Journal of The Korea Convergence Society
Vol. 13. No. 4, pp. 137-145, 2022
e-ISSN 2713-6353
DOI : https://doi.org/10.15207/JKCS.2022.13.04.137

Development of usability evaluation index of convergence technology remote fluid monitoring device for non-face-to-face patient nursing system application and analysis of results

Seon-Chil Kim
Professor, Department of Biomedical Engineering, School of Medicine, Keimyung University

비대면 환자 간호시스템 적용을 위한 융합기술의 원격 수액모니터링 장치 사용성평가 지표 개발 및 결과 분석

김선칠
계명대학교 의용공학과 교수

Abstract The usability evaluation of the remote fluid monitoring device, which was introduced to reduce the work of nurses and increase the efficiency, was performed due to the expansion of the non-face-to-face medical system. Remote fluid monitoring is a fusion of various technologies such as fluid measurement and analysis, error correction technology, and transmission technology. The range of use by users, the information they want to obtain, and the control device, etc. are wide, and the factors that evaluate the product are also diverse. Therefore, it is difficult to improve the product through evaluation. In this study, a quantitative index was developed to help improve the product for commercialization by conducting 20 usability evaluations in three areas of product stability, operability, and satisfaction with the remote sap monitoring system device. It was performed through infrared and load cell-type sap monitoring devices. In terms of stability, there was a difference in installation work such as fixing the pole of the device, and high satisfaction was shown for operability and accuracy. In terms of product satisfaction, the satisfaction of load cell devices was generally high.

Key Words : Ringer, Usability evaluation, Non-face-to-face, Remote monitoring, Nursing

요 약 비대면 의료시스템의 확대로 간호사의 업무 경감 및 효율성을 높이기 위해서 도입되는 원격수액모니터링 장치의 사용성평가를 수행하였다. 원격 수액 모니터링은 수액 측정시술과 분석, 오차 교정기술, 전송기술 등 다양한 기술이 융복합되어 있다. 사용자가 사용하는 범위와 얻고자 하는 정보, 조절 장치 등 사용범위가 넓으며 제품을 평가하는 요소도 다양하다. 따라서 평가를 통해 제품을 개선하는데 어려움이 있다. 본 연구에서는 원격수액모니터링 시스템장치를 제품의 안정성, 조작성, 만족도의 3개 영역에서 20개의 사용성평가를 실시하여 상용화를 위한 제품개선에 도움을 주고자 정량적인 지표를 개발하였다. 적외선 방식과 로드셀 방식의 수액모니터링 장치를 통해 수행하였으며, 안정성에서는 장치의 폴대고정 등 설치작업에 대해 차이가 있었으며, 조작성과 정확성에 대해서는 높은 만족도를 나타내었다. 제품의 만족도에서는 로드셀 장치의 만족도가 대체로 높게 나타났다.

주제어 : 링거, 사용성평가, 비대면, 원격모니터링, 간호

*This work was supported by project for Collabo R&D between Industry, Academy, and Research Institute funded by Korea Ministry of SMEs and Startups in 2021.(Project No. S3088856).

*Corresponding Author : Seon-Chil Kim(chil@kmu.ac.kr)

Received March 16, 2022
Revised March 26, 2022
Accepted April 20, 2022
Published April 28, 2022

1. Introduction

The fluid used in medical institutions refers to a system that supplies the body through the patient's blood vessels for the necessary time to treat diseases [1]. When the infusion fluid is all consumed, the operation of the infusion set must be stopped or the infusion container must be replaced with a new one. If this is not the case, the reflux of blood in the blood vessels into the set of sap occurs, resulting in loss in the course of treatment [2]. Therefore, the range of fluids in patient observation and care is very large and continuous observation for a long time is required. Accordingly, the work of nurses is continuously increasing due to non-face-to-face work [3].

The main dosing monitoring system is dosing time, dosing speed, and end time, and so far, it has been mainly managed through pre-predicted time, but in some cases, medical service losses may occur due to time differences. A system that allows medical institutions to remotely monitor infusion of fluids used in patients without guardians to observe the amount of infusion and injection status has recently been introduced in the medical field [4]. These systems are managed while avoiding direct contact with patients as much as possible, and are expected to help non-face-to-face medical practices in line with recent COVID-19. The infusion set is largely composed of an introduction needle, a drip tube, a flow controller, a connecting tube, and an infusion needle [5]. The drip tube connected to the infusion container through the intravenous insertion needle is used to observe the frequency of dropping of infusion drops to determine the flow rate of the infusion, and the flow controller is attached to the infusion hose and used to control the frequency of drops of infusion [6].

Therefore, the currently proposed technology is a method of calculating the total injection amount by measuring infusion drops in a drip container, and a method of converting the reduced amount in the entire infusion bag into weight. To measure the amount of infusion in the remote infusion monitoring system, the weight or flow rate can be measured from the inside to the outside of the infusion. In this case, there are two types of measurement sensors: infrared sensor and load cell sensor [7]. In previous studies, the infrared method may cause an error due to the droplet smudge phenomenon of the drop tank, and the load cell sensor method may cause an error in weight measurement due to the movement of the fluid tank. Therefore, both sensor methods use an algorithm that overcomes the error based on the initial value and the variable value. In this study, usability evaluation was conducted to find problems that may arise when users use products rather than errors arising from these mechanical problems [8]. The subjects were nurses who were able to obtain fluid management information using both products. When this product is introduced into the medical field, the number of subjects is limited to nurses as it is implemented for the purpose of reducing the workload of nurses and providing quality services to patients.

In addition, the main purpose of usability evaluation was to evaluate the accuracy and satisfaction of the field application device, and the accuracy was to be evaluated based on operability and stability. Through this usability evaluation, the main product was analyzed and compared from the user's point of view to increase the reliability of the product, and at the same time, the research purpose was to improve the completeness of the product in the future by suggesting the problems that were excluded from the development process.

Through this study, when a remote infusion monitoring product is used in the medical field, it is intended to focus on increasing the reliability and completeness of the product.

2. Materials and Methods

This study developed a usability evaluation index that can occur when remote sap monitoring is performed from the user's point of view through literature review of related technologies and similar products and preliminary analysis of manufactured prototypes. The usability evaluation indicators presented here correspond to questionnaire items that are evaluated directly by nurses. Through this study, two prototypes were directly fabricated, and Fig. As shown in 1, it is an infrared sensor type monitoring device and a load cell sensor type device.

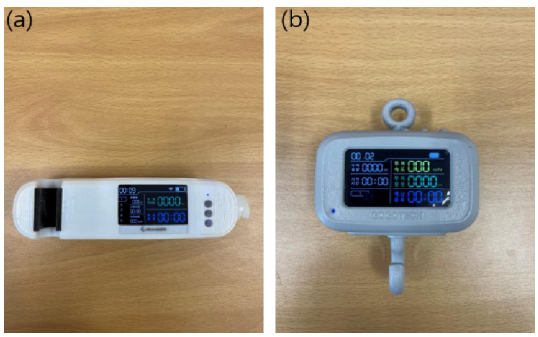

Fig. 1. Injection monitoring device. (a) Infrared sensor type infusion measuring device, and (b) load cell sensor type infusion measuring device

The usability evaluation index of the infusion monitoring device was presented in three main areas: stability, operability, and satisfaction based on the infrared sensor method and the load cell sensor method. First, for safety, it was reviewed whether the problem that the user should not be directly injured in the process of using the product and that there is no damage to the body or surroundings during use was solved. In the case of operability, the second study subject, the product was mainly interpreted from the perspective of reducing the nurse's work. The indicators were developed by analyzing the steps necessary for the nurse to obtain information using the developed device rather than the existing manual observation task and the process of setting the device. Therefore, evaluation factors were developed on the recognition of the operation of the device and the convenience of operation, focusing on the use and operability of the device. Satisfaction, the final evaluation factor, is close to a qualitative evaluation, and in order to understand the part that users feel psychologically in the process of installing, operating, and recognizing the actual product, an index that can evaluate the satisfaction of each part was developed.

The developed usability evaluation index is shown in Table. corresponds to 1.

It is necessary to verify whether the contents of the usability evaluation index developed in this study are valid as a measurement tool. If there are previously developed evaluation tools, validity tests can be conducted through correlation, but this product has not yet been studied on appropriate evaluation tools due to lack of evaluation cases or research cases. Therefore, this study intends to conduct content validity verification by forming a related expert group.

Content validity corresponds to a quantitative explanation of whether the indicator accurately specifies the concept to be generalized or comprehensively covers the concept to be measured [9]. Therefore, nine people from academia, industry, and medical circles were asked to fill out a questionnaire (Likert 5-point scale) on whether the questionnaire they wanted to ask was valid, and the content validity of the evaluation items was evaluated.

Table 1. Overall usability evaluation index of infusion monitoring devices

	Domain	Attribute	Assessment indicator
1	Safety	External safety	Externally safe and robust degree of using the device.
2		Part safety	Even if the pole is moved, the device does not become uncoupled or the pole does not come off.
3		Combination risk	When combined with a pole, do not injure the human body such as fingers.
4		Durability	When used as an infusion device, the appearance of the device must not be altered or deformed.
5		Charger	Check that there are no dangers in the connection part when charging.
6	Operability	Frame connection	When attaching or disassembling a device to a pole, it is well combined without much effort.
7		Ease of operation	Evaluate whether the button operation of the device is easy and convenient at the same time recognized.
8		Charger combination	Is the process of assembling the device and charger easy.
9		Combination of devices	Is it easy to combine and release the fluid monitoring device.
10		Detection sensor	Does the infrared sensor and load cell sensor work well according to the change of the sap drop.
11		Device change input	How well does the device input change on the screen when the device needs to be changed.
12		Sap setting	Is it possible to change, modify, or delete the type and capacity of the infusion smoothly.
13	Satisfaction	Continuous use trend	You can recommend the same device to another user.
14		Battery capacity	Satisfied with the battery capacity required to use the device.
15		User's Guide	The product user manual is well marked, and the level of understanding of use is satisfactory.
16		Charging time	Satisfied with the time it takes to fully charge the battery.
17		External size	The degree to which you are satisfied with the size of the appearance of the two devices.
18		Alarm function	The status indicator that the battery needs to be charged is clearly displayed.
19		Switch size	Satisfied with the size of the information input switch.
20		Information alarm	Alerts and alerts to alerts and cautions on device in use function well.

Content validity is Eq. Analysis was based on the content validity ratio (CVR) as shown in 1 [10].

$$CVR = \frac{N_e - \frac{N}{2}}{\frac{N}{2}} \quad \text{---------} \quad \text{E.q 1}$$

N_e = The number of participants who think the question is valid, N = total number of participants

Based on this usability evaluation index, the questionnaire provided to the user as an evaluation was written on a Likert 5-point scale (very much, yes, moderate, dissatisfied, very dissatisfied) as shown in Table 2 [11].

Subjects in this evaluation were 10 nurses working at K General Hospital in Daegu. The most commonly accepted principle regarding the number of usability evaluation subjects is 'Magic Number 5', that is, if the number of subjects for user evaluation is 5 or more, it is sufficient [12], It was said that the probability of finding a problem with only 5 evaluators is 80% or more, and up to 90% of 10 participants can be found [13]. After pre-training on how to use the two devices for 1 hour, each ward was allowed to use it for 3 to 4 days, and then the questionnaire usability evaluation was conducted. The default settings for accuracy and operation are shown in Fig. 2 was tested.

Table 2. Usability evaluation questionnaire of the fluid monitoring device

	Domain	Assessment indicator survey content	Strongly Disagree ①	Disagree ②	Neutral ③	Agree ④	Strongly Agree ⑤
1	Safety	While the infusion monitoring device is in use, the device can be used without any problems in stability, such as separation or falling.					
2		It is sturdy and does not fall off the sap pole, so it can be used without any problems in operation.					
3		When the device is installed, it can be used well without any risk to the user's body.					
4		If the device being used is exposed to fluid, it works well without any operational problems.					
5		When charging, the device and the power supply are connected well without any problems.					
6	Operability	When connecting to the sap folder, it is convenient to operate the connection part.					
7		It is easy to attach and detach the connection part and install the device.					
8		It is easy to connect to an external mobile phone charger as well.					
9		Installation and disassembly of the device are easy.					
10		The accuracy of the fluid monitoring results displayed on the device is high.					
11		It is easy to enter initial values on the device screen.					
12		It is easy to change, modify, and delete information such as the type of sap.					
13	Satisfaction	The used fluid monitoring device can be recommended to other users.					
14		I am satisfied with the battery life of my device.					
15		The instructions for the device are well explained and easy to understand.					
16		I am satisfied with the charging time of the device.					
17		Appropriate external dimensions and weight of the device.					
18		I am satisfied with the alarm function of the battery charging.					
19		I am satisfied with the size of the information input switch.					
20		I am satisfied with the alarm function that sounds when the infusion is finished or abnormal infusion of the infusion is finished.					

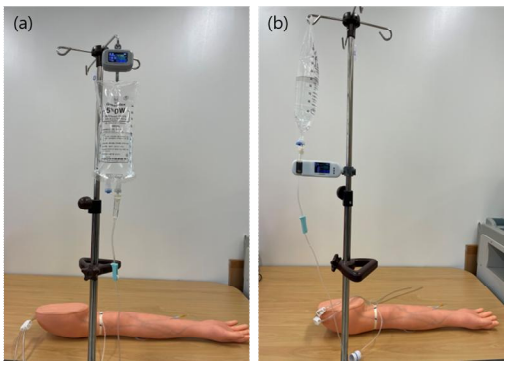

Fig. 2. Injection experiment method of infusion monitoring device

3. Result

A total of 20 evaluation indicators were developed for the usability evaluation of the remote sap monitoring device, and a questionnaire was written for each indicator according to the properties of the product. The same question was asked for both devices, and the basic stability of the device, operability within the range of use of the device, and satisfaction during operation were evaluated. As for the validity of the questionnaire produced

through the previously developed index, the minimum ratio of the questionnaire content validity in the related study was 0.56, In the case of this evaluation question, the minimum ratio of content validity was found to be 0.667, so it was confirmed that the question in the questionnaire was valid [14].

Table 3. Usability evaluation questionnaire of the fluid monitoring device

	Domain	Attribute	Average	
			Infrared method	Load cell method
1	Safety	External safety	4.0	4.2
2		Part safety	3.8	4.2
3		Combination risk	3.5	3.7
4		Durability	4.1	4.1
5		Charger	3.8	3.9
6	Operability	Frame connection	4.0	3.9
7		Ease of operation	4.3	4.3
8		Charger combination	4.2	3.9
9		Combination of devices	3.7	3.8
10		Detection sensor	3.7	3.7
11		Device change input	3.6	3.6
12		Sap setting	4.3	4.2
13	Satisfaction	Continuous use trend	3.8	4.2
14		Battery capacity	4.0	4.3
15		User's Guide	4.1	4.1
16		Charging time	4.6	4.6
17		External size	3.8	4.1
18		Alarm function	4.5	4.5
19		Switch size	4.2	4.2
20		Information alarm	4.5	4.0

For usability evaluation results, the average value was applied on a 5-point scale [15,16]. As a result of usability evaluation, the load cell part received a good evaluation from the outside, and it was found that the infrared method had difficulties in using the infusion pole and the coupling part. As for durability, both devices had good evaluations, and both evaluations of the accuracy of the devices, such as the operation of measurement sensors, were positive. The battery part was satisfied with the charging time, but the load cell sensor device was evaluated as having a better battery life. Although the alarm function transmitted to the outside was generally satisfactory, the satisfaction with the alarm of the infrared sensor device was high when there was a problem with the infusion solution.

There was no significant difference in the usability evaluation of the two devices, but the evaluation according to the appearance such as installation and dismantling of the device differed depending on the user, and the most important accuracy part received positive evaluations. Through this evaluation, it was found that specific improvement plans are needed to secure the stability of the infusion folder and connection method and to adjust the size of the information input switch.

4. Review

In this study, the usability evaluation of the remote sap monitoring device is to suggest a product improvement plan from the user side of the development device through the developed evaluation index, and to test the satisfaction, efficiency, and effectiveness of the product in advance through actual users [17]. Usability is a term that expresses the degree to which the actual user can easily access the product and is easy to perform the purpose of use. ISO 9241-11 describes the degree to which a specific purpose is performed with effectiveness, efficiency, and satisfaction while using a product, and effectiveness refers to the accuracy and completeness of performing the purpose [18]. Efficiency quantitatively expresses the elements necessary to accomplish the purpose, and through this, the time and cost suitable for the purpose of use can be quantitatively expressed. Final satisfaction is a subjective feeling that users feel, and it is evaluated in terms of preference such as frequency of use and degree of discomfort.

Therefore, this evaluation has the advantage of being able to detect and improve product problems early before launching the product on site, making it an essential process in the development stage.

In ISO/IEC 9126-1, understandability indicating the degree of understanding of how to use the product, ease of learning indicating ease of application of accepted information, operability, It is defined as the usability concept of attractiveness, which is the subjective emotion of users, such as recommendations from other users after using the product [19]. Therefore, usability evaluation can be said to be a very effective method to evaluate a product from various perspectives. In this study, a remote sap monitoring device was developed and usability evaluation was conducted to identify the problems and improvements of the device from real users before entering the market. The product was evaluated with the infrared sensor method and the load cell sensor method. Although the evaluated questionnaire items can be viewed as subjective evaluation, in usability evaluation, subjective evaluation and objective evaluation of subjects have a high correlation, so it can be dealt with with usability evaluation [20].

Although the measurement principle for the infusion injection of the two devices is different, the resultant result is the same, so this evaluation tried to find an improvement point for use. From the user's point of view, the problems such as attachment and disassembly of the device and the infusion pole were presented the most, and much attention was paid to the operation button according to the battery life and operation. As for the connection part of the infusion pole, the size of the switch has emerged as a problem to be improved. As a limitation of this study, the remote fluid monitoring system is not a stand-alone device, but a service system and has a limitation in that it must be linked with the hospital information system. However, in order to increase the accessibility of the final product by the user, evaluation was performed through this device. As a limitation of this study, the usability evaluation index for remote monitoring should be added in conjunction with EMR, the hospital information system, for both remote fluid monitoring devices. In this experiment, only partial evaluation of indicators for satisfaction, operability, and safety of the device was performed through the IRB, so it is thought that the process of finding problems in the case of performing remote fluid monitoring through communication in the future should be added.

5. Conclusion

In this study, usability evaluation was conducted for nurses who are real users of the infrared and load cell remote fluid monitoring devices. In order to find product problems and improvement directions, 20 usability evaluations were developed and actual user evaluation was performed. As a result of the evaluation, the operability and satisfaction obtained with the measuring device were generally excellent, but it is thought that this study will contribute to improving the product and improving the completeness in the future by suggesting different opinions on the fixing problem of the device.

REFERENCES

[1] S. Y. Oh & D. H. Kym. (2020), Serum Lactate, Creatinine and Urine Output: Early Predictors of Mortality after Initial Fluid Resuscitation in Severe Burn Patients, 20.0008, *Journal of Korean*

Burn Society, 23-(1), 1-6.
DOI : 10.47955/jkbs.20.0008

[2] Y. N. Kim. (2022). The Influence Factors on Nursing Work Performance by Clinical Nurses, *Journal of the Korea Academia-Industrial cooperation Society 23,* 594-602.
DOI : 10.5762/KAIS.2022.23.1.594

[3] S. J. Bai, J. W. Lee & K. Y. Lee (2010), Fluid therapy: classification and characteristics of intravenous fluids, *J Korean Med Assoc 2010 December, 53(12),* 1103-1112.
DOI : 10.5124/jkma.2010.53.12.1103

[4] J. H. Park & S. K. Chung. (2016). Influence of Emotional Labor, Communication Competence and Resilience on Nursing Performance in University Hospital Nurses, *Journal of the Korea Academia-Industrial cooperation Society, 17(10),* 236-244.
DOI : 10.5762/KAIS.2016.17.10.236

[5] H. M. Lee & Y. H. Pan. (2019). The Medical Supplies KIT Design based on the Intravenous Fluid Therapy for Experience of Medical Staff, *Journal of the Korea Convergence Society, 10(8),* 121-128.
DOI : 10.15207/JKCS.2019.10.8.121

[6] J. S. Choi & J. S. Kim. (2013). Nurses' Perception, Knowledge, and it's Affecting Factors on Performance of Nursing Practice in Hospital with No Guardian. *The Korea Contents Association, All Rights Reserved, 13(10),* 403.
DOI : 10.5392/JKCA.2013.13.10.403

[7] J. H. Park. (2020). Adaptation of VR 360-degree Intravenous Infusion Educational Content for Nursing Students. 165-170, *The Journal of the Convergence on Culture Technology, 6(4),* 165-170.
DOI : 10.17703/JCCT.2020.6.4.165

[8] Rolf Molich, Meghan R Ede, klaus kaasgaard & Barbara Katyukin (2007), Comparative usability evaluation, *Behaviour & Information Technology, 23(2004).*
DOI : 10.1080/0144929032000173951

[9] S. H. Moon, B. G. Kang, J. J. An, H. K. Jo, H. R. Yoo, I. C. Seol & Y. S. Kim. (2008). Study of the Indicators of Each Pattern Identification Based on Korean Standard Differentiation of the Symptoms and Signs for Stroke, *Korean J. Oriental Physiology & Pathology, 22(2),* 487-496.

[10] D. H. Jang & S. K. Cho. (2017). Is the Mid-point of a Likert-type Scale Necessary?: Comparison between the Scales With or Without the Mid-point, *The Korean Assosiation For Survey Research, 17(4),* 1-24.
DOI : 10.20997/SR.18.4.1

[11] C. H. Lawshe. (1975). A quantitative approach to content validity. *Personnel Psychology, 28(4),* 563-575.
DOI : 10.1111/j.1744-6570.1975.tb01393.x

[12] J. Nielsen & T. K. Landauer. (1993). A mathematical model of the finding of usability problems. *Proceedings of the Interact '93 & Chi '93 Conference: Human Factors in Computing Systems, 5(1),* 206-213.
DOI : 10.1145/169059.169166

[13] B. Sullivan. (2000). Designing Web Usability: The Practice of Simplicity. *Technical Communication, 47(3),* 411-413.
DOI : 10.1145/169059.169166

[14] L. J. Cronbach. (1949). Essentials of Psychological Testing. 5th ed. New York : Harper e Brothers.

[15] Y. H. So. (2016), A Comparison Analysis of Usability Evaluation for Simulation Learning based on Web 3D and Virtual Reality *The Journal of the Korea Contents Association, 16(10), 719-729.*
DOI : 10.5392/JKCA.2016.16.10.719

[16] J. S. Yoo, B. S. Kim. (2016), Development of Usability Assessment Indicator of Adjustable Electric Beds for Home Care, *Journal of the Korea Safety Management & Science 18(1).*
DOI : 10.12812/ksms.2016.18.1.45

[17] J. S. Kim & S. H. Han. (2008). A methodology for developing a usability index of consumer electronic products. Int J Ind Ergon, 38(3-4), 333-345.
DOI : 10.1016/j.ergon.2007.12.002

[18] N. Jakob & M. Rolf. (1990). Heuristic evaluation of user interfaces. ACM CHZ'90, 249-256.
DOI : 10.1145/97243.97281

[19] B. C. Kwakl & K. W. Kim. (2021). Design Improvement Direction of ICT Convergence Products through Usability Evaluation, *Journal of Cultural Product & Design, 67,* 141-154.
DOI : 10.18555/kicpd.2021.67.013

[20] E. J. Sin, J. B. Song & S. B. Lim. (2021). Development of Evaluation Indicators and Analysis of Usability on Learning with a Robot for the Elderly - the case of Content using the Humanoid Robot 'LiKU'
DOI : 10.5392/JKCA.2021.21.11.056

김 선 칠(Seon-Chil Kim) [정회원]

· 2003년 2월 : 고려대학교 의료정보기기학과 (공학석사)
· 2009년 2월 : 경북대학교 의료정보학과 (의료정보학박사)
· 2003년 3월 ~ 2015년 8월 : 대구보건대학교 방사선과 교수
· 2015년 9월 ~ 현재 : 계명대학교 의용공학과 교수
· 관심분야 : 방사선 차폐, 의료기기, 의료정보
· E-Mail : chil@kmu.ac.kr