockages in the fluid flow, or alerts for fluid replacement (Akbar

& Gunawan, 2020). This control system was created to ease the workload of nurses, minimize the occurrence of errors, and enhance patient safety (Priyandoko et al., 2021).

The development of technology applied in the nursing science is relatively new, leading to a wealth of literature that supports and demonstrates that the role of technology adds a caring touch to the process of supporting nursing practice. Research on the Internet of Things in intravenous fluid therapy is still considered limited, and many studies are still in the prototype development stage, making a review of these studies very necessary. Therefore, this review is conducted to identify Internet of Things solutions that have high accuracy and are effective, efficient, and realistic for implementation by nurses.

METHODS

This literature review utilized several databases to conduct literature searches, such as ProQuest, IEEE Xplore, SAGE Journals, PubMed, and ScienceDirect. The search was performed using the keywords "Infusion Monitoring," "Intravenous," and "Internet of Things," applying Boolean logic, namely "AND", "OR", and "NOT" to narrow down and expand the scope of the literature search. The PICOT method (Problem: Nurse workload in the ineffectiveness of Conventional Infusion Monitoring, Intervention: IoT-based Infusion Monitoring, Comparison: No Comparison, Outcome: Effective, efficient, and accurate infusion monitoring, Time: 2014-2024) was also used in this literature review to meet the established inclusion criteria. The inclusion criteria set in this literature review were as follows: 1) Original articles, 2) The purpose of the article is to improve the efficiency of Internet of Things-based infusion monitoring, 3) Explains devices or systems for Internet of Things-based infusion monitoring, 4) Full-text articles in English, 5) Published within the last 10 years. The exclusion criteria for this literature review are articles with review methods.

The search results included 1,106 kinds of literature after applied several filters, such as publications in English, journals, and topics covering Medicine, Health Science, Nursing, and Technology. Seventy-seven duplicate articles were found in different databases, resulting in 1,029 remaining kinds of literature. Out of 1,029 kinds of literature, only 20 articles passed the screening stage. However, eight articles had to be excluded for several reasons, such as five articles not discussing the objectives of this literature review, three articles not related to infusion monitoring therapy, and two articles not focusing on infusion monitoring as their main topic. Ultimately, 12 articles were suitable and eligible for review based on the established inclusion criteria. The literature selection process is presented as a flowchart of the search. (Figure 1.)

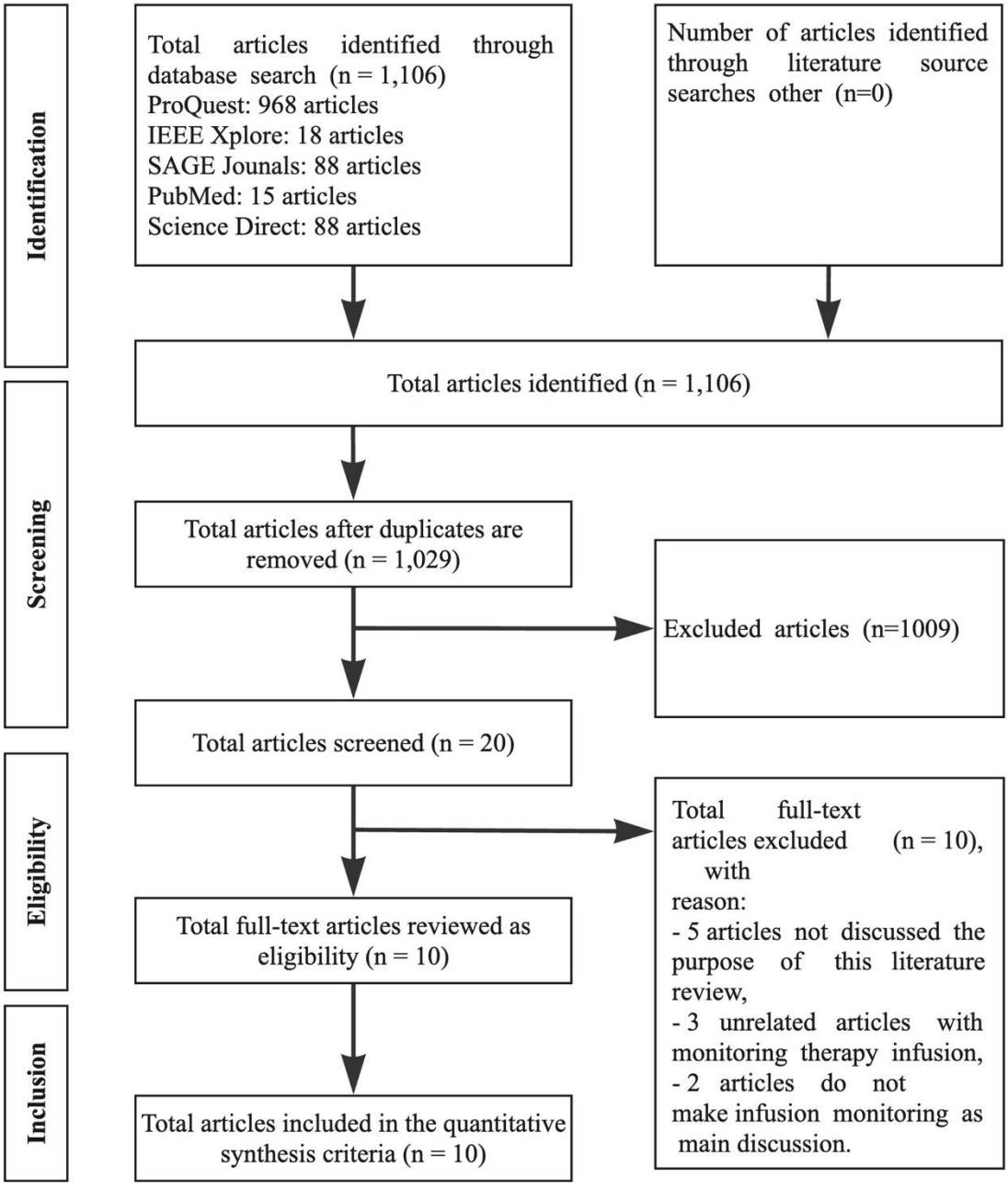


Figure 1. PRISMA (*Flowchart*) Literature Retrieval Flow

RESULTS

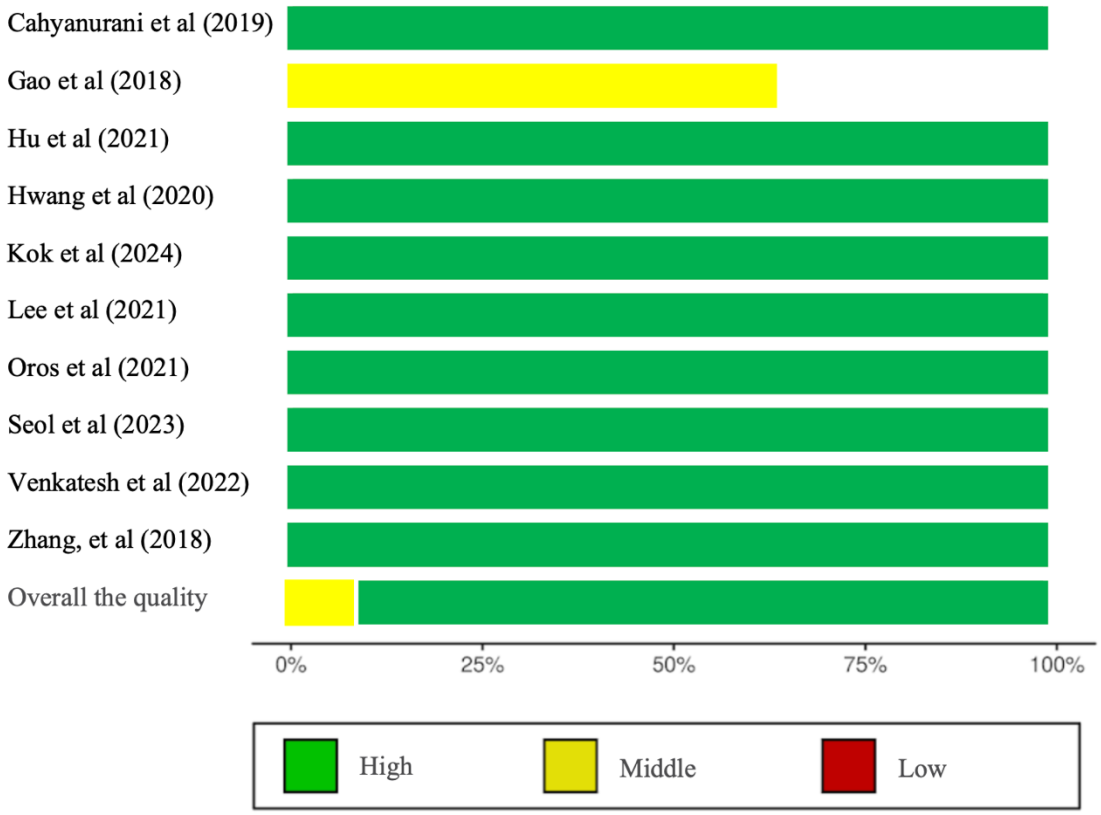
Study Characteristics

In this literature review, a total of ten English articles were assessed for their suitability for use. Most of the literature consists of Original Articles presenting experiments on devices without a population. However, there were 108 populations with characteristics of patients treated at home and receiving intravenous infusion. Narrowband IoT (NB-IoT)

was the most commonly used module in device design (2 studies), followed by Load Cell (2 studies, in combination with Photosensor, NodeMCU ESP8266 & Arduino Uno), Microcontroller ESP32 (1 study), LED WEMOS combined with Node MCU ESP8266 (1 study), Arduino Pro Mini (1 study), YOLO-v2 (1 study), Convolutional Neural Network (CNN) (1 study), and a combination module and acceleration sensor with software based on mathematical algorithms (1 study). The majority of the research from a total of ten literatures was conducted in China (30%) and Korea (30%). Next, there were Australia (10%), India (10%), Indonesia (10%), and Serbia (10%). This study is almost entirely dominated by research without a population sample (Table 2).

To assess the quality of the literature, the author employs the Textual Evidence Checklist: Narrative and Quasi-Experimental Studies from the JBI Critical Appraisal Tools. Nine kinds of literature use the Textual Evidence Checklist: Narrative, and one piece of literature uses the Quasi-Experimental Checklist. Based on the analysis of the checklist, nine kinds of literature can be categorized as High Quality with a green color code due to they met the entire checklist, and there was one of literature that falls into the Middle Quality category since it had a percentage of 58% of the checklist that has not been fulfilled, indicated by a yellow color code. Therefore, the depiction of journal quality based on the JBI Critical Appraisal Tools used is shown below (Table 1).

Table 1. Journal Quality Analysis Using the Textual Evidence: Narrative Checklist from JBI Critical Appraisal Tools



Implementation of Internet of Things-Based Infusion Monitoring2

The effectiveness and accuracy of IoT-based infusion monitoring that optimizes nurses' work and infusion monitoring is the study's objective in the literature review, which can be entirely derived from 10 kinds of literature. Five studies present the accuracy percentage in the calculations from the tested device systems or prototypes. Additionally, two studies show the percentage of deviation in the research experiments. However, three studies present a written conclusion of the research results.

Table 2. Description of Study Analysis

Author/Country	Method	Intervention	Result
Cahyanurani et al (2019) Indonesia	Design and development of a multi-point (multi-intravenous) infusion drip monitoring and control device through an online application.	Monitoring and controlling system for multi-intravenous infusion: Through an online application, it includes photodiodes and LED WEMOSs as well as NodeMCU ESP8266.	The device is capable of measuring infusion volume and detecting infusion drips with an accuracy of 99% and 100%, respectively. The maximum drop per minute (DPM) that can be detected by the device is 135.
Gao et al (2018) China	This research compares 2 groups by considering the conditions in the three days before and after the infusion management system was adopted.	Smart Infusion Management System: with smart terminal equipment combining gravity sensors, acceleration sensors, energy-efficient wireless systems, and other hardware technologies along with a software system of mathematical algorithms.	The infusion management system can calculate and track infusion information for each patient. The system can display detailed nurse data, which includes the type of infusion, input rate, start and end times of the infusion, total infusion time, and so on.
Hu et al (2021) China	The infusion monitoring design connects an automatic sensor device with the Huawei IoT platform via NB-IoT Communication.	*Automatic infusion* monitoring using Huawei Internet of Things, combined with NB-IoT Communication Technology, and the Huawei IoT Cloud Platform.	It accurately detects infusion drops with an accuracy rate of 95%. It has a sensor function for detecting the backflow of infusion fluid and an automatic alarm for infusion monitoring.
Hwang et al (2020) Korea	The overall scheme of the proposed monitoring technique (Infusion-Pump) for real-time multi-modal.	The multi-modal infusion pump (IP) monitoring technique uses a modified membrane sensor for infusion rate (IR) estimation and a Convolutional Neural Network (CNN)-based deep learning technique.	The training, validation, and testing accuracy of the implemented deep learning model after training are 98.3%, 97.7%, and 98.5%, respectively.

Kok et al (2024) Australia	Introducing a low-cost smart infusion device based on IoT technology.	A Novel and Self-Calibrating Weighing Sensor with Intelligent Peristaltic Pump Control Using ESP32 Microcontroller.	The flow rate is set to 0.5 mL/min, and the simulated cumulative error of the PI controller is 0.6%. When the flow rate is set to 1 mL/min, the simulated cumulative error of the PI controller is 1.3%. This is estimated to be caused by greater vibration disturbances due to the increased speed of the peristaltic pump.
Lee et al (2021) Korea	Based on optical sensors, along with the Internet of Things, to address the challenges of IV therapy.	The proposed miniaturized IV detection and monitoring system consists of a Load Cell and a Photosensor.	This system achieves an accuracy of 88% on average in horizontal and vertical movement conditions, respectively. An accuracy of 94% in alert notifications is obtained when the fluid volume is less than 10%. The system can send notifications to the nurse station.
Oros et al (2021) Serbia	A smart IV infusion dosing system to detect, signal, and monitor fluids in IV bottles in remote locations.	Smart Intravenous Infusion Dosing System (SIVIDS) based on Load Cell, Arduino Uno Microcontroller, and NodeMCU ESP8266 Wi-Fi module.	By simultaneously detecting the liquid level in an infusion bottle using ultrasonic and capacitive sensors, and by comparing the obtained data, it was found that the capacitive sensor can reliably and accurately detect the liquid level in the infusion bottle.
Seol et al (2023) Korea	The design of a peristaltic pump with a deep learning algorithm based on computer vision provides real-time video and counts liquid drops.	An automatic flow rate control system for precise infusion during IV therapy using the YOLO-v2 prediction model.	The average accuracy of liquid injection using a peristaltic pump is 99.23%, and the droplet count is the highest at 98.25%. Furthermore, the average accuracy of current flow rates (CFR) using a feedback system is 99.3%.

Venkantesh et al (2022) India	Prototype testing in laboratory conditions. Initial observational investigation at clinical sites and interactions with stakeholders to test the usability and functionality of the device in a clinical environment.	DripOMeter: with control module The 3.3 V, 8 MHz Arduino Pro Mini Microcontroller.	The volume measured using a weighing instrument and readings on the measuring cylinder are very consistent with the volume estimated by the DripOMeter.
Zhang, et al (2018) China	Development of an infusion monitoring device based on infrared sensors integrated with Narrowband IoT (NB-IoT) in Smart Hospitals.	The infusion monitoring device is based on infrared sensors integrated with Narrowband IoT (NB-IoT).	In terms of drop count accuracy, it was found that 80% of the deviations were less than 5 ml, which is acceptable for actual use.

Note. CFR = Current Flow Rates; CNN = Convolutional Neural Network; DPM = Minimum Particle Detection; IoT = Internet of Things; IP = Infusion Pump; IR = Infusion Rate; IV = Intravenous; LED Wemos = Light Emitting Diode Wemos; NB-IoT = Narrowband IoT; PI = Proportional-Integral; SIVIDS = Smart Intravenous Infusion Dosing System; YOLO-v2 = You Only Look Once version 2.

Table 3. Synthesis of Review Results

Item Review	Cahya-nurani et al (2019)	Gao et al (2018)	Hu et al (2021)	Hwang et al (2020)	Kok et al (2024)	Lee et al (2021)	Oros et al (2021)	Seol et al (2023)	Venka-tesh et al (2022)	Zhang et al (2018)
Prototype										
Load Cell						✓[a]	✓[ab]			
Narrowband IoT (NB IoT)			✓[ab]							✓[a]
Micro-controller ESP23					✓[a]					
LED WEMOS	✓[ab]									
NodeMCU ESP8266	✓[ab]						✓[ab]			
Arduino Pro Mini									✓[ab]	
CNN				✓[a]						
Accelera-tion software based on Mathema-tical algorithms		✓[abc]								
Arduino Uno							✓[ab]			
YOLO v-2								✓[a]		

Notes. a = accuracy above 85% and/or cumulative error of less than 1% and acceptable in its application; b = devices that are power-efficient and capable of infecting large networks or transmitting data in real-time; ab = accuracy above 85% and/or cumulative error of less than 1% and acceptable in its application and devices that are efficient in power and capable of infecting a vast network; abc = accuracy above 85% and/or cumulative error of less than 1% and acceptable in its application and devices that are efficient in power, capable of infecting a wide network, and tested in the population.

DISCUSSION

Accuracy of Internet of Things-Based Infusion Monitoring System

The literature synthesis conducted reveals that the IoT-based infusion monitoring system presents promising accuracy. Researchers have presented the accuracy of this device system both quantitatively and qualitatively. Five studies state that the quantitative accuracy ranges from 88% to 100%, and then two studies each quantitatively state that the cumulative error is less than 1% and 80% of the deviations are less than 5 ml. Meanwhile, three studies state qualitative accuracy, indicating that based on trials, the infusion monitoring device system in those studies can reliably and accurately count infusion drops, and the reading results on the infusion tube correspond to what the device estimates.

In the research conducted by Zhang et al., it is mentioned that the Narrowband IoT (NB IoT) module can be connected with IoT in smart hospital systems. This NB IoT also has three infusion monitoring techniques, including the gravity technique to control the medication bottle (infusion), monitoring infusion capacity, and infrared sensors. This system can also be connected with wearable devices, allowing for remote control. The accuracy of the use of this module is assessed from several aspects, namely the performance of the module, the fluid drip, and the remaining volume of the fluid. The use of this module has proven to be effective, with a reasonably high accuracy and good module performance. The fluid drips from the infusion also align with the established system, and the remaining volume of the drug has an accuracy of 80% with manual control. Kok et al. in their research, mention the opposite, namely the use of the IoT-based ESP23 Microcontroller module, which reports results based on the error rate. Based on the research conducted using a closed-loop control sensor, it was found that when the flow rate was set to 0.5 mL, the cumulative error was 0.6%, which is still considered small in the error of creating this prototype (Kok et al., 2024). The error is estimated to be caused by vibration disturbances from the peristaltic pump used in this module.

In another study designed for infusion monitoring, a Load Cell module was used and equipped with a Photosensor. The Load Cell will monitor the volume and changes in the volume of the infusion fluid used, while the photosensor plays a role in monitoring and controlling the infusion drips. In this study, Lee et al. (2021) mentioned that this system can send data in the form of infusion volume, drip rate, and remaining infusion time to a device connected to the network. This system and device can be connected via Bluetooth or Wi-Fi. When this device is connected using Bluetooth, the monitoring distance is limited to 10 meters. In contrast, using Wi-Fi as a connection allows for a distance of up to 100 meters, provided the network strength is between 4G and 5G. The accuracy of using this module has an average accuracy rate of 85 to 88%, with the note that the infusion fluid volume is below 10% of the total initial volume. However, the use of photoresistors in infusion fluid control is only at 80% (Lee et al., 2021). This module is

expected to be beneficial for controlling intravenous fluids in patients who are either lying on a mattress/bed or engaged in activities such as exercise during treatment.

A study conducted in 2020 on the use of IP controlling in infusion systems showed the highest accuracy level with three trial periods, yielding results of 98.3%, 97.7%, and 98.5%, with the final trial being the 36th attempt (Hwang et al., 2021). This research uses a CNN model for monitoring infusions to minimize errors and enhance patient safety. This CNN system monitors the infusion flow in real-time, equipped with an IRset. Although the accuracy level achieved is very high, the use of this IRset shows an error in IRreal of 0.22% - 2.90% and IRref of 0.50% - 2.55%, which ultimately still demonstrates the efficiency of using this IoT-based system model. In fact, there is research that states that CNN integrated with Arduino Uno and ESP8266 is not only capable of accurately monitoring infusions but can also provide precise diagnosis and treatment of diseases based on a continuously updated database, which can be developed as an application-based platform or website (Siddiqui et al., 2023).

The research conducted by Seol et al. (2023) discusses a prototype automatic control system for monitoring intravenous therapy using the YOLO v-2 module. This prototype is designed to determine the volume of therapeutic fluid in the bag/bottle of medication, the volume of fluid entering the patient's intravenous line, the time required for administering intravenous therapy, the drip rate of the fluid, and the volume of drops falling in a time. The way this system works is that when the therapy liquid starts to drip, the infrared light detects the drops and sends a signal to the Raspberry Pi 4B system and the main server. Next, the data is stored and processed into meaningful information, which is the drip rate and the number of drops from the intravenous therapy. Finally, when all the data has been stored, the data within the system will be communicated and controlled. This system is also equipped with a peristaltic pump to assist in controlling the rate and amount of infusion drops. When the processed data is transferred to the peristaltic pump system, the pump will automatically adjust the drops to be produced.

Effectiveness and Efficiency of the Internet of Things-Based Infusion Monitoring System in Its Application.

The existing and tested Infusion Monitoring System has a high level of effectiveness and efficiency. Research that has been conducted shows that all the modules used in the IoT-based monitoring system have relatively low costs and high accuracy and effectiveness. In the study by (Hu et al., 2022), which also adopted Narrowband IoT (NB IoT) modules, an accuracy rate of 95% was achieved. Compared to previous research that had limitations in communication protocols, there is a non-integrated architecture that can connect all smart devices in a smart hospital (Zhang et al., 2018). Meanwhile, recent research has developed a system using Huawei Internet of Things, combined with NB-IoT Communication Technology and Huawei IoT Cloud Platform, which can improve the accuracy of infusion drip detection (Hu et al., 2022). This system also has a sensor function that allows quick handling when there is a backflow of infusion fluid. In addition, this system has an automatic alarm for monitoring infusions, which will reduce the workload of healthcare personnel and prevent errors in monitoring infusions. NB-IoT is a communication protocol or standard introduced by the Third Generation Partnership Project (3GPP), suitable for monitoring patient healthcare, especially for remote

observation and outdoor emergencies, as it is designed to cover and support many devices with low-cost and low-power communication. By being integrated with the Edge–Fog–Cloud computing hierarchy, the constraints that limit the performance of NB-IoT can be addressed (Daraghmi et al., 2022).

Research by Cahyanurani et al. (2019) shows that a device that adopts the LED WEMOS module combined with NodeMCU ESP8266 is capable of measuring infusion volume and detecting infusion drops and is equipped with an animation of an infusion bottle that illustrates the infusion volume. The device can measure infusion volume and detect infusion drops with an accuracy of 99% and 100%, respectively. The maximum DPM that the device can detect is 135 DPM. The application software has an infusion bottle animation that illustrates the infusion volume, making it easier for medical staff to monitor patients. This system requires an average processing time of 1.95 seconds to transmit data from the device to the application. The device is capable of monitoring and controlling fluid infusion drops in a multipoint (multi-intravenous) way through an online application (Cahyanurani et al., 2019).

The infusion monitoring device based on Load Cell combined with NodeMCU ESP8266 and Arduino Uno is found in the research by Oros et al. (2021). Each of these combinations allows for a monitoring device that can send notifications to the nurse station regarding the remaining IV fluid, the current infusion rate, and the expected end time, which can be monitored remotely by medical staff. Furthermore, it can detect, signal, and monitor fluids in IV bottles in remote locations, such as fluid level signals in IV bottles and systems for regulating and stopping infusion flow. Based on the analysis of the results, the researchers concluded that only the proposed Smart Intravenous Infusion Dosing System (SIVIDS) in this paper received a score of 7/7, representing a comprehensive solution for the detection, signaling, regulation, and monitoring of IV infusions in remote locations (Oros et al., 2021). This is made possible because the system consists of (i) a sensing and computing layer to detect and signal the liquid level in the IV bottle and a system to regulate and stop the infusion flow, (ii) a communication layer for wireless information exchange between the hardware components of the system and the client, and (iii) a user layer for monitoring and visualizing the receipt of IV therapy in remote locations in real-time. All layers are modular, allowing for updates to the entire system. Arduino can transfer data in real-time, its integration can be efficiently executed with just a few lines of Python code, and it is suitable for rapid prototyping with basic input-output interactions (Zaffino et al., 2020).

The Arduino Pro Mini module, in the research by Venkatesh et al. (2022) enables the device that adopts it, namely the DripOMeter, and interaction with stakeholders serves as a platform to test the usability and functionality of the device in a clinical environment and to obtain feedback for further design iterations. The results of the observation tests show that the volume calculated using the weight measuring instrument and the readings on the measuring cylinder are consistent with the volume estimated by the DripOMeter. It can be concluded that the drop factor set for the drip chamber used is correct, the DripOMeter does not miss any drops passing through the drip chamber, and the total volume of the infusion performed has been accurately estimated. DripOMeter completed all testing components of the diagnostic test, showing that the assembled Printed Circuit

Board (PCB) is functioning well. The system's performance is consistent under different lighting conditions. The detector continues to detect droplets even when tilted at an angle of 20°. The device also provides accurate alarm indications. The prototype of this device was tested under laboratory conditions. Initial observational investigations were conducted at clinical sites.Looking at the demographic data from the literature, IoT-based infusion monitoring system prototypes have been widely developed in Asian countries such as Indonesia, China, Korea, and India. In addition, European countries like Serbia are also interested in developing this system. Australia is also contributing to the effort to create this infusion monitoring system to develop technologies to enhance patient safety. Each country that develops this system has and uses different types of modules. Based on the literature, the infusion monitoring system developed in Indonesia uses LED WEMOS modules and Node MCU. China uses software algorithm modules and NB-IoT as a form of system development to monitor infusion drops, volume, and infusion time. Korea's development uses Load Cell modules, YOLO-v2, and CNN. Interestingly, the modules used by Korea and Serbia are similar in that they use Load Cells. India and Indonesia also use one of the modules used by researchers from Serbia to develop this monitoring system, such as Arduino Uno and Node MCU ESP8266. In India, the infusion monitoring system was developed using Arduino Mini Pro. Meanwhile, Australia is developing an infusion monitoring system using Microcontroller ESP23. The variety of modules developed by each of these countries opens up opportunities for a more effective, efficient, and accurate infusion monitoring system.

Trial of Internet of Things-Based Infusion Monitoring System

Smart Infusion Management System with smart terminal equipment that combines gravity sensors, acceleration sensors, energy-efficient wireless systems, and other hardware technologies along with software systems for algorithms and mathematical modeling (Gao et al., 2018). The research by Gao et al. (2018) involved 108 inpatients in November 2016 who received intravenous infusions. Selection criteria: patients with the same number in the same ward who are conscious and able to assess and who received routine intravenous infusions in the hospital. Exclusion criteria: patients with mental disorders or those not treated with intravenous infusions. Considering the conditions three days before and after the infusion management system was adopted as the management group and the experimental group, the number of rings from the two groups was compared.

By comparing two groups while considering the conditions three days before and after the infusion management system was adopted, the management group in the three days before using the infusion management system. Nurses conducted routine rounds in the ward; patients and their families participated in infusion management and called the nurses with a beeper when the infusion was finished or when the drip rate was abnormal. Data from the entire infusion process was manually recorded and statistically analyzed. The experimental group is the group that used the smart infusion management system for three days. The smart infusion management system was adopted. The infusion management system can calculate and track infusion information for each patient. The results showed that this system proved to be effective. The system can display detailed data for nurses, which includes the type of infusion, input rate, start and end times of the infusion, total infusion time, etc. The infusion management system can record and

manage infusion information in real-time. Based on this information, nurses can differentiate between primary priorities and sub-issues and organize the workflow reasonably to enhance work efficiency. Early warning of various infusion information allows nurses to save time and space for other nursing tasks, while also avoiding back-and-forth movements, reducing workload and labor intensity for nurses, and increasing efficiency. However, analysis found that the sample's awareness of infusion safety is not very strong, and they often adjust their infusion rates. So, nurses must strengthen health education regarding infusion knowledge for those samples.

Optimizing Nurse Performance with Internet of Things-Based Infusion Monitoring
Technological as Caring Theory in Nursing is a nursing theory presented by Locsin. This theory states that technological competence is essential in patient care (Krel et al., 2022).Technology plays an essential role in assisting nursing practice. As time progresses, technology will be increasingly accepted and implemented to aid nurses in their practice. Based on this theory, technology is also expected to provide a platform for nurses to be closer to their patients. This context relates to technology that will support nurses' work and ease their tasks, allowing nurses to interact more and build closer relationships with patients to provide care. Therefore, innovation and technological development, especially in healthcare, are essential to support the nursing practice.

One of the efforts in technology development in the nursing practice is the infusion monitoring system. IoT-based infusion monitoring has shown a high level of accuracy with various advantages based on reviews. With high accuracy, nurses can trust the calculation of the infusion drip rate to the IoT-based monitoring device system. Feedback in the form of information, such as detailed care data, which includes the type of infusion, input speed, start and end times, total infusion time, etc, is sent to the monitoring device located in the nurse's station (monitoring room). The system can also record and manage infusion information in real-time, helping nurses to differentiate between main priorities and sub-issues and organize workflows reasonably to improve work efficiency (Venkatesh et al., 2022).

Implementing NB-IoT, which can integrate all infusion monitoring information into one ecosystem, makes it easier for nurses to monitor the operation of the device system. This IoT-based infusion monitoring system can also connect to the IoT Cloud to store and manage data and even connect with applications (Hu et al., 2022). Thus, nurses can monitor patients' infusions in real-time. This has a domino effect on nurses' performance. With the real-time monitoring of patients' infusions, patients will be free from the risk of complications due to incorrect infusion drip rates, delays in changing infusions, or even dosage errors that could have fatal consequences (Seol et al., 2023). This will have implications for patient satisfaction with the services provided by nurses. As a result, the performance of nurses will improve. Nurses will work more efficiently without the need to constantly check each patient's IV in every treatment room, thus saving energy and time (Zhang et al., 2018). Nurses can also allocate their time and energy to provide therapeutic services to patients, allowing for more time spent with patients, which enables nurses to understand the patient's conditions better and needs to maximize care.

Study Limitation

This research has limitations. Among the limitations is that most existing studies use the PPRO method. The PPRO method is a prototype research method aimed at producing a prototype before a commercial product is created. The results in the form of prototypes cannot yet be optimally used as a reference for implementation. This is due to the limited research found on IoT. In addition, not all journals show the accuracy values of each described prototype. The authors used the narrative checklist from JBI to analyze the journals because there is currently no checklist available to assess journals using prototype methods.

CONCLUSION

This fluid administration monitoring system was created through the integration of various devices. This monitoring system utilizes the Internet of Things (IoT), where the entire system is organized automatically to assist nurses in monitoring the process and taking immediate action to enhance patient safety. The prototype of this system has been extensively developed and tested in clinical trials. The devices that are the main characters adopt modules such as NB-IoT, Load Cell, ESP83 Microcontroller, YOLO-v2, CNN, LED WEMOS, NodeMCU ESP8266, Arduino Pro Mini, Arduino Uno, as well as several other sensor modules, which are arranged to be paired and integrated with tools and materials for administering intravenous fluid therapy. Most clinical tests in laboratory practice show good accuracy and effectiveness. The accuracy range of using these modules in the infusion monitoring system is 85% to 98.5%, indicating that these modules are effective. Qualitative data from several journals state that this IoT-based infusion monitoring system can be implemented because the device testing has an error rate of less than 1%. The results of this literature review can provide a research gap for developing IoT, especially for implementation in the nursing practice. In addition, information related to the effectiveness and efficiency of IoT can be a consideration for implementation in healthcare facilities for nursing practitioners.

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