Investigation of training needs for Functional Endoscopic Sinus Surgery (FESS)*

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SUMMARY

The use of simulators for training FESS may in the future offer substantial advantages like increased exposure to difficult scenarios, reduced learning curves, and reduced costs. Training simulators may range from very simple, involving only visual simulation, to more complex, involving haptic simulation or force feedback. To effectively employ these training means, insight is needed into the training needs for FESS procedure.
A study was carried out to investigate which subtasks of FESS are hardest to perform and have the longest learning curve. A questionnaire was distributed among two groups of Ear, Nose and Throat (ENT) surgeons participating in a basic, as well as in an advanced sinus surgery course.
Results showed that tasks related to spatial orientation are judged as hardest, whereas manual tasks are considered less difficult.
These results suggest that simulators will not necessarily need haptic feedback to train the most important knowledge and skills needed for FESS.

Key words: FESS, training, learning curve, skill, simulator

INTRODUCTION

The knowledge and the skills needed for FESS surgery are currently learned either from passive training means, like books and lectures, or from more interactive means, like post-mortem resection and supervised surgery on patients. Although it is generally agreed that interactive training means are more effective, post-mortem resection is expensive and only limitedly available, and practicing on patients should be avoided if it adversely affects treatment outcome, and if more economic and effective training means become available.
Future medical training simulators based on virtual reality technology may offer hands on experience in a large variety of surgical scenarios, without the risks that are involved in live surgery, thereby decreasing the length of the learning curve [1]. Task performance could be measured objectively by automatically determined performance metrics, without involvement of training staff.
In the last decade, interactive virtual endoscopy visualizations have emerged, which are based on computer rendering of 3D data obtained, for instance, by CT [2-5]. Evaluations of virtual endoscopy have shown that anatomical structures are clearly displayed, although differentiation between different soft tissues is impossible [6,7]. Based on virtual endoscopy, several prototype training simulators for FESS surgery have been presented [1,8-12]. For instance, the Madigan endoscopic sinus surgery simulator [8] generates virtual endoscopic images, while a real scope and instrument are inserted into the nostrils of a dummy mannequin's head. The instrument is attached to a complex robotic haptic system driven by a computer, which provides force feedback on the tip of the instrument. The endoscope is tracked, without providing haptic feedback, by a separate mechanical arm outside the dummy head in order to control the viewpoint of the virtual endoscope.
Despite considerable technical advances, the use of training simulators for medical applications is in its infancy when compared to the use of simulators in aviation [13]. The technical advances have not been met with an equal advance in educational content [14]. Without proper scenarios, tasks, and performance metrics, the training means are useless.
In order to effectively employ the available training means, and to direct the development of new training means, the training needs have to be established and prioritized [13]. In other words, what subtasks should be trained by the simulator, and to what extent? Complex tasks have to be disassembled into elementary subtasks. For each subtask the requirements for the techniques to train may be different. The training approaches all have their specific advantages, shortcomings, and associated costs. Therefore, careful consideration is need-

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ed for which tasks a specific technology should be employed. Using multiple simple part-task simulators may well be more cost effective and feasible than using a single complex full-task simulator.

Little research has been done on training needs for FESS surgery. Although some reports provide retrospective data about complication rates during residency training programs for FESS procedures [15-19], these studies provide no insight which subtasks cause the most difficulties. Some data are available from a FESS simulator evaluation study, in which experts rate video recordings of live procedures on 12 performance criteria [1]. However, no significant differences were found in the study; this was attributed to the small number of participants. Satava and Fried [20] present a taxonomy of errors for FESS surgery with three main categories being technical errors, related to e.g. scope handling or instrument handling, cognitive errors, related to e.g. knowledge of anatomy or knowledge of procedure sequence, or combined errors, such as injuries that may result both from improper instrument handling and insufficient knowledge about where to cut. Similar main categories may be used for tasks when analyzing training needs, with a distinction between technical or manual tasks, and cognitive tasks.

Most knowledge about training needs may be implicitly present among surgeons in the field. In order to extract this knowledge about training needs of FESS surgery and make it available to developers of training simulators, a questionnaire study was performed among experienced professionals and among residents in training to investigate which tasks are perceived hardest to learn, and how long it takes to learn them.

MATERIALS AND METHODS

In order to assess the training needs for FESS surgery, a questionnaire was distributed among participants of two courses. Course 1 was the International Course in Advanced Sinus Surgery Techniques, which was held in April 2004 at the Academic Medical Centre, Department of Otolaryngology, Amsterdam. There were fifty-five participants in the course, all having prior practical experience with FESS surgery. Participants were experienced ENT surgeons from ten different European countries. Course 2 was the Basic FESS Course, held in September 2004 at the same institute. In this second course, there were sixteen participants from the Netherlands, all ENT residents in training. Both courses consisted of lectures by highly experienced seniors in the field, combined with two post-mortem dissection sessions.

The questionnaire consisted of a short instruction followed by eighteen questions divided in three parts (A, B, C) each. The instruction of the questionnaire read as follows:

"Below are eighteen aspects you need to learn, know or master for FESS surgery. For each aspect indicate with a cross in one of the circles:

A. Current level: Honestly rate your current performance on this aspect (1=very bad, 10=very good).

B. How hard: Indicate how hard you find (or have found) it to learn this (1=easy, 10= very hard).

C. Learning curve: Estimate the total duration it will take you (or has taken you) to completely master this aspect (d=day, w=week, m=month, y=year)."

The goal of Part A was to assess the current skill level of the participants, whereas the goal of Part B, how hard, and Part C, learning curve, was to assess the training needs for subtasks. The 18 questions are given in Table 1.

The scales for Parts A and B ranged from 1 to 10 and for Part C ranged from 1 to 9 divided in: 1 day, 1 week, 1 month, 3 months, 6 months, 1 year, 2 years, 3 years, 10 years. As an example, Question 1 read as follows:

"1. Learning the nomenclature of anatomy.

A. Current level ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10 *very good*
B. How hard ○1 ○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9 ○10 *very hard*
C. Learning curve ○1d ○1w ○1m ○3m ○6m ○1y ○2y ○3y ○10 y"

To stimulate participation and honest answers the questionnaire was completely anonymous. Participation in the study was voluntary for Course 1. Since this resulted in a rather low response of 45% (25 of 55), only 29% was usable, it was decided to make participation mandatory in Course 2.

For each part (A, B and C), statistical analysis was performed with a two-way ANOVA ($p<0.05$) with the between-participants factor Course (1 and 2) and the within-participants factor Question (1-18). Correction for sphericity was applied using Greenhouse-Geisser.

RESULTS

For Course 1, twenty-five questionnaires were returned. However, only sixteen questionnaires were completely filled out with no errors. Only data will be presented of the sixteen complete questionnaires. For Course 2, all 16 questionnaires were returned and completeness of the questionnaires was directly examined when questionnaires were handed in.

For Part A, *current level*, participants of Course 1 not surprisingly gave significant ($F^{1,30}=16.6$) higher scores (mean 7.2) than participants of Course 2 (mean 4.8). Results for individual questions are given in Table 1.

For Part B, *how hard*, and Part C, *learning curve*, no significant differences were found between Course 1 and Course 2 (respectively $F^{1,30}=0.2$ and $F^{1,30}=0.7$), and also no significant differences in the way participants of both courses answered their questions (interaction effects between Course and Question respectively $F^{17,510}=0.7$ and $F^{17,510}=2.0$ for Part B and C). Therefore, data of Course 1 and 2 were combined for these parts. For the combined data, significant differences were found between questions both for Part B, *how hard* ($F^{17,510}=18.0$), and for Part C, learning curve ($F^{17,510}=9.4$).

The clearest differences between questions were found for Part

Table 1. Results of the questionnaire for Part A, current level, and Part C, learning curve.

	Part A, current level		Part C, learning curve			
	Course 1 (N=16)		Course 2 (N=16)		Course 1&2 (N=32)	
Question	Mean	Std	Mean	Std	Mean	Std
1. Learning the nomenclature of anatomy.	7.4	0.9	6.1	1.3	5.2	1.6
2. Learning the variation in anatomy.	6.8	1.5	4.2	1.1	6.9	1.5
3. Learning to recognize anatomy on CT. 7.1	1.2	4.9	1.0	5.8	1.1	
4. Learning to make a 3D mental representation of anatomy based on CT data.	6.2	1.3	4.2	0.6	6.8	1.0
5. Learning to recognize anatomy on endoscopic image (patient not previously operated).	7.4	0.7	4.9	1.1	6.0	0.9
6. Learning to recognize anatomy on endoscopic image (patient previously operated).	7.1	0.8	3.2	1.7	7.1	1.0
7. Learning to make a diagnosis based on CT and endoscopy.	7.3	0.8	5.4	1.1	6.3	0.9
8. Learning to choose the right surgical treatment.	7.4	0.8	4.5	1.1	6.8	1.1
9. Learning to handle and steer a 0 degree endoscope.	8.2	0.8	6.0	1.2	5.0	1.2
10. Learning to handle and steer a 45 degree endoscope.	7.3	1.2	5.0	1.1	5.7	0.9
11. Learning to handle and steer a 70 degree endoscope.	6.3	1.9	3.8	1.3	6.3	1.0
12. Learning to choose the optimal instrument.	7.3	0.7	4.7	1.0	6.1	1.0
13. Learning the correct approach to resection: where to start and in which direction to cut.	7.2	0.6	4.2	0.7	6.6	0.9
14. Learning to steer an instrument to its target (e.g. Blakesley).	7.6	0.9	4.8	1.0	5.8	1.0
15. Learning to judge where you are located exactly with your instrument and endoscope.	7.1	0.6	4.6	1.3	6.8	1.0
16. Learning the manual skill of cutting with an instrument (e.g. Blakesley).	7.3	0.7	5.1	0.9	5.7	1.2
17. Learning to dose force during cutting with an instrument.	7.4	0.7	4.9	1.0	5.9	1.0
18. Learning to handle instrument and endoscope simultaneously.	7.2	0.7	4.9	1.0	6.2	0.8

N=number of participants. Std=standard deviation after removal of variation between participants.

B, how hard (Figure 1). Judged hardest by participants was, “Learning to recognize anatomy on endoscopic image (patient previously operated)” with a mean score of 7.4, followed by ”Learning to make a 3D mental representation of anatomy based on CT data”, with a mean score of 7.1. Easiest was ”Learning to handle and steer a 0 degree endoscope”, with a mean score of 4.1. Results of the post-hoc analysis that tested the differences between individual questions for Part B are incorporated in Figure 1.

Results of Part C, *learning curve*, were similar to those of Part B and a significant positive correlation (R=0.65) was found between these parts. For Part C, *learning curve*, the mean answers range from 5.0 for “Learning to handle and steer a 0 degree endoscope” to 7.1 for ” Learning to recognize anatomy

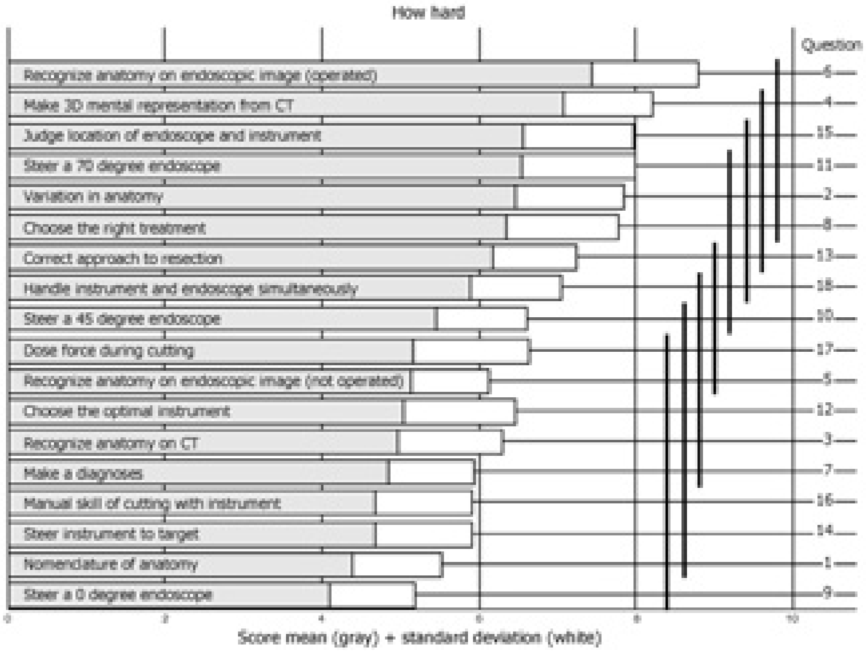

Figure 1. Mean scores on the eighteen questions for Part B, how hard, for Course 1 and 2 combined. The questions are sorted according to their mean score. The standard deviation is calculated after removal of variation between participants. Solid vertical lines overlap those questions that do not differ significantly from each other (tested with posthoc Tukey HSD test, $p<0.05$). For instance, the mean answer for Question 10 ("Steer a 45 degree endoscope") differs significantly from that of Questions 9, 6, 4 and 15 because the Question 10 has no overlap by any of the solid vertical lines with these questions, and Question 1 does not differ significantly from Question 10 because they are connected by a solid vertical line.

on endoscopic image (patient previously operated)", with a score of 5 corresponding to 6 months, and a score of 7 corresponding to 2 years.

Further significant ($p<0.05$) but weak correlations were found between answers belonging to Part A, current level, and Part B, *how hard*, (R= -0.32) and between Part A, *current level*, and Part C, *learning curve* (R=-0.32).

DISCUSSION

In order to get insight into the training needs of FESS surgery a questionnaire was administered among participants of two courses, the International Course in Advanced Sinus Surgery Techniques and the Basic FESS Course, both held at the Academic Medical Center hospital in Amsterdam. As expected, the participants of the two courses differed significantly in their current level (Part A). The more experienced group from Course 1 showed less differentiation between the questions in current level (mean ranging from 6.2 to 8.2) than the less experienced residents from Course 2 (mean ranging from 3.2 to 6.1), which is only logical since the less experienced residents have not yet mastered all tasks.

For Part B, *how hard*, and Part C, *learning curve*, the groups showed consensus and no significant differences were found in the how participants of both courses answered the questions. This indicates that even the inexperienced residents can make a good assessment of how hard the elementary subtasks that were questioned are to learn.

The answers to questions about how hard the 18 different aspects were to learn (Part B), provided the most useful insights into the difficulties experienced in learning the knowledge and skills of FESS surgery. Judged as hardest to learn were aspects that relate to spatial orientation, like "recognizing anatomy on the endoscopic image with the patient being previously operated" (7.4), "making a 3D mental representation from CT" (7.1), or "judging the location of the endoscope and the instrument" (6.6). Apparently even with the CT images present during the operation, it is not easy to understand the relationship between the orthogonal 2D CT-slices and the perspective endoscopic images of the 3D scene. Recognition of structures on the endoscopic image may be experienced as hard because the endoscope offers only a very local and narrow view on the operating field, and because all cells and structures are covered with the same mucosa layer, making the surface of all structures appear very similar to each other.

Recognizing anatomy on the endoscopic image was judged far more difficult when the patient was previously operated (7.4) than if the patient was not operated (5.1). Clearly, surgical resection often removes important visual landmarks, making recognition of the actual instrument location even harder. Simulators that teach recognition of anatomy should contain various postoperative CT data to train the anatomy of operated patients.

Most manual skills were judged as being easy, like steering a 0 degree endoscope (4.0), steering an instrument (4.7), or the manual skill of cutting with an instrument (4.7). However, if an angled scope is used, steering was judged increasingly difficult with angle (45 degree endoscope: 5.4; 70 degree endoscope: 6.5). This suggests that having an angle between the viewing direction of the endoscope, and the direction of the endoscope shaft, creates eye-hand coordination problems, as is well known from laparoscopic surgery [21]. Simultaneous handling of an instrument and an endoscope was judged more difficult (5.9), than controlling only a 0 degree endoscope (4.1). This suggests difficulty with two-handed coordination of instrument and scope in the narrow confinement of the nasal cavities.

As could be expected, the estimation of the duration of the learning curve (Part C) showed a positive correlation with Part B. The harder a subtask is to learn, the longer it takes to learn that task.

The results of Part C showed less differentiation than those of Part B (difference between maximum and minimum mean of 2.1 versus 3.3 respectively). In retrospect, the nonlinear scale that was used for the learning curve might not have been adequate. The five lowest values of the scale differentiated between 1 day and 6 months while the four highest values differentiated between 1 year and 10 years. Given the results, a more sensitive scale should differentiate more in the period between 6 months and 2 years.

The results that were found suggest that having haptic feedback in a training simulator for FESS may not be of critical importance. Many task aspects that were judged hard, involve cognitive skills instead of manual skills. Training the manual skills may well be performed on a simple simulator that lacks visual realism. For instance, a simple dummy head model with a real endoscope could be used to train steering, instead of choosing the more complex approach of virtual endoscopy combined with haptic rendering. Training cognitive tasks such as the recognition of the location of instruments may well be performed on a low-cost simulator that totally lacks haptic feedback. Such a simulator could combine 3D virtual endoscopic visualization, based on CT data of operated patients, with traditional orthogonal, sagittal and axial slice views. By letting trainees mark points in one modality that are indicated in the other, the correspondence between the pre-operative CT and the endoscopic view could be trained. The simulator should be able to easily load CT data from any patient to allow training of a wide variation in anatomy.

Training simulators should focus on those tasks that are most critical to surgical outcome and on the avoidance of complications. Being able to judge the location of instrument and endoscope is of critical importance in the avoidance of complications. If one does not know exactly where resection takes place, complications may easily occur. Given the outcome of this study, developers of training simulators should carefully consider which tasks to focus their training on and adjust the choice of necessary technical means to match this training need.

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