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Transformation of infusion system to automatically complete infusion tasks

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Abstract. In the realm of medical technology advancements, there has been a significant enhancement in methodologies for investigating patient ailments and devising therapeutic interventions, surmounting myriad complex challenges in the process. Concurrently, the healthcare sector has adopted a diverse array of tools to accommodate various treatment modalities. Among these, the infusion device, a staple in clinical settings, is ubiquitously employed yet is considered to be archaic in its operational methodology. Predominantly utilized within hospital environments, the traditional infusion paradigm is notably labor-intensive, necessitating constant supervision to mitigate the risk of errors, a responsibility often delegated to patients or their guardians. This scholarly discourse aims to delineate the extant landscape and historical context of infusion device technology. It will methodically review and analyze existing literature on advancements in automation within the domain of infusion therapy, with the intention of synthesizing a comprehensive solution that epitomizes the zenith of current research findings. By comparing and contrasting various scholarly contributions on the subject, the paper endeavors to construct a cohesive overview of the advancements in automated infusion systems, thereby contributing to the ongoing discourse and potentially influencing future innovations in medical device technology.

Keywords: Infusion improvement; Solution; Automatically; Improvement.

1. Introduction

With the development of medical technology, we have more and better methods to explore the causes of patients and find solutions, overcoming one difficult problem after another. At the same time, the society has various instruments to cope with different medical models. However, there is one instrument that has not changed with the progress of technology. It has been used for a long time and frequently, and it is the infusion device. The infusion device is still the same as before, which can be summarized as a tube with a needle at one end and a medication bag connected to the other end. There is a regulator on the tube that can control the speed of medication flow and requires manual adjustment [1]. It is generally used in hospitals, but this infusion method is very outdated. This mode is very labor-intensive, and each device requires someone to keep an eye on it. Generally, patients or their families pay attention, but this approach can easily lead to errors. They do not have professional knowledge and cannot guarantee the smooth infusion. Therefore, it needs a new type of infusion device that can ensure that it can be automatically completed without external control before inserting the needle until the infusion is completed [2]. This can greatly reduce the need for manpower and make it easier for patients who need infusion.

In the following content, this paper will first elaborate on the current situation and background of infusion devices, then summarize and compare various published papers on automatic infusion improvement methods, and finally integrate the most complete final solution. This paper is looking for two directions, one is to control the infusion speed, and the other is to control the temperature during infusion [3]. In each direction, this paper will find three papers as support and integrate them. Take out the essence from each article, and this paper can complement each other and make further progress.

2. Basic theoretical basis

2.1. Traditional working principles

In traditional way, there was a needle head connected with a long slender tube. Near the top of the tube was a small round bottle and on the top of the tube linked with the bag for loading medication solution. When someone needs to perform infusion, the needle will puncture his skin. With the effect of gravity, the solution will flow from the bag through the tube and the needle, finally infuse to the body. As there were several ways that would come to different parts of one's body, we collectively referred to as the body. At the same time, due to the lower air pressure inside the infusion tube compared to the outside, the presence of atmospheric pressure can also cause the solution to flow into the body. When the infusion begins, there should be someone, sometimes the nurse or the patience himself and his family members, pay close attention to the flow rate of the solution. If the rate is too fast or too slow, the nurse will adjust the button on the small round bottle. It can control the diameter of the tube linked with it in order to accelerate or slow down the amount of solution flow into it in unit time. This is the tradition way we use until now [4].

2.2. Possible optimization methods

The traditional infusion method has many drawbacks, such as observing the flow rate, which requires someone to constantly pay attention to whether the liquid droplet speed is normal. If it is a nurse watching, it is equivalent to wasting medical manpower. If it is a patient watching, sometimes inaccurate situations may occur, and the drawbacks of this method obviously go beyond this. But it is precisely because of its drawbacks that there are ways to improve. Essentially, no matter what kind of optimization it is, its significance is to make the infusion process no longer consume manpower, so that it can be automatically advanced, and the application of manpower is to make the liquid flow smoothly into the human body at normal speed. For liberating manpower, there are two options: one is to automatically replace the medication, but not related to this topic; the other is to automatically adjust the flow rate of the solution, eliminating the need for manual observation. To ensure a stable flow rate of the solution, one is to control the flow within the normal range, and the other is to avoid external interference. In order to no longer require manual control of the flow rate, it is necessary to automate the manual adjustment. Therefore, we need a device that can detect the flow of the solution. By comparing the flow rate of the solution to be higher or lower than the normal value we set, we can send a signal to adjust the device. The adjustment method is not fixed, only automatic control is needed. This adjustment will gradually approach a fixed value in a fluctuating manner, finally reaching a fixed value. At the same time, it is necessary to avoid external interference, the most important of which is temperature, so it is also necessary to keep the temperature inside the infusion set constant. Its principle is similar to controlling flow rate, and it also requires a sensor to detect temperature. The measured temperature is compared with the set normal value, and then the temperature is adjusted closer to the normal value, ultimately reaching the desired temperature. In manual mode, temperature actually does not need to be considered too much, as the flow rate is manually adjusted while also bringing in the temperature. However, automated regulation will only maintain a fixed speed, and if the temperature is not within the consideration range, another device must be used to control the temperature.

3. Liquid flow rate control

In Lin's paper, the author's intention is to adjust the speed of liquid droplets and issue an alarm when the droplet speed is too fast or too slow. The object they detect is the droplet falling speed during the infusion process. The controller automatically detects the droplet falling speed and compares it with the set infusion speed value. Then, a signal is generated to the stepper motor controlling the wall of the tube, which amplifies or reduces the diameter of the droplet tube to control the liquid flow rate and ultimately achieve a stable state. When the speed exceeds the upper and lower limits, it will sound an alarm. Overall, this plan optimizes the control of flow rate and emergency reporting, which can share the attention of staff [5].

In Wang's paper, the author's main objective is to achieve control of liquid flow rate through weight sensors. By real-time monitoring of the liquid quality inside the infusion set, the flow rate of the liquid can be obtained. By calculating the weight change of the liquid per unit time, the average value of the flow rate can be obtained. On this basis, this solution can install software on smartphones, and the infusion situation of the infusion object can be broadcast live on the software. Overall, this plan optimizes flow rate control and supervision methods, allowing patients to ensure normal flow rates without the need for someone to accompany them. It is equivalent to adding monitoring to each infusion device, making the working position of the staff more comfortable. And for weight detection, it can also be convenient to confirm whether the liquid has been completely infused [6].

In Bai's paper, the author proposes an automatic supervised infusion system that uses infrared photoelectric technology to detect the droplet velocity of liquids. The droplet velocity of liquids can be actively set, and the flow rate of liquids and the volume of drugs can be independently set. While detecting the droplet velocity, it can also detect whether there is any liquid remaining in the device without dripping. For this device, there is also a dedicated mobile app that can check the status of infusion. An alarm device has been set up, which can be notified through Bluetooth in case of abnormal conditions. In summary, the system has many functions, including automated supervision, optimized flow rate control, supervision methods, and the ability to actively control. Liberated manpower and simplified work content. On mobile phones, it is also convenient for the caregiver of the infusion recipient to not have to accompany them [7].

Among the three articles mentioned above, the optimization plan in the third one is undoubtedly the most improved, providing optimized branch solutions: flow rate control, regulatory mode, and abnormal state warning. For flow rate control, two or three papers have tested the droplet velocity, but this method is not as effective as the direct detection of liquid quality in the second paper. The droplet velocity is easily disturbed and difficult to detect, but quality detection is very easy. Therefore, quality sensors are used to control flow velocity. In the regulatory model, it is necessary to gather all methods together. On the medical staff side, they can set flow rate and other control content, while obtaining feedback from the regulatory system. On the patient side, they can only obtain regulatory information, reducing the occurrence of erroneous operations. Finally, there is an abnormal state alarm, which has been mentioned in the first three articles, but the content is different. Therefore, the system needs to issue an alarm for abnormal flow rate and solution retention. The system that combines the three is the current optimal solution.

4. Liquid temperature control

In Cha's article, the control of temperature has been improved. It is mentioned that there are differences in infusion at different flow rates, and different methods should be used for fast and slow infusion, otherwise the temperature will change. At the same time, the heating speed also varies at different flow rates. Subsequently, the plan proposed to use different materials to make infusion tubes for high and low flow rates. In summary, this plan optimizes the production plan for the device, allowing different materials to correspond to different application directions, and adds a temperature control system to reduce the impact of external temperature on infusion. It can assist devices under automatic flow rate control, reducing the time it takes for the device to reach normal flow rate and reducing the number of alarms [8].

In Zhang's article, the author believes that it is necessary to heat the infusion device during cold seasons and perform infusion at a constant temperature. It uses the algorithm of fuzzy PID to continuously approach a fixed temperature within a certain period of time. Using STM32 microcontroller as the main controller and NTC thermistor as the temperature sensor, after temperature detection by the sensor, the Peltier temperature control heating element will undergo temperature adjustment. In theory, the entire heating process can reach the specified value in approximately one minute and remain stable. This device can maintain a constant temperature of the liquid in cold weather, reducing the interference of external factors during the infusion process. Under constant temperature, it can maintain stable liquid flow rate and reduce abnormal conditions during automatic infusion [9].

In Tang's article, the author constructs an intelligent monitoring system to monitor the temperature during infusion, using slot type optocoupler sensors and DS18B20 temperature sensors for temperature detection. The device is then heated by a stepper motor and relay, and real-time information can be observed on multiple devices. Devices are connected wirelessly through Bluetooth, allowing for human-machine interaction in this state. This plan is based on the assumption of STM32 microcontroller. This device simplifies traditional manual infusion monitoring and has the advantages of portability, efficiency, high accuracy, and low cost, reducing the occurrence of medical accidents and improving the work efficiency of medical staff. The patient's family members can also obtain the patient's status information from other devices, making the information more public [10].

Based on the above three articles, the content covered in Article 1 is undoubtedly the most comprehensive. However, it mainly relies on infusion tubes made of various materials for temperature control. However, this mode will inevitably lead to excessive demand for the device. Although the idea of different flow rates corresponding to different materials is very advanced, there is currently no affordable method to achieve it, if resources are invested in better heaters, it may actually be more effective. The second article only mentioned heating in cold weather. Although it may not be as good as the first article in terms of equipment, it provides a high-quality algorithm that can be integrated and applied. In the third article, the system it simulates is lightweight and inexpensive, and is equipped with Bluetooth connection. Although software is already available for flow rate control, it should still be added when discussing temperature alone. Combining these three, adding the Bluetooth system from article three to the device that adjusts heating with flow rate in article one, and removing the fact that different devices use different materials, and finally using the fuzzy PID algorithm from article two, is the final optimization solution.

5. Conclusion

After analyzing the above six articles, we can conclude that the theoretically most suitable automatic infusion device measures the mass of the liquid inside the device, calculates the flow rate of the liquid, and adjusts it to accelerate or decelerate. When abnormal conditions occur during the infusion process, such as infusion stopping, an alarm will be issued, and all of the above content can be reflected in practice. At the same time, the automatic infusion device can detect temperature to ensure that the temperature is in an ideal state. There is also a specially designed software that allows doctors and family members to observe the infusion situation, and doctors can also control the infusion speed and temperature on the software.

However, the device still faces many challenges that need to be addressed. For this device, it has multiple functions and requires a high cost to manufacture, which is not accessible to most people who need infusion. Therefore, there are two development directions for this device: one is very durable and will still meet the standards after decades, and the other is to become a low-cost product, so that the benefits it brings can offset the consumption it brings. Not only that, the selection of materials also needs to be considered. Traditional infusion tubes do not have so many functions, they only need to be able to transport solutions, while automatic infusion devices can adjust temperature and control flow rate by changing the infusion tube. Therefore, they need to be able to adapt to frequently changing materials. In addition, it is necessary to consider the issue of matching infusion software, ensuring that the software is compatible with controlling infusion speed and temperature, and ensuring that each infusion device has independent control capabilities, otherwise the software may have adverse effects. In addition to these, this device will also face other challenges, but it will definitely overcome the past and eventually meet us, because it is a product of medical technology progress. Perhaps in the near future, it will be put into use.

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