Learning-Training System for Medical Equipment Operation

Ren Kanehira[1(✉)], Kazinori Kawaguchi[1], and Hideo Fujimoto[2]

[1] FUJITA Health University, 1-98 Dengakugakubo, Kutsukake-Cho, Toyoake, Aichi 470-1192, Japan
kanehira@fujita-hu.ac.jp
[2] Nagoya Institute of Technology, Nagoya, Japan
fujimoto@vier.mech.nitech.ac.jp

Abstract. A clinical engineer has to do a lot of work including the management, the operation, and the maintenance of various medical equipments, requiring highly specialized techniques and up-to-date knowledge. However, it is very difficult for him to master such an enormous amount of knowledge within the limited time as university student, particularly the ability for trouble shooting to ensure safety. In order to solve these problems, this study presents an education system for clinical engineers with a representative education and training case for the operation of heart-lung machines. Although two contents, i.e., the basic operation and trouble shooting, respectively, should be included in such a training system, we pay more attention to the basic operation in this paper.

Keywords: Computer training system · E-learning system · Skill science · Medical equipment · Clinic engineer

1 Introduction

A clinical engineer (CE) has to do a wide range of work including the management, operation, and maintenance of various medical equipments, requiring highly specialized techniques with advanced knowledge [1].

However, it is very difficult to train students or other learners to become qualified CEs who have to master so many techniques within a very limited period of time in university. As the results, the CEs quite often feel the lack of knowledge and skill when they start working in a hospital after graduation.

On the other hand, with the advanced technologies such as computer-support systems, multimedia, CG, and VR, together with a lot of new display equipments, not only visual data but also data for other human senses can be provided to the learner, ensuring a quick and effective training effect [2–6]. Following the advancing trends of medical engineering, we have studied several education/training systems [7–9]. And more recently, a computer-supported education system for clinical engineers focused on operations of medical machines was presented [10, 11].

The conventional E-learning method, though, focuses mostly on the learning of knowledge like that from textbook, paying less attention to how to operate medical

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systems. Obviously, the knowledge learnt from textbook only cannot be compared with that from experience (empirical knowledge), body movements (embodies knowledge), and explicit knowledge in addition to the knowledge from textbook [12]. In this study, we present an education system for clinical engineers with a representative case for the operation. Although two contents, i.e., the basic operation and trouble shooting, respectively, should be included in such a training system, we are discussed by focusing on education and training for basic operation in this paper.

2 Education and Training for Clinical Students

One problem emerges to the students that all of them have to take national licenses for doctor or clinical engineer without much chance to do realistic and enough medical treatments on patients. Furthermore, there may be similarly less chance to operate medical machines even in their practice period in hospitals. Obviously, practice should be done as many as possible for reducing any medical accident. Therefore, effect methods of learning the methods of operation, confirming what is a safety operation, experiencing emergency cases, knowing the avoidance of dangers, and so on, have always been the research subjects of university.

Being the same in the Department of Medical Engineering in our university, the students have to master both medical knowledge and engineering one within their limited university time. Furthermore, they need to be trained with practical techniques to operate various clinical equipments at a high level of safety. The huge contents and limited time span bring to students a lot of pressure.

We did a questionnaire last year on the 4th grade students in our university by asking "did you forget the operation sequence of heart-lung machines after you have become the 4th grade student (right before the hospital practice). Surprisingly, all 31 students regardless of gender answered with "yes, I forgot"! The reasons may be multiple, but "less chance to touch and operate the medical system" becomes the dominant (Fig. 1).

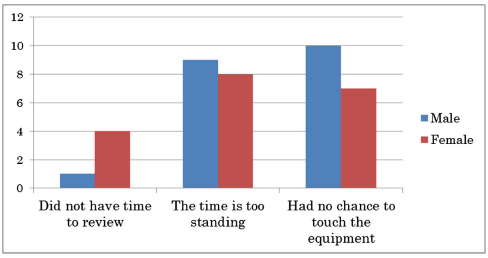

Fig. 1. Questionnaire results (1)

Therefore, it becomes much more important to build up a computer-added training system for CEs to match the increased medical need, and the importance should be increasing with time.

Another questionnaire was put upon the 4th grade students by asking "do you want to use a computer simulation system capable of providing simulated experience in the preparation and review of your text". The answers divided by different training items are shown in Fig. 2, in which 90 % of students answered "yes".

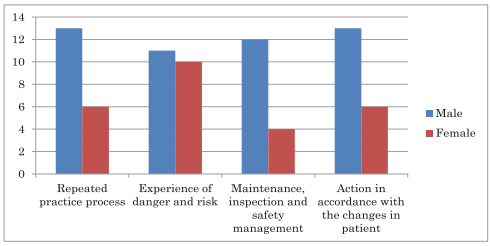

Fig. 2. Questionnaire result (2)

As stated above, it is very much expected by the students to have a training system using the advanced computer technology with multimedia presentation, particularly those with operational capability and towards different clinical equipment.

3 Teaching of Basic Operation Methods on Heart-Lung Machine

3.1 Instruction to the Construction of Extra-Corporeal Circuit

The teaching system is made for students in the 3rd grade for a better understanding on heart-lung machine operation and related knowledge.

A heart-lung machine is such an artificial system to replace temporarily the function of blood circulation and oxygen introduction of a patient. Such a medical treatment is also called "cardio-pulmonary bypass". The heart-lung machine has been taken as a typical example of clinical systems with complex circuits and numerous parts, requiring particular operations and most importantly, directly related to the life supporting of a patient.

We divided the contents of the training system into two parts, i.e., the basic training for the most fundamental operations and the trouble-shooting during practical treatments, as demonstrated in Table 1. This study focuses on the basic operation training.

In learning operation of heart-lung machines, it is considered difficult to master skills from textbook together with necessary operations within a short period of time because the medical machines differ from each other in makers and years of production.

Most importantly, operations must be taken without any mistake because they may relate directly to the patient's life. Therefore, such knowledge as the circuit construction, the machine parts and their functions, the determination of operation parameters, the safety devices and monitors, and the correct operation sequence, are required.

For this purpose, the instruction of basic operations of the extra-corporeal circuit was taken as an example. The figures and graphs from textbook are made comparable

Table 1. Contents of the system

Operation training system of the heart-lung machine			
Fundamentals	**Basic procedures**	Advanced Operations	**Troubleshooting**
	➢ Circuit configuration		➢ The trouble types
	➢ Basic knowledge		➢ The trouble types
	➢ Time series tables of operating procedures		➢ Operation process with detailed operation methods
	➢ The operation presentation by video presentation		➢ Confirmation of learning effect

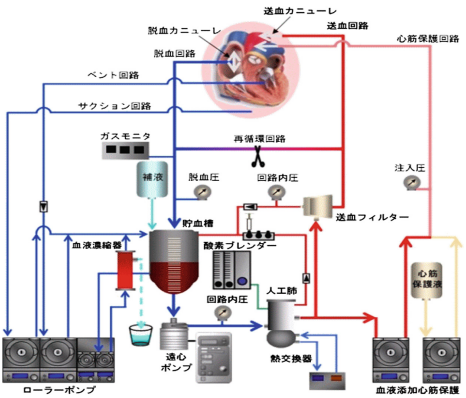

Fig. 3. Extra-corporeal circuit figure in a textbook

to the practical circuits displayed on a computer screen. Figure 3 is the flat figure of the circuits to help the students to get a rough understanding of the system at first.

Figure 4 shows the construction of circuits by photo images taken from a practical machine. It is understood that the shape of each parts, the connection of circuits are demonstrated very vividly. In addition, the names of parts, the detail of each image, and the related knowledge, function, and operation key points, are also demonstrated.

3.2 Operation Sequence by Time Series Presentation

A model operation sequence with video made under the advices of experienced clinical engineers was produced as the time series table. Related knowledge was made into a database, with which the operation contents and sequence, the easy-occur mistakes and the prevent methods were summarized to form digital text and connected with retrievals and networking.

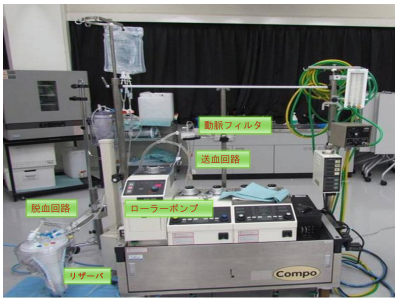

Fig. 4. Circuit construction with practical machine images

The study case using the above operation sequence table is as the following:

(1) To get the total flow of operations; (2) Study the related knowledge and operation points from explanations; (3) Get detailed by retrieval and networking; (4) Summarize the model video into the time series and make it visible when necessary.

Figure 5 shows the time series table of the operation. Knowledge/Images/Video in the right hand are linked with operation sequence in the left hand. For example, the star mark links to the related knowledge to the related page with knowledge represented by instructions with description sentence and tables. When click the Image, it is demonstrated as a detailed photo and suitable descriptions.

手順	ポンプ	心筋保護液	知識	写真	動画
<1> ポンプスタートの準備	・ポンプが停止していることを確認 ・脱血サイド(1本)、送血サイド(1本)、リサーキュレーション回路(1本)に鉗子で閉めてあるかしっかり確認する。		★	■	●
	・リザーバレベルを一番高いレベルにする。 ・手の届く位置に鉗子、手回し用クランクを用意する。		★	■	●
<2> ポンプスタート (部分体外循環開始)	・ヘパリン投与とACT値確認 ※ACT値400以上でないと開始してはいけない。		★	■	●
術野の指示で開始	・送血チューブの鉗子外す。 ・チューブを手で軽く押し拍動を確認 ・『ポンプスタートします。』 ・100～200ml送血 ・『脱血開始します。』 ・インデックス2.4にあわせる。→術野に知らせる。	※送血圧に注意する！ ※イニシャルドロップを避ける	★	■	●
<3> トータルバイパス (完全体外循環開始)	・冷却スタート		★	■	●

Fig. 5. Time series table of operation sequence

3.3 Instruction with Model Video

It is easier to memorize an operation with one's eyes tracking the traces of a moving body than keeping them staring at typed words in textbook. In fact, the model operation text was produced using the images and video taken from a real machine and real operation after consulting experienced clinical engineers. The parts in text can be emphasized by magnifying, added with new words or red colored to help the students for better understanding. Figure 6 demonstrates an example of operation instruction by video.

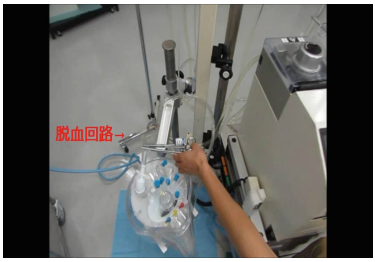

Fig. 6. Operation instruction with model video

4 Conclusions

A training system for operations on heart-lung machines was studied for the "Practice of Circulation Support Technologies" of the 3rd grade student in university.

As the content for the basic operation knowledge learning, the circuit construction and model operation methods were presented with digital text. Instruction on operation sequence was provided with time series table with necessary links to related knowledge, images and videos. A combination of audio-visual stimuli provided by multimedia led to a better understanding and higher efficiency in the training.

The effect of system was evaluated with the questionary on the trained students of the department. Over 80 % of them confirmed the usefulness of the system in helping them to master necessary skills and knowledge during study. It is expected that a much higher training efficiency can be obtained with further accomplishment of the present training system.

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