Construction of Training Environment for Surgical Exclusion with a Basic Study of Multi-finger Haptic Interaction

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Abstract

Virtual reality based surgical simulator allows a repetitive training without spoiling patients. Exclusion is an important surgical manipulation of pushing aside organ to make a hidden tissue visible. The authors propose an organ exclusion training simulator with multi-finger haptic interaction and stress visualization. The system equips FEM-based soft tissue deformation and exoskeletal haptic device CyberForce. Real-time simulation was achieved with a prototype system. Results of training trial suggested effectiveness of stress visualization especially in early training days. Subjective evaluation by surgeons cleared its potential. Results of a basic study showed decrease of required refresh rate in multi-finger interaction compared with single finger interaction. It suggested the system can keep realism even if calculation time is increased by multi-finger interaction.

1. Introduction

Repetitive experience is a basic approach to obtain a manual skill, which is strongly related to haptic sensation. In medicine, less and less training opportunity becomes a problem, because animals tend to be forbidden to be sacrificed for training. Residents cannot avoid training their skills with real patients, although it has a risk of damaging them. Organ exclusion is a surgical manipulation of pushing aside organ to make a hidden tissue visible or to enlarge workspace as shown in Fig.1. A surgeon excludes liver with multiple fingers to make a hidden vessel visible. Improper manipulation causes fatal damage of the manipulated tissue.

In this paper, exclusion training simulator with multiple fingers is developed with a basic study of multi-finger haptic interaction with an elastic object.

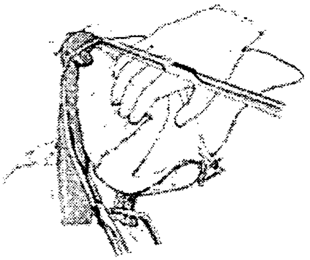

Figure 1. Liver exclusion. A vessel behind liver becomes visible by exclusion with fingers.

2. Background

Virtual reality based surgical simulator has been intensively studied and several simulators are commercially available [1]. Some simulators give an opportunity to know surgical procedures with a specific instrument (e.g. endoscopic forceps). The others provide training environment of a surgical tool (e.g. knife, needle). However, manual training of exclusion, which includes multi-finger haptic interaction, has never been provided. The system should support multiple-finger interaction with an elastic object. Virtual reality system has a strong advantage of showing hidden information in real world

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e.g. internal deformation of deformed object or stress concentration. The system will enable efficient surgical training, if physical status of soft tissue can be simulated in real-time and displayed to the user interactively.

Several force feedback devices for multiple fingers have been developed [1, 2, 3]. However, developed applications with multi-finger haptic interaction are very few. One of possible reasons is "refresh rate" problem, especially for displaying high stiffness of rigid wall, which requires high refresh rate (more than 1,000Hz). If an object is softer, a system can provide realistic force sensation with lower refresh rate.

Some studies investigated the requirements of refresh rate for realistic interaction with a virtual stiff wall. Soft tissue has far less stiffness. Psychophysical studies of haptic perception in finger's manipulation have been done intensively. Pang et al. investigated JND (Just Noticeable Difference) of force in squeezing manipulation [4]. Lederman and Klatzky ensured the importance of spatially distributed fingertip force in a palpation-like task [5]. However, difference of perceptual features of haptic interaction with single and multiple fingers is unclear. The condition of used fingers might effect on required refresh rate.

There are many variations of finger manipulations with an elastic object (e.g. pushing, grasping, stroking). In surgical exclusion, a surgeon holds/grasps the object by fingers to control its location and deformation. Cutkosky and Howe categorized grasp into two grasps: power grasp and precise grasp [6]. Power grasp is a manipulation not only with fingertips but also with middle phalanx and a palm for exerting much force on the object. On the other hand, precise grasp is a manipulation only with fingertips for exerting fine force on the object with sensing reaction force at the same time. Surgical exclusion is categorized into precise grasp and then a manipulation with fingertips is significant, because improper manipulation causes fatal damage to organ.

3. Exclusion simulation with multi-finger haptic interaction

3.1. Requirements

Exclusion training system should allow interactive manipulation with realistic force sensation on fingertips. The system of suggesting danger of a manipulation will help understanding a nature of the relationship between manipulation and its effect and help acquiring a skill. If stress exceeds a limit, soft tissue is destructed and loses its function. In exclusion, a manipulation of avoiding stress concentration is an essential skill. Information of stress distribution will be helpful. Although information can be displayed in various manners like visual, haptic and audio display, visual display gives easy understanding of spatial information such like stress distribution.

Therefore, requirements of exclusion training system can be defined as follows.

- Visual display of accurate and interactive soft tissue deformation based on physics
- Haptic display of accurate reaction force
- Visual display of stress distribution based on physics
- Multi-finger haptic interaction with elastic object

3.2. Multi-finger interaction environment

Fig.2 illustrates interaction method of multiple fingers with an elastic object. The method considers passive contact which is arisen by other finger's action to the object. In grasping simulation with a rigid body, a solution of treating passive contact not by processing once but by processing at several steps as active contacts are used. The simulation loop runs very fast (300Hz or more than 1kHz [7]) and then temporary simulation results (invasion of a finger into an object) is not perceivable to users from visual information. On the other hand, simulation with physics-based deformable model can provide realistic haptic sensation with less haptic refresh rate (100Hz or less). In this case, if the procedures are separated to several steps, temporary deformation can be visually perceived by users and lacks realism. In exclusion simulation, both active and passive contacts between a finger and an object are considered.

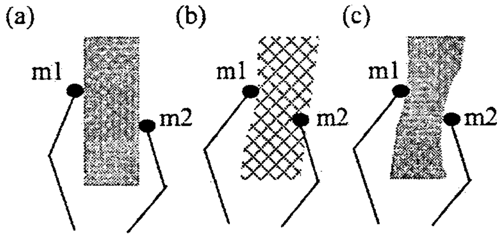

Figure 2. Temporary deformation based multi-finger interaction method with an elastic object. (a) Initial state. (b) Temporary state. The object is deformed by a manipulator (m1). Other manipulator (m2) invades into the object. (c) Contacts by manipulators are considered.

Interactive simulation system with haptic display requires high refresh rate of reaction force and fast calculation of the simulation. In the study of surgical simulation, finite element method (FEM) has been

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recognized as one of the most accurate deformation methods. The real-time simulation of non-linear elastic deformation is hard with current CPU power. Hirota proposed a method of real-time calculation of reaction force with linear finite element model [8]. Reaction forces at contact fingers are calculated in real-time.

3.3. Perceptual features of multi-finger haptic interaction

Sufficiency of refresh rate of force feedback provided by a system determines realism of the simulation. However, necessary refresh rate is not clear. Few studies can be found for investigating the difference between single and multi-finger interaction [9]. One question is whether a person requires same refresh rate even in a situation using with multiple fingers or not. In general, in the case of multi-finger interaction, more calculation time for deformation and reaction force is needed compared with single finger interaction. However, if required refresh rate is decreased in multi-finger interaction, increase of computation and decrease of required refresh rate can balance out or at least necessary additional computational resource is changed.

4. Prototype system

As shown in Fig.3(a), the system consists of PC (Intel Xeon 2.6GHz x 2, 1GB memory, RADEON9600 256MB graphic board), display and CyberForce system (CyberForce, CyberGrasp, CyberGlove). Position data is updated at 100Hz. Low refresh rate is enough with low stiff object like soft tissue.

In order to allow various manipulations with multiple fingers in wide workspace, exoskeletal haptic device CyberForce^{TM}[1] as shown in Fig.3(b) was used. The device not only gives force sensation on fingertips but also provides force to resist hand movement.

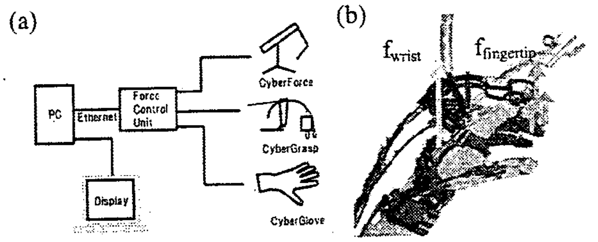

Figure 3. (a) System configuration. (b) Multi-finger haptic device CyberForce. Forces can be displayed to each finger and a wrist.

FEM with linear elasticity and Hirota's method [8] are employed in the system. In order to provide accurate sensation, calculated reaction force with FE model must be displayed to fingers. However, due to device's restriction of freedom of fingertip movement, only tangential component of reaction force is displayed to finger and remaining force is displayed only to wrist. In real world, when a person pushes an object, applied force on a fingertip is conveyed and internal force arises on wrist. However, a mechanism of the device cannot convey the force to wrist. Thus, internal force in wrist is simulated by displaying force on wrist. Sum of calculated reaction forces on fingertips by FE model is displayed on the wrist. The force is same as real world in the ideal situation where great acceleration does not arise in fingers and wrist movement. Displayed forces on a finger and wrist are shown in Equation 5 and 6.

$$\mathbf{f}_{fingertip}(i) = \mathbf{f}(i)\cos\theta \qquad (5)$$

$$\mathbf{f}_{wrist} = \sum^{5} \mathbf{f}(i) \qquad (6)$$

$$(i = 1,2,3,4,5)$$

where $\mathbf{f}(i)$ is calculated reaction force on a finger by FEM, $\mathbf{f}_{fingertip}(i)$ is displayed force on fingertip, $\mathbf{f}_{wrist}$ is displayed force on a wrist.

5. Experiment of perceptual features of multi-finger interaction

An experiment investigates threshold of refresh rate of force perceived as vibration. A hypothesis in this experiment is "a person is less sensitive to discrete changes in force feedback, perceived as step changes in force or vibration, when performing multi-finger interaction with an elastic object".

The experiment was conducted with a developed system described in section 4. A plate object (20cm x 20cm x 1.5cm in size) was set in virtual environment. The object consists of 1334 vertices and 4745 tetrahedron (0.2MPa Young's modulus and 0.4 Poisson's ratio). 7.5% of both left and right sides of the object was fixed in the environment as shown in Fig.4. The rest part of the object deforms by user's manipulation and reaction force is displayed to the user.

Six volunteer students participated in the experiment. A subject pushes a plate object with designated fingers and answers if he/she feels displayed force as continuous force or vibration. If refresh rate is high enough, a subject feels it as continuous force. In contrast, if refresh rate is low, a subject feels it as vibration. A task was to find a threshold of refresh rate to feel vibration.

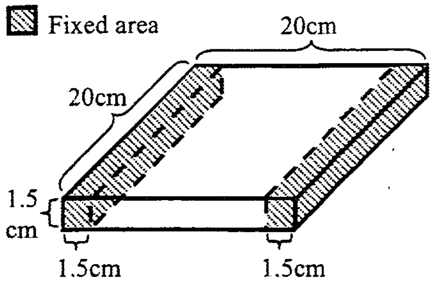

Figure 4. Elastic object used in the experiment.

In order to standardize a condition in each subject, a subject was told to exert 0.5N force on the object first and additionally exert force up to around 1.0N by pushing manipulation, not by stroking manipulation. Visual information helps for a subject to know exerted force, where pushed area was colored blue when the exerted force was around 0.5N and colored red around 1.0N. 250 patterns of refresh rate r (Hz) were prepared by selecting a number i from 1 to 250 as shown in Equation 7. In this equation, a difference of refresh rate can be set smaller in lower rate. This equation was used, because small difference of refresh rate has a great importance in lower refresh rate than in higher rate. If the number i increases, refresh rate decreases like 100Hz, 77Hz, 51Hz, 38Hz, 31Hz, 26Hz, 22Hz, 19Hz, 17Hz, 15Hz...

$$r = \begin{cases} 100 & (i = 1) \\ \dfrac{1}{0.0065 \times i} & (2 \le i < 250) \end{cases} \tag{7}$$

Table 1 shows average thresholds and standard deviations (SD) of refresh rate of force perceived as vibration with single and multi-finger interaction.

Table 1. Threshold of refresh rate in single and multi-finger interaction.

		Refresh rate [Hz] (SD)
Single finger	Index finger	21.3 (35.0)
	Middle finger	14.5 (25.8)
	Third finger	20.8 (33.0)
	Little finger	6.6 (24.9)
Multiple fingers	Index + Middle fingers	4.9 (11.2)
	Middle + Third fingers	3.5 (9.8)

Thresholds ranged from 3.5 to 21.3Hz. If stiff object was used or stroking manipulation was performed, discrete changes would be perceived at higher refresh rate. Statistical difference was found in average thresholds of refresh rate between single and multi-finger interaction by t-test (p=0.021). The result supported the above hypothesis. Although statistical difference was not found in the difference of used finger, it was probably because of small samples at each condition.

6. Evaluation of training simulator

6.1. Simulation results

Real-time simulation is essential for virtual reality system with interactive manipulation. Table 2 shows calculation time for reaction force and deformation with 820-noded object, which has cylinder shape and is shown in Fig.6 (a1). Calculation time for reaction force must be sufficient for haptic refresh rate. Deformation time must be below visual refresh rate. Theoretically, calculation time for reaction force increases at O(3^n) according to the number of simultaneous contact fingers. The results approximately showed such an increase of calculation time. Deformation time includes calculation of displacement of all vertices in addition to reaction force calculation. From the results in section 5, as average refresh rates of single and multi-finger interaction was 15.8 and 4.2, respectively, required refresh rates was decreased to approximately one third. Therefore, increase of computational requirements and decrease of required refresh rate by increase of contact fingers are well balanced. Figure 5 shows achieved refresh rate at this system and required refresh rates at multiple contact fingers. Required refresh rates of single and double-finger interaction are derived from the results in section 5 and the rate of more than two contact fingers are estimated by assuming required refresh rate becomes one third by increasing number of contact fingers. The result suggested that realism would be achieved even with many contact fingers.

Fig.6 shows a simulation example of multi-finger haptic interaction with soft tissue models and stress visualization with a vessel. Fig.7 shows stress concentration in the case, where an object has several parts of different stiffness and stress concentration arises around the boundary. The object is modeled as a lung, which has a harder part in the bronchus and pulmonary artery.

Table 2. Calculation time for reaction force and deformation with multiple fingers [msec]

Number of contact fingers	Reaction force	Deformation
1	0.20	1.32
2	0.63	1.95
3	2.36	4.41
4	8.18	12.29
5	29.7	32.36

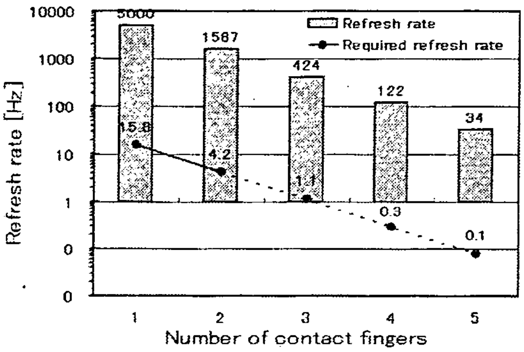

Figure 5. Required and achieved refresh rate of reaction force in multiple contact fingers

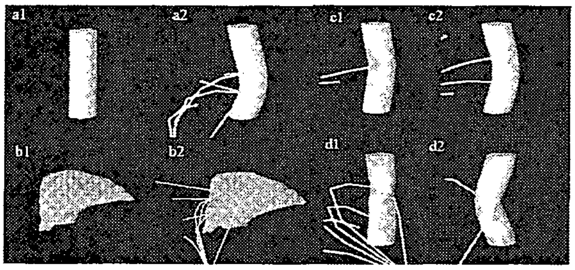

Figure 6. Exclusion simulation of vessel (a1, 2) and liver (b1, 2). Stress distribution caused by different finger numbers (c1,2) and by different finger manipulation (d1,2).

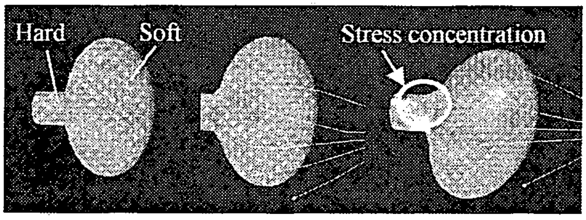

Figure 7. Stress concentration occurred in a simplified lung situation

6.2. Training trial with non-medical persons

The effectiveness of a developed prototype system for exclusion training was examined by training trial. Fig.8 shows two environments of the experiment (object A and B). Each object has features of liver and lung, respectively. Object A has groove like liver, which has several regions and groove can be found in the border. Object B has bronchus and pulmonary artery like lung described in previous subsection. Object A has 0.3MPa Young's modulus (0.4 Poisson's ratio) in the whole body, and object B has 0.1MPa in the soft region and 1.0MPa Young's modulus (0.4 Poisson's ratio) in the hard region in Fig.8. A task was to push aside a target object until a hidden line behind the object is kept visible for a second. 13 volunteers performed 30minutes training in each day for 5days. Stress visualization is provided to group1 (7 persons) and not to group2 (6 persons). A subject was told that he/she tried performing a task with less maximum stress value. 3minutes training and a test without stress visualization was performed in each day.

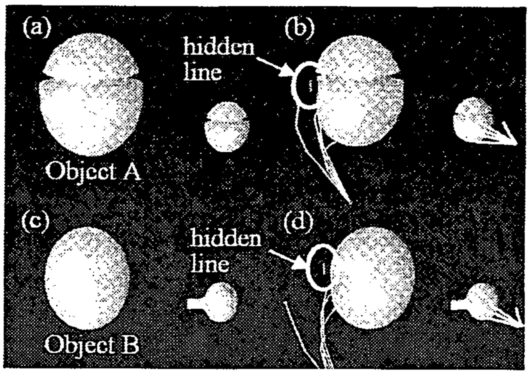

Figure 8. Two environments of training trial. Left side is a front view and right side is a side view. To make a hidden line behind the object visible is a task.

Fig.9 and 10 shows results of the experiment. The result of training trial with object A showed that a learning effect is higher than without displaying stress distribution especially during first two days. The result with object B showed that maximum stress went down in both groups with an exception of the second day, which has higher stress than in first day. This might be why the place of stress concentration in the object B was clear if stress was visible.

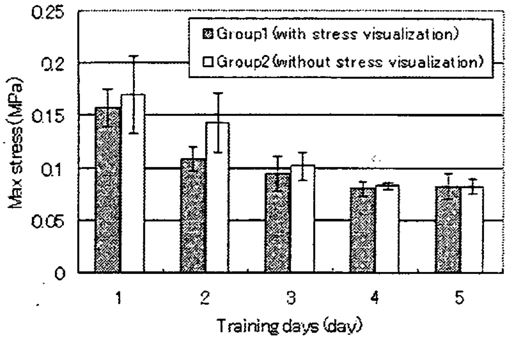

Figure 9. Result of training with object A

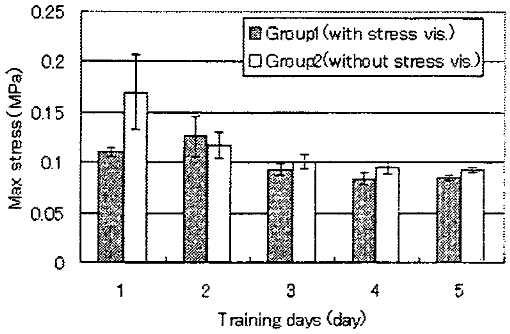

Figure 10. Result of training with object B

6.3. Subjective evaluation by medical doctors

Three surgeons evaluated developed exclusion simulator. The system configuration was described in section 4. Obtained answer was 5 point scale (-2,-1,0,+1,+2) with a questionnaire. Questions and average scores were as follows.

1. The system provides haptic sensation of organ. (avg. score: +1.3)
2. The system is useful for training of organ exclusion. (avg. score: +1.7)
3. Stress visualization is beneficial (avg. score: +1.7)

Results of the questionnaire showed high evaluation of the system in effectiveness for training by surgeons with some room for improvement.

Comments for haptic sensation of organ manipulation:

- The organ gives three-dimensional existence and stiffness is similar with real liver
- Manipulation is not perfectly supported, because organ can be touched only with fingertips.

Comments for effectiveness for training use:

- Exclusion of aorta and great vein is done in digestive surgery in addition to liver. Palm is used sometimes in liver exclusion.
- Considerably effective. Perfectly suit for OSCE (Objective Structured Clinical Examination) of medical student and training of residents

7. Conclusion

This paper proposed an organ exclusion training simulator with a basic study of multi-finger haptic interaction. The results of experiments and subjective evaluation by surgeons suggested that the system was effective for exclusion training especially in early training days. Results of other experiment showed decrease of required refresh rate in multi-finger haptic interaction. Clinical trial with residents is a future work of the training system. Further studies are needed for analyzing multi-finger haptic interaction.

Acknowledgement

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Toward Visualization of Skill in VR: Adaptive Real-Time Guidance for Learning Force Exertion through the "Shaping" Strategy

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Abstract

The authors aim to make principles of expert's haptic interaction explicit on a Virtual Reality (VR) based simulator. Our approach is based on visualization of significant components of the interaction with consideration on their importance which acts as the foundation for manual skill.

Delicate force exertion, which is the basis for various fine-motor skills, was chosen as an example. Expert's haptic interaction was recorded and presented to novices. Two visualization techniques were compared as a training aid by overlaying guidance on a simulator's screen: 1) tracking force curve (traditional technique), and 2) tracking the components of pre-defined "skill" (proposed technique). The visual presentation adapts to the components' importance: maximum power, duration, and force curve. The results support the possibility of using the proposed visualization technique for mediating principles of haptic interaction from experts to novices through a VR system.

1. Introduction

Our work aims to make manipulation-level principles of expert's manipulation and components of skill explicit in VR-based training. Today, training simulators with haptic feedback are a major research field, but relatively little is known about how to enhance simulators' efficiency for training. The future's training simulator should be capable of visualizing what should be learned, i.e. what the expert's "skill" consists of. This approach would add value to simulator-based self-learning by making invisible aspects of interaction visible to the learner.

Training simulators are envisioned to become complete learning environments. Shaffer et al. [1] introduced the idea of a surgical simulation system that enhances the simulation beyond instruction that could be given in the real world. Their vision covers artificial intelligence based instruction for decision making, such as guidance by "highlighting performance problems and by pointing out the relevant cues that the trainee should attend to," developed for flight simulators [2].

"Shaping" is a learning strategy for decomposing complex tasks, and it is one of the approaches desired in simulator-based training, e.g. in surgery [3]. The task is constructed little by little so that the difficulty can be mastered gradually. In haptic VR systems, the amount of information that can be measured from the expert's demonstration can be overwhelming. The expert's insight is required to clarify the importance of each component of the interaction.

This study presents a concrete design that aims to the above-mentioned visions. A visualization technique which represents only the essential components of skill of the expert's demonstrations is proposed. The technique is demonstrated in a force exertion experiment with a medical expert's pre-recorded example motions. Force exertion is considered as a general root level skill. The skill was defined to consist of correct maximum force, duration, and complete force curve as time-series. Following the "shaping" learning strategy, the visualization was "built" little by little to meet all the criteria of the skill.

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2. Related work

There are two research fields significant to this study. VR training systems have been studied extensively for the last decade. Psychophysics studies provide the basis for our visualization technique.

2.1. Skill training systems

2.1.1. Traditional approach. The traditional approach to learn movements and motor skills is based on observation and mimicking expert's examples. This approach has been incorporated into VR-based training environments. For example Just Follow Me (JFM) [4] supports learning from expert's recorded example movements by displaying the examples as a "ghost" that guides the user in a virtual environment. However, this approach does not draw attention to any components of skill, and it is capable of presenting the example as a single state only. In practice, the first trials with this approach require playback of the example as it is and practice using slow-motion playback. The learning process is based strongly on "shaping", but the insight of what the skill is composed of has to come outside the system.

2.1.2. Haptic training systems. As one of the early works, Yokokohji et al. [5] studied what data should be recorded and how it should be presented to the learner in order to transfer skills from human to human via a computer system. The initial results did not show any significant advantages in haptic guidance. Since the early studies, much research has been carried out. Feygin et al. [6] reviewed latest developments of haptic training systems. Most systems try to enhance learning by some kind of restrictions to the novice's actions on the haptic modality. Haptic video [7] presented a pro-active motor-skill training method but the results on the learning effect were not fully conclusive.

Haptic guidance has not yet met a grand theory and more sophisticated methods are continuously studied.

Our goals require discussion on definitions of what should be learned from the simulator and a design for presenting that information to the user. Haptic training systems have proposed novel approaches for learning manual skills, but have not really addressed what the skill actually is. All observable information about the example motion is not always relevant to the success of a task, which leaves room for visualization of skill from the expert's point of view.

The intention of this paper is to demonstrate the visualization of skill as a method that draws attention and abstracts the actual example to consist only of the relevant components of skill. Since only visual cues are used, the proposed technique does not have any restriction to pro-activity during interaction.

2.2. Psychophysics

Studies by Pang et al. [8] and Tan et al. [9] have shown that Just Noticeable Difference (JND) of human is about 7% of force (tested at 2.5-10N), i.e. the perception of force through tactile feedback cannot be expected to be more accurate than 7%.

Srinivasan and Chen [10] studied human's force control ability with the aid of visual feedback. Subjects followed example time profiles: constant, ramp and sinusoidal shape. Their target maximum forces ranged 0.5-1.5N. Mean average error during each moment of time was about 0.046N±0.007SD (standard deviation) in a case of sinusoidal force profile with 0.5N maximum power and duration about 7 sec. In comparison to the results of Pang et al. [8], it was found that the error was about 11-15%. Later, Chen and Srinivasan [11] examined the similar interaction further with soft objects with different levels of force: 2, 4 and 8N. When tracking visually displayed level of constant target force, the subjects usually managed to maintain the force level at about 2% error. When trying to maintain the same force level without visual feedback, the error became 4-11%.

These results suggest that a graphical presentation can be used as a training aid for force exertion. In our study, expert's recorded force exertion is presented to subjects, who practice the task by mimicking the visualized components of skill one by one in a way that follows the "shaping" learning strategy.

3. Visualization of skill

Visualization of skill is yet an unexplored area of VR. In the real world it is not possible for a novice to perceive the skill as it is, since the skill itself cannot be presented, only the appearance of one of its instances at a time. VR offers total freedom for any kind of presentation, which is often undermined.

Our design for visualization of skill is based on simplicity of the 2D visual cues and hiding the exact appearance of the example interaction so that only the essential components of the skill are presented to the user. The possibility for this type of presentation exists only in VR. Visualization serves four purposes:

- Principle of interaction is directly perceivable, i.e. playback of the interaction itself may not be needed.

- Accurate real-time feedback is achieved during training.
- Fully proactive training, i.e. the haptic modality is not restricted in any way.
- Also applicable to other phenomena than direct haptic interaction, for example indirect effects of actions on the target.

3.1. Problems with the traditional visualization

Normally time-series data is shown as a curve (as in Fig. 1) to display maximal amount of details of the phenomena presented. This technique is capable of presenting the future states of an example, thus giving the user information that aid planning ahead how skilful motion should be produced.

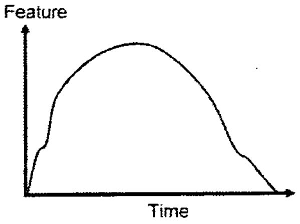

Fig. 1. TRADITIONAL visualization of time-series data as a curve.

By presenting all the details, the user's attention is drawn to every aspect of the example. Presentation of all the details may not be relevant to what the skill actually is composed of. The traditional curve presentation does draw the attention to different levels of significance of its components.

3.2. General design for visualization of skill

The abstract presentation for skill can be constructed by using the simplest two-dimensional graph presentation for the chosen components. This is illustrated in Fig. 2. Assignment of the X and Y axes determines what the skill is composed of. This presentation is flexible to be adjusted to various components of skill.

By presenting combinations of the components in the order of importance during training, the "shaping" learning strategy is supported. Practice of a complex skill can be started with a simple one-dimensional and later two-dimensional representations of one feature (e.g. use of force). When the first feature has been learned, another can be introduced (e.g. inflicted stress on the target).

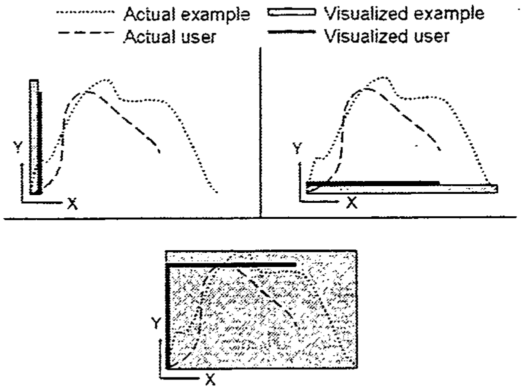

Fig. 2. GENERAL design for visualization of skill with a few example and user's performance presented in 1 and 2 dimensions. X and Y can be assigned to any feature of interaction.

3.3. Design for force exertion skill

Force exertion was chosen to be a concrete example to demonstrate skill visualization of a fundamental interaction. If the proposed technique is beneficial in a relatively simple task, more complex tasks can be introduced to the user by adding more features to the presented example. Fig. 3 presents the visualization for each of the components and their combination (compare to the general design in Fig. 2.).

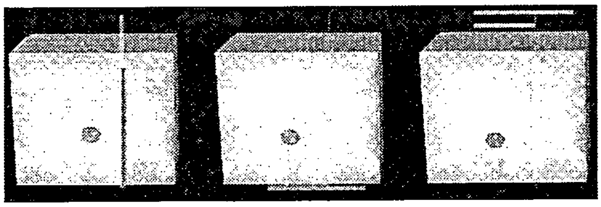

Fig. 3. VISUALIZATION of force exertion that consists only of maximum power (vertical) and duration (horizontal). Blue: example, red: user.

By displaying only the maximum preferred power of force exertion on the Y axis, the user's attention is drawn to exactly that component of skill. Duration is also presented only as one dimension, the X axis.

The combined display (Fig. 3, right) is capable of presenting two aspects accurately: maximum power and duration as a box. Further information about the exact features of the example is hidden from the user.

Force exertion is presented here as a demonstration, yet, the same visual presentation could be applied to any other phenomena in the interaction with objects.

For example, skill could be defined as an ability to move an object from a place to another without exceeding certain pressure threshold, to touch an object at frequent distance interval, or to tear tissue without inflicting too high stress on any part of the object.

4. Experiment

4.1. Expert's example data

A cardiovascular surgeon from Kyoto University Hospital performed palpation of the aorta on the MVL simulator [12] (Xeon 3.2GHz dual CPU with 4GB RAM) capable of real-time Finite Element Method based computation of deformation and reaction force for haptic feedback. His example performance using a Sensable PHANToM ™ was recorded at 100Hz sampling. Two excerpts were selected from the recorded data. The chosen curves and their appearance on the simulator are presented in Fig. 4.

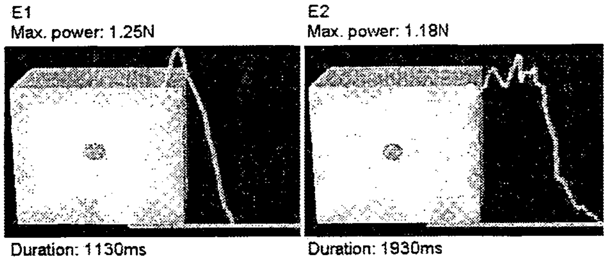

Fig. 4. EXAMPLES E1 and E2 selected from the expert's recorded performance. Blue: example force curve, red: user's curve (no force).

4.2. Conditions

Two main conditions (training modes) were tested: curve visualization (CC, as in Fig. 4) and the proposed visualization technique, skill visualization (CS, Fig. 3).

Evaluation criteria for the force exertion skill were correct maximum power (*max.p*), duration (*dur*) and curve (*cur*) compared to the expert's example. *max.p* was evaluated as error percentage to the example's maximum power, *dur* as error percentage to the example's duration and *cur* as error percentage to the example's power at each moment sampled at 100Hz.

Following the "shaping" strategy, training phases were defined as *max.p*, *max.p+dur* and *cur* for E1, and *dur*, *dur+max* and *cur* for E2. The training mode differed for the two first phases so that for E1, CS consisted of vertical bars indicating the maximum powers in Phase 1 (Fig. 3, left), 2-dimensional bars in Phase 2 (Fig. 3, right) and the curves in Phase 3 (Fig. 4, left). The example was shown as a template into which the user's performance was drawn in real-time (visual RT feedback). For E2, CS contained horizontal bars displaying the durations in Phase 1 (Fig. 3, middle), 2-dimensional bars in Phase 2 (Fig. 3, right) and the curves in the last phase (Fig. 4, right). CC showed the curves as they were. CS was expected to draw attention to the selected components of the skill before displaying the full curve and, thus, to provide smaller errors at least in the first two phases.

On a screen of 1280x1024 pixels resolution 1 pixel on the X axis equaled to 10ms. The Y axis minimal perceivable difference for both E1 and E2 was 0.00625N/pixel. Thus, height of the curve was about 200 pixels on the y-axis for all the presentation modes. The visual aid was aligned near the contact location but not exactly on top of the manipulator.

Virtual mesh models (782 triangles) representing elastic cubes were prepared with two stiffness parameters: 1.0MPa and 0.1MPa Young modulus. Poisson's ratio was set to 0.4. The 1.0MPa model had the same parameters as the aorta model that was used during the expert's recording. The stiffness difference was to a) make the user to perform larger motions and b) give clearer visual cues about the cube's deformation, which could produce different results.

Table 1 summarizes the conditions and the order of tasks. 6 subjects were divided into Group A and B. Group A started with Session 1 and continued to Session 2 the next day. Group B started with Session 2. Each task was performed in trial pairs: tracking the example with RT feedback and repetition from memory with knowledge of result presented for 2 seconds after the trial as two overlapping bars or curves. There were 7 trial pairs in each training phase, resulting in 42 trials per task, 336 per subject and 2016 in total. In each phase, the subjects were advised to focus on the evaluated component(s) of skill. With CC the subjects were told to focus on each component at the time, even though the curve was fully visible. CS visualized only the evaluated components.

Table 1. CONDITIONS of the experiment.

Training mode	Example task: name, *max.p* (N), *dur* (ms)	Stiffness (MPa)	Order of training phases 1, 2 and 3
Session 1			
CC	E1, 1.25, 1130	1.0	*max.p, max.p+dur, cur*
CC	E2, 1.18, 1930	1.0	*dur, max.p+dur, cur*
CC	E1, 1.25, 1130	0.1	*max.p, max.p+dur, cur*
CC	E2, 1.18, 1930	0.1	*dur, max.p+dur, cur*
Session 2			
CS	E1, 1.25, 1130	1.0	*max.p, max.p+dur, cur*
CS	E2, 1.18, 1930	1.0	*dur, max.p+dur, cur*
CS	E1, 1.25, 1130	0.1	*max.p, max.p+dur, cur*
CS	E2, 1.18, 1930	0.1	*dur, max.p+dur, cur*

5. Results and discussion

Mean averages from 168 recorded trials per training mode in each phase were compared in order to see the training effect differences between CS and CC. ANOVA was performed with $p<0.05$ to each finding discussed below. Fig. 5 summarizes the results.

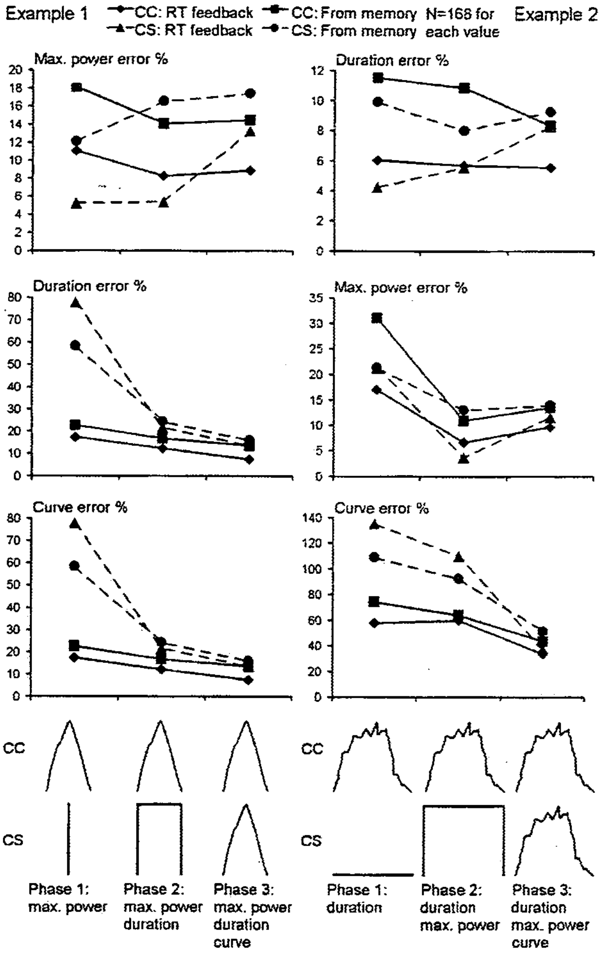

Fig. 5. RESULTS: mean averages of error % for each component of skill in the force exertion tasks grouped by the training phases 1-3. At the bottom: visual representations of the examples. Trials were performed in 7 trial pairs: with RT feedback, then from memory.

5.1. First example task: E1

E1 in Phase 1, where CS presented only *max.p*, CS provided for clearly more accurate tracking of the example (mean average of error 5.22%, standard error 0.99) than CC (11.05%, 0.99). This resulted also in better performance from memory: 12.14%, 1.77 (CS) against 18.11%, 1.77 (CC). With CC, when the subjects saw the curves all the time but were told to pay attention only to *max.p*, they tended to follow the example curve anyway (duration error 17.28%, 4.69 with RT feedback and 22.61%, 3.76 from memory). *Dur* and *cur* were not presented in CS, which helped the subjects to focus on *max.p*, as expected. Errors were smaller on the softer cube, which was suspected to result from longer motions and better hand control.

In Phase 2, where *dur* was added to the evaluation criteria, the training modes provided similar results in *max.p*: 8.25%, 0.79 (CC) and 5.34%, 0.78 (CS) with RT feedback, and 14.04%, 1.32 (CC) and 16.55%, 1.29 (CS) from memory. In terms of *dur*, CS provided worse results (21.58%, 1.98 with RT feedback and 24.26%, 1.97 from memory) than CC (12.05%, 2.0 and 16.6%, 2.02). This was due to the fact that it was the first time that duration was displayed in CS. Results with CS in Phase 2 correspond to the results with CC in Phase 1.

In Phase 3, error percentages provided by CC were smaller than with CS when RT feedback was present, but statistically the same when performed from memory. *Max.p* errors: 8.88%, 1.13 (CC) and 13.11%, 1.11 (CS) with RT feedback, and 14.49%, 1.73 (CC) and 17.43%, 1.69 (CS) from memory. *Dur* errors: 7.32%, 1.19 (CC), 13.52%, 1.18 (CS) with RT feedback, and 13.53%, 1.62 (CC) and 15.86%, 1.58 (CS) from memory. *Cur* errors: 28.12%, 1.67 (CC) and 34.51%, 1.65 (CS) with RT feedback, and 42.06%, 2.47 (CC) and 48.09%, 2.42 (CS) from memory.

5.2. Second example task: E2

E2 demonstrated similar results as E1. In Phase 1, *dur* errors were statistically significant (6.02%, 0.55 with CC and 4.22%, 0.55 with CS) with RT feedback but about the same when performed from memory (11.5%, 1.3 with CC and 9.93%, 1.3 with CS).

In Phase 2, *dur* errors were the same with RT feedback (5.7%, 0.57 with CC and 5.56%, 0.57 with CS), but statistically different when performed from memory (10.83%, 0.79 with CC and 8.0%, 0.79 with CS). In *max.p*, instead, the difference was found from the performances with RT feedback (6.69%, 0.55 with CC and 3.75%, 0.55 with CS), but not from memory (10.9%, 1.19 with CC and 12.97%, 1.19 with CS).

In Phase 3, only one significant difference was found: CC provided for *dur* error 5.55%, 0.67 whereas CS only 8.31%, 0.67 with RT feedback. However, performance from memory was about the same (8.33%, 0.89 with CC and 9.24%, 0.89 with CS). Errors in *max.p* (RT: 9.69%, 0.82 with CC and 11.59%, 0.82 with CS; From memory: 13.5%, 1.15 with CC and 13.94%, 1.15 with CS) and *cur* (RT feedback: 33.62%, 1.53 with CC and 37.38%, 1.53 with CS; From memory: 43.39%, 2.85 with CC and 51.19%, 2.85 with CS) were not significant. *Cur* errors in E2 were clearly higher than in E1 due to more complex shape of the curve, but still smaller in Phase 3 than in 1 or 2.

5.3. Conclusions

When comparing the performances from memory after the trial, training with CS demonstrated advantages in comparison to CC: since CC made the subjects follow the curve during training with RT feedback despite the verbal instructions, the subjects could not perform as well as with CS when evaluating the performance in the first two phases. Restricted training with CS did not hinder the performance in the last phase which was evaluated by all the criteria. CS reached CC's results despite the fact that with CC the curves were shown to and followed by the subjects in all phases whereas with CS the full curves were shown only in the last phase. With CS, the most essential components of skill were mastered in Phases 1 and 2.

6. Summary

We presented the design for skill visualization for VR training simulators and demonstrated its benefits in a simple haptic sensation based task. The technique was proven to have benefits in "shaping" style training of delicate force exertion so that the user's attention can be drawn to specific aspects of skill without hindering the overall outcome of the training later on.

Here, the example data consisted only of individual excerpts. Our future goal is to include variation of several experts' examples recorded into a database, which would give information about true limits of "good" performance to trainees. More complex skills have to be examined using various learning strategies.

7. Acknowledgements

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デジタル・フォレンジックを取り入れた手術動画像生体情報同時記録システムの開発

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Development of video recording system for surgical procedure under the concept of digital forensics.

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Abstract: Recently, increase in the conflict related to medical practice leads to demands for retrospective inspection of the past medical procedures. Medical practitioners are required to prepare the precise medical record in the legally reliable form in order to demonstrate their own innocence. In the field of endoscopic surgery, all the endoscopic procedure should be continuously recorded throughout the surgery because they require high levels of surgical technique and would be a cause of legal action. Despite the recording with normal video tape is easily altered, technology in digital forensics serves as useful tool against deception in any medical records, especially of surgical procedures. In this study, we established a recording system for digital forensics, which is suitable for routine archive of endoscopic surgery. In this system, patient's data, such as blood pressure and SpO2, and time stump are simultaneously recorded. In order to confirm the quality of recorded information, we used the movie of endoscopic mucosal resection (EMR) for early gastric cancer and laparoscopic surgery for gastrointestinal diseases. For the laparoscopic surgery, MPEG2 (4M) specification is sufficient for retrospective analysis. In the EMR, however, detailed mucosal patterns are carefully examined, non-compressed movie are necessary. Consensus and guidelines related to the digital forensics in medical fields are needed to provide some solution for conflicts in medical malpractices.

Keywords: Digital Forensics, Endoscopic surgery, Video recording

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1. はじめに

近年、医療事故が社会的問題化するなか、医療行為を事後的に検証する必要性が増大してきている。医療者は自らの民事および刑事的責任を回避するために、証拠能力の高い形式での医療行為の記録を保存し、自らの医療行為が医療水準に適合した適切なものであったことを証明することが求められる場面が今後増えると予想される1)。

特に内視鏡的治療および内視鏡外科手術は、高度な技術を要する局面が多くその適否が紛争の対象になりうるため、手術映像をルーチンに記録することが望ましいと考えられる。これまで映像は通常のビデオテープに録画されることが一般的であったが、これは改竄可能なものであるため法的紛争・訴訟において必ずしも高い証拠性をもつものではない。

我々は訴訟上の証拠能力を高めるため、デジタル情報の改ざん・毀損等の有無を検出可能とするデジタル・フォレンジックの技術を導入して、事後的な検証が可能な水準の画質で手術映像を患者生体情報と同期して記録するシステムを開発した。

2. 対象と方法

対象症例は2006年5月から8月に、慶應義塾大学病院にて内視鏡治療または腹腔鏡手術を受けた患者である。患者には書面で同意を取得した。

方法は、まず前臨床検討として録画済みの映像を種々の方式で圧縮し、記録内容が適正に事後的に検証可能かどうか判定した。判定は2人の内視鏡外科医が独立に行った。

さらに臨床での検討(Fig.1)として、内視鏡治療または腹腔鏡手術の手術用内視鏡映像および室内映像と、血圧、心拍数、酸素飽和度等の生体情報を同期して暗号化処理し、外部のタイムスタンプ局の時刻とともに記録・保存した。非改ざん性を担保するためのトークンは治療の都度取得した(Fig.2)。臨床例として早期胃癌に対する内視鏡的粘膜下切除術および消化器疾患に対する腹腔鏡下手術を用いた。暗号化には、広帯域の動画像でも効率的かつ堅牢に処理しうるストリーム系共通鍵暗号2)であるC4S　暗号技術を採用した。臨床評価では、画質・検証可能性の評価以外に、手術室での動作安定性等も検討した。

3. 結果

前臨床で検証可能な画質を評価したところ、腹腔鏡手術症例ではMPEG2 (4M) による圧縮でも手術操作の適切性は検証可能であった。しかし内視鏡的粘膜切除術では早期胃癌を取り扱うため病変の範囲を診断する上で微細な粘膜模様を見極める必要があり非圧縮映像が適切と考えられた。ただし治療デバイスによる操作の検証は、MPEG2 (4M) による圧縮でも可能であった。

臨床での評価について、まず外部時間へのアクセスとして院内のネットワークを利用した場合、ポートの制限などにより安定して接続し得なかったため、PHSに

よる無線でのアクセスを行うことで支障なく記録しえた。暗号化は有意な遅延なく可能であった。画質の検討では、前臨床評価と同様で、手技の記録としてはMPEG2 (4M) による圧縮においても十分事後的検証か可能であったが、早期胃癌の粘膜模様の評価には非圧縮映像が必須であった。

図1 内視鏡治療における記録システムの臨床応用
右上の室内カメラにより術者の手元の映像が、内視鏡画像および生体情報と同期して記録される。

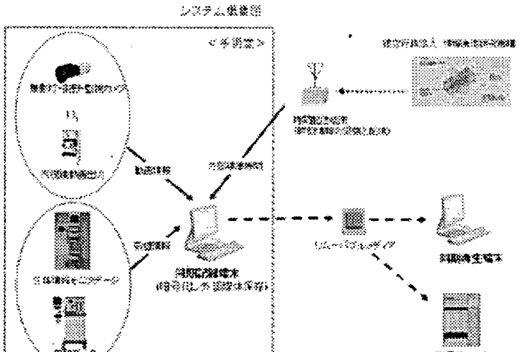

図2 システム構成
手術映像と生体情報が外部時間と同期して記録される。

4. 考察

我々は1999年10月以来、遠隔医療の一環として鏡視下手術における遠隔手術指導システムを実用化してきた[3]。当初はISDN3回線を用いた動画・音声圧縮転送システムを用いていた。しかし、ブロードバンド通信の普及に伴い、安価で質の高い情報が伝送しうる社会的基盤が整備されつつあり、医療の分野でも応用が期待されるようになった。現在、ADSLや家庭用光ファイバー(FTTH)では、ベストエフォートのサービスながら、月々数千円の負担で1～100Mbpsの帯域が得られる。一方でこのような広域ネットワークでは、類型的に要保護性の高い医療情報を扱う上では、高度にセキュリティを確保することが要求される。外科領域における遠隔手術指導では高画質な動画像がリアルタイムで伝送されることが必須の条件となるが、このような大容量の情報を強固に防御するには、従来、高性能のコンピュータを必要としたため実用化が困難であった。そこで暗号強度と通信速度が両立可能な新しい暗号技術により高いセキュリティーを確保しつつ、インターネットを介してリアルタイムに動画像を転送しうるシステムを構築した。これを用いて腹腔鏡補助下幽門側胃切除術(LADG)や内視鏡的胃粘膜切除術(EMR)の遠隔指導を安全に施行しえた。帯域保障のないベストエフォート型のサービスであっても、比較的安定した環境で動作しうるため、今後、広く普及する可能性があると考えられた。

さらに実用的な遠隔手術の形態として、遠隔共同手術システムを開発し臨床応用した[4]。システム構成として、内視鏡はオリンパス社製ImageTrack を用い、遠隔支援コントローラーは、EndoALPHA を利用した。デジタル画像伝送装置は富士通ネットワークテクノロジー社製DVSTREAM II を用いた。通信回線は日本テレコム社のWide-Ether (70Mbps、外部からアクセスできない閉域網)を利用し、相方向のDVTSで動画像転送を行った。2004年3月25日、49歳、女性の有症状の胆石症患者に対して、腹腔鏡下胆嚢摘出術において遠隔共同手術を行い、安全かつ効果的に内視鏡外科手術を遠隔地の指導医と共同で施行しうることを確認した。

このような外科臨床へのITの応用を進める中で、昨今の社会情勢からフォレンジック性を確保したシステム構築が急務と考えている。

また、医療におけるデジタル・フォレンジックに関してコンセンサスの形成とガイドライン策定が望まれる。

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［臨床研修修了後の教育］

大学病院の場合

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キーワード　専修医　専門医制度　大学院教育　プライマリケア

はじめに

平成16年度より新医師臨床研修制度が開始された．医師の卒後研修の初めの2年間に，スーパーローテート方式によりプライマリケアの基本的能力を身に付け，幅広い診療能力と医師としての高い倫理観と豊かな人間性を養うことを基本理念としている．今年度，新医師臨床研修制度の1期生が初期臨床研修を終え，より専門的な研修（いわゆる後期臨床研修）を開始している．なお，“後期”臨床研修という表現では，新制度で必修化された「臨床研修」との関係が不明確となりうるため，筆者の施設では，このいわゆる後期臨床研修を受けている医師に対して専修医という名称を用いている．

専修医課程では，かかりつけ医の機能に代表される基盤的診療能力とのバランス，専門医制度との整合性に関する問題，有給化を基盤とした身分保障，大学院教育や大学の医局人事との兼ね合いなど多くの問題が山積しているのが現状である．本稿では大学病院の視点から臨床研修修了後の教育の現状と今後の課題について概説する．

Ⅰ．専門教育とプライマリケア

新医師臨床研修制度が開始される以前は，研修医の7割が大学病院で，主として医局・講座制度の下，縦割りの枠組みでストレート方式による研修を受けていた1)．このことが医師のプライマリケアにおける基本的能力の低下の一因と指摘され，研修医教育を見直すうえでの1つの契機となった．一方，大学病院においては，高度先進医療を担う専門医を養成し，あるいは新しい診断・治療法を開発する研究者を育成する責務を有している．この基盤的診療能力の研修と専門的分野の教育・研究は個別に分けて考えるべきではなく，本来，並行して実施されることが望ましいと考えられる．専修医課程のなかでは，特定領域の診療を専門的に研鑽すると同時に，当該診療科およびその境界領域に関して幅広く診療できる能力を研修することが必要である．

たとえば，外科においては消化器外科，乳腺外科，移植外科など高度専門化・細分化した分野があり，質の高い医療を求める国民のニーズに応えるためにも，それぞれの分野で先進医療を提供し，それを担う人材を養成していく必要がある．しかしながら，初診外来で的確な診断を行い，必要に応じて適切な専門医に紹介することや，多くの臨床的問題を有する患者に対して全人的に対応する能力を身に付けること，学生や後輩への教育・指導のためにも，外科学一般に関しても幅広く研修できるシステムを構築

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する必要があることはいうまでもない．これが大学病院における基本的理念といっても過言ではない．

Ⅱ．プライマリケアと医師不足

近年，地方の基幹病院における医師不足が社会問題化していることは周知の事実である．2005年，厚生労働省大臣官房統計情報部が発表した2004年医師・歯科医師・薬剤師調査の概況[2]では，医師数は27万371人で増加しているが，産婦人科は4.3%（455人），外科は2.6%（628人）減少している．診療科によっては今後マンパワーの低下が深刻化する可能性がある．現状では，各病院に各科の専門医を十分に取り揃えることは不可能であり，限られた医師数で幅広い分野で質の高い医療を提供する必要がある．そのためにはプライマリケアがしっかり実践できる医師を養成し，基幹病院に偏りなく配置すれば，専門医はそれほど多くなくてもよいと考えられる．

ただし，このような第一線の病院でプライマリケアを担う医師には十分な評価を与えて，モチベーションを維持できる仕組みを整備する必要があると思われる．特に2年間の研修でプライマリケアを学んだ後に，さらにレベルの高い教育が実施可能なシステムを大学病院で構築することが望ましいと考えられる．

Ⅲ．専門医制度

臨床研修修了後の臨床修練では，専門医取得をめざして研鑽を積むことが一般的である．多くの学会が専門医制度を有するが，後期臨床研修ではまず基幹領域の学会（内科学会，小児科学会，皮膚科学会，精神神経学会，外科学会，整形外科学会，産科婦人科学会，眼科学会，耳鼻咽喉科学会，泌尿器科学会，脳神経外科学会，医学放射線学会，麻酔科学会，病理学会，臨床検査医学会，救急医学会，形成外科学会，リハビリテーション医学会）の専門医取得をめざすことになる．

広告可能な専門医資格を得るには，原則5年間以上の専門研修を受け，資格審査ならびに試験に合格する必要がある[3]．そのため，多くの施設では，専門医取得を意識した後期臨床研修プログラムが編成されているのが一般的である．また，同時に，消化器病学会，循環器学会，呼吸器学会などのsubspecialtyの学会や，内視鏡外科学会や癌治療学会などの多領域にわたる横断的に関連する学会の専門医取得も大学病院における専門的研修として重要な意味をもっていることは否定できない．大学病院の多くはこのような専門的な学会の認定施設として承認されており，専修医教育の期間中にカリキュラムを遂行しsubspecialtyの学会の専門医取得を可能としている．

Ⅳ．大学院における教育

臨床研修修了後の進路として大学院（博士課程）進学も大きな選択肢の1つである．多くの場合は4年制であり，基礎医学と臨床医学においてすぐれた研究を遂行しうる研究者・専門家の養成が行われる．

大学院進学といわゆる後期臨床研修との関係は大学や診療科によってさまざまである．全国医学部長病院長会議の集計[4]においても，後期臨床研修修了後に大学院進学，大学院修了後に後期臨床研修，後期研修の中途で大学院進学など，それぞれの大学，診療科においても多種多様な結果を示しており，一定のルールはない．

新医師臨床研修制度開始後，専門医取得に対して，一方で学位取得を目標とする研修医が減少傾向にあるとの実状は周知の事実である[5]．日々，いろいろな刺激にあふれた臨床現場での研修に没頭するなかで，多くの臨床経験に興味を抱き，若い研修医や専修医の将来目標が一般

臨床に傾斜していくのは当然のことと思われる．しかし，地道なこととはいえ，現在の医学で難治性疾患の病態などを基礎的あるいは臨床的に究明し，新たなる治療法を開発しようとする高い志をもった若い医師が少なからず存在することも紛れもない事実である．

今後，わが国の医学が世界を先導していくためにも，基礎医学と臨床医学との融合により，高い水準の教育・研究を推し進める大学院を整備していくことは重要である．そのような観点から，文部科学省の推進する21世紀COEプログラムは大学院教育の充実への貢献として評価されるべきである．医学教育の中心を担うべき大学および大学病院の弱体化がさらに進めば，将来の医療の質の低下と医師の偏在による地域医療の崩壊などを招来する可能性があり，わが国の医師養成システムの根幹を揺るがす事態が懸念されることになる．

V．専修医の身分保障

従来の研修制度では，専修医の多くについて処遇，特に経済的保障が必ずしも十分とはいえず，無給の医員として処遇されることが少なくなかったことは否定できない．無給医の多くは年齢的には少なくとも26歳であり，なかには家庭をもつ者もある．また，学会活動や書籍購入にも少なからず費用が必要であることはいうまでもない．必然的に収入を得るためにアルバイトをせざるをえず，研修や研究に専念できない状況も存在している．また，このような環境が一部で，いわゆる名義貸し問題として社会問題化した状況の温床となっていた面も指摘されている．医師の臨床研修の必修化に当たっては，医師としての人格を涵養し，プライマリケアの基本的な診療能力を修得するとともに，アルバイトせずに研修に専念できる環境を整備することを基本的な考え方として，制度が構築されてきた．

専修医の教育課程においても，この理念は当然継承されるべきであるが，実際の待遇は各大学ごとに多様である．全国医学部長病院長会議の調査3)によると，職務形態にはバラつきがあり，非常勤職員，契約職員，大学構成員，医療錬士研修生，準正規職員，正規職員，専任職員とさまざまな名称で在籍していることが明らかとなった．報酬も9万5,000円から約40万円まで大きな格差がみられた．若い医師の教育は，国民の福祉にとっても重要な意味をもつものであり，何らかの公的支援も含め，今後改善すべき大きな問題と考える．

VI．専門教育と医局人事

従来，わが国では専門教育と医局人事は密接な関係をもっていた．一線の市中病院で学会認定による専門医に求められる臨床症例を経験することが必須であるため，医局を介して大学の関連病院に若い医師を出張させることが一般的であった．その場合，赴任希望者の少ない病院であっても順番に公平性に配慮しながら人材を供給する仕組みが構築されているため，大学医局は，結果としてわが国の地域医療の維持と発展に重要な役割を果たしていた．

実際，新医師臨床研修制度の導入と共に大学病院の医師不足の結果生じた，いわゆる"医師の引き揚げ"による医師の欠員は，地域医療に大打撃を与え社会問題化したことからも，大学医局制度が社会に貢献してきた面を活用していく新たなシステムが求められる．一方で，医師派遣の見返りとして大学に寄付を求めた事例なども一部で報道されており，新たに構築される制度の透明性，説明責任は担保されなければならない．

VII．研修病院の評価

専修医教育において，専門医取得を主要なア

ウトカムの1つとすれば，専門医取得に必要な条件を達成できるかどうかは，プログラム，症例数や指導医の能力など研修施設としての評価になる．今後は，研修医が専門教育施設の客観的な総合評価を参考にして後期臨床研修を選択する傾向が強まると考えられる．よく整備された研修環境と質の高い研修プログラムを構築し，指導力のある上級医の下で効果的な研修が行われるかどうか，研修医が臨床研修修了後の研修先を選択するための資料として，情報公開されるべきと考えられる．

近年，ITの進展・普及により，ホームページ等を通じて各医療施設から情報発信がなされているが，その質や正確性は保証されていない．第三者機関による評価が実現すれば，研修医にとってメリットが多いと考えられる．

おわりに

各分野で医師が不足しているとされているが，各機関で若い医師を奪い合うことは，医療界の健全な発展や国民の福祉のためには好ましいことではない．北里柴三郎慶應義塾初代医学部長は，「わが新しき医科大学は多年医界の宿弊たる各科の分立を防ぎ，基礎医学と臨床医学の懸隔を努めて接近せしめ，融合して一家族の如く」と述べている．医育機関として医師養成の中心的役割を果たしてきた大学病院の教育・研修機能および組織をここで再び自己評価し，良医育成の基幹施設であることを強く認識し，そのためにも一層強化・改善するとともに，新制度下で混乱を招いた地域医療にも貢献できるような制度を，医学界が全体で知恵を集約し構築することが急務であると考える．

さらに，勤務医の勤務条件や待遇を改善し，今後はインセンティブ導入により専門医取得のメリットを明らかにすることで，わが国の医療水準を高度に保つことが国民の医療・福祉にも十分な貢献ができると確信している．

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