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Comparative analysis of fusion factors affecting the accuracy of injection amount of remote fluid monitoring system

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원격 수액모니터링 시스템의 주입량의 정확도에 영향을 주는 융합인자의 비교 분석

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Abstract Recently, the prevalence of remotely managed patient care systems in medical institutions is increasing due to COVID-19. In particular, in the case of fluid monitoring, hospitals are considering introducing it as a system that can reduce patient safety and nurses' work. There are two products under development: a load cell method that measures weight and a method that detects drops of sap by infrared sensing. Although each product has differences in operation principle, sensor type, size, usage, and price, medical institutions are highly interested in the accuracy of the data obtained.In this study, two prototypes with different sensor methods were manufactured and the total amount of infusion per hour was measured to test the accuracy, which is the core of the infusion monitoring device. In addition, when there was an external movement, the change in the measured value of the sap was tested to evaluate the accuracy according to the measurement method. As a result of the experiment, there was a difference of less than 5% in the measurement value error of the two devices, and the load cell method showed a difference in the low-capacity measurement value and the infrared method in the high-capacity measurement value. As a result of this experiment, there was little difference in accuracy according to the sensor method of the infusion monitoring device, and it is considered that there is no problem in accuracy when used in a medical institution.

Key Words : Ringer, Load Cell Sensor, Infrared Sensor, Accuracy, Patient Nursing

요 약 최근에는 COVID-19 인해 의료기관에서 원격으로 관리되는 환자케어 시스템의 보급이 증가되고 있다. 특히 수액모니터링인 경우 환자의 안전과 간호사의 업무를 줄일 수 있는 시스템으로 병원에서 도입을 고려하고 있다. 현재 개발되어 있는 제품은 무게를 측정하는 로드셀 방식과 적외선 센싱으로 수액 방울을 검출하는 방식의 두 가지 제품이 있다. 각 제품은 동작원리, 센서의 종류, 크기, 사용법, 가격등의 차이가 있지만, 의료기관에서는 획득되는 데이터의 정확도에 관심이 높다. 본 연구에서는 센서 방식이 다른 두 가지 시제품을 제작하여 수액모니터링 장치의 핵심인 정확도를 실험하기 위해 시간당 총 수액량을 측정하였다. 또 외부의 움직임이 있을 경우 수액 측정값의 변화를 실험하여 측정방식에 따른 정확도를 평가하였다. 실험 결과 두 장치의 측정값 오차는 5% 미만의 차이가 있었고, 로드셀 방식은 저용량 측정값에서 적외선 방식은 고용량 측정값에서 차이를 보였다. 본 연구결과 수액모니터링장치의 센서방식에 따른 정확도 차이는 거의 없었고, 향후 의료기관에서 사용할 경우 정확도의 문제는 없을 것으로 사료된다.

주제어 : 링거, 로드셀 센서, 적외선 센서, 정확도, 환자 간호

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1. Introduction

Intravenous infusion among medical practices is an effective means to effectively treat diseases, and occupies a large amount in actual nursing work[1]. Currently, most of them apply passive observation systems that are directly observed with the naked eye. In some cases, proper observation is not made, which can lead to safety accidents such as side effects of exhausted fluids connected to empty infusion sets [2]. These passive fluid monitoring systems are demanding new systems because they cannot accommodate the various needs of users, such as abnormal fluid drop rate or injection endpoint prediction [3].

Recently, due to COVID-19, the demand for non-face-to-face patient care systems in each medical institution is increasing [4]. In the medical information system, all basic biosignals are analyzed by self-measurement of medical data, and external transmission systems through remote monitoring are being studied a lot [5]. Among the individual monitoring systems in medical wards, the most accessible are the biosignal systems such as body temperature, blood pressure, and oxygen saturation, as well as the management system for status changes such as urine accumulation and fluid injection[6]. In particular, since infusion monitoring is an intravenous injection method, it can be said that there is a high risk of medical negligence and medical accidents [7]. Therefore, in the infusion monitoring system, accurate information on the progress of administration, the injection speed, and the injection amount should be recognized. When an infusion is injected into a subject in a hospital, the infusion time per patient is generally about 30 minutes to a maximum of 5 hours, and the time required to check the fluid is 10-15 minutes, which is about 90 hours due to monthly average fluid monitoring. [8]. Therefore, a remote infusion monitoring system is being developed to solve the problem of such infusion management monitoring. There are two main methods for measuring the injection amount in the fluid monitoring system developed so far. One is to count infusion droplets in infrared rays, and the second is to calculate the amount of infusion reduced by calculating the initial amount of infusion by weight. Therefore, in this study, two types of device prototypes were manufactured and analyzed to see which method would be effective when fluid monitoring is actually implemented in a medical institution[9,10].

In this study, a load cell-based weight measurement method was developed, and to compare the efficiency of this method, a prototype of the infrared measurement method was manufactured and the advantages and disadvantages according to the infusion injection environment were analyzed. In particular, an experiment was conducted to check the accuracy of comparing and observing whether the measured value of the injection amount changes according to the movement and the presence or absence of an error between the actual value and the measured value of the injection amount[11].

Therefore, through this study, we intend to present the evaluation results of the two devices by evaluating the accuracy of the fluid monitoring device, which is currently being introduced in medical institutions for the purpose of efficient use of non-face-to-face medical environments and convenience of nursing work. Through this, we want to secure the reliability of the infusion remote monitoring device from the user's point of view.

2. Materials and Methods

In this study, the method of measuring the infusion amount by applying the infusion weight using a load cell sensor is shown in Fig. It was manufactured as in (a) of 1, The advantage of this method is that it is easy to install and the operation method is simple depending on the type of sap. However, due to movement for vibration, a change in the reference value occurs due to a change in the measurement value of the load cell sensor, so a variable value application algorithm is required. In this study, the problem of variation value error occurring in motion was solved by applying a window algorithm that applies a certain section as an average value [12].

Fig. (b) of 1 is an infrared measurement method, and the number of drops of sap is measured by installing the light emitting and receiving sensors in a straight line opposite structure using the infrared sensor in the drip container. Unlike load cells, this method has no error in movement, but the amount of information varies depending on the location of the sensor, In particular, if there is sap on the wall of the drip bottle, an error may occur due to a malfunction of the infrared sensor, Since there is a physical structure, an additional calculation method that settles the average value over time must be applied [13]. Therefore, the structural problems of the two devices can be solved through the program.

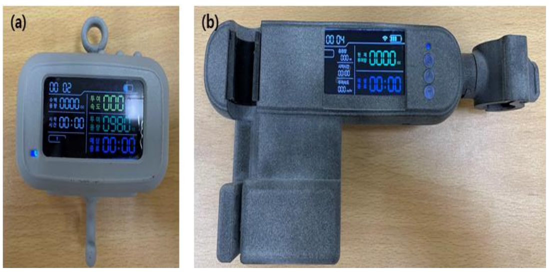


Fig. 1. Prototype of fluid monitoring measurement device. (a) Load cell-based measuring device, (b) Infrared measuring device

In this research experiment, the accuracy of the two methods was compared and evaluated. The accuracy of the final injection amount of the infusion solution was compared using the same 1000 cc infusion (glucose, 5%). The design was shown in Fig. 2 so that the infusion administration rate was set to 60cc/hr (20gatt/hr) and the experiment could be performed in the same way. At this time, the appropriate time was measured in the amount of intermediate and final input at intervals per minute, and the accuracy of the dose was compared and analyzed based on reaching the infusion amount of 300 cc.

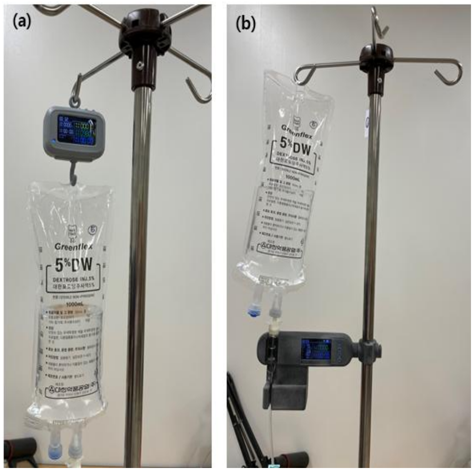


Fig. 2. Fluid injection amount test method (a) Measuring the amount of infusion using a load cell-based measuring device, (b) Measuring the amount of infusion using an infrared sensor type measuring device

In the second experiment, in order to evaluate the accuracy of the infusion amount according to the movement, a vibration device that can give a constant left and right vibration of 0.3 m/min, which is the vibration that occurs when the pole is moved, is used to determine whether there is a change in the injection amount according to the movement.

Experimental observation was carried out as in

3. The two measured values of the load cell sensor method and the infrared sensor method were compared with the actual injected dose displayed on the device under the same vibration and observed whether there was an error.

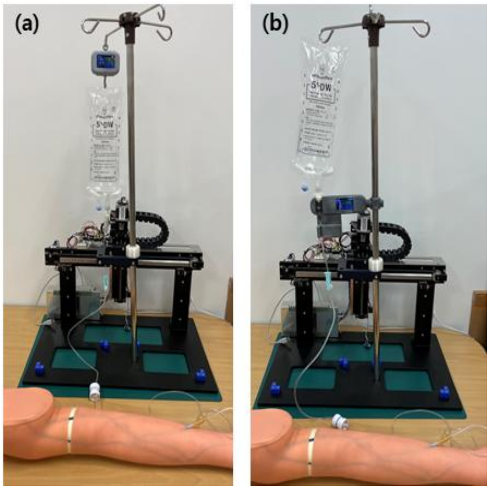


Fig. 3. Experimental method of comparing errors in injection measurement according to left and right movements. (a) It is a load cell-based measuring device, (b) Infrared measuring device.

3. Result

As for the basic information of the infusion monitoring device, the total volume of the infusion to be injected and the infusion start time should be basically provided, and the administration speed and expected end time are important factors [14]. Table 1 shows the results of comparative analysis with the actual injected amount by setting the injection amount per minute to 60cc per hour, the first experiment to evaluate the accuracy of the dose of the load cell sensor-based device and the infrared sensor device. Measurement was performed 10 times and the average value was used. Analysis of the measurement results shows that it is almost consistent with the actual input amount, Based on the actual input amount, the load cell showed a stable result as the error increased and the amount of sap increased when the capacity was low. The infrared method, on the contrary, showed that the accuracy was almost identical when the sap was low in volume. Both devices have a small error of less than 5% compared to the actual dose, so the accuracy is very high because the amount is smaller than the dose administered to the infusion line in the actual situation.

Table 1. Comparison of dosage analysis between load cell method and infrared method

Time (Minutes)	Load cell Measurement value (cc)	Infrared sensor Measurement value (cc)	Actual input capacity (cc)
10	8.42	9.10	9.12
20	17.20	18.11	18.51
30	28.12	29.41	24.6
60	51.96	55.85	56.02
120	115.30	110.25	112.30
180	170.25	165.10	170.23

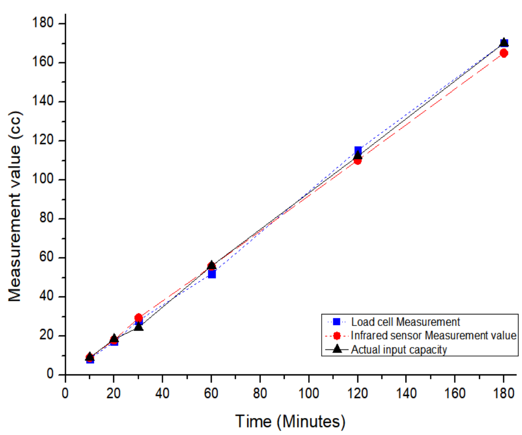
Since the fluid monitoring measuring device is sensitive to movement, the values measured through the same experiment in a given left and right vibration are shown in Table 2. The measured values of the error for motion existed in both measuring devices, and in particular, the error of the load cell method was large. However, in both devices, the accumulated infusion volume was less than 20cc at the maximum, so there was a slight error in the actual patient's measurements.

Table 2. Comparison of dose analysis according to movement in load cell and infrared devices

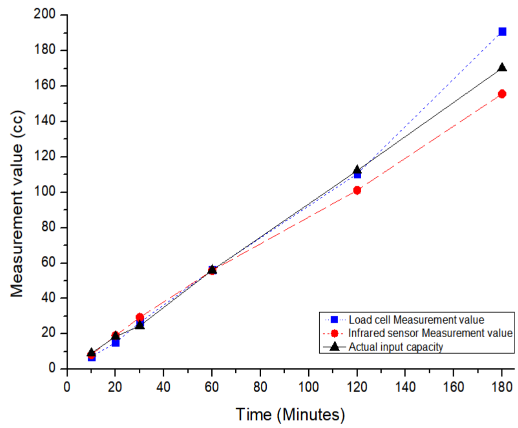
Time (Minutes)	Load cell Measurement value (cc)	Infrared sensor Measurement value (cc)	Actual input capacity (cc)
10	7.02	8.24	9.12
20	15.10	19.02	18.51
30	26.54	29.41	24.6
60	56.21	55.85	56.02
120	110.52	101.20	112.30
180	191.01	155.65	170.23

In both experiments of the accuracy test, errors occurred, and the difference in actual input amount was the amount lost in the infusion tube wall, In the device of the load cell sensor method, there was a tendency that the movement of the ring part had a large amount of vibration transmission from the left and right vibrations, and there was no significant change according to the movement in the infrared method, Due to a malfunction of the sensor hitting the tube wall, some errors occurred in the overall measurement data. Both devices use a method to solve motion errors with an algorithm, so results that are difficult to point out as errors in use were derived.

Therefore, as shown in Fig. 4, the injection amounts of the two devices were compared in a graph based on the actual input amount. As shown in Fig. 4, the changes on the graph appear almost the same, indicating that the error range is not large compared to the dose. However, when the input time is continuous vibration, the occurrence of errors tends to increase due to the cumulative vibration coefficient, but, Considering that there is no clinical environment with the same vibration for 3 hours, it can be called reliable accuracy.



(a) Comparison of changes in the total amount of fluid injected



(b) Trend of injection amount change according to movement

Fig. 4. Comparison graph of fluid injection amount according to sensing method

4. Review

When prescribing an intravenous infusion to stabilize the patient's condition or to treat a disease, the infusion rate and injection volume control are very important factors depending on the patient's condition or the course of the disease [15]. Therefore, it is necessary to monitor the patient's fluid in real time, and it must be able to accommodate the observation requirements of patients, guardians, and nurses. The remote infusion monitoring device presented in this study was researched and developed to help nurses control their work and efficient patient management such as caregivers and guardians.

The remote fluid monitoring system can be divided into a machine part that measures the amount of fluid, a program that analyzes it and provides information, and a communication system. The communication system that transmits the information collected from the device is a wireless LAN (Wireless Local Area Network) called WiFi (Wireless Fidelity) and BLE (Bluetooth Low Energy), a Bluetooth technology that enables low-power, low-capacity data transmission and reception in the 2.4GHz frequency band. method can be applied. The final collected real-time data is a screen shared by medical staff and can be configured as a user request screen by linking with the hospital information system.

The communication method of the remote sap monitoring device can be applied differently depending on the hospital environment, but most of the beds are close to each other, so the BLE method is now widely applied, and the WiFi method is generally used in medical institutions. The fluid measuring device has the disadvantage of short battery life, so it can only be used for up to 72 hours on a single charge. Therefore, it can be seen that the size of the device is mainly determined by the sensing part and the battery part.

As in this study, a device that can monitor the amount of infusion can be provided based on a load cell, which is a weighing sensor, as shown in this study, so it has economic competitiveness. On the other hand, the infrared sensing method can accurately determine the amount of low-dose injection and can even control the amount of infusion in the future, which is helpful for microscopic observation of the patient's fluid administration. In both devices, there is an error of less than 5% in accuracy, but it is considered that there is no problem in monitoring because the difference from the total input amount is not large. However, a problem arises in the case of total input amount, fine input amount, and low capacity management in seconds.

As a limitation of this study, problems such as the material of the dropper in the IV set were not considered. In particular, in the infrared sensing method, a large error occurred when light scattering occurs due to sap on the wall of the drip container, which can be considered to be affected by the material and thickness of the drip container. Therefore, in future research, an experiment that considers the characteristics of the drip tray will be required, In this study, standard products supplied to medical institutions were purchased and used.

5. Conclusion

A remote infusion monitoring device is a system for caring and managing patients in a ward, and the accuracy of data obtained from the device is a very important factor. In this study, the accuracy of the load cell method, the infrared method, and the two sensor method devices were compared and evaluated. The evaluation showed that the load cell method had a slight error range in case of a low capacity, and the infrared method showed that the error changed as time increased. For movement, the load cell showed a larger error range. However, both devices have less than 5% error, which does not affect the actual injection, and it is judged that there will be no major problem in use.

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