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A Study on Serious Game-Based Learning Method for Epiduroscopy: Game Experience Evaluation

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Abstract

Background: An epiduroscopy is a highly effective minimally invasive surgery operated for chronic lumbago and lumbar disc herniation. An effective learning method is needed because epiduroscopy requires a high-level surgical capability, which is hard to be trained.
Objective: In this paper, we propose serious game-based learning method for epiduroscopy.
Methods: The proposed method enables trainees without epiduroscopy experience to improve surgical understanding through self-directed learning. Serious game used in the proposed method provides training which inserts catheter path of epiduroscopy.
Results: We performed an experiment to examine feasibility of the proposed method to actual education. In the experiment, 20 neurosurgeons learned catheter path of epiduroscopy according to the proposed method. From the experimental results, it was confirmed that trainees could insert the catheter quickly and safely (with less collision) in virtual environment of serious game through the proposed method. In addition, it was confirmed that 75% of trainees were "highly satisfied" or "satisfied" from a survey about the feasibility of the proposed method to actual education.
Conclusions: The proposed method is useful for catheter path learning of epiduroscopy and can be applied to actual education.
Keywords: Epiduroscopy; Serious game; Self-directed learning; Surgical training; Endoscopic education.

I. INTRODUCTION

Background

Traditional endoscopic education has been performed by an apprenticeship one [1]. The apprenticeship education consists of concept learning, repeated observation, expert tutoring training, and self-directed training [2]. The traditional epiduroscopic education has problems such as lack of practical opportunities [3], inconsistent feedback of an expert [4, 5], low safety by practice [6, 7]. To solve these problems, researches on simulation-based training (SBT) are underway [1].

SBT provides trainee simulation that can be self-directed learning [8, 9]. This means providing trainee-centered education environment unlike teacher-centered traditional education environment [10]. SBT is effective for supplementing traditional apprenticeship education because it can provide various practical opportunities, enhance patient safety, and standardize feedback [11, 12, 13]. SBT improves surgical skills more safely and effectively than the traditional epiduroscopic education [11, 12]. SBT is known to be effective when included in a systematic learning method [14-17], and can be further enhanced through gamification [18]. Recently, serious game that has the advantage of motivation and Immersion is used not only in endoscopic education but also in general medical education [19]. However, a research on serious game considering a systematic learning method is just beginning. Therefore, the research on a serious game-based learning method is required.

Objectives

In this paper, we propose serious game-based learning method for epiduroscopy. The proposed method aims to improve the surgical understanding of trainees without epiduroscopy experience through self-directed learning.

II. MATERIAL AND METHODS

Study Design

Epiduroscopy is a highly effective minimally invasive surgery (MIS) operated for chronic lumbago and lumbar disc herniation [20]. High-level surgical capability is required because MIS should obtain a field of view through two-dimensional (2D) computed tomography (CT) image and insert a subminiature endoscope (1 mm diameter) and laser into the body cavity [21]. Epiduroscopy aims at treating a disc lesion minimizing patient's pain. As quick and safe endoscopic insertion is required while guaranteeing minimizing patient's pain, it is very important to acquire anatomical knowledge enhancement and understand the catheter path in epiduroscopy education. Therefore, this study focuses on the catheter insertion among epiduroscopy composed of local anesthesia, disinfection, anesthetic injection, cannula installation, catheter insertion, and treatment (medication or laser). Figure 1 shows the catheter path (learning target) inserted into the disc lesion passing various organs and nerves in the human body.

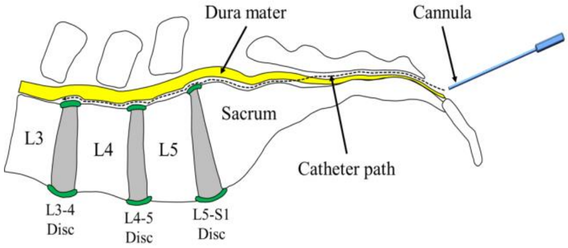

Figure 1. *Catheter path of epiduroscopy.*

Analysis and Design

Typical endoscopic surgery, which can be learned without guidance inside virtual organs. However, it is hard for trainee (in particular, who has not experienced) to be trained without guidance because catheter in epiduroscopy must be inserted into a specific path. Therefore, the proposed method is designed as shown in Figure 2. In step 1, the trainee understands important human organs (bone, nerve, disc, etc.) in epiduroscopy by watching the catheter insertion process in a virtual environment. For this, serious game shows the catheter path to the trainee by moving the camera from the starting position (of the catheter insertion) to the final destination (disc lesion). In step 2, the trainee acquires a knowledge of the catheter path by catheter insertion training with path guidance. For this, serious game allows movement of the catheter only within the virtual fixture [22] installed to guide the catheter path. In step 3, the trainee enhances the knowledge level of the catheter path by catheter insertion training without path guidance. For this, serious game provides visual feedback to the trainee whenever collision between the catheter and important organs occurs.

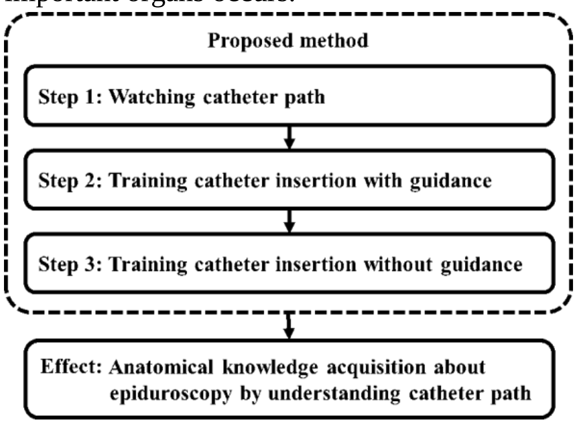

Figure 2. *Design of the proposed learning method*

III. RESULTS

Evaluation

We performed an experiment to examine feasibility of the proposed method to actual education. 20 neurosurgeons participated in the experiment were selected in randomized manner. The sample size (n=20) of the participants was calculated with a 0.05 significance level, 0.8 power, and 0.6 effect size using G*Power 3 (Heinrich Heine University Düsseldorf, Germany) [24]. Table 1 shows participant demographics including age, gender, handedness, prior experience with epiduroscopy, years in practice, and prior experience with simulation. Participant's the prior experience in epiduroscopy and the years in practice were evenly distributed. All participants (n=20, mean age=42.05) were male with right handedness, and had no experience with simulator.

Table 1. *Participant demographics.*

Mean age (years)	42.05 (CI 30-52)
Gender, male (n, %)	20 (100 %)
Handedness, right (n, %)	20 (100 %)
Prior experience with epiduroscopy (n) 0-2 years 3-5 years 5-9 years >10 years	 7 4 6 3
Years in practice (n) 0 years 1-5 years 6-20 years >20 years	 5 9 4 2
Prior experience with game, not experience (n, %)	0 (100 %)

The experimental environment consists of serious game and input device as shown in Figure 3. The experiment used EpiduroSIM [23], which was validated in our previous study, as serious game, and used gamepad [25], which was a higher precision and user preference than a mechanical master device and joystick, as an input device.

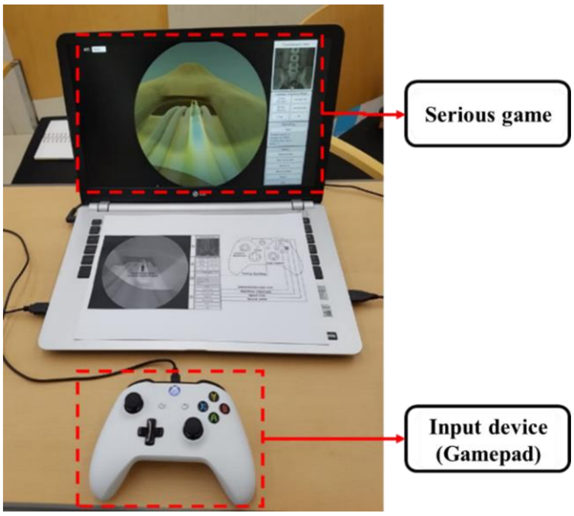

Figure. 3. *Experimental environment.*

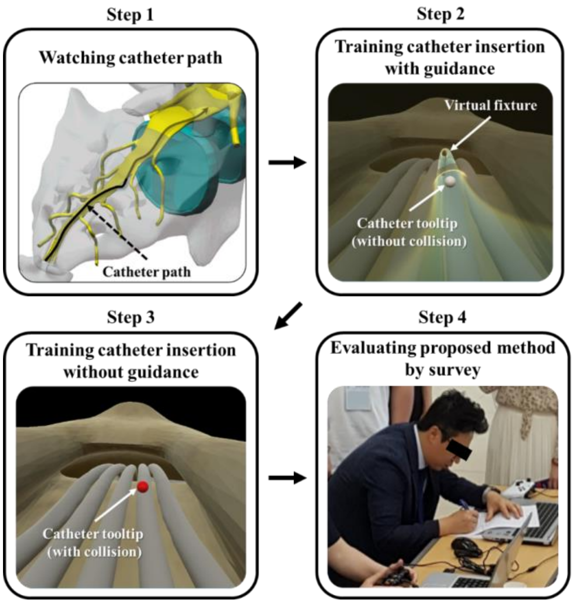

Figure 4. *Experimental procedure*

An experimental procedure consists of four steps as shown in Figure 4. In step 1, the trainee watches the catheter insertion process in the virtual environment. The virtual environment consists of the catheter insertion path and the important organs (bone, nerve, disk, etc). In step 2, the trainee performs the catheter insertion training with path guidance. The catheter insertion training with path guidance is performed without time limitation until the trainee decides that the catheter path learning is sufficient. In step 3, the trainee performs the catheter insertion training without path guidance. The number of repetitions on the catheter insertion training without path guidance was set to 5 based on the conventional study [25]. In the repeated training the first and last training results (completion time, collision time) are used to evaluate the learning effect enhanced by the proposed method. In step 4, the trainee evaluates the proposed method through survey.

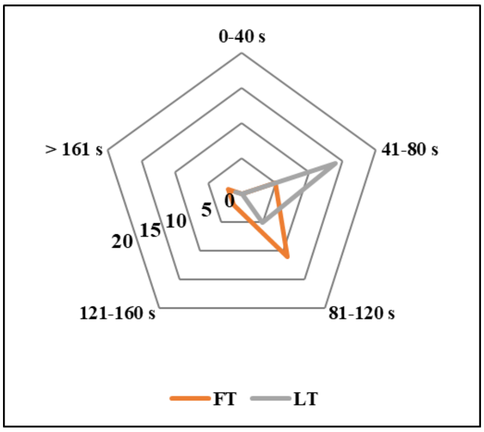

Figure 5. *Distribution of training result (Training time) on first training (FT) and last training (LT).*

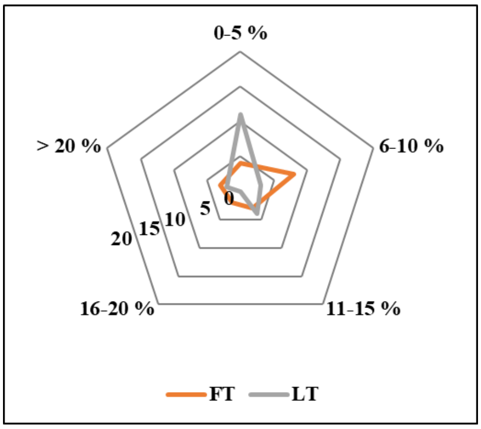

Figure 6. *Distribution of training result (Collision time) on first training (FT) and last training (LT).*

Neurosurgeons learned catheter path of epiduroscopy according to the experimental procedure. Figure 5 and Figure 6 show the distribution of the training results on first training (FT) and the last training (LT) measured in the repeated training. Figure 5 shows the distribution of completion time. The average completion time was measured as 102 seconds and 74 seconds for FT and LT, respectively. This means that trainees have completed the catheter insertion in LT faster than FT. Figure 6 shows the distribution of collision time. Because the completion time for each training were different, we used ratio of the collision time divided by the completion time. The average collision time was 10% and 6% for FT and LT, respectively. This means that trainees have completed training with less collision in LT than FT.

Table 2 shows the Likert scale-based survey used to evaluate the proposed method. The survey responses are as shown in Table 3. 75% of trainees were "highly satisfied" or "satisfied" with the evaluation factors (Question 4 in Table 2) of the proposed method. 75% of trainees were "highly satisfied" or "satisfied" with the anatomical knowledge acquisition (Question 3 in Table 2) by the proposed method. 75% of trainees were "highly satisfied" or "satisfied" with the feasibility of the proposed method to actual education (Question 6 in Table 2).

Table 2. *Questionnaire for evaluation on the proposed learning method.*

No	Question	HS	S	N	U	HU
1	The evaluation factors of the proposed method (completion time, collision time) were appropriate.					
2	The proposed method was helpful in anatomical understanding of the catheter insertion path.					
3	The proposed method will be useful in actual education.					

* HS: Highly satisfied; S: Satisfied; N: Neutral; U: Unsatisfied; HU: Highly unsatisfied

Table 3. *Summary of statistical results obtained from survey.*

No	**HS (%)**	**S (%)**	**N (%)**	**U (%)**	**HU (%)**	**Mean**
1	15	60	20	0	5	3.8
2	25	50	15	5	5	3.9
3	45	30	20	0	5	4.1

* HS: Highly satisfied; S: Satisfied; N: Neutral; U: Unsatisfied; HU: Highly unsatisfied

IV. DISCUSSION

Principal Results

In this paper, we proposed serious game method for epiduroscopy. The proposed method enables trainees without epiduroscopy experience to improve surgical understanding through self-directed learning. Serious game used in the proposed method provides training function which inserts catheter path of epiduroscopy. We performed an experiment to examine feasibility of the proposed method to actual education. In the experiment, 20 neurosurgeons learned catheter path of epiduroscopy according to the proposed method.

From the experimental results (Figure 5 and Figure 6), it was confirmed that trainees could insert the catheter quickly and safely (with less collision) in virtual environment of serious game through the proposed method. In addition, three points were confirmed from the survey results (Table 3). First, it was confirmed (positive response: 75%) that the completion time and the collision time are adequate to factors for evaluating the epiduroscopic training level. Second, it was confirmed (positive response: 75%) that the proposed method is useful for catheter path learning of epiduroscopy. Third, it was confirmed (positive response: 75%) that the proposed method can be applied to actual education.

Comparison with Prior Work

In general, endoscopic education is consisted of theory learning and practice [27]. Most of conventional learning methods based on VR simulator provide a virtual environment similar to the actual surgical environment because it aims to enhance the surgical skill in the practice. Also, this method uses actual instruments or haptic master devices as interfaces. The conventional learning method is hard for self-directed learning of a beginner (trainee without epiduroscopy experience) because it requires skill about prior knowledge and interfaces for the simulator. Therefore, the proposed method is designed step by step for self-directed learning of beginner. In addition, the proposed method used gamepad (which is easy-to-operate) as controller instead of actual surgical instruments or haptic master device (which is hard to manipulate for the beginner). From the evaluation experiment of the proposed method, the beginner had improved their surgical understanding through self-directed learning using the gamepad as a manipulation tool. The experimental result means that serious game-based learning method is effective for short-term learning (improvement of surgical understanding), similar to outcome of conventional studies [28, 29] that evaluated serious game for medical education.

Limitations

The proposed method has a limitation that does not provide the same experience as actual surgery such as kinesthetic sensory, but it provides high-level accessibility to the beginner for self-directed learning without prior knowledge of the simulator. Serious game-based learning method with high-level accessibility is effective for short-term learning and can be applied to actual education. Furthermore, in order to apply serious game-based learning to medical education, follow-up studies on the effects of long-term learning are required.

V. CONCLUSIONS

Serious game effectively improves surgical skills [30]. In addition, it is also an interesting educational solution that provides higher immersion than VR simulators [31]. In the future, we expect the use of serious game in endoscopic education to increase, and we hope that the results of this study will be used in serious game studies for endoscopic education.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

ABBREVIATIONS

SBT: Simulation-Based Training
MIS: Minimally Invasive Surgery
2D: Two-Dimensional
CT: Computed Tomography

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