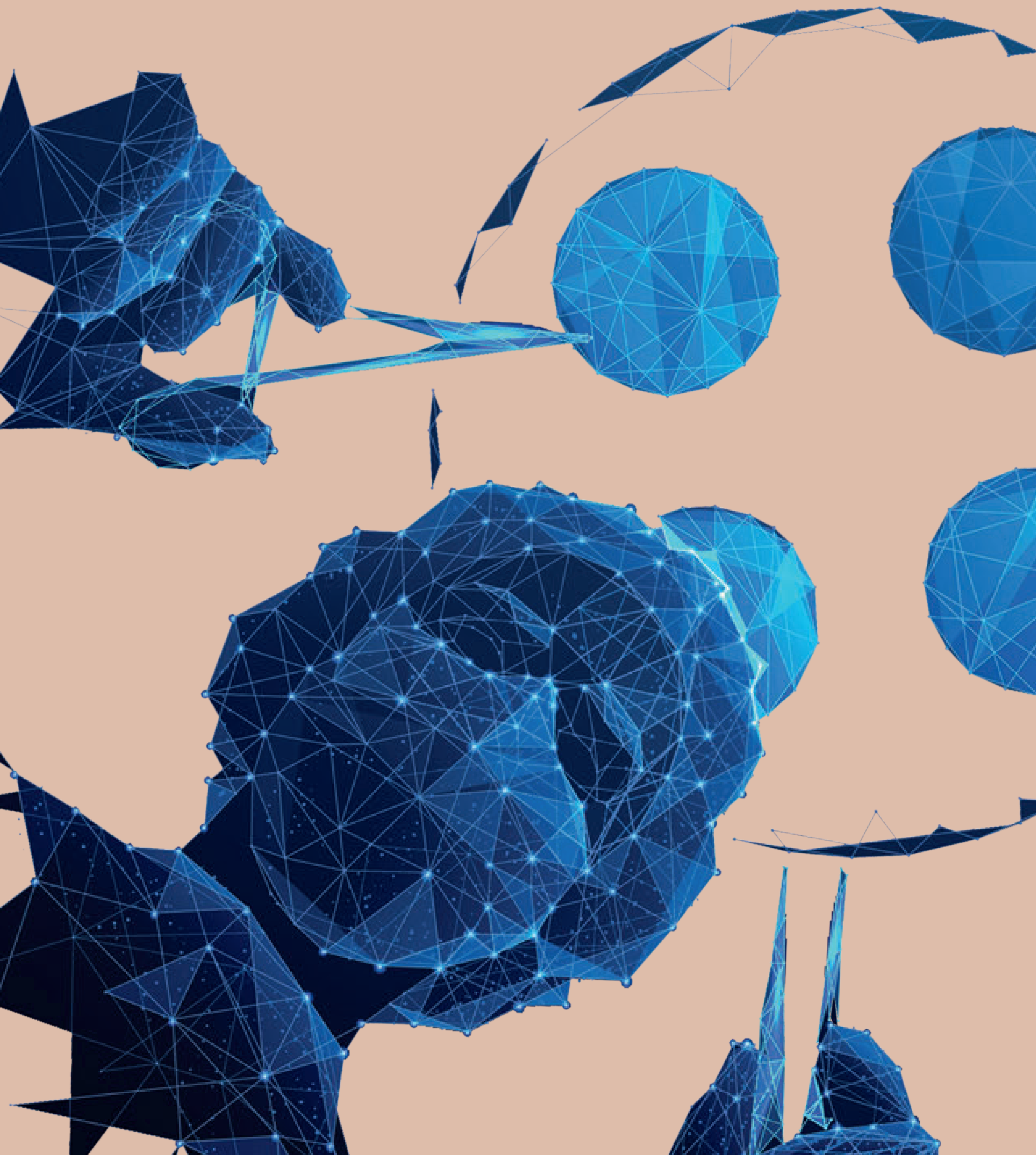
STRUCTURED LEARNING OF SURGICAL PROCEDURES

Tahmina Nazari



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Voor papa en mama

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1

GENERAL INTRODUCTION

Throughout history, surgical procedures have been taught in the operating room, where the surgical resident starts by observing the surgeon and is progressively allowed to perform surgical procedures until he or she is proficient without supervision. This is known as a master-apprentice model.[1] This method of learning depends on the ability of the expert to transfer his or her knowledge and skills to the trainee. However, research has shown that experts unintentionally omit up to 70% of crucial information whilst explaining a complex task.[2] An explanation may be that as surgeons gain knowledge and skills, they perform tasks largely automated and unconsciously.[3] For them expert knowledge and knowing how to perform surgical steps blend together.

Nowadays, the traditional master-apprentice method of learning has been adjusted due to many factors. Firstly, the importance of patient safety, ethical considerations and the general opinion not to practice on patients led to a need to reconsider the training model. Secondly, the duty hour restriction has led to less exposure time of surgical residents to the operating room (OR) and decreasing educational outcomes.[4] These changes require better preparation in view of the sparse time they have available in the OR.[4-5] Thirdly, to prepare for surgical procedures a multitude of new resources, such as online videos, are available now.[6-7] Lastly, the training of one surgical trainee is established by a team of different surgical trainers, where the relationship of the trainee with his or her trainers is imperative for training.

Due to these factors, an efficient method to transfer surgical procedural knowledge is needed. This thesis will focus on the efficiency of structured learning of surgical procedures. In this chapter, the cognitive theory of multimedia learning and segmentation principle, a method to facilitate learning, is discussed. Then, the focus will be on three learning levels: learning by observing, learning by doing, and learning by reflecting.

Cognitive Theory of Multimedia Learning

For understanding the mechanism of learning, the cognitive theory of multimedia learning (CTML) can be used.[8-10] This learning theory explains the mechanisms of processing and storing new information in the human mind. When new information is observed or heard, a selection of it is actively processed in working memory by integrating it with existing knowledge in long-term memory (**Figure 1**). It is then stored in long-term memory as cognitive schemas. This processing and storing of information is bound by the limited cognitive capacity.[11]

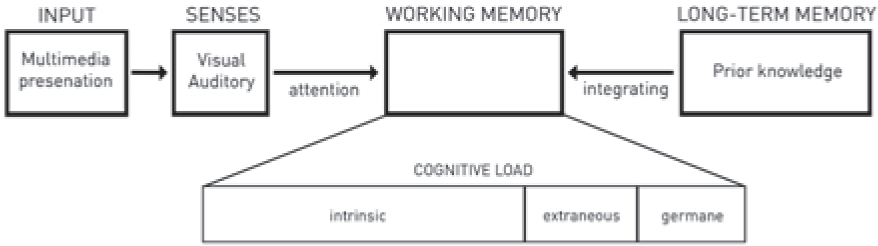

Figure 1. Cognitive Theory of Multimedia Learning (CTML) Adapted from Mayer et al[11]and de Leeuw[12]

The amount of cognitive capacity needed to process new information in the working memory is known as cognitive load.[11, 13] Three types of cognitive load can be distinguished: intrinsic, extraneous and germane cognitive load.[14] The intrinsic cognitive load is determined by the complexity of new information and the prior knowledge of the learners. This load is higher for novices, and as the learner progresses and learns more, the intrinsic cognitive load decreases. The extraneous cognitive load is determined by the presentation of new information,[15-16] where suboptimal presentation results in higher extraneous load. Finally, germane cognitive load is the capacity that is desired. This load is determined by the construction and use of cognitive schemas, and represents the capacity of the working memory that integrates new information into long-term memory.[17-18]

While processing new information, the total load of these three types of cognitive load cannot exceed the total working memory capacity available, as the bucket in **Figure 2** will overflow.[19] During simple tasks that yield low intrinsic cognitive load, the learner will be able to manage the task even if the extraneous cognitive load is high. On the contrary, during high complexity tasks, such as closely observing or performing a surgical procedure, the intrinsic load will be high. Therefore, the extraneous cognitive load should be reduced as much as possible so that genuine learning and the corresponding germane load can still occur.

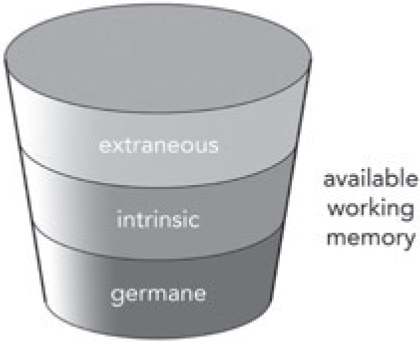

Figure 2. Types of cognitive load

Segmentation principle

To manage the cognitive load and to facilitate learning, the segmentation principle can be applied.[16] With the segmentation principle, the information (for example a surgical procedure video-demonstration) is divided into smaller parts with pauses in between, allowing learners to completely process one segment before moving on to the following segment. Novices tend to learn better when complex, transient information is presented in learner-paced segments, rather than as one continuous unit.[20-22]

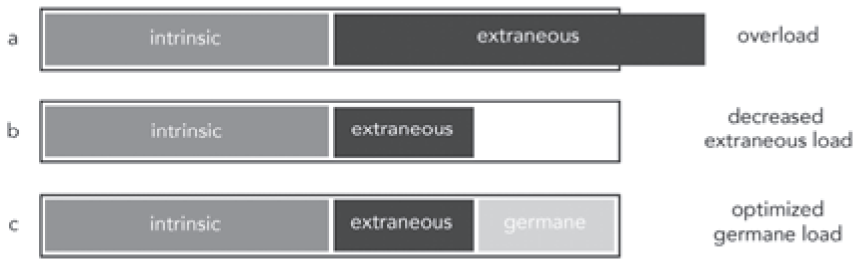

Figure 3. Optimizing cognitive capacity: lowering extraneous load and providing opportunity for germane processing (adapted from Sweller, van Merrienboer & Paas, 1998).[23]

Theoretically, unsegmented surgical procedure video-demonstration demands a high extraneous load (**Figure 3a**). Especially as the presented video displays information that is disappearing from the screen, while learners need to retain and process this information in working memory in order to grasp the whole procedure.[20] The application of the segmentation principle on video-based learning of surgical procedures could reduce the extraneous cognitive load, because it provides additional processing time (**Figure 3b**). This extraneous load reduction gives more opportunity for germane processing (construction of cognitive schemas; **Figure 3c**), and subsequently improves the learning of the surgical procedure.[11]

Alignment of learning levels

In surgery, as in other domains, learning procedural skills is better when learning outcomes (e.g. procedures), learning activities (e.g. watching videos) and assessment are well aligned. Thus, learning a surgical procedure is better when all three phases of learning are aligned: observing, doing and reflecting. A trainee starts learning by observing the surgical procedure in books, lectures, videos, et cetera. Then, the observed surgical procedure is practiced in a safe simulated environment. When proven qualified in the simulated environment, the trainee can perform the surgical procedure in the operating room under supervision of a surgeon who provides effective feedback.

Learning by observing

In recent decades, surgical trainees have had increasing access to online resources – besides the OR, text and anatomy books, to learn by observing.[24] While textbooks possess high educational quality, online video demonstrations, for example on YouTube, are increasingly being used to study anatomy or an entire surgical procedure.[25] There are evident advantages of video-based learning to prepare for a surgical procedure compared to textbooks.[26-28] However, the learning yield of internet videos varies as the educational quality of many online videos is doubtful.[29-30]

An online video-based surgical educational platform (Incision Academy, Incision Group, Amsterdam, The Netherlands) provides a wide range of surgical videos supervised by expert surgeons, anatomists and surgical educators. Today over 500 courses can be accessed on this online video-based platform. Each course includes a step-by-step video demonstration and a detailed textual description of the surgical procedure. The step-by-step demonstration follows the segmentation principle. The courses include supporting chapters regarding surgical anatomy, surgical objectives, pre-operative measures such as positioning of the patient, postoperative complications, and knowledge tests.

Learning by doing

In current surgical education, simulation training can be an adjunct to preparation for real OR experiences.[31] Surgical simulation models allow the trainees to acquire their skills in a safe environment without risking patient safety.[32] The positive effects of simulation training have been proven, however, its implementation into the residents' curriculum remains challenging as it is often unstructured or provided as a 'one-time' event at courses.[33-34]

Learning by reflecting

The final phase in learning is processing feedback. During surgical training, the delivery of external feedback has shown to be a crucial part in technical skill development of a novice surgeon.[35-37] Feedback can be provided based on direct observation of technical skills.[38-40] Within the surgical field, different observational assessment tools are available today.[41]

A global rating scale to assess competencies during a surgical procedure that is commonly used and accepted 'gold standard' assessment tool is Objective Structured Assessment of Technical Skills (OSATS).[42] While global rating scales, such as OSATS, are easy in use, they can be imprecise.[42-44] For more precise feedback, a task-specific method may be useful.[41] A task-specific assessment method is the Observational Clinical Human Reliability Analysis (OCHRA).[41] The OCHRA checklist assesses in a stepwise manner if a surgical step was correct or incorrect.[45] Both OSATS and OCHRA assessment tools have shown to be valid for providing constructive feedback.[45] However, OCHRA feedback might be more effective when the surgical procedure is also learned in a stepwise manner.[41, 46]

To create a surgical procedure specific assessment tool, a stepwise description of the surgical procedure must be created first.[24] The assessment tools that are surgical procedure-specific use extensive, time-consuming and logistically-challenging methods to construct such a stepwise description of the surgical procedure.[45, 47-50]

RESEARCH QUESTIONS

This thesis focuses on the effects of structured learning of surgical procedures to be more efficient using the cognitive theory of multimedia learning and the segmentation principle. Multiple research questions will help to investigate this on the three learning levels.

Part I Learning by observing

Q1. What is the validity of the step-by-step framework – a method to segment surgical procedures in a standardized manner?

Q2. What learning method – traditional versus video-based learning – is more efficient for learning a surgical procedure?

Q3. What are the effects of learning a surgical procedure in a segmented versus continuous manner?

Q4. What are the effects of an online surgical education platform that uses the segmentation principle?

Part II Learning by doing

Q5. What are the preferred learning methods of surgical residents?

Q6. What is the validity and usefulness of a low-cost open inguinal hernia repair simulation model?

Part III Learning by reflecting

Q7. What is the accuracy and usefulness of an OCHRA-checklist created using the step-by-step framework?

Q8. Which assessment and feedback tool – a global rating scale OSATS versus a task specific OCHRA – is more efficient for learning a surgical procedure?

OUTLINE OF THESIS

Part I Learning by observing

In the first part of this thesis, the structuring of learning of surgical procedures is addressed. First, a method to structure surgical procedures into steps and substeps will be described.

In **Chapter 2,** the development and validation of a step-by-step framework to segment surgical procedures in a standardized manner into steps, substeps and to identify hazards will be described (Q1).

Chapter 3 compares traditional learning methods (reading and lectures) to video-based learning for surgical procedure learning in a systematic review and meta-analysis (Q2).

The effects of the step-by-step framework are explored in the next chapters.

In **Chapter 4** the effects of a structured stepwise description on learning surgical anatomy is compared to continuous learning in pre-novices (Q3).

In **Chapter 5**, the effects of a structured stepwise description on performing a surgical procedure are compared to continuous learning in medical students (also answering Q3).

The next two chapters describe the applicability of an online video-based surgical education platform (Incision Academy) that uses the step-by-step framework.

Chapter 6 describes the feeling of preparedness, comprehensibility, usefulness and satisfaction with the use of this online platform during surgical clerkships (Q4).

In **Chapter 7**, this online platform is compared to a control group (also answering Q4).

Part II Learning by doing

In the second part of this thesis, practicing surgical procedures will be addressed.

In **Chapter 8**, the preferences of surgical residents to learn the open inguinal hernia repair will be outlined (Q5).

In **Chapter 9,** the development and validation of a low-cost open inguinal hernia repair simulation model will be described (Q6).

Part III Learning by reflecting

In **Chapter 10** a stepwise description will be constructed using the step-by-step framework and its accuracy is explored. Then, an OCHRA-checklist will be produced using the constructed stepwise description and its accuracy and usefulness are assessed (Q7).

In **Chapter 11**, the effects of feedback using the OCHRA will be compared to the OSATS (Q8).

In **Chapter 12,** a general discussion of the findings of this thesis and the future perspectives are presented.

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PART I
LEARNING BY OBSERVING

2

CREATION OF A UNIVERSAL LANGUAGE FOR SURGICAL PROCEDURES USING THE STEP-BY-STEP FRAMEWORK

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J. J. G. van Merriënboer, J. F. Lange and T. Wiggers

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ABSTRACT

Background

Learning of surgical procedures is traditionally based on a master–apprentice model. Segmenting procedures into steps is commonly used to achieve an efficient manner of learning. Existing methods of segmenting procedures into steps, however, are procedure-specific and not standardized, hampering their application across different specialties and thus worldwide uptake. The aim of this study was to establish consensus on the step-by-step framework for standardizing the segmentation of surgical procedures into steps.

Methods

An international expert panel consisting of general, gastrointestinal and oncological surgeons was approached to establish consensus on the preciseness, novelty, usefulness and applicability of the proposed step-by-step framework through a Delphi technique. All statements were rated on a five-point Likert scale. A statement was accepted when the lower confidence limit was 3.00 or more. Qualitative comments were requested when a score of 3 or less was given.

Results

In round one, 20 of 49 experts participated. Eighteen of 19 statements were accepted; the 'novelty' statement needed further exploration (mean 3.05, 95 per cent c.i. 2.45 to 3.65). Based on the qualitative comments of round one, five clarifying statements were formulated for more specific statements in round two. Twenty-two experts participated and accepted all statements.

Conclusions

The international expert panel consisting of general, gastrointestinal and oncological surgeons supported the preciseness, usefulness and applicability of the step-by-step framework. This framework creates a universal language by standardizing the segmentation of surgical procedures into step-by-step descriptions based on anatomical structures, and may facilitate education, communication and assessment.

INTRODUCTION

Throughout history, surgical procedures have been taught in a master–apprentice model.[1] The apprentice starts by observing the master performing a surgical procedure, and he or she is gradually allowed to take over parts of the procedure until he or she can perform the entire surgery without supervision. This model relies on the ability of expert surgeons to provide a demonstration with clear explanation of surgical procedures, but research has shown that information regarding the surgery becomes self-evident for experts. Consequently, they unintentionally omit critical information when explaining a procedure to apprentices.[2]

Decreased teaching time due to regulation of working hours and the emphasis on operating room efficiency has made it more challenging to teach procedures to surgical residents (trainees).[3] The priority should therefore be on learning before setting foot in the operating room. When residents are preparing for procedures, many sources are available to them, such as books, articles and videos. Often these sources describe or demonstrate the surgical procedures as a continuous text or video. Different step-by-step descriptions of the same procedure can vary greatly in terms of steps, structures, components and demarcations.

To facilitate the learning process, the cognitive limitations of learners must be taken into account. Cognitive learning theory explains the mechanism of processing and storing new information. When information is seen or heard, it can be actively processed in working memory by connecting it to existing knowledge in the long-term memory, and then be stored in long-term memory as cognitive schemas. This processing and storing of information is bound by a limited cognitive capacity.[3] To use this capacity optimally, complex transient information (such as video or animation) should be presented in segments rather than as a continuous stream.[4] Segmentation divides information into smaller pieces with pauses in between that provide the learner time to process one segment before moving on to the next segment. In addition, segmentation could aid in constructing a cognitive schema representing the procedure. This works especially for novices as they do not yet possess the cognitive schemas necessary to understand a newly presented procedure quickly.[5]

To create a universal language of surgical procedures that keeps the segmentation principle in mind, a generic framework should be designed. The definition of a framework is 'a structure underlying 'something' serving a specific purpose',[6] or as the *Oxford Living Dictionary* defines it: 'a basic structure underlying a system, concept, or text'.[7] This framework should clearly describe how to structure a surgical description and where to segment.

Previous attempts at creating a generic framework have not been implemented universally yet. The definitions used for the steps and other elements in the previous frameworks were unclear and ambiguous[8-9] which decreases the reproducibility and transferability of these frameworks. Other described procedure-specific methods were time-intensive, as the steps were derived from expert panels[10-11] or after video-recording and observing multiple operations.[12] The segmentation of surgical procedures is lacking a unified and standardized approach.

In this article, one generic framework is proposed to structure the segmentation of surgical procedures into steps and substeps. This framework could create one common language of surgical procedures for daily use among surgeons and surgical residents. It would offer a foundation for surgical education concerning descriptions of surgical procedures in books, courses and articles. The aim of this study was to assess whether international experts agree on the preciseness, novelty, usefulness and applicability of a newly developed step-by-step framework to segment surgical procedures into steps.

METHODS

The step-by-step framework

The proposed step-by-step framework structures the description and demonstration of surgical procedures. This framework is not procedure-specific and aims to be broadly applicable to all surgical disciplines. Within the framework, steps and substeps are defined based on the anatomical structures encountered during the described procedure (**Figure 1**). A step is performed in one surgical region to reach a predetermined goal that has to be evaluated before continuing to the next step. Each step is named according to its goal. By doing so, the surgery is broken down into meaningful events. A step consequently consists of substeps.

A substep is based on an anatomical structure or implant, such as a mesh or osteosynthesis material, and contains one or more actions. The description of every action is a single verb (such as transect or incise). If the predetermined goal of a step has not been achieved, the course of its substeps has to be reviewed and revised until the goal is reached. In the specification of a substep, an explanation is provided for the combination of an anatomical structure with an action. A specification containing hazardous parts is called 'hazards', and suggestions for the learner's convenience are 'tips'.

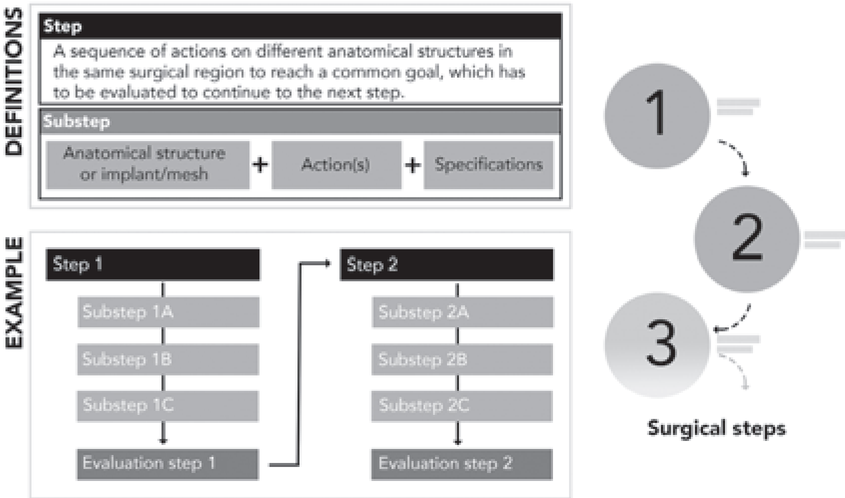

Figure 1. The step-by-step framework.

Delphi method

A Delphi method was used to establish consensus on the step-by-step framework. The Delphi method is used to gather anonymous feedback of an expert panel via questionnaires with statements in order to establish group consensus.[13] The experts scored their agreement with each statement, in this case on a five-point Likert scale.[14] The responses are then analysed and the statements are either accepted, rejected or further explored by additional statements, until group consensus is achieved.

Expert panel

An international panel was selected with the main objective that the surgeons were responsible for the training and education of surgical residents. Special attention was paid to include different disciplines (general, oncological and gastrointestinal) and global spread in both high-, middle- and low-resource settings (**Table 1**). The surgeons were not approached before the Delphi rounds. The online questionnaires were sent directly via e-mail.

An anonymous questionnaire facilitates decision-making as individuals might be more open and honest with their ratings.[15] The Delphi rounds, therefore, were completely anonymous and all experts were approached for the second round. Each round lasted 2 weeks, during which the experts were reminded twice via e-mail.

Round one

As the framework was developed before commencing the Delphi method, the first 19 statements were constructed based on the step-by-step framework, its characteristics and applicability. The statements were in the following categories: preciseness (9 items), novelty (1 item), usefulness (3 items), and applicability (6 items) (**Table 2**; **Appendix A and B**). The applicability was tested with the steps of open inguinal hernia repair and open small bowel resection. Each statement was rated on a five-point Likert scale (1, strongly disagree; 5, strongly agree). The experts were requested to give qualitative comments when a score of 3 or less was given, although comments were not mandatory.

Each statement was analysed to determine whether it was accepted or not. Statistical analysis was based on the findings of a previous study.[11] For each statement a score between 1.00 and 5.00 was possible. The mean with the 95 per cent c.i. was calculated per statement. A statement was accepted if the lower confidence limit was 3.00 or more. A statement was rejected if the upper confidence limit was less than 3.50. A statement was further explored in the second round when it did not meet the above-mentioned criteria. The internal consistency per category was determined using Cronbach's α; preciseness (9 items), usefulness (3 items) and applicability (6 items). The analyses were performed using the SPSS® version 24.0 (IBM, Armonk, New York, USA).

Round two

As the responders could not be identified from the non-responders in the anonymous online questionnaire, the questionnaire for round two was send to all experts. Any statements from the first round that were not accepted or rejected were explored further, leading to new statements for the next round. These statements were based on the qualitative comments that were gathered in the first round. The new statements were sent out in the second round. These were scored and analysed in the same manner as those in round one.

RESULTS

Expert panel

Forty-nine expert surgeons, of whom 22 were full professors in surgery, were invited to participate. Of these 49 experts, 20 replied and assessed the statements in round one. In the second round, these statements were again sent to all 49 experts, of whom 22 replied and assessed the statements.

Table 1. Country of origin experts (n=49)

		Total (n=49)	**Round one (n=20)**	**Round two (n=22)**
Europe	Austria	1		1
	Bulgaria	1		
	Denmark	2		
	France	3	3	
	Georgia	1	1	1
	German	1	1	1
	Italy	3	2	1
	Netherlands	9	2	6
	Poland	4	2	1
	Russia	1	1	1
	Slovenia	1		1
	Spain	1		1
	Sweden	1		
	United Kingdom	7	2	2
Africa	Ghana	5	2	2
	South Africa	1		
South America	Brazil	2	2	
Central America	Curacao	2	1	1
North America	United States of America	2		1
Asia	Afghanistan	1	1	1

Round one

In the first round, the experts originated from 12 different countries and four different continents (**Table 1**). Fifteen experts had more than 20 years post-residency experience, three had 10–20 years, and two had up to 10 years. Of the 19 statements, 18 were accepted and one needed further exploration (**Table 2**). The internal consistency for preciseness was Cronbach's α = 0.862, usefulness Cronbach's α = 0.830 and applicability Cronbach's α = 0.877.

Table 2. Statements round 1

	Statements	**Mean**	**95% CI^**
Preciseness (Cronbach's alfa = 0.862)			
1	Each surgical procedure is constructed of multiple steps that have to be performed.	4.45	4.09 - 4.81
2	Alternative routes within one procedure are possible.	4.25	3.75 - 4.75
3	Each surgical step starts with determining the wanted goal.	4.65	4.42 - 4.88
4	To accomplish the determined goal, one or more structures are encountered and dealt with.	4.60	4.36 - 4.84
5	Each step ends with evaluation whether the common predetermined goal is achieved.	4.65	4.42 - 4.88
6	To accomplish the common predetermined goal of a step, one or more smaller steps have to be taken.	4.40	4.02 - 4.78
7	The substep is a combination of one structure with one or more actions.	4.35	3.97 - 4.73
8	A substep is based on an anatomical structure or an implant.	4.40	4.12 - 4.68
9	A substep can be based on non-anatomical structures, like meshes and implants.	4.50	4.26 - 4.74
Novelty			
10	The proposed step by step concept is new in the surgical world.*	3.05	2.45 - 3.65
Usefulness (Cronbach's alfa = 0.830)			
11	The proposed step by step concept is useful in communication with other surgeons.	4.55	4.31 - 4.79
12	The proposed step by step concept is useful in research concerning surgical procedures.	4.55	4.31 - 4.79
13	The proposed step by step concept is useful in teaching surgeons in training.	4.75	4.54 - 4.96
Applicability (Cronbach's alfa = 0.877)			
Tested on the steps of the open inguinal hernia repair			
14	The steps divided represent the natural moments of evaluation during surgery.	4.45	4.21 - 4.69
15	The start of this step is a natural moment to determine a new goal during the surgery.	4.55	4.31 - 4.79
16	The end of this step is a natural evaluation moment prior to moving on to the next step during the surgery.	4.60	4.36 - 4.84

Statements		Mean	95% CI^
Tested on the steps of the open small bowel resection			
17	The steps divided represent the natural moments of evaluation during surgery.	4.15	3.80 - 4.50
18	The start of this step is a natural moment to determine a new goal during the surgery.	4.35	4.08 - 4.62
19	The end of this step is a natural evaluation moment prior to moving on to the next step during the surgery.	4.30	3.99 - 4.61

^ Confidence interval; * Statement in need of further exploration

Table 3. Qualitative comments on statement 'The proposed step by step concept is new in the surgical world.'

Not new	Not new, but now defined
Several old books present step by step procedures. , e.g. Zollinger	The concept is not new, but now it seems to be properly evaluated, appreciated, & defined
In the description of procedures, the step by step approach is sometimes used	This is how I was taught, and have been teaching. The steps were however not always strictly defined
The consideration step by step procedure in surgery has always been respected since long time ago	See my published research on INVEST for lap cholecystectomy, however, this is the first research to accurately define the step/substep concept
This has been known for years	It may not be universal in practice but is highly recommended for standardization and audit
I am not sure it's entirely new	A procedure is always a progression. I don't see really what is new except a formalization surgery by surgery which could help to establish standard report for example

Round two

One statement from the first round was in need of further exploration: 'The proposed step-by-step concept is new in the surgical world'. The qualitative comments on this statement concerning novelty were analysed. Of the ten gathered comments, five concerned its preciseness. The comments were divided in two categories: 'not new' and 'not new, but now defined' (**Table 3**). The emphasis in the second round shifted from 'novelty' in the surgical world to 'preciseness' (**Table 4**). The experts were approached again. In the second round, 22 experts of the 49 approached participated. All statements were accepted.

Table 4. Statements round 2

Formulated statements		Mean	95% CI^
Existence step by step descriptions			
1	Describing surgeries in steps exists in the surgical world.	4.09	3.71 - 4.48
Preciseness			
2	Describing a surgical step is procedure-specific as the goals vary between the different surgeries.	4.23	3.99 - 4.46
3	Describing a substep can be used generic as it is based on anatomical structures or implants combined with one or multiple actions.	4.00	3.66 - 4.34
4	Describing substeps based on anatomical structures or implants combined with one or multiple actions is relevant.	4.45	4.23 - 4.68
5	Describing substeps based on actions from a predefined list is an improved addition in the step by step concept.	4.32	4.11 - 4.53

^ Confidence interval

DISCUSSION

In this study, a framework to segment surgical procedures into a uniform and standardized method was proposed. The framework aimed to be broadly applicable to all surgical disciplines. It was presented to an international expert panel consisting of general, gastrointestinal and oncological surgeons to assess their agreement on its preciseness, novelty, usefulness and applicability. In the first round, one statement concerning novelty needed further exploration: 'The proposed step-by-step concept is new in the surgical world'. The original statement from round one was rephrased in five clarifying statements exploring different aspects of the presented step-by-step framework. The focus of the statements shifted from 'novelty' to 'preciseness'. The panel established consensus in two Delphi rounds on the preciseness, usefulness and applicability of the framework. Consensus was not achieved on the novelty of the step by step framework. The use of substeps, being based on anatomical structures with a predefined list of subsequent actions, was found to be an improvement in the step by step framework.

The novelty of the framework was not agreed upon. Segmenting surgical procedures into steps and substeps is not new in the surgical world, as old books described procedures in a step-by-step manner. Previously published studies have described their own method of segmenting surgical procedures, but these have not yet been implemented widely. One explanation might be that the previous frameworks were unclear and ambiguous in the definitions used for the steps and other elements.[8-9] Another explanation may be the time-intensive process of defining the steps. Sarker and colleagues[16] described a method that used a surgical task analysis to construct a surgical description. This method consisted of reviewing literature and textbooks, expert panel discussions and video-recordings. It is thorough, but time-consuming. Furthermore, it is applicable only to one surgery. Other studies performed video analyses[9, 17-18] or expert panel discussions[10-11, 19] to segment one surgery.

Even though step-by-step descriptions are not new, the clear and unambiguous defining within a framework is. In particular, the definition of substeps being based on anatomical structures and using a predefined list of subsequent actions was seen as an improvement in the step-by-step framework. With the step-by-step framework, the steps can be defined for all surgical procedures in a unified and time-efficient manner. The steps of different operations segmented by this framework are generic and compatible with one another. This has many practical implications. The international expert panel supported the usefulness of the step-by-step framework. It may facilitate the education of surgeons and other surgical staff, communication between all surgical staff, and the assessment of surgeons (in training).

The segmenting principle of cognitive learning theory was applied to the step-by-step framework to facilitate education. Efficiency of learning is higher when prior knowledge can be referred to for creating new knowledge.[3] Within surgery, anatomical knowledge is fundamental, so anatomy is the basis of the proposed step-by-step framework.[5] The step and substep definitions of the step-by-step framework were assessed as clear, concise and unambiguous by the international expert panel. All aspects of a surgical procedure can be fitted into the framework. The definitions are mutually exclusive and collectively exhaustive. With the step-by-step framework, segmentation of surgical procedures into steps can be performed in a unified and standardized manner, creating one universal language for surgical procedures.

The framework can structure and standardize information transfer and communication between surgical staff regarding surgical procedures; this may lead to improved surgical safety.[20] The use of standardized and structured methods to improve surgical safety is widely used and effective. For instance, implementation of the surgical safety checklist has led to a significant reduction in postoperative complications and death rates.[21-22] Furthermore, van de Graaf and co-workers[23] defined key moments during colorectal surgery, which were video-recorded to augment the traditional written synoptic operation reports. The operative notes demonstrated improved availability of essential information when the videos were combined with the traditional reports. One of the reasons suggested by the authors was the stepwise approach employed during systematic video registration.

Assessment of surgeons can be performed using checklists, such as the commonly used Objective Structured Assessment of Technical Skills (OSATS).[24] OSATS uses a global rating scale to assess a surgeon. A surgery-specific method is the Observational Clinical Human Reliability Analysis (OCHRA), which assesses each surgical step for procedural and executional errors. Procedural errors occur when a step is not performed in the correct order or is omitted entirely, whereas executional errors contain the technical errors made within a step.[25-26] To use OCHRA adequately to assess a procedure, the surgical steps have to be defined in a standardized, generic and time-efficient manner, which can be accomplished with the step-by-step framework. The steps of different surgical procedures segmented by the step-by-step framework are compatible, facilitating the assessment of a surgeon. In a training environment, this method provides the trainee with specific feedback for each step of the procedure.

This was a study with an international expert panel including surgeons from countries with high-, middle- and low-resource settings. The framework was found to be applicable in all of these settings, as expected, because the main emphasis of the framework is on anatomical structures, not equipment or materials.

The experts were completely anonymous during this study, facilitating decision-making, as individuals might then be more open and honest with their ratings.[15] This anonymity, however, meant that the round two questionnaires had to be sent to all expert surgeons (not only those who participated in round one), resulting in participants in the second round who had not participated in the first.

In this study, experts of general, gastrointestinal and oncological surgery were included, and the number of procedures assessed during the rounds was limited to two. In further research, other fields of surgery should be included, as this framework should be applicable to any surgical specialty. Participants in further research should be able to test the framework on their own procedures in a training setting.

Even though two reminders were send out per round, the participation rate of 20 of 49 in the first round and 22 of 49 in the second round was lower than anticipated. The first reason might be that the experts were not approached before conducting the research. In addition, this Delphi method was carried out as an online questionnaire, notorious for low response rates.[27]

The step-by-step framework is suitable for the standardized segmentation of surgical procedures into a uniform step-by-step description and demonstration. This framework creates a universal language of surgical procedures that may facilitate education, communication and assessment.

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3

THE EDUCATIONAL EFFECTIVENESS OF INSTRUCTIONAL VIDEOS ON SURGICAL PROCEDURE KNOWLEDGE: A META-ANALYSIS

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Submitted

ABSTRACT

Background

Instructional videos have potential to improve surgical procedure learning by providing visual and auditory cues that help build mental reconstructions of procedural steps and spatial anatomy. However, its educational effectiveness is often evaluated only in terms of technical skills performance and not at a procedural level. The objective of this study was to perform a systematic review and meta-analysis of the educational effect of instructional videos in terms of acquired surgical procedure knowledge in comparison with standard ways (books and lectures) of preparing for surgery.

Methods

This review was conducted and reported according to PRISMA standards and best evidence medical education collaboration methods. Literature search of English articles was performed using EMBASE, MEDLINE and Cochrane CENTRAL databases from January 2000 until May 2020. Study selection, data extraction and study appraisal were performed independently by two reviewers. Studies were appraised for methodological quality using the Medical Education Research Study Quality Instrument and the Cochrane Collaboration's tool for assessing the risk of bias. Standardized mean differences, used as effect size, were computed using a random-effects model.

Results

A total of 11617 citations were obtained of which 77 underwent a full-text review. Ultimately, 7 randomized controlled trials were included in the meta-analysis. An effect size of 1.28 was observed in favor of instructional videos as compared to standard ways of preparing for surgery (95% CI 0.49-2.06; P = 0.001).

Conclusions

Instructional videos are more effective in improving surgical procedure knowledge than traditional ways including lectures and readings from anatomical and surgical atlases. Future research should focus on how learning with instructional videos can be optimized in relation to instructional design variations and learners' individual characteristics.

INTRODUCTION

Decreasing working hours of surgical training worldwide have led to decreased time spent in the skills lab and the operating room by residents.[1] Additionally, surgical residents experience difficulties with learning spatially complex procedures and tend to feel less confident in performing such procedures despite of a proper preparation.[2] Residents need to be better prepared to make efficient use of the available time in the operating room. Subsequently, the need for additional teaching methods, that can effectively be used for learning and teaching surgical procedures, is increasing. The way residents use these methods has been shifting throughout the years. A decade ago, anatomy books, surgical atlases and surgical texts were one of the most common sources used for preparation.[3] Nowadays, residents mostly learn and prepare from online resources including medical apps, books and videos.[4] Especially instructional videos are increasingly popular among residents.[5,6] This is not surprising, since videos provide both visual and auditory cues that facilitate mental visualization of procedural steps including three-dimensional (3D) aspects of anatomy.

The beneficial effect of visual animations has been widely explored and supported in the field of educational psychology.[7,8] Moreover, in a meta-analysis comparing visual animations with static images, the effect size was largest for acquiring procedural-motor knowledge (d=1.06).[7] The working mechanism is explained within the cognitive load theory (CLT).[9,10] This theory assumes that the capacity of human working memory, that is required for processing new information, is limited. Within this framework, three sources of cognitive load are distinguished: intrinsic (content of learning material), extraneous (the way learning material is presented) and germane (actual learning process) cognitive load. The sum of the three cognitive loads should not exceed the working memory capacity, if it does, cognitive overload occurs which eventually impairs learning. To avoid cognitive overload and to improve learning, one can reduce extraneous cognitive load by altering the instructional design, e.g., the way learning material is presented. Presenting surgical procedures in an animated format instead of static pictures and text is one of these examples.

Although the use of instructional videos for surgical procedures has been widely explored in the literature, its effect on surgical procedure learning remains unknown. A recent systematic review of video-based education has shown that most studies focused on technical skills evaluation rather than evaluation of surgical procedure knowledge.[11] Distinction between technical skills and surgical procedure knowledge is essential to make, since technical skills alone are insufficient to fulfill the criteria for optimal surgical performance of a trainee. Optimal surgical performance can be best described at the three levels of human behavior, as proposed by Rasmussen in 1983: *skill-based*, *rule-based,* and *knowledge-based* behavior.[12,13] *Skill-based behavior* represents automated and highly integrated patterns of behavior, which are performed unconsciously by the surgeon (**Table 1**). Example of these patterns are the acquired technical skills, which allow a surgeon to place a suture smoothly without conscious control over his or her own movements. *Rule-based behavior* is applied on the next level, which is controlled by rules and, where a stored rule is triggered by a sign ("if this…, then that…"). The rules can be instructions such as the knowledge of consequential steps of the surgical procedure and relevant anatomy that are applied. *Knowledge-based behavior* is applied during unplanned situations, such as an unexpected anatomical variety, complications or technical flaws, and when no guidelines are available. This model of human behavior provides a convenient conceptual framework for designing and evaluating effective and efficient teaching methods in surgical education.[13]

The illustrated model emphasizes the importance of mastering the procedural knowledge and surgical anatomy next to technical skills in order to achieve optimal surgical performance. Therefore, the aim of this study was to perform a systematic review and meta-analysis of the educational effect of instructional videos on surgical procedure knowledge, thus on the level of rule-based behavior.

Table 1. Surgical performance on three levels of human behavior[9]

Levels of behavior	**Description**	**Example**
Skill-based behavior	Automated motor movements / technical skills	Placing a suture, tissue handling
Rule-based behavior	Procedural knowledge and recognition of relevant anatomy is essential	Identifying the nerve and separating it from the neurovascular bundle before transposing the pedicled artery flap
Knowledge-based behavior	Planning and solving unexpected events/ situations	Stanching an unexpected bleeding, dealing with an unexpected anatomical variation

METHODS

The review was conducted and reported conforming the PRISMA Standards of quality for reporting systematic reviews and best evidence medical education (BEME) collaboration methods.[14,15]

Information sources and search strategy

EMBASE, MEDLINE and Cochrane CENTRAL were searched for publications in English from 2000 until May 2020. The search was augmented with manual searches in key journals and secondary screening through reference lists of existing reviews. The search was conducted by the librarian and included following key terms: surgical training, surgical procedure and education. The full search strategy can be found in **Appendix C**.

Eligibility criteria and study selection

All titles and abstracts were screened independently by two reviewers (KB and TN or KB and VW). The remaining articles underwent an independent, full-text screening by the same reviewers. Disagreements were solved through consensus. If consensus was not reached, a third reviewer TW was consulted. Studies were selected according to the following hierarchical eligibility criteria:

1. Study was an original, full, peer-reviewed article written in English. *Conference papers, letters to editors, comments and study protocols were excluded.*
2. Study had a randomized controlled study design.
   Non-randomized comparative study, single group with pretest and posttest, single group posttest only and cross-sectional study designs, and reviews were excluded.
3. Study subjects were residents, fellows and/or medical students in any surgical field. *Subjects form other residency programs (i.e. family medicine residents), nursery, dental and veterinary programs were excluded*
4. Study intervention involved teaching method with the use of instructional video or animation of a standardized surgical procedure on the level of rule-based behavior. *Instructional videos to enhance surgical performance on the level of skill-based behavior (e.g., basic technical, laparoscopic and robotic skills), level of knowledge-based behavior (e.g., communication skills, problem- solving skill) and other than surgical performance (e.g., overall clinical skills, physical examination skills) were excluded.*

5. Study control involved traditional teaching method including lectures, online readings and readings from textbooks.
6. Study reported outcomes that included objectively assessed improvements of surgical procedure knowledge on paper (level 2 of the Kirkpatrick's model, adopted by Steinert et al.[16] (**Appendix D**)

Data extraction

Following items were extracted from the collected data using a piloted extraction sheet: type of study design, target group and surgical field, inclusion or exclusion criteria, number of participants, type of instructional video, duration of learning session, type of assessment tool, outcome level, outcomes and their definitions. When some information was missing, reviewer (KB) requested this information from authors via e-mail.

Study appraisal

Methodological quality of individual studies was assessed using the validated Medical Education Research Study Quality Instrument (MERSQI), which was developed for appraisal of the methodological quality of medical education research.[17] This assessment tool applies to a broad range of study designs and consists of 10 items clustered in the following six domains: (1) study design, (2) sampling, (3) type of data, (4) validity of evidence for evaluation instrument scores, (5) data analysis, and (6) outcome. For each domain, a minimum of 1 and maximum of 3 points can be awarded resulting in a total score ranging from 5 to 18.

Risk of bias was assessed using the Cochrane Collaboration's tool for assessing risk of bias.[18] This tool consists of seven domains: sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting and 'other issues'. For each domain, 'low risk', 'high risk' or 'unclear risk' was assigned based on the criteria provided by the Cochrane Handbook.

Data-analysis

A descriptive analysis was performed to summarize the included studies. A meta-analysis was performed to assess the effect of instructional videos on the acquired surgical procedure knowledge. Standardized mean differences (d), used as the effect size, were calculated based on means and standard deviations. If the study included both pre- and posttests, only post-test scores were used for the analysis. Heterogeneity between studies was quantified by I^2 statistics.[19] In case of large inconsistency ($I^2 > 50\%$), a random-effect model was used to pool the weighted effect sizes. Sensitivity analysis was performed by excluding studies with low methodological quality (MERSQI score < 12) or with at least one assigned 'high risk' of bias. Publication bias was assessed using funnel plots and Egger's test.[20] Review Manager (version 5.3, The Cochrane Collaboration, Oxford, England) was used for the analyses.

RESULTS

After removal of duplicates and identification of additional records through other sources, a total of 9252 citations were identified through the search strategy. From these, 77 potentially eligible articles were identified and a total of 7 studies were included in the qualitative analysis.[21-27]

Study characteristics

Study designs included randomized controlled trials with pre-and post-test[22,23,26,27] (n = 4) and post-test only[21,24,25] (n = 3) (**Appendix E**). The included studies involved 370 participants who were 261 medical students and 119 surgical residents and fellows. The most common types of procedures were performed in the field of orthopedic surgery[21,24] (n = 2) and obstetrics & gynecology[23,25] (n= 2), followed by general surgery[27] (n = 1), cardiac surgery[22] (n = 1) and plastic and reconstructive surgery[21] (n=1). The allocated preparation time varied between 20 minutes to unlimited access for 30 days. Instructional videos were provided either in a segmented format[21,22,24,27] (n = 4) or continuous[22,24,26] (n = 3) format. In all studies (n = 7), the acquired procedural knowledge was assessed by a written knowledge test including multiple choice questions (MCQ)[21-25,27] (n = 6) and marking / open questions[26] (n = 1).

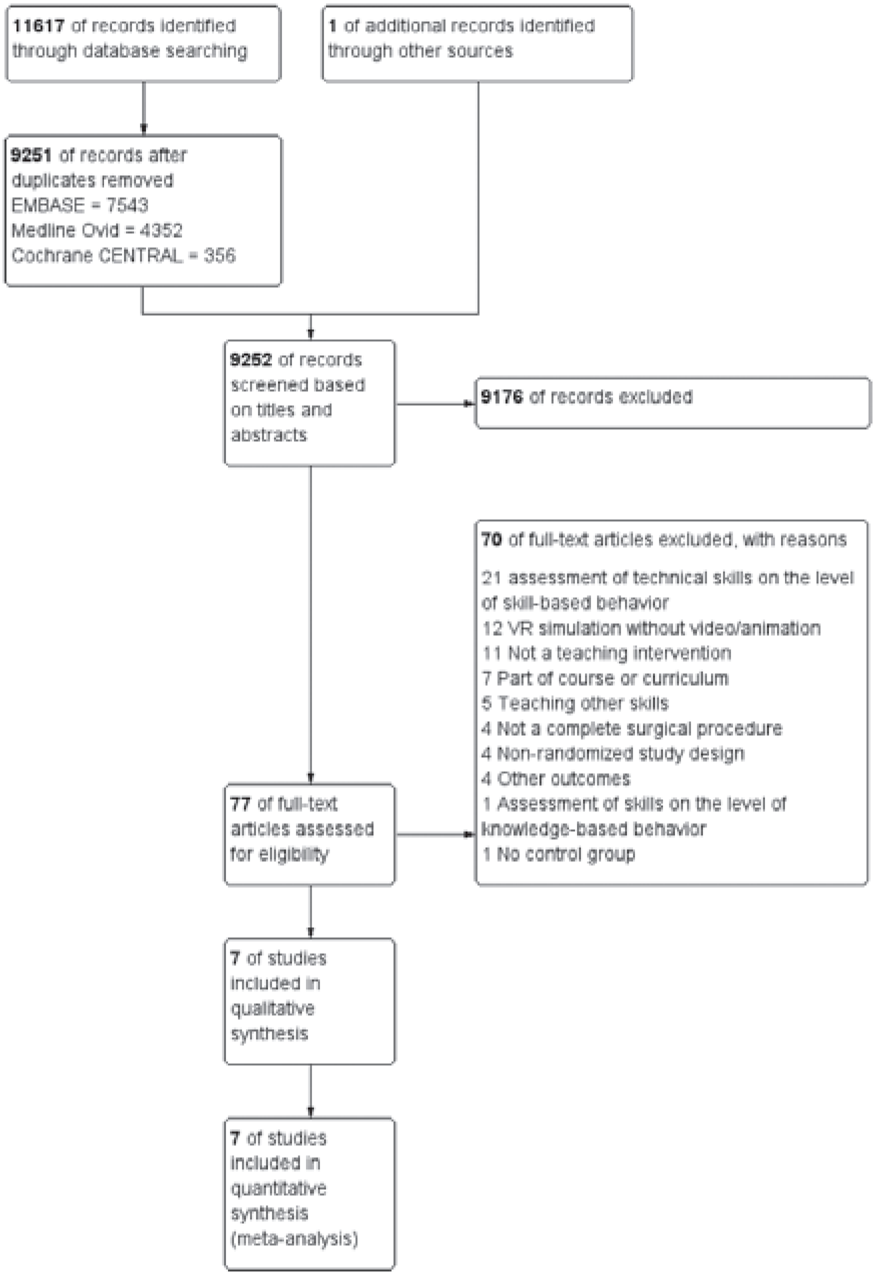

Figure 1. Flow diagram of study selection

Study appraisal

The appraisal of methodological quality and the assessment of risk of bias of the included studies are reported in **Table 2**. The mean MERSQI scores for the included 7 studies was 13.4, ranging from 11.5 to 14.5 High risk of bias was assigned within two studies on domains Sequence Generation and Incomplete Outcome Data.

Table 2. Methodological quality appraisal with the Medical Education Research Study Quality Instrument (MERSQI) and assessment of risk of bias with the Cochrane Collaboration's tool for assessing risk of bias.

Author	**MERSQI score**	**Domains with an assigned 'high risk' of bias**
Total mean score (N = 7)	13.4	
Amer et al., 2017[21]	13.5	Sequence generation (randomization was based on birth year)
Friedl et al., 2006[22]	12.5	-
Harzif et al., 2018 [23]	13.5	-
Hearty et al., 2013[24]	14.5	-
Norris et al., 2020[25]	13.5	-
Plana et al., 2019[26]	14.5	-
Shariff et al., 2015[27]	11.5	Incomplete outcome data (< 75%)

Meta-analysis

A significant positive effect on overall surgical procedure knowledge was observed in favor of instructional videos (ES = 1.28, 95% CI 0.49-2.06; P = 0.001; I^2 = 90%; n = 7) (**Figure 2**).

The funnel plot of included studies, as shown in **Figure 3**, showed a slight asymmetry suggesting that publication bias cannot be ruled out completely. Egger's test could not be performed due to a small number of studies (n < 10).

Sensitivity analysis was performed by excluding studies with low methodological quality (MERSQI score < 12) or with at least one assigned 'high risk' of bias. Two studies[21,27] with low methodological quality and/or high risk of bias were removed. The effect size was slightly increased in favor of instructional videos (ES = 1.37; 95% CI 0.29 - 2.45; *P* = 0.01; I^2 = 90%; n = 5).

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Amer et al., 2017	89.3	6	50	75.6	8.7	50	15.8%	1.82 [1.35, 2.29]
Friedl et al., 2006	76.7	13.3	69	76.9	11.1	57	16.2%	-0.02 [-0.37, 0.33]
Harzif et al., 2018	66.93	11.58	7	52.71	3.9	7	11.8%	1.54 [0.30, 2.79]
Hearty et al., 2013	90.9	6.8	14	73.5	6.4	14	13.0%	2.56 [1.52, 3.59]
Norris et al., 2020	8.42	0.79	12	7.11	1.36	12	13.9%	1.14 [0.26, 2.01]
Plana et al., 2019	5.17	1.86	18	2.11	1.27	17	14.2%	1.87 [1.06, 2.68]
Shariff et al., 2015	6.6	5.1	25	4.89	3.66	18	15.2%	0.37 [-0.24, 0.98]
Total (95% CI)			195			175	100.0%	1.28 [0.49, 2.06]

Heterogeneity: $Tau^2 = 0.96$; $Chi^2 = 60.34$, $df = 6$ ($P < 0.00001$); $I^2 = 90\%$
Test for overall effect: $Z = 3.19$ ($P = 0.001$)

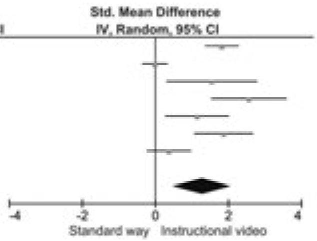

Figure 2. Pooled effect size for studies comparing instructional videos with traditional ways of preparing for surgeries. 95% CI, 95% confidence interval.

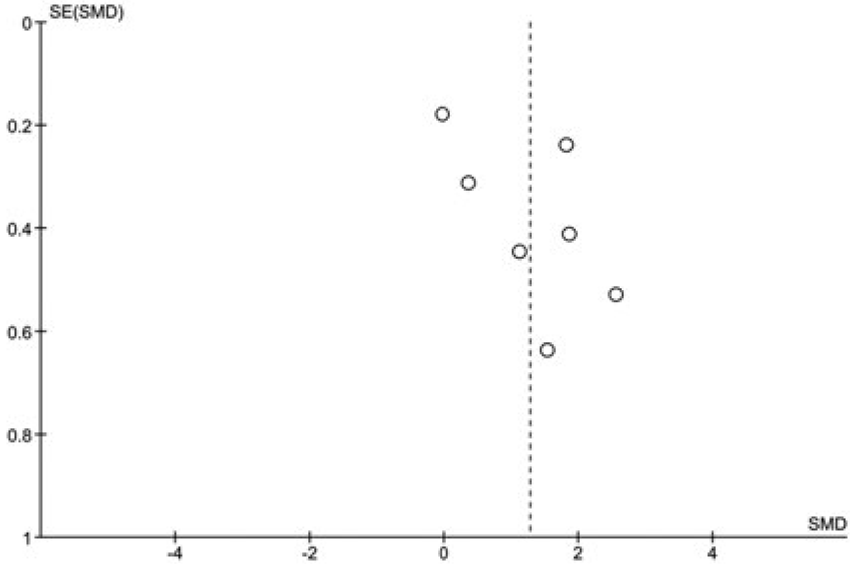

Figure 3. Funnel plot for studies included in the meta-analysis comparing instructional videos with standard ways of preparing for surgeries.

DISCUSSION

The findings of the meta-analysis indicate that the instructional videos contribute to a better comprehension of surgical procedure knowledge than conventional educational tools including lectures and readings with two-dimensional (2D), static, images. The learning effect of instructional videos on surgical performance was assessed on the level of rule-base behavior which refers to mastering surgical procedure knowledge and anatomy as one of the building blocks of optimal surgical performance. These findings support the evidence that visual animations can reduce extraneous cognitive load by providing both visual and auditory cues that help build mental reconstructions. This in turn leaves sufficient amount of cognitive resources for actual learning, as previously explained within the framework of Cognitive Load Theory.[9]

Although this review did not focus on specific features of instructional method and individuals' characteristics of learners, these factors can potentially affect learning under specific circumstances and need to be addressed in more depth. Specific characteristics of instructional videos include segmented versus continuous format, stereoscopic (3D) versus monoscopic (2D) visualization and active versus non-active user control. For instance, segmentation of procedural steps can potentially improve learning, as has been previously demonstrated by Nazari et al.[28] In their study, watching an instructional video of an open inguinal repair in a segmented format, step by step, has resulted in lower extraneous cognitive load and fewer procedural errors among medical students as compared to continuous format. In the current meta-analysis, segmented format was used in four studies. Another important feature concerns the ability to view a surgical video in real 3D, or stereoscopically. Providing visual-spatial depth can help build mental reconstructions of procedural steps and spatial relations of anatomical structures, especially in spatially complex procedures. As has been demonstrated by Bogomolova et al. watching instructional videos in 3D can potentially enhance learning, depending on the level of visual-spatial abilities and level of expertise of the learners.[29]

It is also important to note that the participants of the included studies were both medical students and residents. The various levels of expertise and prior knowledge could have affected the results of individual studies. Nevertheless, regardless of the level of expertise, the results still pointed out towards the significant effect sizes in favor of instructional videos. Another important aspect, which is almost unavoidable in the context of educational research, is the diversity of surgical procedures included in the studies. Although, these were all spatially-complex procedures, the complexity of individual procedures may differ significantly between studies and consequently affect their individual results.

Appraisal of the included studies was performed evaluating both methodological quality and risk of bias. Overall, the methodological quality was above the average MERSQI score of 12 points. Only one study showed relatively weak methodological quality with 11.5 points and one assigned high risk of bias to incomplete data analysis/follow up.[27] When this study was excluded from the meta-analysis, the overall effect size remained significantly positive and in favor of instructional videos. The publication bias, on the other hand, could not be fully ruled out.

Limitations

This study has several limitations. First, the heterogeneity across the studies was relatively high. However, it could not be avoided due to the methodological diversity that is quite common in educational research. Along with this diversity, second point concerns the fact that no distinction was made between different types of procedures, learners and duration of the learning session. Due to a relatively small number of studies, the described distinctions could not be made within the meta-analysis. Third, the standard ways of preparing for surgeries slightly differed across studies and could have affected the outcomes. Lastly, publication bias could not be fully ruled out.

CONCLUSIONS

In this meta-analysis, the educational effect of instructional videos on surgical procedure knowledge on the level of rule-based behavior was evaluated. Overall, instructional videos of surgical procedures are more effective than the standard way of preparing for surgeries that including lecture and readings form anatomical and surgical atlases. Future research should focus on how learning with instructional videos can be optimized in relation to variations in instructional design and learners’ individual characteristics.

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4

CONTINUOUS VERSUS STEP BY STEP TRAINING FOR LEARNING SURGICAL ANATOMY ON AN OPEN INGUINAL HERNIA MODEL

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ABSTRACT

Background

Segmentation of surgical procedures may facilitate learning. The step-by-step framework segments surgical procedures in a standardized manner based on anatomy. The effects of the framework are compared to a continuous approach, on learning anatomy on an inguinal hernia model by pre-novices.

Methods

Students from 10 high schools located in or near Rochester, Minnesota, were randomized into continuous and step-by-step groups. They trained using step-by-step versus continuous video-demonstrations of an open inguinal hernia repair on a simulation model. Anatomical knowledge and cognitive load were assessed.

Results

In total, 220 students participated (156 female; mean age 15 years). In the selection that watched the video-demonstration, the step-by-step group answered 1.9 questions correctly, and the continuous group 2.4, p=0.010. The cognitive load did not differ between the groups.

Conclusions

In pre-novices, anatomy knowledge transfer might be better using continuous rather than step-by-step video-demonstrations.

INTRODUCTION

To prepare for a surgical procedure, learners may use many resources (journals, books, video, et cetera) including learning from their superiors by watching them perform the surgery in the operating room, known as the master-apprentice model.[1] Due to work hour regulations and decreased exposure time in the operating room, the emphasis today in surgical education is on better preparation before entering the operating room.[2-3] A framework based on anatomical structures has been proposed by our group to segment surgical procedures into steps in a standardized manner.[4] An international expert panel supported the preciseness, usefulness, and applicability of the step-by-step framework. We pondered that the step-by-step framework may also facilitate surgical training for anatomical knowledge using the video-demonstration of a surgical procedure.

The process of learning and the effectiveness of instructional design choices should be understood to optimize the teaching process. The cognitive theory of multimedia learning can explain the learning process from dynamic visualizations such as video and animation.[5] An assumption in this theory is that learners have a limited cognitive capacity available to process new information.[6]

The cognitive capacity needed to process new information is known as cognitive load.[7] When this new information is presented as a video or animation (streaming information), the cognitive load can be high because information that is disappearing from the screen needs to be retained and processed in working memory, or otherwise information that is later presented on the screen cannot be understood (also called transiency of information).

To lower the cognitive load, the segmentation principle in the cognitive theory of multimedia learning can be applied.[8] With the segmentation principle, the video is divided into smaller parts with pauses in between, allowing learners to completely process one segment before moving on to the following segment. Segmentation could also lower the cognitive load by constructing a cognitive schema of the task.[9] The construction of cognitive schemas is especially useful for novices as they do not possess the schemas to comprehend a complex task yet.[8]

In the surgical field, the effects of the step-by-step framework on learning surgical anatomy have not been proven. The current study aimed to investigate the effects of an online course based on the step-by-step framework, consisting of a video-demonstration and textual description of the knowledge of the surgical anatomy of a surgical procedure in pre-novices, such as high school students. The primary endpoints are anatomical knowledge and cognitive load.

METHODS

Design

It was a randomized study with two groups: an online course containing continuous video-demonstration and textual description (continuous group) and an online course containing segmented video-demonstration and textual description (step-by-step group). Random assignment to one of the two groups was realized on school level in which all students of each participating school were included within the same group to prevent contamination. This cluster randomization was chosen as students from the same classes, and teachers cannot be randomized on an individual basis as there is too much risk of contamination. The risk of cluster randomization is an imbalance between the groups, a recruitment bias, such as different teachers, different amounts of attention to the study, etcetera. This problem has been addressed by a large sample size.[10] The randomization was blinded for the researchers.

The open inguinal hernia repair was chosen as a surgical example for the study since this procedure is complicated and execution cannot be performed without adequate anatomical knowledge. One week before the test, the high school students were granted access to their group-specific online course to prepare for the test. During the test day, the students filled in a questionnaire and were examined on their anatomical knowledge using a simulation model representing all relevant anatomical structures. **Figure 1** outlines the study design.

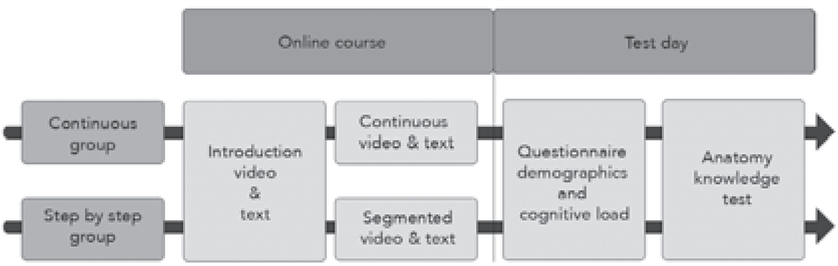

Figure 1. Study design

Participants

The participants were 220 high school students (64 male and 156 female) from 10 high schools in or near Rochester, Minnesota, in the United States. The participants' average age was 15 years (SD ±2, range 12 to 18) with a median grade of 11 (range 7th to 12th grade).

The study took place within the Mayo Clinic in Rochester, Minnesota, as part of a more extensive seminar involving other medical learning experiences (The "Saving Lives with Gus" seminar offered exposure to CPR, using a defibrillator, tying surgical knots, using an ultrasound machine, et cetera.) Participation was voluntary and all participants consented to the study.

MATERIALS

Online course

One week before the seminar, the students could access an online course where they were instructed to study a surgical procedure (open inguinal hernia repair) and anatomy (male groin). The students had one week to study the course. The course consisted of an introduction, the video-demonstration and textual description of the open inguinal hernia repair including all the anatomical terms. The difference between the two groups was a continuous video-demonstration and textual description versus a step-by-step video-demonstration and textual description of the surgical procedure. The rest of the course, including the information about anatomy, was identical.

The introduction contained a text and a video of 2:39 minutes, which explained an inguinal hernia. The text also explained a hernia and medical jargon such as medial and lateral. The introduction was similar for both groups.

The video demonstrated surgery on an open inguinal hernia simulation model of a male patient. The simulation model mimicked the abdominal wall as each felt layer corresponded with an abdominal wall layer, for example, Camper's fascia, Scarpa's fascia, external oblique aponeurosis, internal oblique muscle and transversalis fascia. In the video-demonstration, all the encountered anatomical structures were emphasized. These structures were mentioned by the voice-over, shown by highlighting the structure and were named on the screen (**Figure 2**).

The simulation model was used to create a realistic environment for the student in order to motivate them.

Figure 2. Open inguinal hernia repair simulation model

The continuous group accessed the online course containing the introduction and on a separate page the continuous video-demonstration of the open inguinal hernia repair (10:56 minutes). The continuous textual description was below the video. The step-by-step group reached the online course containing the identical introduction as the continuous group. On a separate page were the step-by-step video-demonstration of the open inguinal hernia repair and textual description. For the step-by-step group, the video was 11:14 minutes in length; six segmented surgical steps, and title frames with the name of the step of 3 seconds before each step. Below the video was the step-by-step textual description in table-form with steps, substeps, and the actions. Each substep, a combination of an anatomical structure and an action, had its explanation.[4] This information was the same as the information for the continuous group but formally structured. Both groups could view the video-demonstration and textual description simultaneously. The videos could be watched as often as wanted and could be paused whenever the participant desired.

Questionnaire

The high school students were asked to fill in a questionnaire regarding their time spent studying the online course and how they perceived their cognitive load during the online course (**Appendix F**). The questionnaire also inquired if the teacher had discussed the course in class, and if so, how many hours.

The cognitive load during preparation was measured using a shortened rating scale of Leppink.[11] The questionnaire included four statements concerning cognitive load (**Table 5**). Each statement was scored on a 10-point Likert scale, ranging from 0 “not at all” to 10 “completely”.

Anatomy knowledge test

The learning outcomes were assessed using an anatomy knowledge test in which the students had to recognize the correct anatomical structures in the model. During the exam, the high school students received a list of 8 anatomical structure names that had to be linked to the 6 questioned anatomical structures in the model (**Table 1**). The maximum score was 6 correct answers. The model used during the experiment was identical to the model used in the video-demonstration during the online course.

Table 1. Eight anatomical structures within the open inguinal hernia simulation model

1. Skin
2. Camper’s fascia
3. Scarpa’s fascia
4. External oblique aponeurosis
5. Internal oblique muscle
6. Spermatic cord
7. Inguinal ligament
8. Transversalis fascia

Statistical analysis

All statistical analyses were done with SPSS (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.). The dependent variables were the number of correct answers on the anatomy knowledge test and the scores on the modified cognitive load questionnaire. The independent variable was the type of online course;

continuous or segmented based on the step-by-step framework. The Chi-square test or the Mann Whitney U test were used to compare the groups. The internal consistency for the cognitive load was determined using Cronbach's α. P-values of less than 0.05 were considered statistically significant.

RESULTS

A total of 220 high school students from ten high schools participated. The continuous group consisted of 108 students with 85 females (78.7%) and an average age of 17 years (range 15-18). The step-by-step group (n=112) consisted of 71 females (63.4%) with an average age of 14 years (range 12-18) (**Figure 3**). More students in the step-by-step group watched the introduction video regarding the open inguinal hernia repair (*p*=0.002), while more students in the continuous group watched the video-demonstration (*p*=0.006). There was no difference in study time on the website, additional lessons of the high school teacher, or explanation time of the high school teacher (**Table 2**).

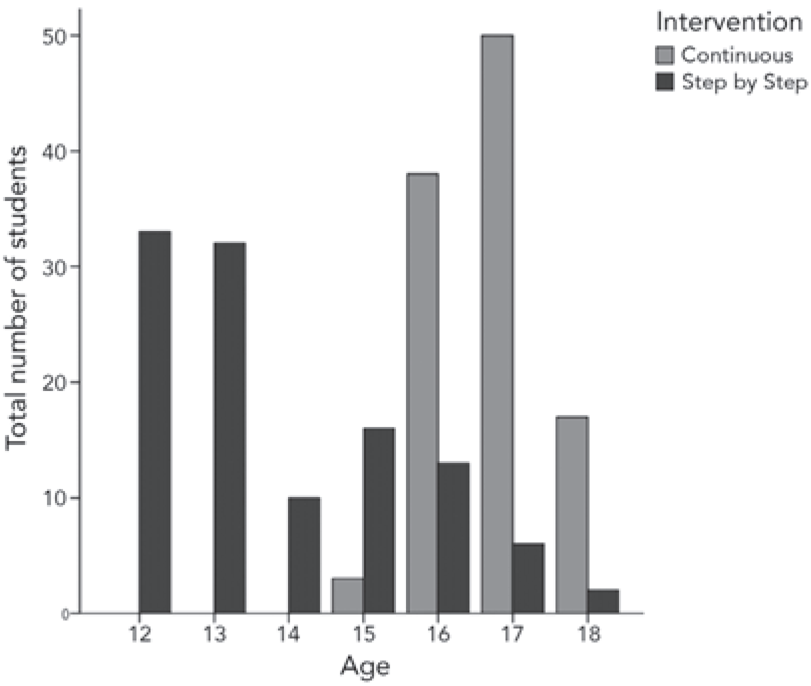

Figure 3. Age distribution

Table 2. Preparation

		Continuous group (n=108)	Step-by-step group (n=112)	*p*-value
Gender	Female (n)	85 (78.7%)	71 (63.4%)	
	Male (n)	23 (21.3%)	41 (36.6%)	0.012^*
Age in years (median; range)		17 (15-18)	13 (12-18)	<0.001†*
Watched introduction video	Yes (n)	86 (79.6%)	105 (93.8%)	0.002^*
Watched video-demonstration	Yes (n)	71 (65.7%)	53 (47.3%)	0.006^*
Study time on website (n)	0 hours	1 (0.9%)	1 (0.9%)	0.734^
	0-1 hour	101 (93.5%)	102 (91.1%)	
	1-2 hour	6 (5.6%)	7 (6.3%)	
	2-3 hour	0 (0%)	1 (0.9%)	
	≧ 4 hours	0 (0%)	1 (0.9%)	
Additional lessons of high school teacher (n)	Yes	21 (19.4%)	24 (21.4%)	0.715^
Explanation time high school teacher (n)	0 hours	88 (81.5%)	90 (80.4%)	0.132^
	0-1 hour	20 (18.5%)	18 (16.1%)	
	1-2 hour	0 (0%)	4 (3.6%)	

^ analyzed using Chi square test; † analyzed using Mann-Whitney U test; * statistically significant

In the complete selection (n=220), the continuous group had an average of 2.1 answers correct (±SD 1.2) out of the 6 anatomy knowledge questions compared to 1.7 in the step-by-step group (±SD 1.3), U=4826, p=0.008 (**Table 3**). Variables that had a significant effect on the number of correct answers on the anatomy knowledge test were watching the video-demonstration (U=3916, p<0.001), age (p=0.017) and additional lessons of the high school teachers (U=2857, p=0.004).

Table 3. Comparison of the students that watched the video-demonstration versus that did not watch the video-demonstration within the continuous and the step-by-step group

		Continuous group (n=108)			Step-by-step group (n=112)		
		Watched video-demonstration	**Not watched video-demonstration**	**Statistical analysis**	**Watched video-demonstration**	**Not watched video-demonstration**	**Statistical analysis**
Total participants (n)		71	37		53	59	
Gender	Female (n)	54	31	p=0.352^	35	36	p=0.582^
	Male (n)	17	6		18	23	
Age (mean; in years)		17	17	U=1096 p=0.127^f	14	14	U=1432 p=0.432^f
Additional lessons of high school teacher	Yes (n)	17	4	p=0.102^	18	6	p=0.002^*
	No (n)	54	33		35	53	
Explanation time high school teacher	0 hours (n)	53	35	p=0.011^*	35	55	p=0.001^*
	0-1 hour (n)	18	2		14	4	
	1-2 hour (n)	0	0		4	0	
Number of correct answers (mean)		2.4±1.0	1.5±1.5	U=788 p<0.001^f*	2.0±1.3	1.4±1.3	U=1205 p=0.031^f*

^ analyzed using Chi square test; ^{f} analyzed using Mann Whitney U test; * statistically significant

As shown in **Table 3**, independent of the intervention, the students that watched the video-demonstration answered 2.2 anatomy knowledge test questions correctly in comparison to 1.5 correct answers in the students that did not watch the video-demonstration, U=3916, p<0.001. Within the continuous and step-by-step group, the students that watched the video-demonstration scored significantly higher on the anatomy knowledge test than students that did not watch the video, p<0.001 and p=0.031, respectively (**Table 4**). The gender and age of the students that watched and did not watch the video-demonstration were similar. In the continuous group, more students watched the video-demonstration when the high school teacher spent more time in class discussing the online course (p=0.011). In the step-by-step group, more students watched the video-demonstration when the high school teacher gave additional lessons (p=0.002) and spent more time in class (p=0.001).

Table 4 shows the subanalysis of the students that watched the video-demonstration. Of the 124 participants (56.4%) that watched the video-demonstration of the surgical procedure, the students within the continuous group answered an average of 2.4 questions correctly, and the students in the step-by-step group answered 1.9 questions correctly, *U*=1392, *p*=0.010. In this sub-selection, age (*p*=0.111) and additional lessons of high school teachers (*U*=1227, *p*=0.058) were non-confounding variables.

Table 4. Effect of variables on the number of correct answers on the anatomy test

		All participants (n=220)		Participants watched video-demonstration (n=124)	
		Mean amount of correct answers ± SD	**Statistical analysis**	**Mean amount of correct answers ± SD**	**Statistical analysis**
Intervention	Continuous	2.1±1.2	U=4826 p=0.008^{f}*	2.4±1.0	U=1392 p=0.010^{f}*
	Step-by-step	1.7±1.3		1.9±1.3	
Age			p=0.017^*		p=0.111^
Gender	Female	1.9±1.2	U=4732 p=0.535^{f}	2.2±1.1	U=1556 p=0.993^{f}
	Male	1.8±1.5		2.2±1.3	
Watched the video-demonstration	Watched	2.2±1.2	U=3916 p<0.001^{f}*	Not applicable	
	Not watched	1.5±1.4			
Additional lesson high school teacher	Yes	2.4±1.2	U=2857 p=0.004^{f}*	2.5±1.2	U=1227 p=0.058^{f}
	No	1.8±1.3		2.1±1.1	
Time high school teacher spend			p=0.146^		p=0.549^

^ analyzed using Chi square test; ^{f} analyzed using Mann-Whitney U test; * statistically significant

On the different statements of the cognitive load (internal consistency of Cronbach's alfa=0.707) and the total rating of the cognitive load, no significant differences were found between the continuous and the step-by-step group (**Table 5**).

Table 5. Shortened cognitive load rating

	Continuous group	Step-by-step group	Statistical analysis (Mann-Whitney U)	
	Mean±SD	Mean±SD	U	p-value
The content of this activity was very complex.	5.3±2.2	5.4±2.1	5402.5	0.801
In this activity, complex terms were mentioned.	6.1±2.5	6.2±2.4	5387	0.775
I invested a high mental effort in this activity.	6.0±2.5	5.7±2.6	5064.5	0.306
This activity really enhanced my understanding of the content that was covered.	6.5±2.4	6.7±2.6	5104.5	0.350
Total rating cognitive load	6.0±1.9	6.0±1.7	5503	0.984

DISCUSSION

In this study, the effects of a video-demonstration of a surgical procedure based on the step-by-step framework on anatomy knowledge and cognitive load were compared to a continuous video-demonstration. High school students studied a surgical procedure with an emphasis on anatomical structures and were tested on their anatomical knowledge. The continuous group answered slightly more questions correct on the anatomy knowledge test compared to the step-by-step group. The cognitive load was similar for the continuous group and the step-by-step group.

The continuous group was on average older than the step by step group, which was a confounding variable. In the sub-selection of the students that watched the video-demonstration, age was, however, no confounding variable. A more critical factor for answering more correct answers was the preparation by watching the demonstration video. Our results suggest that the transfer of anatomical knowledge in pre-novices may be better when information is presented continuously.

Based on previous studies, the expectation was that the step-by-step group would score higher on the anatomy knowledge test and lower on the cognitive load.[12-14] Moreno reported that the segmentation group outperformed the continuous group and had a lower cognitive load.[14] In both experiments of Moreno, they included pre-service teachers (average age 25 years old) in an introductory educational psychology course in their last semester of the teacher education program. Moreno selected participants with knowledge in the field they were tested in, contrary to our students that did not know the open inguinal hernia repair. Our participants were also younger compared to Moreno's participants. In a study with elementary school students (age 9 to 11), studying the causes of day and night, the segmented group outperformed the continuous group.[15]

Our high school students studied a surgical procedure with its relevant anatomy, which might be more complex to comprehend for high school students compared to the causes of day and night. The students in both groups had a low number of correct answers in the anatomy knowledge test, indicating they might have been too novice and had too little prior knowledge to be able to learn the open inguinal hernia repair and its anatomy adequately. They were likely unfamiliar with the medical jargon used in the video-demonstration and textual description. Exposing students to information that is too complex for their level of expertise, risks overloading their cognitive abilities and impairs learning.[5, 16-17] Further research comparing step-by-step to continuous video-demonstration should be performed in participants with more medical knowledge, such as medical students, surgical residents or surgeons.

The data suggested a similar experienced cognitive load in both groups. This was, however, not measured immediately after viewing the course, but during the test day. Furthermore, the assessment included the entire online course and not the video-demonstration exclusively, which could also explain the same cognitive load in both groups.[11] We expected that some high school teachers would discuss the online course in class. In the continuous and the step-by-step group, the number and the duration of additional lessons were similar. As high school teachers are no experts in open inguinal hernia repair, they likely could only either stimulate the students to do the online course or could watch the video-demonstration in class. Within the sub-selection of students that watched the video-demonstration, there were no effects of the high school teachers' additional lessons on the number of correct answers on the anatomy knowledge test.

In the step-by-step group, we built-in a pause of 3 seconds after each segment. All participants could pause and rewatch the video-demonstration themselves. Indeed, in the continuous group, this perhaps led learners to create their own segmentation. We could not monitor how many times the students paused or watched the video-demonstration. In case the continuous group students watched or paused the video-demonstration more times compared to the step-by-step group, the segmentation effect of the step-by-step group may have been diminished.[12]

The cluster randomization occurred by school in order to avoid students sharing access to the continuous and step-by-step video-demonstrations. Unfortunately, this led to a significant difference in the age distribution between the groups. In the complete selection, older age resulted in significantly more answers correct in the anatomy knowledge test. Within the selection that watched the video-demonstration, age did not affect the mean correct answers of the anatomy knowledge test. Before cluster randomization, the differences per high school should have been assessed.

CONCLUSIONS

In summary, we found that the continuous group scored slightly higher on the anatomy knowledge test compared to the segmented step-by-step group. The subjects in this study might have been too novice as both groups answered a low number of anatomical questions correct. Further research on online video-based course on inguinal hernia repair should test more experienced learners to investigate the hypothesis that a step-by-step framework facilitates learning by optimizing the use of the cognitive capacity and subsequently, the learning process.

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5

ONE STEP AT A TIME: STEP BY STEP VERSUS CONTINUOUS VIDEO-BASED LEARNING TO PREPARE MEDICAL STUDENTS FOR PERFORMING SURGICAL PROCEDURES

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ABSTRACT

Background

The objective of this study was to compare the effects of cognitive load and surgical performance in medical students that performed the open inguinal hernia repair after preparation with step-by-step video-demonstration versus continuous video-demonstration. Hypothetically, the step-by-step group will perceive lower extraneous load during the preparation of the surgical procedure compared to the continuous group. Subsequently, fewer errors will be made in the surgical performance assessment by the step-by-step group, resulting in better surgical performance.

Methods

In this prospective study, medical students who were enrolled in extracurricular anatomy courses at Erasmus University Medical Center, Rotterdam, the Netherlands, were randomly assigned to the step-by-step or continuous video-demonstration. They completed questionnaires regarding perceived cognitive load during preparation (10-point Likert scale). Their surgical performance was assessed on a simulation hernia model using the Observational Clinical Human Reliability Assessment.

Results

Forty-three students participated; 23 students in the step-by-step group and 20 in the continuous group. As expected, the step-by-step group perceived a lower extraneous cognitive load (2.92±1.21) compared to the continuous group (3.91±1.67, p=.030). The surgical performance was not statistically significantly different between both groups; however, in subanalyses on a selection of students that prepared for 1 to 2 hours, the step-by-step group made less procedural errors, 1.67±1.11, compared to the continuous group, 3.06±1.91, p=.018.

Conclusions

Our results suggest that preparation using step-by-step video-based learning results in lower extraneous cognitive load and subsequently fewer procedural errors during the surgical performance. For learning purposes, demonstration videos of surgical procedures should be presented in a segmented format.

INTRODUCTION

Since the dawn of the digital age, surgical education has undergone an immense evolution, from its initial 'master and apprentice' model in which apprentices learned from observing in the operating room to a time in which the 21st-century learner has the availability to learn by observing a multitude of online resources, for example, medical apps, books and videos.[1] Online videos are used frequently by medical students and residents and are known to be excellent tools to build anatomical and surgical knowledge.[1-3]

To understand how a trainee learns surgical procedures from observing videos, the limited cognitive capacity of the human brain must be taken into account. The cognitive capacity can be burdened when new and complex information is presented in a dynamic and transient format, as in a video-demonstration of a surgical procedure. To grasp the entire surgical procedure video-demonstration, the cognitive load can be high as disappearing information from the video needs to be retained and processed in working memory to understand the information that is presented in the video later.[4] Novices tend to learn better when this complex and transient information is presented in learner-paced segments, rather than as one continuous unit.[5] The learner-paced chunks result in lower perceived cognitive load and, subsequently, in potentially better learning.[5-6] In cognitive learning theory, this is referred to as the segmentation principle.[7]

The segmentation principle is an approach to prevent cognitive overload.[5] As shown in **Figure 1**, three types of cognitive load can be distinguished: intrinsic, germane and extraneous cognitive load.[8-9] The complexity of new information determines intrinsic cognitive load. This type of cognitive load is higher for novices, and as the learner advances, the intrinsic cognitive load decreases. Germane cognitive load is determined by the construction and automation of cognitive schemas and is often categorized together with the intrinsic load.[10] Finally, extraneous cognitive load is determined by the suboptimal presentation of new information.[11-12]

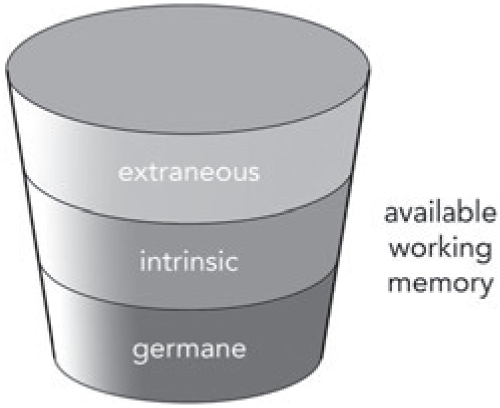

Figure 1. Cognitive load types

While processing new information, the total load of these three types of cognitive load cannot exceed the working memory available as the bucket in **Figure 1** will overflow.[8] During simple tasks that yield low intrinsic cognitive load, the learner will be able to manage the task even if the extraneous cognitive load is high. On the contrary, during complex tasks, such as closely observing or performing a surgical procedure, the intrinsic load will be high. Therefore, the extraneous cognitive load should be reduced as much as possible so that learning and the corresponding germane load can still occur. Theoretically, as shown in **Figure 2**, unsegmented surgical procedure video-demonstration demands high extraneous load (**Figure 2a**). The application of the segmentation principle on video-based learning of surgical procedures would reduce the extraneous cognitive load because it provides additional processing time (**Figure 2b**). This extraneous load reduction gives more opportunity for germane processing (construction of cognitive schemas; **Figure 2c**), and subsequently improve the performance of the surgical procedure.[13]

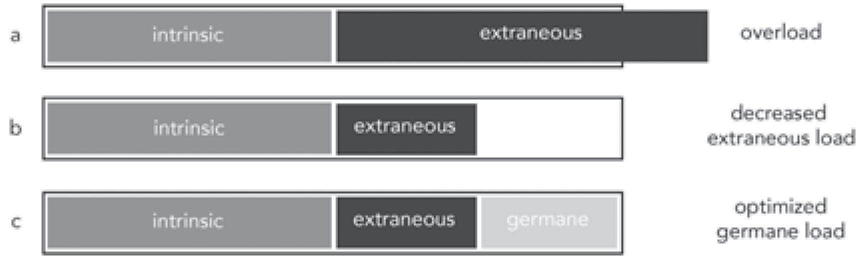

Figure 2. Optimizing cognitive capacity: lowering extraneous load and providing opportunity for germane processing (adapted from Sweller, van Merrienboer & Paas, 1998).

Segmenting surgical procedures into steps and substeps can be done in a standardized approach using our developed step-by-step framework.[14] A step is defined as a surgical goal that needs to be reached and evaluated before proceeding to the next step. A step consists of one or more substeps, which is the combination of an anatomical structure with an action (for example, incise, transect, dissect, et cetera).

Surgical performance can be assessed using various methods. For a stepwise assessment, a validated option is the Observational Clinical Human Reliability Assessment (OCHRA).[15] The OCHRA is a systematic assessment checklist assessing errors on a substep level. Each substep could be assessed as 'correct,' 'procedural error,' or 'executional error.' A substep is assessed as a 'procedural error' when a substep was not performed, partially performed, repeated, or done out of sequence. Executional errors concern a substep performed with too much or too little force, speed, depth, or distance, or a substep executed in the wrong direction or on a wrong structure.

To investigate the effects of segmentation in video-based learning, the Lichtenstein open inguinal hernia repair (LOIHR) was chosen as an example surgical procedure as it is a complex procedure with multiple steps. Medical students prepared themselves using either a step-by-step video-demonstration or a continuous video-demonstration to perform the LOIHR surgery in a controlled environment using an open inguinal hernia repair simulation model.[16] The hypotheses are that the step-by-step group will perceive lower extraneous load during the preparation of the surgical procedure compared to the continuous group. Subsequently, fewer errors will be made in the surgical performance assessment by the step-by-step group, resulting in better surgical performance.

METHODS

Participants, setting and design

Medical students of Erasmus University Medical Center, Rotterdam, the Netherlands who were enrolled in extracurricular anatomy research courses, were approached for participation. The extracurricular anatomy research courses at Erasmus University Medical Center select their students on the grounds of significant interest and knowledge of surgical anatomy. Participation was voluntary, and written consent was gathered before the study. This study among medical students did not require institutional board review according to Dutch law.

During this prospective randomized trial, the participating medical students were randomly assigned to two groups; the step-by-step group (n=23) or the continuous group (n=20). Randomization was stratified per study year. **Figure 3** shows the study design.

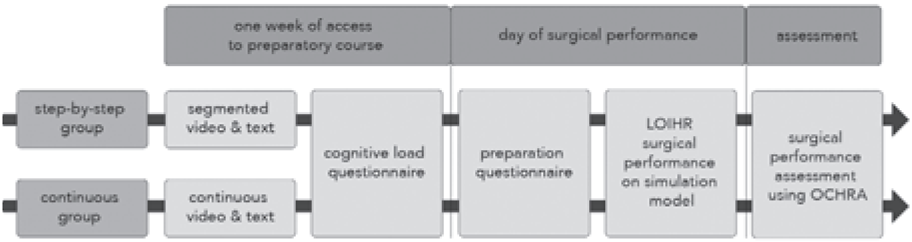

Figure 3. Study design

Step-by-step versus continuous preparatory course

Before the participants performed the surgical procedure, they were granted one week of access to their assigned online preparatory course: the step-by-step or continuous online preparatory course.

The step-by-step group had access to the segmented video-demonstration alongside the associated textual description. The segmentation of the LOIHR video-demonstration and description consisted of 6 steps and 25 substeps, which were constructed using the step-by-step framework.[14] In this step-by-step course, the student was presented the video-demonstration one step at a time. After viewing the video-demonstration of one step (**Figure 4a**), the student had to press on the 'next' button to continue to the next webpage to view the associated textual description of this step (**Figure 4b**). This process was repeated for all six steps (**Table 1**).

Table 1. Duration video-demonstrations

Step-by-step video-demonstration	**Duration (mm:ss)**
Step 1 External oblique aponeurosis exposure	01:38
Step 2 Inguinal canal exposure	00:30
Step 3 Spermatic cord mobilization	00:24
Step 4 Hernia sac removal	00:52
Step 5 Mesh placement	03:22
Step 6 Wound closure	01:02
Total duration	07:48
Continuous video-demonstration	
Total duration	07:30

The continuous group had access to a continuous video-demonstration of the LOIHR procedure and its associated textual description without segmentation. The continuous video-demonstration and textual description were displayed on separate webpages. After viewing the video-demonstration, the students could access the textual description of the procedure on a separate webpage in the online course by pressing on the 'next' button.

The participants were allowed to study the online preparatory course at their own pace. The students could pause and rewatch the videos on demand. The content of the online courses (video-demonstrations and textual descriptions) were identical in both groups, with segmentation being the only difference.

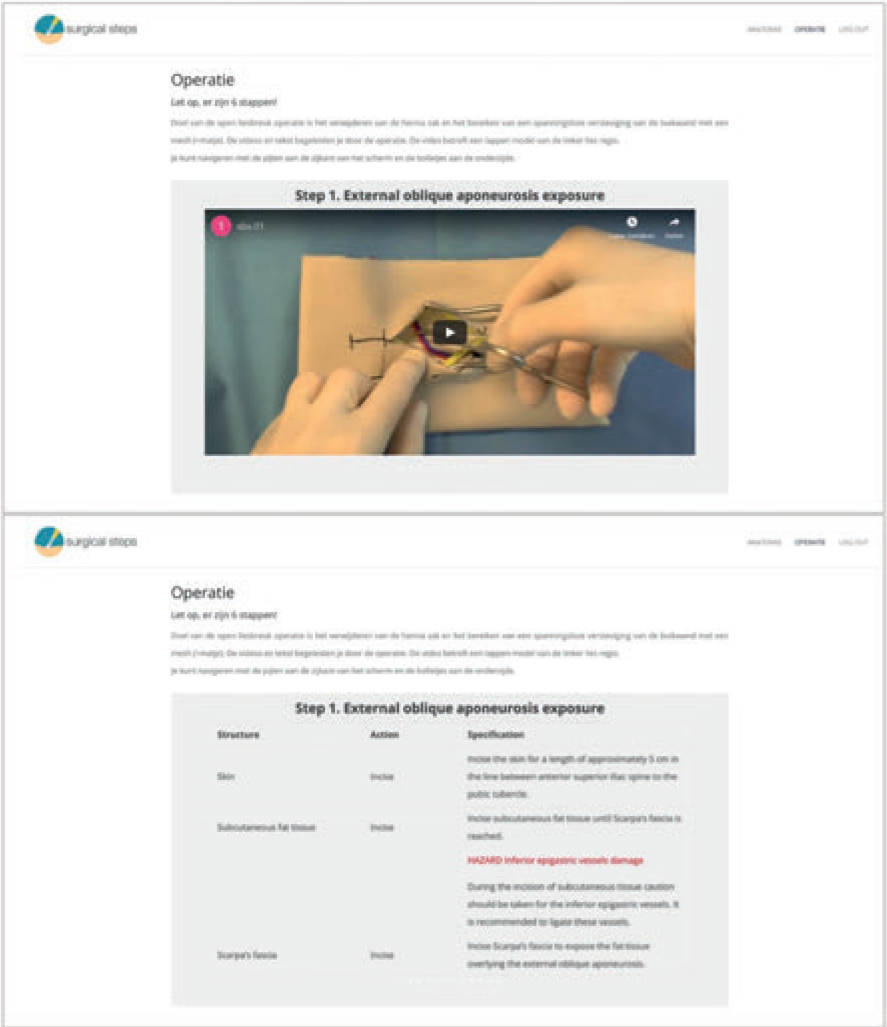

Figure 4a. Step by step video-demonstration and b. textual description on the website

Cognitive load questionnaire

At the end of the online preparatory course, students were requested to fill out a questionnaire on their perceived cognitive load during the entire online course. A modified version of an existing questionnaire was used, composed of 12 statements assessing the intrinsic/germane cognitive load (8 statements) and the extraneous cognitive load (4 statements).[11] All statements were rated on a 10-point Likert type scale, ranging from 1=totally disagree to 10=totally agree.

On the day of the surgical assessment, students were asked to fill out a questionnaire regarding their preparation (time spent on self-study during the online course in hours, use of other sources for self-study, and satisfaction during online preparation on a 10-point Likert scale, ranging from 1=not at all to 10=completely liking the teaching method).

LOIHR surgical performance

All students performed the LOIHR surgical procedure on a simulation model.[16] This model mimicked the human abdominal wall anatomy, as each textile layer corresponded with a layer of the abdominal wall. The blood vessels, nerves (ilioinguinal, iliohypogastric, genital branch of the genitofemoral nerve), the spermatic cord, and an indirect hernia sac were placed in the correct anatomical position within the textile layers. The simulation model used in the surgical performance assessment was identical to the model used in the preparatory video-demonstration.

To perform the LOIHR surgical procedure, each student received the necessary instruments and materials, such as a scalpel, forceps, scissors, retractor, mesh, needle driver, sutures, ligatures, marker, and a Penrose drain (**Figure 5**). The students had a maximum of 30 minutes to perform the LOIHR surgical procedure. The students were allowed to ask for help. Each time a student requested help regarding the execution or the correct order of the steps, this was flagged by one of the experimenters (TN or FvdG) as 'requiring help.' Requests for an extra pair of hands by the students, such as cutting threads or holding retractors, were provided but not flagged as 'requiring help.'

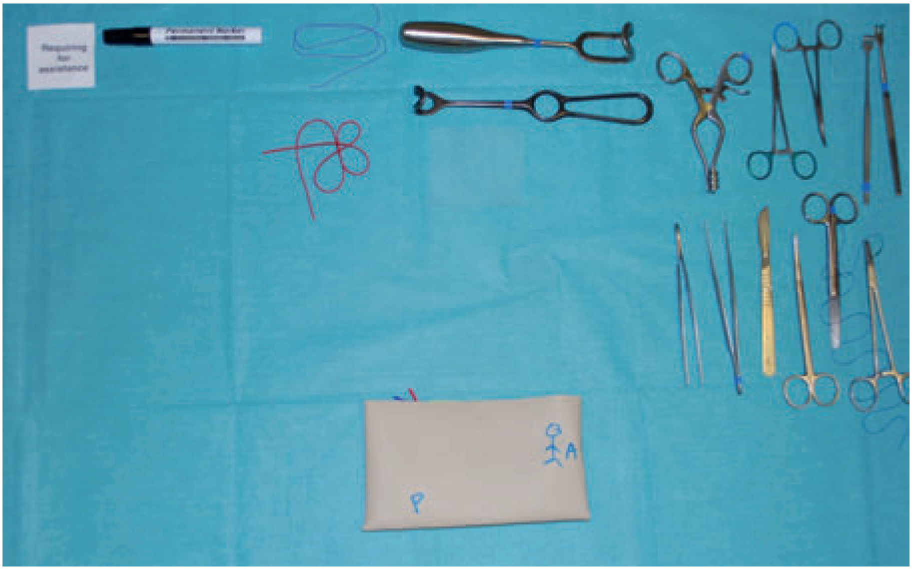

Figure 5. Set up operating table

Surgical performance assessment

The LOIHR surgical procedures were video recorded using a head-mounted GoPro Hero 5 Black (GoPro Inc. San Mateo, CA, United States of America), with the following settings: resolution 720p, 60 frames per second; FOV: Narrow; White Balance 4000k; Locked exposure. The video recordings were anonymized and stored. Two trained assessors (TN, FvdG) were blinded for the randomization and reviewed the video recordings independently. Any discrepancies were discussed and reviewed by the two assessors and resolved through consensus. The assessment was done according to the principles of Observational Clinical Human Reliability Assessment (OCHRA).[15] As shown in **Figure 6**, a performed substep could be assessed as 'correct,' 'procedural error' or 'executional error.' When the substep was not performed, this could be categorized as a 'procedural error' if the students skipped this substep, or as 'due to time' if it was caused by time constraints. The number of errors were registered for each medical student.

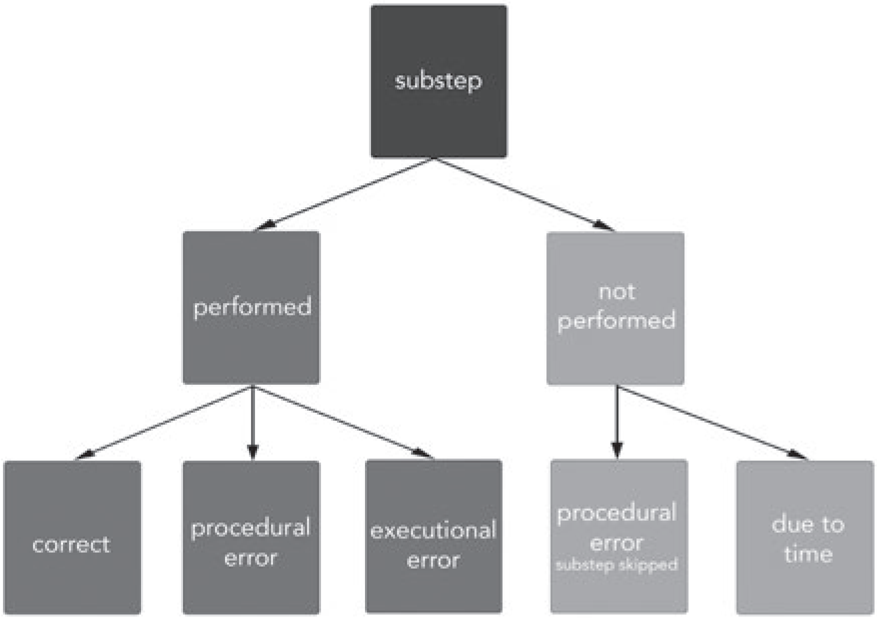

Figure 6. Assessment of a substep using Observational Clinical Human Reliability Assessment

Statistical analysis

Data were tested for normality using the Shapiro-Wilk test and presented as means and standard deviations, or as medians and interquartile ranges [Q1-Q3], according to their normality of distribution. If normal distribution was present, an independent samples t-test was used; otherwise, the Mann-Whitney U test was conducted. Categorical data were presented as numbers and percentages and compared using the Chi-square test. For the performance assessed by the OCHRA checklist, the mean of each category was presented. Subanalyses were performed on comparable subgroups of participants that spent 1-2 hours preparing the online course. A *p*-value of less than .05 was considered statistically significant.

Effect sizes (ES) were calculated using Cohen's delta (d). Different formulas were used for parametric and non-parametric data.17 Effect sizes of .20 were considered small, ≥ .50 were considered medium, and ≥ .80 were considered large.18 The internal consistency was determined using Cronbach's alpha (α). Data were analyzed with IBM SPSS Statistics for Windows (IBM Corp. Version 24.0, Armonk, NY, USA).

RESULTS

A total of 43 students participated in this study, of which 23 students were randomly assigned to the step-by-step group and 20 students to the continuous group. There were no statistically significant differences between the two groups regarding time spent during preparation, satisfaction during the preparation, and usage of other resources (**Table 2**).

Table 2. Total group of students – demographics and preparation

		Step-by-step (n=23)	Continuous (n=20)	*p*-value
Gender *(n)*	Female	13	9	.451^
	Male	10	11	
Age in years *(median [IQR])*		20 [19-21]	20 [19-21]	.805[f]
Year of study *(n)*	Year 1	6	5	.744^
	Year 2	6	6	
	Year 3	8	7	
	Year 4	3	1	
	Year 5	0	1	
Time spent during preparation				
How much time did you spend studying the online course? *(n)*	0 - 1 hour(s)	5	2	.326^
	1 - 2 hours	15	16	
	2 - 3 hours	1	2	
	3 - 4 hours	2	0	
Satisfaction during the preparation				
Over all, I appreciated the way the procedure was taught *(median [IQR])*	Scale 1-10	8 [7-9]	8 [6.25-8]	.053[f]
I felt well prepared after watching the video and studying the text *(median [IQR])*	Scale 1-10	7 [6-8]	7 [4.50-8]	.487[f]
Usage of other learning resources				
Did you, besides the online course, use other resources or materials to prepare for the surgery? *(n)*	Yes	12	12	.606^
	No	11	8	
Which other different resources or materials did you use? *(n)*	Books	3	2	.758^
	Other websites	4	6	
	Other videos	3	3	
	Other…	1 anatomy images	1 Google	
How much time did you spend studying other resources or materials? *(n)*	0 - 1 hour(s)	10	12	.286^
	1 - 2 hours	1	0	

IQR interquartile range [Q1 – Q3]; ^ analyzed using Chi square test; [f] analyzed using Mann Whitney U test

The perceived cognitive load and surgical performance are shown in **Table 3**. The mean (SD) extraneous cognitive load was perceived lower by the step-by-step group, 2.92 (1.21), than by the continuous group, 3.91 (1.67), with a medium effect size (t (41) = -2.24, *p* = .030, *d* = .68, Cronbach α = .836). The surgical performance was not significantly different between both groups on any of the measures. The median [Q1-Q3] satisfaction during preparation tended to be higher in the step-by-step group, 8 [7-9], than in the continuous group, 8 [6.25-8], with a small effect size (*U* = 153.00, *p* = .053, d = .09).

Table 3. Total group of students – cognitive load and surgical performance

	Step by step (n=23)		Continuous (n=20)		*p* - value
	Mean	**SD**	**Mean**	**SD**	
Cognitive load					
Intrinsic/germane cognitive load Cronbach α = .807	6.10	1.17	6.43	1.10	.351^
Extraneous cognitive load Cronbach α = .836	2.92	1.21	3.91	1.67	.030^*
Surgical performance					
Total performed substeps					
Correct substeps	7.30	2.80	7.75	2.31	.531[f]
Procedural error	0.39	0.50	0.90	1.07	.109[f]
Executional error	6.00	2.00	5.25	1.89	.215^
Total not performed substeps					
Procedural error (skipped substeps)	1.48	1.31	1.70	1.46	.644[f]
Due to time	9.52	3.18	9.05	2.31	.109[f]
Total times asked for help	1.26	1.57	1.30	1.63	.868[f]

^ analyzed using independent samples t-test; [f] analyzed using Mann Whitney U test; * statistically significant

Additional subanalyses were run on comparable subgroups that spent the same amount of time studying the preparatory course (1-2 hours). In this selection, gender, age, years of study, satisfaction during the preparation, and usage of other sources for preparation were not statistically significantly different between the groups (**Table 4**). As shown in **Table 5**, in the subanalyses, the step-by-step group perceived a lower level of extraneous cognitive load than the continuous group, with a medium effect size (t (29) = -2.091, *p* = .045, *d* = .75, Cronbach α = .827). Furthermore, the step-by-step group made less 'performed – procedural errors,' mean (SD) of 0.33(0.49), than the continuous group, 1.13 (1.09), with a small effect size (*U* = 65.00, *p* = .018, *d* = .15).

Table 4. Students with 1-2 hours preparation – demographics and preparation

		Step by step (n=15)	**Continuous (n=16)**	***p*-value**
Gender *(n)*	Female	10	7	.200^
	Male	5	9	
Age in years *(median [IQR])*		20 [19-21]	20 [19-21]	.896[f]
Year of study *(n)*	Year 1	4	3	.764^
	Year 2	4	6	
	Year 3	5	5	
	Year 4	2	1	
	Year 5	0	1	
Satisfaction during the preparation				
Over all, I appreciated the way the procedure was taught *(median [IQR])*	Scale 1-10	9 [8-9]	8 [7-8.75]	.090[f]
I felt well prepared after watching the video and studying the text *(median [IQR])*	Scale 1-10	7 [7-8]	7 [4-8.75]	.340[f]
Usage of other learning resources				
Did you, besides the online course, use other resources or materials to prepare for the surgery? *(n)*	Yes	7	10	.376^
	No	8	6	
Which other different resources or materials did you use? *(n)*	Books	2	2	.752^
	Other websites	2	4	
	Other videos	1	3	
	Other…	1 anatomy images	1 Google	
How much time did you spend studying other resources or materials? *(n)*	0 - 1 hour(s)	5	10	.182^
	1 - 2 hours	1	0	

IQR interquartile range [Q1 – Q3]; ^ analyzed using Chi square test; [f] analyzed using Mann Whitney U test

Table 5. Students with 1-2 hours preparation – cognitive load and surgical performance

	Step by step (n=15)		Continuous (n=16)		*p*-value
	Mean	SD	Mean	SD	
Cognitive load					
Intrinsic/germane cognitive load Cronbach α = .827	6.53	1.08	6.59	1.10	.879^
Extraneous cognitive load Cronbach α = .827	2.87	0.92	3.92	1.74	.045^*
Surgical performance					
Total performed substeps					
Correct substeps	7.80	2.43	7.19	2.20	.460[f]
Procedural error	0.33	0.49	1.13	1.09	.018[f*]
Executional error	6.00	2.17	5.44	1.63	.425^
Total not performed substeps					
Procedural error (skipped substeps)	1.33	1.18	1.94	1.48	.247[f]
Due to time	9.33	3.29	8.94	2.18	.286[f]
Total times asked for help	1.00	1.36	1.44	1.78	.531[f]

^ analyzed using independent samples T-test; [f] analyzed using Mann Whitney U test; * statistically significant

DISCUSSION

Video-demonstrations create high extraneous cognitive load for managing the transiency of information as relevant information disappears quickly from the screen.[6, 9] Segmentation provides smaller portions of information with pauses in between to reduce the extraneous load. In our study, this theory was affirmed as the segmented step-by-step group showed a lower extraneous cognitive load compared to the continuous group. The intrinsic cognitive load was not statistically significantly different between the groups, as was expected since the complexity of the new information – the LOIHR surgical procedure for the medical students – was similar in both groups.

When comparing students in our study with the same preparation time (1-2 hours), the step-by-step group made fewer procedural errors than the continuous group. Procedural errors are errors concerning the performance of the surgical procedure in the correct order and are determined by a trainee's procedural knowledge. A likely explanation for fewer procedural errors in the step-by-step group is that surgical knowledge was better learned while watching the segmented video leading to higher surgical performance compared to the continuous group. The executional errors were not significantly different between both groups.

The executional errors concern surgical skills, such as knotting and suturing. Surgical skills are determined by repetitive practice and are therefore not solely dependable on video-based preparation.

To our knowledge, this is the first study to demonstrate the effects of segmentation of video-based surgical procedure learning on cognitive load and surgical performance. The findings of this study need to be viewed in light of several limitations. First, our prospective experimental design allowed students in both groups to pause and rewatch the video-demonstration on demand, similar to reality. The option to pause continuous videos effectively segments videos by providing smaller portions of information at a time. The continuous group had thus the option to compensate for potential suboptimal teaching in this condition by investing more study time in preparation for the surgery (e.g., by pausing or rewatching the video, consulting other resources, et cetera). Additional subanalyses were therefore performed on the selection of students with the same preparation time of 1 to 2 hours in order to correct for potential compensation. This selection concerned the majority of the students, 31 of the 43 participating students.

In this study, the effects of segmentation were investigated in medical students as they form a homogeneous group with similar surgical experience and are more readily available compared to surgical residents. The next step is to investigate the segmentation effect in surgical residents. Finally, the segmentation in this study was performed using the step-by-step framework.[14] Further research is needed to investigate if the step-by-step framework offers the best way to define these segments.

CONCLUSIONS

This study compared the effects of a step-by-step versus a continuous video-demonstration of a surgical procedure on perceived cognitive load and surgical performance. The step-by-step group perceived a lower extraneous cognitive load compared to the continuous group. Among students with the same preparation time (1-2 hours), the step-by-step group showed a lower extraneous cognitive load and higher performance, specifically, fewer procedural errors. Based on the findings in our study, we suggest presenting surgical video-demonstrations in a segmented format.

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6

JUST IN TIME: THE EFFECTS OF STRUCTURED ONLINE PREPARATION FOR MEDICAL STUDENTS ASSISTING AT SURGERY

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Submitted

ABSTRACT

Background

The feeling of unpreparedness by medical students hinders learning in the operating room. The effects of an online structured video-based platform (Incision Academy) were analyzed during surgical clerkship.

Methods

In a prospective longitudinal study, medical students in their surgical clerkship were approached for participation. Self-reported preparedness, comprehensibility, usefulness and satisfaction with the video-based platform (7-point Likert scale) were compared between the start of the 3-week preparatory course (T0) and before (T1) and after (T2) the 8-week clerkship.

Results

The feeling of preparedness significantly increased between T0 and T1 ($p < 0.001$), and between T1 and T2 ($p < 0.001$). At T2, the feeling of preparedness was an average of 5.50 [5.00 – 6.00]. The comprehensibility, usefulness and satisfaction were all rated a median of 6.00 [5.00 – 6.00].

Conclusions

An online structured surgical education video-based platform increased the feeling of preparedness to assist a surgical procedure by medical students, and was found to be comprehensible, useful and highly satisfactory.

INTRODUCTION

For most medical students, surgical clerkship is the first time they enter an operating room (OR). Medical students recognize 'increased knowledge of surgical procedures and anatomy' as relevant learning outcomes of the surgical clerkship.[1] This clerkship can be conducted in general teaching and university hospitals with a different profile of surgical procedures performed. The feeling of unpreparedness was reported as one of the main barriers to fully profit from participating in surgeries in the OR.[1] Currently, medical students have – besides traditional text and anatomy books – the availability of vast online resources, such as videos, podcasts, and social media to prepare themselves.[2] Though medical students report textbooks possessing a high educational quality,[3] they increasingly use online video demonstrations, for example YouTube, to learn about a surgical procedure and anatomy.[4-5] Studies have shown the benefit of video-based learning to prepare for a surgical procedure in comparison to textbooks,[6-8] however, the learning yield of internet videos varies. The educational quality of most online videos is doubtful.[9] Many videos miss a proper explanation of the surgical steps, which is deemed relevant to 'master' the whole procedure. Also, many internet videos show rare cases ('How I do it') or new and complex surgical techniques, which are less appropriate for medical students as learning and preparing tool. Altogether, it can be challenging for novices to choose the appropriate videos and structure their learning on short notice since schedules of the operations are often available the day before the actual surgery.

An online video-based surgical education platform was established (Incision Academy, Incision Group, Amsterdam, The Netherlands) including a wide range of surgical videos which making and editing was supervised by expert surgeons, anatomists and surgical educators. Over 450 video courses can be accessed on this online video-based platform. Each course includes a step-by-step video demonstration and a detailed textual description of the surgical procedure,[10] and supporting chapters regarding the surgical anatomy, surgical objectives, pre-operative measures such as instrument selection and positioning of the patient, postoperative complications, and knowledge tests (**Figure 1**). A course takes on average 30 to 45 minutes to finish.

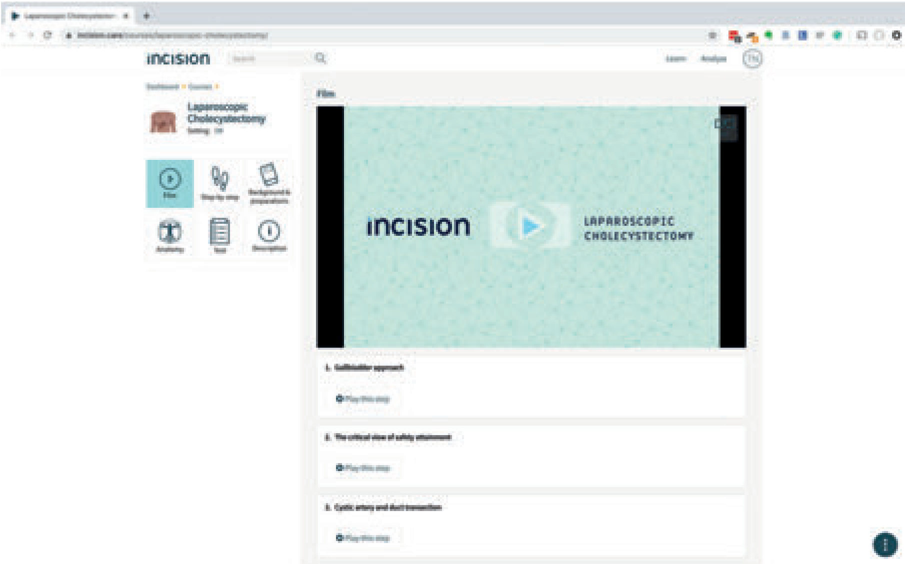

Figure 1. User interface of the structured online video-based surgical education platform

In this longitudinal prospective study, an online video-based surgical education platform was introduced to medical students. The effects on preparedness for participating during surgical procedures were studied along with an assessment of the comprehensibility, usefulness, and satisfaction of the platform.

METHODS

Participants, setting and design

Each medical school in the Netherlands consists of a three-year bachelor and a three-year master curriculum.[11-12] The master curriculum entails clerkships in different specialties in a fixed order. End fourth-year medical students of the Radboud University Medical Center, Nijmegen, The Netherlands starting with their ‘surgical episode’ were approached for participation in the study. Written consent was obtained. Formal approval was waived for this type of study by the institutional board review according to Dutch law.

The surgical episode consists of twelve weeks, including three weeks of a preparatory course at the university campus, eight weeks of clerkship (in the academic hospital or one of six affiliated teaching hospitals), and one week of reflection and professional development activities. The three-weeks preparatory course is characterized by self-directed and blended learning and contains flipped classrooms, simulation training of basic surgical (laparoscopic) skills, and surgery-oriented conversation training with volunteer patients (spot-diagnosis anamnesis, comfort talk, bringing bad news).

In this study, an online structured video-based surgical education platform (Incision Academy) was assessed for use and learning yield. Each student was provided with personal access credentials to this online platform. During the surgical episode, the platform was an adjunct to the curriculum for the students. Its use was entirely voluntary and not formally incorporated into the preparatory course or in the surgical clerkship.

Surveys

Online surveys were sent at the end of the first week of the preparatory course (T0), at the start of the eight-weeks clerkship (T1) and at the end of the clerkship (T2). The questions in the survey regarded the use, feeling of preparedness (6 statements), comprehensibility (2 statements), usefulness (4 statements), and satisfaction (7 statements). Each statement was rated on a 7-point Likert scale. Data about user activity until (T1) and (T2) were exported from the website.

Statistical analysis

The internal consistency of the surveys was determined using Cronbach's α. Normality was tested using the Shapiro-Wilk test. The non-normal distributed data were described by the median and range or interquartile range (IQR). Due to skewed data, the Wilcoxon signed-rank test was used to compare the outcome measures between T0 and T1 and between T1 and T2. The statements within the categories of the feeling of preparedness, comprehensibility, usefulness, and satisfaction in the second cohort were rated on a 7-point Likert scale. One-sample Wilcoxon signed-rank test was used to compare the median of these categories to the neutral value of 4.

A *p*-value of less than .05 was considered statistically significant. All statistical analyses were done with SPSS (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.).

RESULTS

The survey was sent to 187 students and completed by 165 students during the preparation course (88%), by 113 students at the start of the clerkship (60%), and by 108 students at the end of the clerkship (58%; Table 1). In the end, 79 students completed all three surveys (42%), 53 students two surveys (28.3%), 43 students one survey (23%), and 12 students no surveys (6.4%). The average age at the beginning of the surgical episode was 22 years (range 21 – 36).

Table 1. Demographics

	Preparation weeks (T0)	Start clerkship (T1)	End clerkship (T2)
Students (n; %)	165 (88.2%)	113 (60.4%)	108 (57.7%)
Male (%)	24.1%	16.0%	13.9%
Age in years (median [IQR])	22 [22 – 23]	22 [22 – 23]	22 [23 – 23]

The online video-based courses were mostly used during the clerkship (Table 2). The median number of videos watched was 0 [0 – 0] during the preparatory course and 18 [10 – 30] during the clerkship (Z = -11.51, p <.001). The self-reported activity on the Academy platform was a median of 1 hour [0.5 – 2] during the preparatory course and a median of 5 hours [0 – 10] during the clerkship (Z = - 5.72, p <.001).

Table 2. Use of platform

	During preparatory course median [IQR]	During clerkship median [IQR]	*p* - value^
Objective measurements			
Courses completed	0 [0 – 0]	1 [0 – 3]	<.001*
Videos played	0 [0 – 2]	18 [10 – 30]	<.001*
Tests made	0 [0 – 0]	0 [0 – 2]	<.001*
Subjective measurement			
Self-reported time spent on Incision Academy (in hours)	1 [0.5 – 2]	5 [0 – 10]	<.001*

IQR interquartile range [Q1 – Q3]; ^ Analyzed using Wilcoxon signed-rank test; * Statistically significant

As shown in **Table 3**, the internal consistencies of the category 'feeling of preparedness' during T0, T1, and T2 were acceptable (Cronbach α = .831, Cronbach α = .820 and Cronbach α = .767, respectively). The feeling of preparedness was lower than the neutral value at the beginning of the preparatory course with a median score of 3.00 [2.38 – 4.00], Z = -.806, p <.001. At T1 and T2, the feeling of preparedness was above the neutral value, median 4.00 [3.50 – 5.00], Z = 2.10, p = .036, and median 5.50 [5.00 – 6.00], Z = 8.88, p <.001. As shown in **Figure 2**, the feeling of preparedness significantly increased between T0 and T1 (p <.001), and between T1 and T2 (p <.001).

Table 3. Evaluation of the platform at T0, T1 and T2

	Preparation weeks (T0)	Start clerkship (T1)	End clerkship (T2)
Feeling of preparedness			
Cronbach's α	.831	.820	.767
Median [IQR]	3.00 [2.38 – 4.00]	4.00 [3.50 – 5.00]	5.50 [5.00 – 6.00]
p-value^	<.001*	.036*	<.001*
Comprehensibility			
Cronbach's α	-	.903	.817
Median [IQR]	-	5.00 [4.00 – 6.00]	6.00 [5.00 – 6.00]
p-value^	NA	<.001*	<.001*
Usefulness			
Cronbach's α	-	.928	.734
Median [IQR]	-	5.00 [4.00 – 6.00]	6.00 [5.00 – 6.00]
p-value^	NA	<.001*	<.001*
Satisfaction			
Cronbach's α	-	-	.891
Median [IQR]	-	-	6.00 [5.00 – 6.00]
p-value^	NA	NA	<.001*

Statements rated on 7-point Likert scale; 1=strongly disagree to 7=strongly agree
IQR interquartile range [Q1 – Q3]
^ Analyzed using one-sample Wilcoxon signed ranked test, compared to neutral value of 4
* Statistically significant; NA not applicable

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The category 'comprehensibility' had an excellent and good internal consistency at T1 and T2, respectively (Cronbach α = .903 and Cronbach α = .817, respectively). At the beginning and end of the clerkship, students rated the structured online learning positively on this topic (median 5.00 [4.00 – 6.00], Z = 6.36, p <.001 and median 6.00 [5.00 – 6.00], Z = 8.68, p <.001, respectively). From T1 to T2, the comprehensibility increased significantly, p <.001. Usefulness had an excellent and fair internal consistency at T1 and T2, respectively (Cronbach α = .928 and Cronbach α = .734, respectively). The usefulness was rated at both moments to be positive. This rating increased significantly over T1 and T2, p <.001. The overall satisfaction measured at T2 was very positive, with a median of 6.00 [5.00 – 6.00], $Z = 8.33$, $p < .001$.

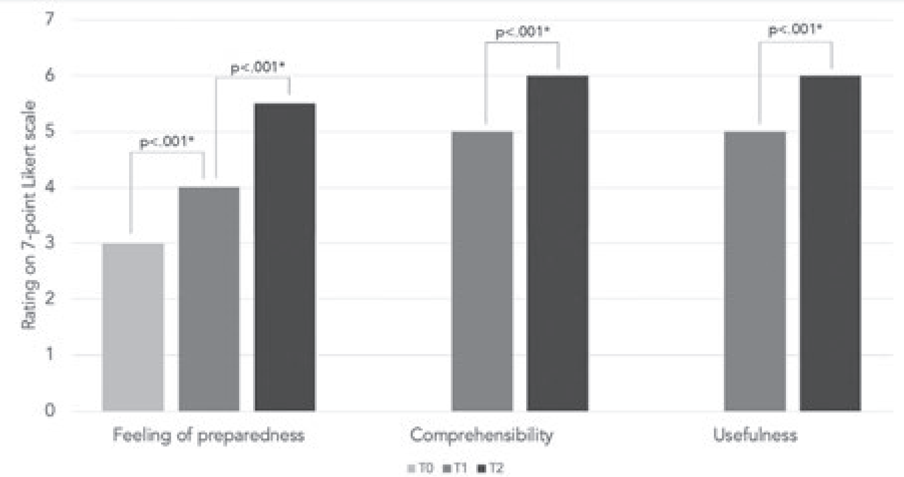

Figure 2. Preparation using the platform - comparison T0 and T1, and T1 and T2 (analyzed using Wilcoxon signed-rank test)

DISCUSSION

Initial qualitative evaluation of a structured online video-based surgical education platform shows that students feel increasingly better prepared during the clerkship. This type of structured preparation was most effective during the clerkship. The students found the platform comprehensible, useful and were satisfied with its use. These findings hold promise for including this platform as just in time teaching and learning strategy in surgical clerkships in hospitals with a different clinical profile.

The use of online – mostly YouTube – videos at the discretion of students has been reported before, and we share with most authors the concern regarding the quality and learning yield of these 'educational' sources for a surgical clerkship.[4-5, 13-15] In general, online surgical videos are unstructured and do not aim at knowledge and skill development.[15] YouTube videos are ranked by popularity and not by educational value, and the video content may even be misleading, showing protocol violations of surgical procedures.[16] A recent study confirmed the lack of quality and even drawback of laparoscopic cholecystectomy videos on YouTube as half of the videos showed hazardous surgical maneuvers, and only one in ten videos demonstrated the 'critical view of safety' step.[9] The critical view of safety step is deemed essential for avoiding serious complications and is an indispensable step in the surgical procedure according to national and international guidelines on laparoscopic cholecystectomy and in detail presented in the Incision Academy film performed by an expert in this field.[17-18] A review of 68.000 'educational videos' for basic criteria such as adequate neurovascular examination and employing traction during application of the cast regarding distal radius fracture immobilization revealed only 16 videos that met the basic criteria.[19] These reports underline the importance of helping students to find their way in the massive marketing of surgical videos on the internet and to put effort in supporting medical students with online videos of surgical procedures with high educational quality and controlled by the surgical community.

In this study, students used the online video material mainly during the clerkship. This was surprising considering the introduction of the Incision Academy at the start of the preparatory course. During this preparatory course, the students receive general information about surgery and not detailed knowledge of specific procedures. Apparently, students use this educational tool at the time they must prepare for the surgical procedure they are going to attend during the clerkship. This underlines the "just-in-time" learning strategy of students.20 This learning strategy is logical since they work in hospitals that differ considerably in their surgical practice profile and daily scheduling of procedures. Online educational videos are appropriate just in time learning resources because they can deliver education to students when and where they need it.

Although the median number of online videos watched seems adequate, there was a considerable variation between students, and the median time spent in the second cohort was only 5 hours, with some students being not active at all. While the use of other sources of preparation was not assessed, we speculate that the learning yield of the online video-based surgical education platform would increase when the platform would be incorporated as an obligatory learning and teaching tool in the clerkship for students and teaching staff. Participants should be fully aware about the content of the platform as it contains surgical procedural knowledge, surgical anatomy, and surgical skills content. The values of using the structured online video-based platform in the preparatory course,[21] particularly the surgical anatomy and skills parts, needs to be determined in future research.

There seems to be a discrepancy in expectations between surgeons and medical students and what they consider as well prepared.[22-23] Surgeons expect general attributes in the operating room, such as arriving on time and showing interest, and do not expect broad and detailed surgical knowledge.[23] However, medical students found it distressing if they miss detailed information on surgical procedures and are unable to anticipate because they lack knowledge of the course of actions and events during an operation.[22-23] Using structured videos with texts describing the procedural steps of a surgical procedure and explaining the rationale behind the steps' order seemed to fulfil the expectations of the students considering the increasing feeling of preparedness during the clerkship.

Strengths and limitations

In the present study, we investigated voluntarily use of online videos as an educational tool by a large cohort of medical students in the surgical clerkship. This implies that study outcomes are not affected by the maladaptation of students to a new online video-based surgical education platform. The number of students who participated in the surveys was high, strengthening the conclusion that online videos increase self-reported preparedness and confidence in participating in surgeries in the operating room. However, the decreasing number of participants taking part in the subsequent surveys might have overestimated the reported learning effects of the platform. It is possible that mostly students who were highly motivated for a surgical specialty or who preferred online learning continued to fill out the surveys. We could not gain insights into this bias. Although self-reported outcomes such as preparedness and confidence are considered relevant for assessing the impact of surgical educational methods, they may be over- and underestimated by students depending on contextual factors and personal traits.[24] Acknowledging the difficulty of objectifying the effect of this educational intervention on the competency of medical students participating in the operating room, a future study will include audio- and video-recording of student activities in the operating room with and without using the Incision Academy platform for preparing the surgery.

Implications for educational practice and future research

The initial learning yield of the voluntary use of the Incision Academy platform as an adjunct to other educational activities and tools in the surgical clerkship is encouraging. With increased use by medical students in and outside the Netherlands, the optimal package of videos needed to be prepared for successful participating in a surgical procedure can be defined and specified for each medical school. Efforts should be put in comparing online video-based learning with other educational means regarding efficacy, resources needed, time spent, and financial costs. We expect that the learning yield of structured online video-based surgical education will increase when it becomes fully integrated into the surgical clerkship and also surgical teachers use it as a teaching tool. Due to the continuing growth in skills videos, surgical attitude, surgical anatomy and more structured videos of surgical procedures, also more complex operations, the platform becomes more attractive for medical students as residency and fellowship programs.

CONCLUSIONS

A recently online structured surgical education video-based platform which was found to be comprehensible, useful and demonstrated high satisfaction, increased the feeling of preparedness to participate in a surgical procedure. These findings hold promise for including this platform as just in time teaching and learning strategy in surgical clerkships in hospitals with a different clinical profile.

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7

MASTERING SURGERY: THE ADVANTAGES OF STANDARDIZED VIDEOS IN ADDITION TO THE CURRICULUM IN MEDICAL EDUCATION FOR SURGICAL CLERKSHIPS

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Submitted

ABSTRACT

Background

Medical students are expected to translate the theoretical knowledge gained during their study to practical knowledge during the clerkships. A surgical educational platform with standardized videos may be the solution. However, the effects of a structured online video-based platform in addition to the standard curriculum on students' self-reported and tested surgical knowledge during the surgical clerkship must be assessed.

Methods

Fourth-year medical students (n=179) starting their surgical clerkship at Erasmus University Medical Center (Erasmus MC), Rotterdam, The Netherlands and 11 affiliated general hospitals, were approached. Ninety-one students followed the usual surgical curriculum (control group), followed by 88 students who were given voluntary access to a video-based surgical educational platform of Incision Academy (video group). At the start (T0) and end (T1) of the clerkship, both groups filled out a surgical knowledge test and a survey regarding their self-reported surgical knowledge and their access to available study sources. Supervisors were blinded and surveyed concerning students' performance and their acquired knowledge. We analyzed the data using paired and unpaired student t-tests and linear regression.

Results

At the end of the clerkship, students in the video group indicated that they had better resources at their disposal than the control group for surgical procedures (p=0.001). Furthermore, students in the video group showed a greater increase in self-reported surgical knowledge during their clerkship (p=0.03) and in objectively tested surgical knowledge ($p<0.001$).

Conclusions

An online surgical educational platform with standardized videos is a valuable addition to the current surgical curriculum according to students and their supervisors. It improves their test scores and self-reported surgical knowledge. Students feel better prepared and more able to find the information necessary to complete the clerkship.

INTRODUCTION

The understanding of surgical anatomy and procedures is important for medical students, regardless of their future specialty. However, the first 2 to 4 years of medical school are comprised predominately of theoretical learning and rarely include clinical experience in the operation room.[1] This makes the transition to the clinical part of their education challenging. An earlier study has shown that instruction in performing specific skills and procedures improves individuals' evaluated competence in performing that skill.[2]

In the Netherlands, the medical training consists of a three-year bachelor program and a three-year master program, but the specific content of the curricula may vary among universities.[1] The bachelor program is predominantly theoretical learning and the master program involves practical learning through clerkships. The surgical master program at the Erasmus University Medical Center (Erasmus MC), Rotterdam, The Netherlands consists of a 6-week preparatory course prior to a 10-week surgical clerkship. The preparatory course involves e-learnings, web-lectures, and texts from books and articles, accompanied by hands-on workshops, discussion meetings, and lectures led by attending physicians or faculty.

Although medical students complete a 6-week preparatory course together, for the 10-week clerkship students are allocated in the academic or affiliated general hospitals. These hospitals all have their specialties and differences in patient populations based on their unique clinical profile. Students, therefore, might not have the opportunity to see the same surgical procedures. It may thus occur that some medical students see liver transplantations and Whipple's procedures whereas other see general surgical procedures such as inguinal hernia repair and laparoscopic cholecystectomies. Additionally, individual surgeons might have their own approach and preferences for a certain procedure which hinders students to learn a standardized approach. Lastly, not all surgeons provide the same explanation before, during, or after surgical procedures and not all students dare to ask questions about the procedures in the operating room (OR). However, a similar level of understanding of basic surgical procedures for all students at the end of their medical training is important, regardless of their future specialization. To cope with this unbalance in the clinical palette between different clinics and with the instruction styles of individual surgeons, a list of 10 common practical key surgical procedures was composed that all our students should have knowledge about at the end of their clerkship (**Table 1**).

Table 1. Ten preselected courses that were considered mandatory for all students (control group and video group) to study during the clerkship.

Procedures
Toenail avulsion
Inguinal Hernia Repair - Open - Indirect Hernia
Cholecystectomy - Laparoscopic
Appendectomy - Laparoscopic
Lumpectomy - General Principles
Carpal Tunnel Release - Cadaver
Lipoma Excision
Abdominal Wall Incision - Midline
Colectomy - Laparoscopic (Right)
Colectomy - Open (Left)

Video instruction can help to fill the gap between theoretical instruction of surgical, clinical and anatomical knowledge and expert hands-on instruction or as an independent teaching module.[3] Medical students and surgical trainees frequently use online video resources for their learning, which often includes viewing surgical videos on YouTube.[3] However, YouTube is not an accredited medical educational resource, and any individual or organization can upload videos to the site. The content is not organized by quality, but rather search results appear in order of popularity and other algorithms. Another study found that the highest-ranked laparoscopic cholecystectomy videos on YouTube displayed suboptimal technique; furthermore, half of the videos exhibited unsafe maneuvers and only 10% demonstrated a satisfactory critical view of safety.[4] Additionally, the videos lacked an explanation of pre- and postoperative aspects such as indications, complications, surgical anatomy and information regarding patient selection that were deemed essential knowledge for surgical trainees.[5]

Consequently, we provided students access to a structured online video-based surgical educational platform with standardized, high-quality educational videos.[6] It has been designed to prepare students and residents for specific surgical procedures and contained over 300 surgical video demonstrations at the moment of the study, including the aforementioned 10 determined key-procedures. All available courses on the platform include a step-by-step description and video-demonstration of a skill or surgical procedure. Additionally, each course is accompanied by supplemental introductory, preoperative and postoperative textual sections, anatomical illustrations, multiple-choice examinations and in most courses also interactive anatomical 3D models.

We hypothesized that these educational videos would help to standardize and improve the learning experience of the medical students in the video group compared to students who did not have access to the platform. We also hypothesized that these videos would help to ensure that all medical students get optimal exposure to the 10 pre-defined key-procedures, regardless of the actual attendance in the different hospitals.

The purpose of this study was to assess the educational value of instructional videos on surgical knowledge of essential basic surgical procedures as well as feelings of preparedness before and during the general surgery clerkship as reported by students and their supervisors.

METHODS

Study population

Between February 2019 and June 2019, 178 fourth-year medical students of the Erasmus MC were approached at the start of their surgical clerkships for inclusion in this study. Written consent was obtained. The study protocol was approved by the medical ethical committee of the Erasmus MC, Rotterdam, The Netherlands (METC-2019.0564).

All students participated in a 6-week preparatory course followed by a 10-week clinical clerkship. During this clerkship, students were distributed over 12 teaching hospitals in the region of Rotterdam (3-15 students per hospital, depending on the size of the hospital).

Approximately 450 students participate in the course and clerkship each year, divided by the university into 5 consecutive starting cohorts of 90 students on average based on progress in the first 3 years of medical school (bachelors program). For this study, we chose to use the university’s consecutive cohorts to divide the students into the “control group” and the “video group”. The first approximately 90 students that followed the standard surgical curriculum were included in this study as the control group (**Figure 1**) and were advised to study the 10 key-procedures (**Table 1**). The second group of approximately 90 students was included as the video group and also followed the standard surgical curriculum, and in addition received unlimited, voluntary access to a structured online video-based surgical educational platform on surgical procedures, skills, and anatomy.[6] Students in the video group had access to all courses including the videos on the online platform and were advised to complete the ten preselected courses covering the key-procedures (**Table 1**).

Surveys

Both the control and video group were given a survey at the end of their 6-week preparatory course (T0) and at the end of their 10-week clerkship (T1), which they could fill out anonymously (**Figure 1**). The first survey (T0) included questions related to the student demographics and preparation for the clerkship. Questions were about two domains: 9 questions regarding self-reported knowledge on surgical anatomy, surgical objectives, and complications. Overall student self-assessment was rated on a 5-point Likert scale. This survey was followed by a knowledge test including questions focused on the surgical and anatomical knowledge of the students. The questions concerning students' knowledge included different surgical disciplines (general, oncological, orthopedic/trauma, and gastrointestinal) and did not influence the students' official grades. The questions were written by 4 teachers involved in this study (J.S., E.A, T.W., J.J.) whom all have experience in writing test questions for medical student examinations and educational surveys. Students were not informed about the results of the pretest after they completed it. The second questionnaire (T1) included 35 questions concerning their experiences (observed surgical procedures and preparation time) during the clerkship, the multimedia sources they used in preparation of and during the clerkship, and their overall opinion regarding these 10 weeks. The knowledge test at T1 covered the same topics as in the pre-test. All questionnaires (T0 and T1) in both groups were filled in on paper in the presence of an attending physician to prevent students from looking up the correct answers and discussion amongst students. Data about user activity on the Incision Academy were directly retrieved from the platform.

At the end of the clerkship (T1), all supervising surgeons in affiliated hospitals received a digital questionnaire regarding the surgical knowledge and overall performance of the medical students on a 5-point Likert scale. This questionnaire

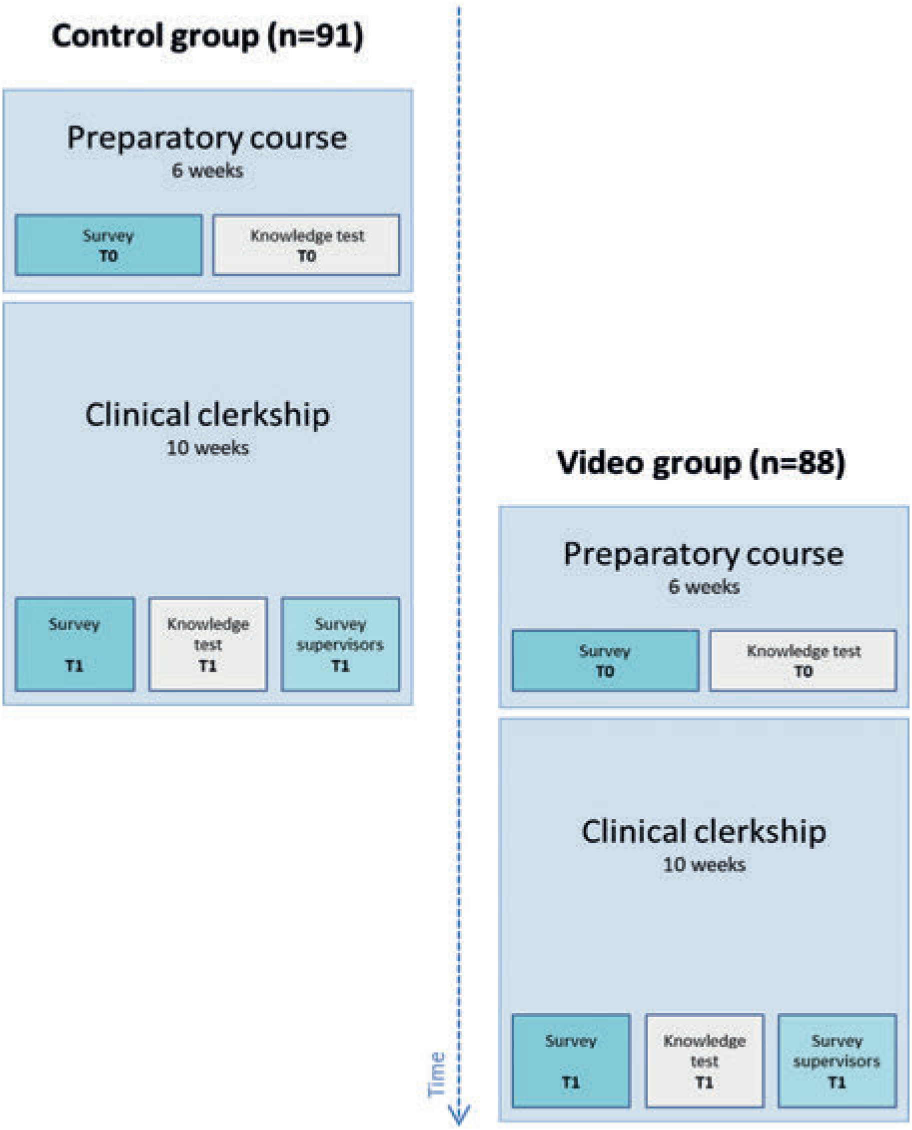

Figure 1. Flow-chart study design

was not about individual students, but the groups as a whole and was, therefore, sent twice – once for the control group, and once for the video group (**Figure 1**). Supervising surgeons were informed that a study was being conducted on the availability of study sources for students during the clerkship, they were however blinded and not informed that the video group had access to an online video-based surgical educational platform.

Outcomes and definitions

The difference in self-assessed knowledge and test results between the control group and the video group was the primary outcome of the study. Secondary outcomes were the length of preparation time, number of observed surgical procedures, types of study sources students used to study, and their evaluation. Also, the overall evaluation of both groups on group level by the supervising surgeons was considered a secondary outcome.

Statistical analysis

The Shapiro-Wilk test was used to test normality. Normally distributed data were analyzed using paired Student t-test when comparing pre- and post-procedural knowledge test results. The unpaired Student t-test was used when comparing results based on differences in demographics, course participation, and post-clerkship (T1) results between groups. The non-normal distributed data were described by the median and range or interquartile range (IQR). The Mann-Whitney *U* test was used to compare ordinal data between groups and the χ^2 test was used for categorical data. Differences in outcome measures between T0 and T1 in both groups were compared by using linear regression.

All statistical analyses were done with SPSS (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.). A *p*-value of less than 0.05 was considered statistically significant.

RESULTS

Baseline characteristics

A total of 91 students were included in the control group and 88 in the video group. In the control group 60 students (66%) filled out the survey at T0 and 46 (51%) at T1. In the video group, 77 students filled out the survey at T0 (90%) and 45 (52%) at T1.

Table 2. Comparison of baseline characteristics between the control group and the video group

	Control group (n=60)	**Video group (n=77)**	***p-value***
Gender			0.39
Female (%)	39 (65)	54 (70)	
Male (%)	21 (35)	23 (33)	
Mean age (SD)	24.5 (2.7)	24.7 (3.3)	0.85
Experience†			0.42
No prior experience	28	28	
Work experience in non- surgical specialty	23	34	
Work experience in surgical specialty	9	12	
Pursue career in surgery‡	3 (2-4)	3 (2-4)	0.84

† Practical working experiences (e.g. student job) in a hospital before the current internship
‡ I would like to pursue a career in a surgical specialty (1 = definitely not - 5 = yes, definitely).

Participants in the control and video groups did not differ in age (mean 24.5, SD 2.7 years vs mean 24.7, SD 3.3 years; *p*=0.85) or gender (39 female (65%) vs 54 female (70%); *p*=0.39). Students also did not differ in prior surgical experience (*p*=0.42) nor in their desire to pursue a career in surgery at T1 (*p*=0.84) (**Table 2**).

Self-reported surgical knowledge and test results

The internal consistency of the measurements at T0 and T1 were reliable. Students in the control group had a marginally better self-reported knowledge at the start of the clerkship (**Table 3**). The increase in self-reported knowledge during the clinical clerkship in the video group was significantly greater (*p*=0.03, **Figure 2**). Furthermore, students in the control group scored slightly better on tested surgical knowledge prior to the clerkship (**Table 3**). Similarly, the increase in the percentage of correctly answered questions was significantly greater in the video group. Scores on the knowledge test in the control group increased from 43.6 (SD 10.9) to 58.5 (SD 12.4) versus 40.2 (SD 11.0) to 66.3 (SD 7.9) in the video group ($p<0.001$, **Figure 3**).

Table 3. Results survey at T0 andT1 for both groups

	Control group		**Video group**		***p-value***
	Before start (T0)	**End (T1)**	**Before start (T0)**	**End (T1)**	
I feel I have sufficient sources					
Cronbach's α	0.72	0.88	0.76	0.84	
Median (IQR)	3.6 (3.2 – 4.0)	3.8 (3.3 – 4.2)	3.5 (3.0 – 4.0)	4.2 (3.8 – 4.6)	0.001
I feel I have sufficient knowledge					
Cronbach's α	0.69	0.77	0.77	0.81	
Median (IQR)	3.4 (3.0 – 3.7)	4.0 (3.7 – 4.2)	3.2 (3.0 – 3.7)	4.1 (3.9 – 4.4)	0.03
Multimedia					
Cronbach's α		0.80		0.80	
Median (IQR)		3.9 (3.6 – 4.3)		4.4 (3.8 – 4.8)	0.002
Knowledge test scores (%)					
Mean (SD)	43.6 (10.9)	58.5 (12.4)	40.2 (11.0)	66.3 (7.9)	0.0001

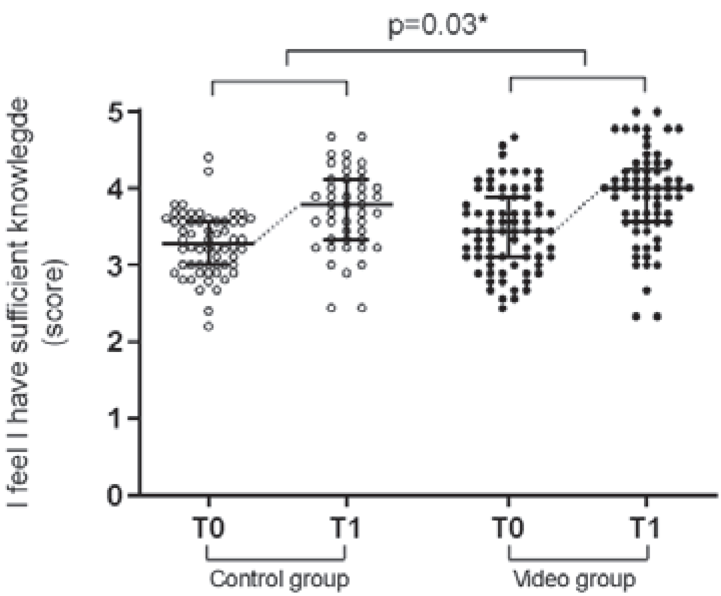

Figure 2. Responses to survey questions regarding self-reported knowledge combined of students in the control group (clear dots) on T0 and T1 and students in the video groups (black dots) on T0 and T1 (median + IQR). The increase in score over time was significant

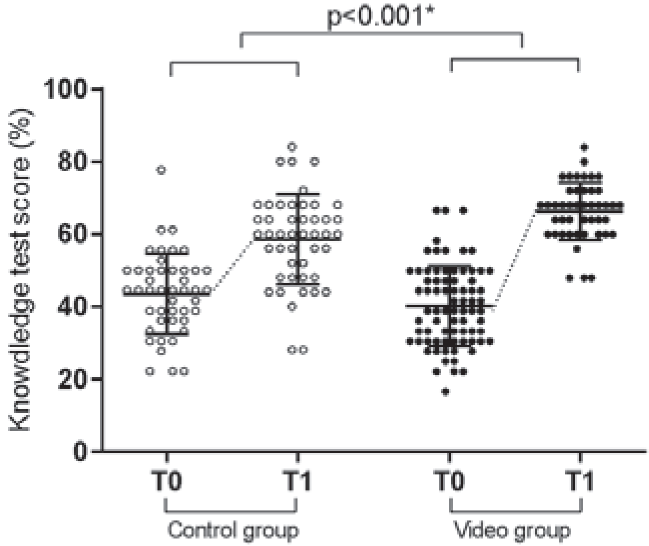

Figure 3. Percentage of questions correctly answered in the control group (clear dots) on T0 and T1 and correctly answered questions in the video group (black dots) on T0 and T1. Both groups performed better at the end of the clerkship (T1) than at the start (T0)

Observed surgical procedures

The median number of self-reported observed surgical procedures did not vary significantly between groups (*p*=0.83); median 50 (IQR 40 – 66) in the control group and median 50 (IQR 40 – 80) in the video group. Neither did the self-reported number of surgical procedures in which the student was able to participate actively or was scrubbed in; median 30 (IQR 22 – 40) in the control group and median 30 (IQR 20 – 46) in the video group (*p*=0.836).

Furthermore, the self-reported time spent on preparation for a procedure did not differ between the control and video group; median 30 minutes (IQR 20 – 45 min.) in the control group and median 30 minutes. (IQR 19 - 45 min.) in the video group (*p*=0.17).

Study sources

On average at T1, students in the control group reported using 4 different sources to prepare themselves for procedures (median 4 (IQR 3 – 5) and 4 in the video group (IQR 3 – 4, *p*=0.79). In both groups, a Dutch website dedicated to operative notes and descriptions was most frequently reported as an important source (65% in the control group and 62% in the video group). Furthermore, in both groups, almost half of the students reported using YouTube[7] as one of their main sources for preparing for surgical procedures (n=24 (52%) and n=22 (49%); *p*=0.76). Other sources included other internet sites (e.g. UpToDate[8], MedInfo[9]; 29% overall), anatomy books (e.g. Gray's Anatomy[10], Sobotta[11]; 78% overall), guideline databases (e.g. AO trauma[12], Guidelines by the Dutch Federation of Medical Specialists[13]; 27% overall) and the e-learnings and lectures from the course prior to the clerkship (31% overall).

The earlier described Incision Academy video platform had 2221 visits by 79 students (92%) (mean 27 visits per student) in the 10 weeks the website was available to them. Only 3 students with an account did not use their account (4%). At the time of this study, the website hosted 374 courses and students watched a total of 257 different courses (69%) and completed 136 of these courses (53%).

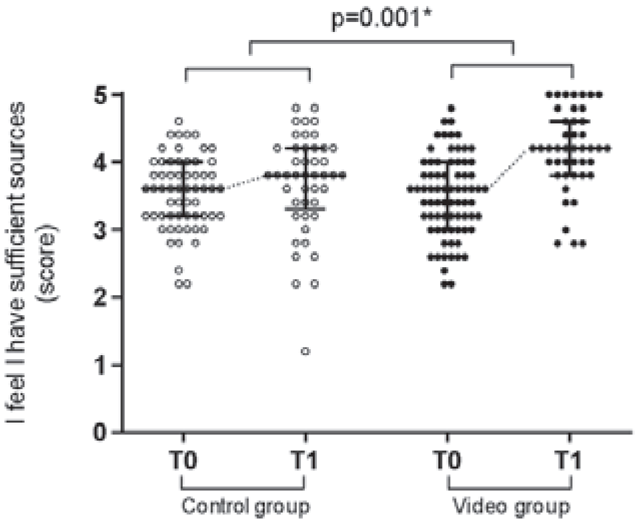

Figure 4. Responses to survey questions regarding the availability of study sources combined of students in the control group (clear dots) on T0 and T1 and students in the video groups (grey dots) on T0 and T1 (median + IQR). Scores in the video group increased significantly more than those in the control group (p=0.001) as is represented by the dotted line between medians.

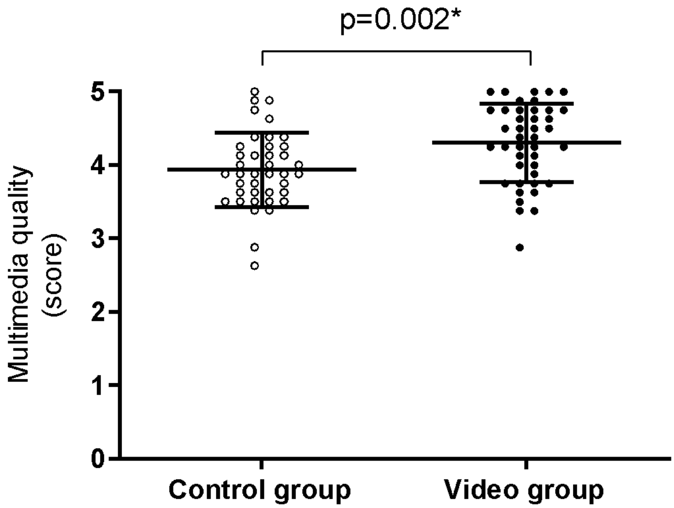

Figure 5. Responses to survey questions regarding multimedia quality and usefulness combined in one factor of students in the control group (clear dots) and the video group (black dots) on T1 (median + IQR). Students in the video group rated the quality of the multimedia they used significantly higher than those in the control group (p=0.002).

Students in both groups started their clerkship with a low overall rating of the availability of study sources to prepare themselves for the clerkship, general procedures, basic surgical skills, specialized surgical procedures, and surgical anatomy (**Figure 4**). At the end of the clerkship, both groups showed an increase in the evaluation of the availability of study sources, although this increase was significantly greater in the video group (control group: ∆0.2; video group: ∆0.7, p<0.001). Furthermore, the students in the video group rated the quality of the multimedia sources they used significantly higher (control group; 3.9 (IQR 3.6 – 4.3), video group; median 4.4 (IQR 3.8 – 4.8), **Table 3; Figure 5**). The vast majority (98% of students) rated the online video platform as indispensable for future students in the clerkship.

Supervising surgeons

Of the 12 participating hospitals, 10 supervising surgeons filled out the survey concerning students in the control group (83%) and 7 for the video group (58%). They had a median of 5 years of experience in supervising medical students (range 1 – 20 years) and all of them had input from their colleagues on all of the students when giving feedback and filling out the survey. On questions regarding students' knowledge (Cronbach's α = 0.798), the control group scored lower than the video group (median 2.9 (IQR 2.7 – 3.5) versus 3.5 (IQR 3.3 – 4.0)); which was not significantly different (p=0.17). On questions regarding the availability of study sources (Cronbach's α = 0.837), the video group scored higher (median 3.75 (IQR – 3 – 4.3)) than the control group (median 3.4 (IQR 3 – 3.8)), p=0.49). The self-confidence of students in general and in the OR specifically (Cronbach's α = 0.856), was similar (median 3 versus 3). However, 3 out of 10 supervisors ranked the self-confidence of students "low" in the control group, versus none in the video group.

Six of the 10 surgeons indicated students in the control group lacked high-quality video material to prepare themselves for procedures. In the video group, no supervisor indicated the students lacked preparation material, and 2 supervisors specified that they had noticed significant improvements in peri-operative knowledge in students in the video group.

DISCUSSION

Students are expected to acquire surgical skills and knowledge during the clinical clerkships, while time and exposure to different procedures are limited. The need to ensure similar medical education to all students, in a landscape of increasing differentiation among surgical (sub) disciplines and hospitals and thus decreasing exposure to all facets of surgery, is a challenge to every medical school. However, newer learning tools, such as online surgical videos and courses to supplement traditional didactic lectures and hospital-based learning are becoming available. In this study, we found that surgical knowledge increased significantly during the surgical clerkship when students are provided access to a structured online video-based surgical education platform in addition to the standard surgical curriculum. More importantly, surgical knowledge was more uniformly spread in students in the video group, despite the inhomogeneous exposure to different "live" surgical procedures due to differences in teaching hospitals. Also, self-reported knowledge increased significantly over the course of the clerkship in the video group compared to students who did not have access to this platform and who used publicly available sources. Students felt more prepared due to better tools and sources for the clerkship in general and for the different interventions they were going to see specifically. They almost unanimously rated the platform essential for future students in the clerkship. Furthermore, the supervising surgeons (n=10) in this study rated the knowledge of the students in the video group higher compared to the control group.

Earlier studies have reported comparable positive results of increased knowledge and self-confidence of students from educational surgical videos.[14–17] Several features of this type of education can explain these effects. First, students have the time to prepare themselves beforehand by viewing an uncomplicated procedure, and therefore know what to expect. These videos can be watched and -selectively - rewatched at the students' desired pace and moment (just in time). Consequently, they will be able to concentrate better on the next procedural steps during the live operation and have fewer problems determining surgical anatomy. Feeling prepared also increases student confidence and therefore facilitates optimal learning in the operating theatre.[18–20]

Furthermore, the structured step-by-step explanations of surgical procedures decrease the cognitive load by fragmentation of the study material.[16] The structured pre-, per- and post-operative objectives form an essential part of the preparation for the procedure and provide relevant information based on validated sources and guidelines. This is especially important because inexperienced students may not be able to tell if a shown procedure on a non-official platform is following national or international guidelines.[21,22] Although the majority of students use YouTube as a learning tool in medical school, recent studies have shown that half of the educational videos of laparoscopic cholecystectomies on YouTube showed dangerous situations and only 10 followed the international guidelines in demonstrating the "critical view of safety".[4,23,24] Another review that focused on videos on the treatment of distal radius fractures found that only 16 of the 68.000 videos met the international criteria.[25] Videos of knee arthrocentesis were deemed suitable for educational purposes in 62% of cases.[21] A study focusing on face-lift procedures points out that videos for educational purposes did not cover pre- and postoperative aspects as indications, complications, and patient selection.[26] These results indicate that students need to be cautious when using YouTube videos in their learning and preparation.[3,27–31] The courses on the online video-based surgical education platform in this study follow international guidelines and are supervised by expert surgeons, anatomists, and surgical educators.

In this study, the use of this platform by students was voluntary. By incorporating the platform as an obligatory learning and teaching tool for students and teachers, the learning yield may increase. And although this study or its contents were not officially included in the final exams, we did see overall higher scores on the exam in the video group (data not shown).

Lastly, structured, high quality, educational videos offer a more homogeneous education for students, independent of the surgeons and procedures they encounter during their clerkship. One of the problems we wanted to overcome with the incorporation of an online video-based educational platform was the differences in surgical exposure for the students enrolled in the academic center (Erasmus MC) or one of the eleven affiliated community hospitals. Even though several studies have found no differences in performance and study results between students in academic or community hospital clerkships, we found in this study that students assigned in the university center for the clerkship reported longer preparation times for procedures (data not shown).[32,33] Procedures performed in tertiary centers are generally more complicated and information on these procedures is less readily available and more complex. Understandably, these students also reported lower numbers of observed interventions and fewer operations in which they actively participated. However, the location of the clerkship did not affect students' test scores on the knowledge test (p=0.06) or the mandatory university test (p=0.15; data not shown).

Strengths and limitations

Unfortunately, randomization in this study was unfeasible. Due to the nature of the intervention in the video group, two consecutive cohorts were needed to avoid contamination of the groups by cross-contact of the students in daily life or via social media as much as possible. As mentioned, the selection for these consecutive cohorts was made by the university and based on students' progress in the previous 3 years of medical school. Therefore, students that progressed faster through the first 3 years were placed in the first group (control group), and the students that required more time for the first 3 years in the second group (video group). This effect is visible in the knowledge test scores at T0 where the control group had slightly higher scores (p=0.09), but that is reversed at T1 with higher scores for the video group, underlining the effect of the intervention (p=0.001).

Although a large number of students participated in this study, the decreasing number of students filling out the second survey might overestimate the increase in self-reported knowledge and test scores. Highly motivated students may engage more in available study materials and may have been more eager to fill out the surveys. We did see a difference between the control and video group in the number of surveys filled out at T0 (66% vs 90%) because the second group had already had an introduction to the platform prior to filling out the first survey. This difference in the number of filled out surveys was not seen at T1. Furthermore, we did not see a significant difference in students interested in a career in a surgical specialty in both groups or in scores on the knowledge test in students that indicated to be interested in a career in surgery and those who were not.

Also, because theoretical knowledge is the easiest to test, this might misjudge technical abilities, clinical thinking, and skills like communication, professionalism, and teamwork in students. Although we did see a clear trend in more positive opinions of the surgeons on students in the video group in this regard, these results were not significantly different due to the small number of surgeons in our cohort.

Implications

This study demonstrates intensive use by students, an increase in self-reported and tested knowledge, and better evaluations of supervising surgeons. This is especially true in the case of differences in exposure that occurs between hospitals. With increased use, the database of courses including videos can be expanded to include more complex operations and different approaches to certain procedures. When used internationally, a more standardized universal language for surgical procedures can be created which may facilitate (research) collaborations in the future within the surgical community and beyond.

CONCLUSIONS

The addition of high quality and structured video courses of surgical procedures and skills to standard surgical curriculum improved self-reported knowledge and tested knowledge in students during their surgical clerkship. Student satisfaction regarding the availability of high-quality study sources was higher in the video group and students felt more prepared for the clerkship in general and for specific procedures. Furthermore, supervising surgeons scored the knowledge and skills of the students with access to the online video platform higher. The various courses on this platform facilitate learning objectives prior to the procedure students will see or participate in and ensure a homogeneous surgical experience for all students. Based on the findings in our study, we suggest providing access to a high-quality video platform to all students in the clinical phase of their training.

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PART II
LEARNING BY DOING

8

LEARNING INGUINAL HERNIA REPAIR? A SURVEY OF CURRENT PRACTICE AND OF PREFERRED METHODS OF SURGICAL RESIDENTS

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Hernia 2020

ABSTRACT

Background

During surgical residency, many learning methods are available to learn an inguinal hernia repair (IHR). This study aimed to investigate which learning methods are most commonly used and which are perceived as most important by surgical residents for open and endoscopic IHR.

Methods

European general surgery residents were invited to participate in a 9-item web-based survey that inquired which of learning methods were used (checking one or more of 13 options) and what their perceived importance was on a 5-point Likert scale (1 = completely not important to 5 = very important).

Results

In total, 323 residents participated. The five most commonly used learning methods for open and endoscopic IHR were apprenticeship style learning in the operation room (OR) (98% and 96%, respectively), textbooks (67% and 49%, respectively), lectures (50% and 44%, respectively), video-demonstrations (53% and 66%, respectively) and journal articles (54% and 54%, respectively). The three most important learning methods for the open and endoscopic IHR were participation in the OR (5.00 [5.00–5.00] and 5.00 [5.00–5.00], respectively), video-demonstrations (4.00 [4.00–5.00] and 4.00 [4.00–5.00], respectively), and hands-on hernia courses (4.00 [4.00–5.00] and 4.00 [4.00–5.00], respectively).

Conclusions

This study demonstrated a discrepancy between learning methods that are currently used by surgical residents to learn the open and endoscopic IHR and preferred learning methods. There is a need for more emphasis on practicing before entering the OR. This would support surgical residents' training by first observing, then practicing and finally performing the surgery in the OR.

INTRODUCTION

Inguinal hernia repair (IHR) is one of the first surgical procedures that surgical residents learn during their training,[1] as it is a relatively simple surgical procedure to familiarize residents with the importance of understanding surgical anatomy and essential surgical skills. The European Hernia Society's updated guideline for the treatment of inguinal hernia in adult patients recommends either the open or laparo-endoscopic approach – providing the surgeon has expertise in that approach – as best-evidence based options for IHR.[2-3] The open IHR is easier to teach surgical residents compared to the endoscopic IHR[4] and fewer surgical procedures are required for proficiency.[5]

The training of surgical residents is evolving from the traditional "see one, do one, teach one" model towards preparation before stepping into the operating room (OR).[6] One of the reasons being the duty hour restriction which has led to less exposure time in the OR[7] and decreasing educational outcomes.[8] Additionally, patient safety and the general opinion not to practice on patients forces surgical training to change. Surgical residents can learn complex skills in a variety of ways. Knowledge can be learned using books, articles, lectures, videos or e-learnings;[9] skills can be trained in a simulation setting,[10] followed by performing the surgical procedure in the OR, with repeated practice and feedback.

Basically, these learning methods aim to improve surgical performance to a level of proficiency. The surgical performance can be assessed by many available yet resource-intense tools. Therefore, the number of surgical procedures performed is commonly used as a proxy for proficiency.[5] Also, operative time[11] or complication rates[12] can be used. The extent of proficiency experienced by surgical residents reflects their confidence and knowledge level; however, to our knowledge, no information is available on when surgical residents consider themselves to be proficient for the IHR.

Even though the aforementioned stages to learn complex skills and achieve proficiency are known – observing, practicing, performing and receiving feedback – it is unclear which learning methods – aiming both at theoretical learning and skills learning – are in fact most commonly used by residents, and which are perceived as most important for open and endoscopic IHR. This study aims to address these two questions. Additionally, the resident's self-perceived proficiency levels for both procedures were assessed.

METHODS

European general surgery residents were invited to participate in this study from the 28th of July to the 20th of October 2019 and from the 1th of May to 1th of June 2020 by distributing the survey amongst members of the European Hernia Society and the Dutch Association of Surgical Residents. Participation was voluntary, and data was collected anonymously.

A 9-item, English-language web-based survey was developed to investigate the most commonly used learning methods, the perceived as most important learning methods and the resident's self-perceived proficiency levels. The most commonly used learning methods were inquired by asking residents to select one or more methods that they had used to learn the IHR during their residency. For the importance of the learning methods a 5-point Likert scale was used to rate each learning method (1 = not at all important to 5 = very important).

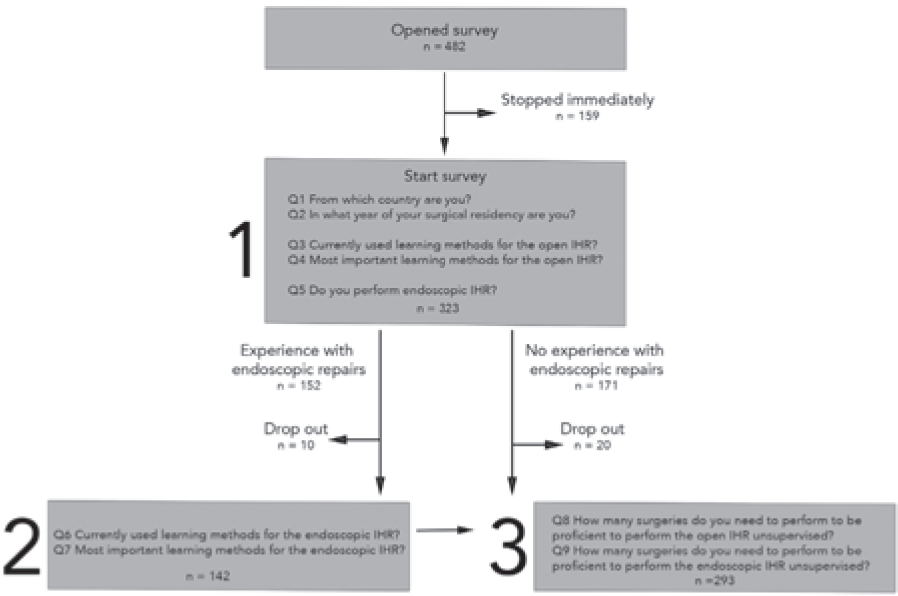

Figure 1. Study design

As shown in **Figure 1**, the survey was split into three sections. The first section included questions regarding demographics (2 questions), currently used learning methods, what trainees perceived as the most important learning methods for the open IHR (2 questions) and whether the participant had experience with endoscopic IHR (1 question). The second section was exclusively for participants with endoscopic IHR experience and contained questions regarding currently used learning methods and what trainees perceived as the most important learning methods for the endoscopic repairs (2 questions). All participants were included in the third section, with questions concerning the supposed number of surgical procedures needed to achieve proficiency for the open and endoscopic IHR (2 questions).

Descriptive data of the currently used learning methods were presented using percentages. The descriptive data of the perceived importance of learning methods were presented as medians and interquartile range (IQR). Means were used for ranking these learning methods. All analyses were performed using SPSS® version 24.0 (IBM, Armonk, New York, USA).

RESULTS

In total, 482 general surgery residents opened the online survey, of whom 159 dropped out immediately and 323 completed the first section (**Figure 1**). Hundred fourty-two residents completed the second section concerning endoscopic repair. Finally, 293 completed the proficiency questions in the third section. The surgical residents were on average in their third year of residency [2.0 – 5.0] and originated from 19 different countries, most of them were from Italy, the Netherlands and Spain (**Table 1**).

The five most commonly used learning methods for the open and endoscopic IHR were participation in the OR (98% and 96%, respectively), textbooks (67% and 49%, respectively), lectures (50% and 44%, respectively), video-demonstrations (53% and 66%, respectively) and journal articles (54% and 54%, respectively) (**Figure 2**). The least used learning methods for the open and the endoscopic IHR were the use of the animal models (2% and 5%, respectively) and bench simulation model (9% and 12%, respectively).

Table 1. Demographics

Participants	*n*	*%*
Total opened survey	482	
Open IHR section completed (1st)	323	67
Endoscopic IHR section completed (2nd)	124	26
Proficiency section completed (3rd)	293	61
From which country are you?	*n=323*	*%*
Italy	90	27.9
The Netherlands	66	20.4
Spain	65	20.1
United Kingdom	39	12.1
Denmark	19	5.9
Sweden	17	5.3
Czech Republic	7	2.2
Portugal	5	1.5
Germany	3	0.9
Greece	2	0.6
Austria	2	0.6
Macedonia	1	0.3
Romania	1	0.3
Poland	1	0.3
Ukraine	1	0.3
Ireland	1	0.3
Iceland	1	0.3
Albania	1	0.3
Estonia	1	0.3
Year surgical residency	*n=323*	*%*
1	53	16.4
2	51	15.8
3	65	20.1
4	49	15.2
5	60	18.6
6	45	13.9
Experience endoscopic IHR	*n=323*	*%*
No	171	52.9
Yes, supervised	77	23.8
Yes, unsupervised	75	23.2

As demonstrated in **Table 2**, what trainees perceived as the top three most important learning methods for the open and endoscopic IHR were; participation in the OR (5.00 [5.00 – 5.00] and 5.00 [5.00 – 5.00], respectively), video-demonstrations (4.00 [4.00 – 5.00] and 4.00 [4.00 – 5.00], respectively), and hands-on hernia courses (4.00 [4.00 – 5.00] and 4.00 [4.00 – 5.00], respectively). The two lowest-ranked learning methods for the open and endoscopic IHR were participation in a journal club (3.00 [2.00 – 4.00] and 3.00 [2.00 – 4.00], respectively) and practicing on animal models (3.00 [2.00 – 4.00] and 3.00 [1.00 – 4.00], respectively).

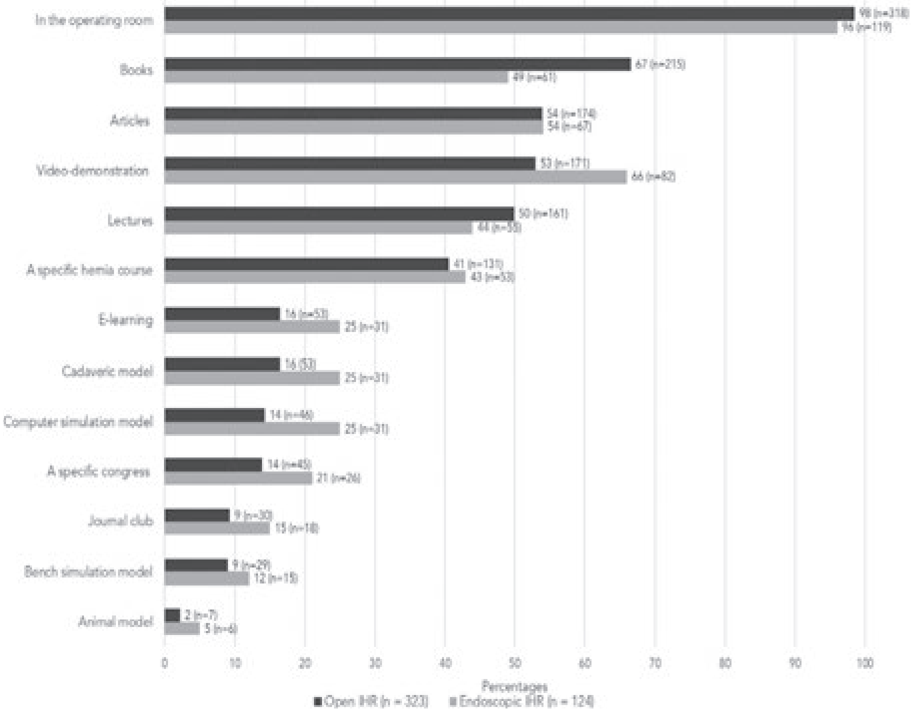

Figure 2. Currently used learning methods for the open and endoscopic inguinal hernia repairs

The number of open IHR needed for proficiency was estimated by the surgical residents to be median 30 to 40 surgical procedures (range 20 – 50) (**Figure 3**). The supposed proficiency number for the endoscopic IHR was median 50 to 75 surgical procedures (range 25 – 100).

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Table 2. Open and endoscopic inguinal hernia repairs – importance learning methods

	Open IHR (n= 323)			Endoscopic IHR (n= 124)		
	Median [IQR]	**Mean**	**Rank**	**Median [IQR]**	**Mean**	**Rank**
In the operating room	5.00 [5.00 – 5.00]	4.90	1	5.00 [5.00 – 5.00]	4.96	1
Video-demonstration	4.00 [4.00 – 5.00]	4.26	2	5.00 [4.00 – 5.00]	4.50	2
A specific hernia course	4.00 [4.00 – 5.00]	4.26	3	5.00 [4.00 – 5.00]	4.35	3
Cadaveric model	4.00 [3.00 – 5.00]	4.00	4	4.00 [3.00 – 5.00]	3.84	6
Articles	4.00 [4.00 – 4.00]	3.85	5	4.00 [3.00 – 5.00]	3.88	5
Lectures	4.00 [3.00 – 4.00]	3.83	6	4.00 [3.00 – 5.00]	4.06	4
Books	4.00 [3.00 – 4.00]	3.81	7	4.00 [3.00 – 5.00]	3.77	7
Bench simulation model	4.00 [3.00 – 5.00]	3.79	8	4.00 [3.00 – 5.00]	3.52	11
Computer simulation model	4.00 [3.00 – 4.00]	3.65	9	4.00 [3.00 – 5.00]	3.75	8
E-learning	4.00 [3.00 – 4.00]	3.58	10	4.00 [3.00 – 5.00]	3.67	9
A specific congress	3.00 [3.00 – 4.00]	3.50	11	4.00 [3.00 – 5.00]	3.64	10
Journal club	3.00 [2.00 – 4.00]	3.03	12	3.00 [2.00 – 4.00]	2.94	12
Animal model	3.00 [2.00 – 4.00]	2.99	13	3.00 [1.00 – 4.00]	2.78	13

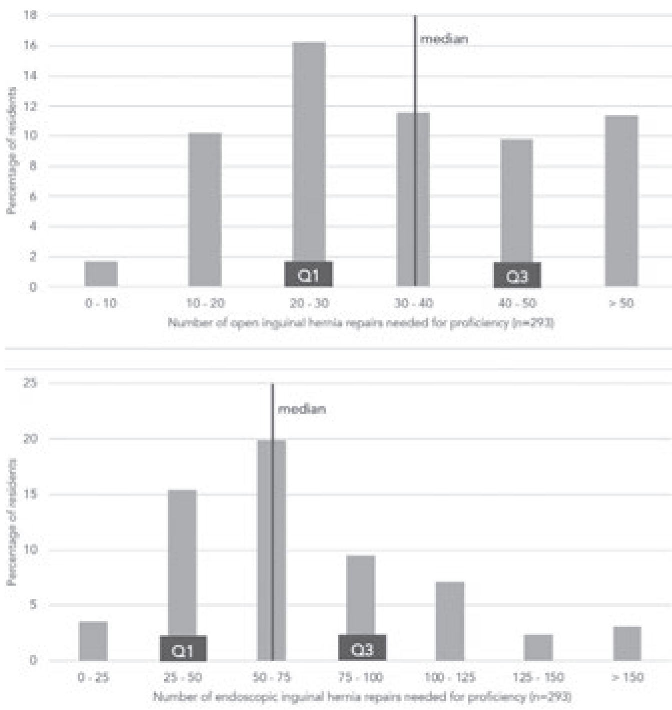

Figure 3. Estimated number of surgical procedures needed for proficiency in a. open and b. endoscopic inguinal hernia repair

DISCUSSION

The most frequently used learning methods in inguinal hernia surgery by surgical residents were participation in the OR, video-demonstrations, lectures, textbooks and articles, while the perceived most important learning methods were participation in the OR, video-demonstrations and hands-on hernia courses. The residents prefer, besides the traditional learning methods, hands-on practice during specific hernia courses.

Currently traditional learning methods, video-demonstrations and learning in the OR are mainly used. Ideally, a resident is trained by observing the surgical procedure, then practicing it in a safe environment and finally executing it in the OR while receiving feedback to improve further. A safe environment to practice their surgical knowledge and skills without compromising patient safety is provided by simulation training.[13] Several studies have proven the positive effects of simulation training,[13-15] however, its implementation into the residents' curriculum remains challenging.[13] The challenging implementation is underlined by our findings as the simulation methods are not frequently used (**Figure 2**). Often, simulation training is unstructured or provided as 'one-time' events at courses.[13] The unstructured delivering of simulation training leads to not fully exploiting its potential, which would be the case in the aforementioned sequence – practicing in a simulation environment before operating on a patient. Despite the advantages of simulation, our participating surgical residents found the bench simulation model and computer simulation model to have low importance as learning methods for the IHR. The low importance is in contrast to a previous study in which 82% of surgical residents found simulation to be an important educational method for the IHR.[6] Although numerous bench simulation models[15-16] and computer simulation models have been validated for the IHR,[17-19] we wonder if the unfamiliarity of the participating surgical residents with these bench simulation model or computer simulation model could explain the perceived low importance of these learning methods. These validated simulation models should find their way to day-to-day use for IHR training.

Video-demonstrations were mentioned as one of the most important learning methods in our study. Zahiri and colleagues found video-demonstrations to be

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important for 87% of surgical trainees.[6] An advantage of online videos is that they can be accessed on demand by surgical residents – any time and any place – known as the just-in-time principle.[20] YouTube is the most preferred streaming video source among medical students, surgical residents and faculty members.[21] However, in general and especially if the contributor is unknown, surgical videos on YouTube lack educational value and may display inadequate or even unsafe manoeuvres.[22-24] As YouTube is not a peer-reviewed platform, videos are ranked on popularity and not on quality.[25] WebSurg is another online platform for open source videos of minimally invasive surgical procedures only.[26] The WebSurg videos regarding the total extraperitoneal procedure for IHR were found to be of suboptimal quality in terms of educational value.[27] Teaching grade video-demonstrations of surgical procedures should be peer-reviewed and have high educational value.[22, 24, 27] A rather new online surgical educational platform is Incision Academy with surgical videos containing standardized procedural steps[28] and of which the content has been supervised by surgeons and anatomists.

Surgical training is aimed at reaching a proficiency level in performing a surgical procedure independently. In this study, surgical residents were asked to indicate how many procedures they need to become proficient in the IHR. Our participating surgical residents estimated 30 to 40 procedures (range 20 – 50) were required to achieve proficiency in open IHR. In previous studies, around 40 open IHR,[1] or even 64 repairs were needed for proficiency.[29] In our survey, the estimated number of endoscopic IHR needed to become proficient were 50 to 75 surgical procedures (range 25 – 100). Previous study indicated that more than 100 endoscopic repairs are required to achieve outcomes comparable to open anterior mesh repair.[5] However, in-line with our results, other articles referred to 65 procedures as a minimum volume necessary to train for endoscopic inguinal hernia repairs.[30-31] Due to this discrepancy between the numbers estimated for proficiency by our surgical residents and the numbers needed for proficiency, the question arises whether surgical residents overestimate themselves, or the trainees underestimate the residents. Some surgical residents require less surgical procedures than others to achieve proficiency.[32] A comprehensive yet easy to use assessment tool should be used to assess the performance of a surgical procedure, and to indicate one's proficiency more accurate. Possible options could be competence tracking using Observational Clinical Human Reliability Assessment (OCHRA) or Surgical Quality Assurance (SQA).[33-34]

Future perspectives

The sequence of a surgical residents' training – observing, practicing, performing and reflecting on a surgical procedure – should be facilitated. First to facilitate observing of surgical procedures, accurate video-demonstrations should be provided. Secondly, as the learning yield of surgical simulation training is promising, the perceived low importance amongst surgical residents should be explored. Perhaps the familiarity of qualitative simulation models is lacking to incorporate simulation training into surgical residents' training programs. Especially, the timing of the simulation trainings should be optimized so a resident can train in a safe environment and then progress to performing the surgical procedure in the OR. Finally, to facilitate the reflection on a surgical procedure and to evaluate the residents' proficiency, the applicability of the OCHRA or SQA should be further researched.

Limitations

This study has a number of limitations that need to be considered. Of 482 surgical residents that opened the survey, 159 residents stopped immediately. It is possible that these surgical residents had different views on learning methods. Secondly, the majority of the residents originated from Italy, the Netherlands and the Spain (n = 221 of 323) which might have made the results less representative for Europe, although the participants from the various European countries indicated similar experienced and preferred learning modalities. Thirdly, in order to keep our survey short and concise, we surveyed the learning methods without specifying which learning goal was desired, such as theoretical knowledge or technical skills. We also did not ask how many open or endoscopic surgical procedures the residents had performed.

CONCLUSIONS

In conclusion, this study demonstrated a discrepancy between learning methods that are currently used by surgical residents to learn the open and endoscopic IHR and preferred learning methods by them. There is a need for more emphasis on practicing before entering the OR. To achieve this more simulation models for IHR are needed. This would support surgical residents' training by first observing, then practicing and finally performing the surgery in the OR. It is highly recommended to implement simulation based training in educational residency programs.

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9

VALIDITY OF A LOW-COST LICHTENSTEIN OPEN INGUINAL HERNIA REPAIR SIMULATION MODEL FOR SURGICAL TRAINING

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ABSTRACT

Background

Simulation training allows trainees to gain experience in a safe environment. Computer simulation and animal models to practice a Lichtenstein open inguinal hernia repair (LOIHR) are available; however, a low-cost model is not. We constructed an inexpensive model using fabric, felt, and yarn that simulates the anatomy and hazards of the LOIHR. This study examined the fidelity, and perceived usefulness of our developed simulation felt model by surgical residents and expert surgeons.

Methods

A total of 66 Dutch surgical residents and 10 international expert surgeons were included. All participants viewed a video-demonstration of LOIHR on the simulation felt model and subsequently performed the surgery themselves on the model. Afterward, they assessed the model by rating 13 statements concerning its fidelity (6 model, 3 equipment, and 4 psychological) and 6 usefulness statements on a 5-point Likert scale. One-sample Wilcoxon signed-rank test was used to compare to the neutral value of 3.

Results

The fidelity was assessed as being high by residents (model 4.00 [3.00-4.00], equipment 4.00 [3.00-4.00], psychological 4.00 [3.00-4.00]; all p's<.001) and by expert surgeons (model 4.00 [3.00-4.00], p=.025; equipment 4.00 [3.00-5.00], p<.001; psychological 4.00 [3.00-4.00], p=.053). The usefulness was rated high by residents and experts, especially the usefulness for training of residents (residents 4.00 [4.00-5.00], p<.001; experts 4.50 [3.75-5.00], p=.015).

Conclusions

Our developed Lichtenstein open inguinal hernia repair simulation felt model was assessed by surgical residents and expert surgeons as a model with high fidelity and high potential usefulness, especially for the training of surgical residents.

INTRODUCTION

In current surgical education, learning by simulation training is a frequent adjunct to preparation for real operating room experiences.[1] Surgical simulation models allow the trainees to gain their experience in a safe environment,[2] without risking patient safety.[3]

One of the core procedures in training surgical residents is the inguinal hernia repair. The open inguinal hernia repair with the placement of a tension-free mesh was introduced in 1984 by Lichtenstein.[4] Even though the use of the laparo-endoscopic repair of the inguinal hernia is rising, the European Hernia Society's updated guideline for the treatment of inguinal hernia in adult patients recommended both the Lichtenstein and the laparo-endoscopic technique as the best-evidence based options.[5] The open inguinal hernia repair technique is simpler to teach compared to the laparo-endoscopic techniques.[6] In many low resource regions, laparoscopic surgery is not available.

Simulation models to practice the open inguinal hernia operation, such as a computer simulation[7-9] or animal models[10] are available. However, to our knowledge, no low-cost model simulating the Lichtenstein open inguinal hernia repair (LOIHR) has been published. We sought to construct a model using inexpensive materials that simulates the anatomical structures and hazards of the LOIHR.

Fidelity determines the extent to which the simulation model resemblances reality. It measures the degree in which the appearance and behavior of the simulation model match the real experience.[11] Fidelity consists of three domains suggested by Rehmann: 'environment' which was, in this case, the simulation model, 'equipment' and 'psychological'.[12] This study aimed to examine the fidelity, and potential usefulness of our developed Lichtenstein open inguinal hernia repair simulation model.

METHODS

Participants and design

This study was conducted among surgical residents and expert surgeons in order to assess the open inguinal hernia repair simulation model. The surgical residents were invited for inclusion during the education days of the Dutch Association of

Surgery. The surgical residents were shown a video-demonstration of the LOIHR with the placement of a tension-free mesh on the model first. Afterward, the surgical residents performed the surgery themselves on the model and filled out the rating scale questionnaires. Participation was anonymous and voluntary.

The international expert surgeons had significant experience in performing the LOIHR. Ten expert surgeons were invited per email for participation. All experts confirmed participation. After confirmation of participation, they were sent a package containing a LOIHR simulation model and an instruction letter including their login credentials to a website where they could view the video-demonstration of the LOIHR performed on the simulation model and where they could fill out the rating scales concerning the model. First, they were asked to view the video-demonstration, then to perform the surgery themselves and lastly to fill out the rating scales. Informed consent was obtained from all individual participants included in the study.

Lichtenstein open inguinal hernia repair simulation model

The LOIHR simulation model mimicked the human male groin region, including the abdominal wall layers and the contents of the inguinal canal. Each structure included in the model was crucial for the LOIHR. Positioned within the correct layers were the hazardous structures, such as the superficial epigastric vessels, the spermatic cord, and the ilioinguinal, iliohypogastric nerves and genital branch of the genitofemoral nerve (**Figure 1**).

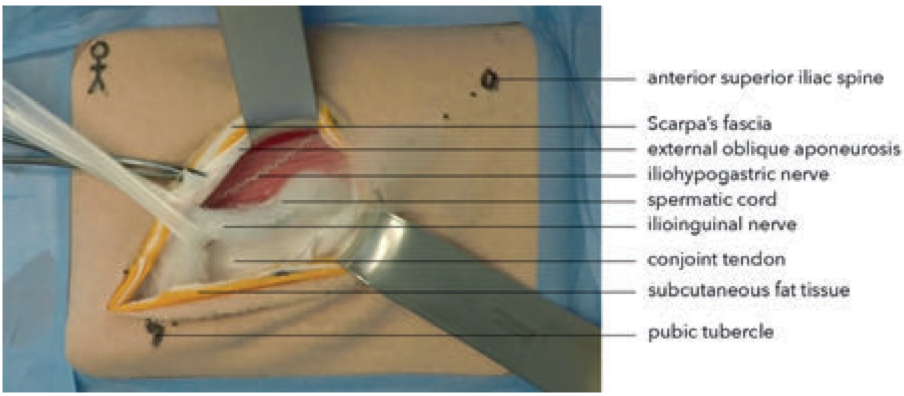

Figure 1. Open inguinal hernia simulation model, left male groin

The model was constructed using low-cost materials. The tan-colored fabric was used to mimic the skin. White felt to mimic Scarpa's fascia, and yellow felt layers to mimic the subcutaneous fat, and red felt was used to mimic the internal oblique muscle. A broad white braided elastic band mimicked the conjoint tendon. White cotton layers were used to represent the anterior rectus sheath and the external oblique aponeurosis, including an opening to simulate the external ring of the inguinal canal and a fold representing the inguinal ligament. The spermatic cord was constructed using batting. Within this batting, a small transparent plastic bag was added to simulate an indirect hernia. Red, blue, yellow, and white yarn were used to mimic the arteries, veins, nerves, and the vas deferens, respectively. The material cost per model was less than 5 US dollars. This model was identical to the one used for the video-demonstration.

The model was first developed at the Mayo Clinic and was initially reported by Rowse et al.[13] After using the initial model for training of surgical residents in the Mayo Clinic and Ghana and critical assessment of the model by the senior authors, adjustments were made to optimize the model. Due to the adjustments, the conjoint tendon and a separate anterior rectus sheath were added to the model. The spermatic cord was pasted to the conjoint tendon to allow trainees to dissect it. Finally, the iliohypogastric nerve was adjusted so it would run towards the subcutaneous fat tissue underlying the skin.

Video demonstration

The video-demonstration showing the LOIHR on the simulation model was 8:00 minutes (video-demonstration LOIHR available online). The surgery was based on the description of Amid [14] and was divided into steps using the step-by-step framework [15] (**Appendix A**). The step-by-step framework breaks down surgical procedures – based on anatomical structures and implants– into steps and substeps.

Rating scales

After the surgical residents and surgeons operated on the simulation model, they were instructed to fill out the rating scales. The questions were adapted from a previously used questionnaire in a study on fidelity and its different domains using 6 model, 3 equipment, and 4 psychological statements [16] (**Appendix G**).

An example of a model-related statement was “This simulation model provides a realistic representation of the abdominal layers.” The equipment fidelity was assessed using statements as “On this simulation model, I could demonstrate the precise movements of the open inguinal hernia repair.” Statements as “My experience with the simulation model seemed (overall) consistent with my real-world experiences” were used to assess the psychological fidelity.

The usefulness of the model as a teaching entity and for specific groups (medical students, residents, surgeons) were assessed using 6 statements (**Appendix H**). All statements were rated on a 5-point Likert scale (1= Strongly disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly agree).

Statistical analysis

All statistical analyses were performed using SPSS (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.). Descriptive data were presented as medians and interquartile range (IQR) of the statements per domain of fidelity and for the usefulness were calculated. The Mann Whitney U test was used to compare the surgical residents and expert surgeons. One-sample Wilcoxon signed-rank test was used to compare the median per domain of fidelity and usefulness to the neutral value of 3. The internal consistencies for the three domains within fidelity and for the usefulness rating scales were determined using Cronbach’s α. P-values of less than .05 was considered statistically significant.

RESULTS

In total, 66 Dutch surgical residents were included. Their average age was 32 years (**Table 1**). None of the surgical residents were in their first year of training, 3 in their second, 32 in their third, 24 in their fourth and 7 in their fifth or sixth year. The included experts were 10 surgeons from 7 different countries and 3 different continents. As can be seen in **Table 2**, the average age was 55 years (range 37 to 69). One expert had less than 10 years of post-residency experience, one had 10 to 20 years, and eight experts had more than 20 years. Five expert surgeons had performed more than 3000 open inguinal hernia repairs in total, and two expert surgeons had performed more than 10.000. Five experts had published more than 50 hernia-related papers.

Table 1. Demographics surgical residents

		Surgical residents (n=66)
Age (median; range)		32 (29 – 36)
Sex (%)	Female	35.4%
	Male	64.6%
Year surgical training (mean±SD)		3.55±0.778
Total amount of open inguinal hernia repairs seen (%)	< 10	4.5%
	10 to 20	12.1%
	20 to 30	18.2%
	> 30	65.2%
Total amount of endoscopic inguinal hernia repairs seen (%)	< 10	10.6%
	10 to 20	24.2%
	20 to 30	21.2%
	> 30	43.9%
Total amount of open inguinal hernia repairs performed (%)	< 5	7.6%
	5 to 10	6.1%
	10 to 15	16.7%
	> 15	69.7%
Total amount of endoscopic inguinal hernia repairs performed (%)	< 5	45.5%
	5 to 10	12.1%
	10 to 15	6.1%
	> 15	36.4%

Table 2. Demographics expert surgeons

		Expert surgeons (n=10)
Age (median; range)		55 (37 – 69)
Sex (%)	Female	2
	Male	8
How many years of surgical experience (postgraduate) do you have? (n)	< 10	1
	10 to 20	1
	> 20	8
What is the total amount of open inguinal hernia repairs performed in your clinic annually? (n)	< 200	2
	200 - 400	4
	400 - 600	1
	> 600	3

		Expert surgeons (n=10)
What is the total amount of open inguinal hernia repairs performed personally by you in a year? (n)	< 100	4
	100 - 200	5
	> 300	1
What is the total amount of open inguinal hernia repairs performed personally by you in total? (n)	> 100	1
	> 1.000	3
	> 3.000	2
	> 6.000	1
	> 10.000	2
	Unknown	1
What is the total amount of endoscopic inguinal hernia repairs performed personally by you in a year? (n)	< 100	8
	100 - 200	1
	> 300	1
How many hernia-related papers did you publish in total? (n)	< 25	1
	> 25	3
	> 50	3
	> 75	2
	Unknown	1

As shown in **Table 3**, the model fidelity was rated 4.00 [3.00 – 4.00] by the surgical residents and the expert surgeons (U=277.00, p=.393). The surgical residents rated the equipment fidelity 4.00 [3.00 – 4.00] compared to 4.00 [3.00 – 5.00] rated by the experts (U=2796.5, p=.615). The psychological fidelity was found to be both 4.00 [3.00 – 4.00] by the surgical residents and the experts (U=5054, p=.892). For the surgical residents, these were all significantly higher compared to the neutral value of 3 (all p's <.001). In the case of the experts, this was true for model (Z=2.24, p=.025) and equipment (Z=3.20, p=.001). The internal consistency of the fidelity rating scale was found to be good (environment .876, equipment .836, psychological .857).

Table 3. Fidelity

	Surgical residents n=66 median [IQR]	**Expert surgeons n=10 median [IQR]**	**Experts vs residents *p*-value^**	**Surgical residents vs neutral value of 3 *p*-value§**	**Experts vs neutral value of 3 *p*-value §**
Model Cronbach α = .876	4.00 [3.00 – 4.00]	4.00 [3.00 – 4.00]	.044*	<.001*	.025*
Equipment Cronbach α = .836	4.00 [3.00 – 4.00]	4.00 [3.00 – 5.00]	.615	<.001*	.001*
Psychological Cronbach α = .857	4.00 [3.00 – 4.00]	4.00 [3.00 – 4.00]	.892	<.001*	.053

IQR interquartile range [Q1 – Q3]
^ Analyzed using Mann Whitney U test; § Analyzed using one sample Wilcoxon signed rank test
* statistically significant

The usefulness of the LOIHR simulation model was assessed to be 4.00 [3.00 – 5.00] by the surgical residents and the surgeon experts (**Table 4**, U=11759.5, p=.946, Cronbach α = .824). In both groups, this was significantly different compared to the neutral value of 3 (surgical residents p<.001; experts p<.001). Both groups found the model useful in teaching the importance of the open inguinal hernia repair and of placing a tension-free mesh. The surgical residents found the model to be useful for the training of surgical residents (Z=6.48, p<.001) and for medical students (Z=6.56, p<.001). The experts found it useful for training surgical residents (Z=2.43, p=.015).

Table 4. Usefulness

	Surgical residents n=66	Expert surgeons n=10	Experts vs residents	Surgical residents vs neutral value of 3	Experts vs neutral value of 3
	median [IQR]	median [IQR]	*p*-value^	*p*-value§	*p*-value§
Overall usefulness of the LOIHR simulation model (Cronbach α = .824)	4.00 [3.00 – 5.00]	4.00 [3.00 – 5.00]	.946	<.001*	<.001*
The LOIHR simulation model teaches the importance of performing the open inguinal hernia repair	4.00 [4.00 – 5.00]	4.00 [4.00 – 5.00]	.717	<.001*	.012*
The LOIHR simulation model teaches the importance of placing a tension-free mesh	4.00 [4.00 – 5.00]	4.50 [3.50 – 5.00]	.414	<.001*	.024*
The LOIHR simulation model is a useful tool to learn open inguinal hernia repair surgery	4.00 [4.00 – 5.00]	4.00 [3.75 – 5.00]	.421	<.001*	.018*
The LOIHR simulation model is useful for training of experts	3.00 [2.00 – 4.00]	3.50 [1.00 – 4.25]	.838	.590	.903
The LOIHR simulation model is useful for training of surgical residents	4.00 [4.00 – 5.00]	4.50 [3.75 – 5.00]	.817	<.001*	.015*
The LOIHR simulation model is useful for training of medical students	4.00 [3.00 – 5.00]	3.50 [2.00 – 5.00]	.487	<.001*	.248

IQR interquartile range [Q1 – Q3] ^ Analyzed using Mann Whitney U test; § Analyzed using one sample Wilcoxon signed rank test *statistically significant

DISCUSSION

Simulation models to practice the open inguinal hernia model, such as a computer simulation[7-8] or animal models[10] are available. However, to our knowledge no low-cost model simulating the open inguinal hernia repair is available. Surgical residents assessed our developed low-cost Lichtenstein open inguinal hernia repair simulation model as a model with high fidelity. The surgeon experts only valued the model to have a high equipment fidelity. Both the surgical residents and the experts rated the usefulness of the model as high, especially for the training of surgical residents.

Animal or cadaveric models are typical examples of high fidelity models, and they may resemble reality more than our model.[2] In a comprehensive systematic review and meta-analysis, the authors found that a simulation model could be high or low fidelity depending on which domains were assessed.[17-18] In contrary to the three domains of fidelity (model, equipment and psychological) we used during this study, Allen, et al divided fidelity into two domains; physical fidelity (how the simulator appears) which may resemble our model domain, and functional fidelity (what the simulator does) which resembles our equipment domain.[19] Allen's domains do not include the psychological domain. When this study would have only used the domains of Allen, the surgical residents and the experts would have both assessed the fidelity of the model as high. Apart from which domains need to be assessed, the learning objectives of a simulator are more relevant. The learning objectives should determine the degree of fidelity of a simulator.[20] In our simulation model, the aim of creating the model was to carefully position the hazardous structures within the model to achieve the highest resemblance to reality. The trainee could cause the same complications in our model as in a real patient.

Simulation models are a step between theoretical learning and performing surgery on patients, as it allows trainees to learn and practice without risking patient safety.[3] With this LOIHR simulation model, the anatomical and procedural knowledge, together with the surgical skills of trainees, could be assessed. These features made the model particularly useful for training surgical residents in an uncomplicated case. Both the surgical residents and the expert surgeons found this to be true. However, in many cases, the reality differs due to variations caused by the patient (e.g., obesity), the disease (e.g., direct hernia) and anatomy (e.g., abnormal position of the iliohypogastric nerve). These variations demand an adjustment of the surgical procedure. Our model lacked these variations consciously, as this simulation model allows the trainee safe repetition until proficient to be able to perform the standard surgery supervised on a patient. The trainee will encounter the numerous variations possible during the LOIHR when he or she performs the surgery supervised in the OR. The point of proficiency can be determined by systematically tracking the competence of the trainees, for example by using the essential step by step description of the surgical procedure and the Observational Clinical Human Reliability Assessment (OCHRA).21 The OCHRA assesses the errors made during the surgical procedure.

Advantages of the model are low-cost, producible by anyone, and usable anywhere allows widespread usage, especially in low-resource environments. The LOIHR simulation model was constructed using non-expensive materials. The price of all components to construct one model was less than 5 US dollars. The cost of computer simulators, animal or cadaveric models often lacked in reports, however, in our own experience, these resources are significantly (> 100 times) more expensive than our model.[2, 8, 22] The construction of a single model took 30 minutes. With proper instruction, anyone can construct the model. We have experience with making the model by tailors in Ghana. We made an instruction video on how to make the model, and after the first initial trials, the model was very accurate. Lastly, in order to practice with this model, only basic surgical instruments are needed, in comparison to advanced computer systems, or an animal or cadaveric laboratory.

Concluding, our developed low-cost Lichtenstein open inguinal hernia repair simulation model was assessed as a model with high fidelity and high perceived usefulness, especially for the training of surgical residents.

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PART III
LEARNING BY REFLECTING

10

ACCURACY AND USEFULNESS IN ASSESSING PROFICIENCY OF THE OBSERVATIONAL CLINICAL HUMAN RELIABILITY ASSESSMENT CHECKLIST OF THE OPEN INGUINAL HERNIA REPAIR PROCEDURE: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background

The Observational Clinical Human Reliability Assessment (OCHRA) can be used to score errors during surgical procedures. To construct an OCHRA-checklist, steps, substeps, and hazards of a surgical procedure need to be defined. A step-by-step framework was developed to segment surgical procedures into steps, substeps, and hazards. The first aim of this study was to investigate if the step-by-step framework could be used to construct an accurate Lichtenstein open inguinal hernia repair (LOIHR) stepwise description. The second aim was to investigate if the OCHRA-checklist based on this stepwise description was accurate and useful for surgical training and assessment.

Methods

Ten expert surgeons rated statements regarding the accuracy of the LOIHR stepwise description, the accuracy, and the usefulness of the LOIHR OCHRA-checklist (eight, seven, and six statements, respectively) using a 5-point Likert scale. One-sample Wilcoxon signed-rank test was used to compare the outcomes to the neutral value of 3.

Results

The accuracy of the stepwise description and the accuracy and usefulness of the OCHRA-checklist were rated statistically significantly higher than the neutral value of 3 (median 4.75 [5.00–4.00] with p=.009, median 5.00 [5.00–4.00] with p=.012, median 4.00 [5.00–4.00] with p=.047, respectively). The experts rated the OCHRA-checklist to be useful for the training (5.00 [5.00–4.00], p=.009), and assessment (4.50 [5.00–4.00], p=.010) of surgical residents.

Conclusions

This preliminary study showed that the stepwise LOIHR description constructed using the step-by-step framework was found to be accurate. The LOIHR OCHRA-checklist developed using the stepwise description was also accurate, and particularly useful for the training and assessment of proficiency of surgical residents.

INTRODUCTION

Adverse events are frequent within the surgical field. A systematic review reported surgical adverse events in approximately 14% of patients, which were potentially preventable in more than one-third of cases.[1] These adverse events are mainly due to human errors. To specifically assess surgical errors during surgical procedures, the Observational Clinical Human Reliability Assessment (OCHRA) was developed.[2] The OCHRA distinguishes executional and procedural errors.[3] Executional error concerns technical execution, for example, a skin incision placed at an incorrect location, or an incision created too long or too deep. Procedural errors concern actions during surgery, which are wrongfully not performed, partially performed, or done out of sequence.[3]

For the development of a surgical procedure-specific OCHRA-checklist, the surgical procedure of choice needs to be segmented into steps and substeps in the order considered ideal for perfect execution, while potential hazards need to be identified.[4] Currently, the construction of an OCHRA-checklist is a time-consuming effort using historical technical protocols,[2, 5-6] expert panels,[7-9] and textbooks and literature combined with a thorough video-analysis of the surgical procedure.[10] Typically, expert panels are also used for the identification of hazards.[4] Although extensive research concerning the usefulness of the OCHRA for the assessment of surgical trainees has been conducted,[2-3, 5, 7, 9, 11-14] the OCHRA-checklist is currently not widely used yet. The unavailability of an efficient method to segment surgical procedures might be hampering the broad implementation of the OCHRA within the surgical field. To make this process potentially more efficient, a standardized step-by-step framework has been developed to break down surgical procedures into steps and substeps with the identification of hazards.[15] A step is defined as a surgical goal that needs to be achieved and evaluated before proceeding onto the next step. Each step consists of one or more substep(s), which are based on anatomical structures or implants. The step-by-step framework used in this study allows segmentation of every surgical procedure of choice into steps and substeps in a standardized and comprehensive manner, without the need of an expert panel or other time-consuming efforts. Since the stepwise description of a surgical procedure and the OCHRA-checklist are based on steps and substeps, a surgical procedure-specific OCHRA-checklist can then be effortlessly established using the step-by-step framework.

The first aim of this study was to investigate if the step-by-step framework can be used to construct an accurate stepwise description of a surgical procedure, including its hazards. The second aim was to investigate if the developed LOIHR OCHRA-checklist based on this stepwise description was accurate and useful for surgical training and assessment of medical students, surgical residents, and surgical experts. The Lichtenstein open inguinal hernia repair (LOIHR) was used as an example surgical procedure in this study as it is a common procedure for training residents containing multiple steps with significant errors. A simulation model was used in this study to resemble the standard anatomy and pathology for the LOIHR to assess the stepwise description and the OCHRA-checklist in a standardized environment.

METHODS

Stepwise description

The stepwise description of the LOIHR was constructed according to the step-by-step framework.[15] Under the direct supervision of a surgical expert, a medical doctor constructed a standardized stepwise description based on literature and available evidence-based guidelines.[16-20] This process for the LOIHR stepwise description consumed approximately eight hours in total. The surgical procedure concerned an indirect inguinal hernia repair (see **Appendix A**). The LOIHR stepwise description was additionally visualized in 8:00 minutes step-by-step video-demonstration of the surgical procedure being performed on an open inguinal hernia simulation model.

OCHRA-checklist

The OCHRA-checklist was constructed using the components of the stepwise description of the LOIHR (**Appendix I**). A sample of the first three steps of the LOIHR OCHRA-checklist is shown in **Figure 1**. The first column shows the steps of the LOIHR stepwise description, the second column shows the substeps based on the anatomical structures, and the third column describes the actions to be performed on these anatomical structures. The correct performance of a substep can be documented in the fourth column. Executional and procedural errors can be listed in the fifth and sixth columns, respectively. The hazards are stated in the final column.

Surgical steps			Performed correctly?	Procedural error	Executional error	Consequential?
Step	Substep	Action				
1. External oblique aponeurosis exposure	A. Skin	1. Incise				HAZARD – Iliohypogastric nerve damage
	B. Subcutaneous tissue	1. Incise				HAZARD - Superficial epigastric vessels damage
	C. Superficial epigastric vein	1. Transect				
	D. Scarpa's fascia	1. Incise				
	E. Subcutaneous tissue					
2. Inguinal canal exposure	A. External oblique aponeurosis	1. Identify				
		2. Incise				HAZARD - Ilioinguinal nerve damage
		3. Dissect				
3. Spermatic cord mobilization	A. Spermatic cord	1. Isolate				HAZARD - Genital branch of genitofemoral nerve
		2. Encircle				

Figure 1. Sample of the LOIHR OCHRA-checklist

Participants and design

Ten international hernia expert surgeons with significant surgical and research experience on the LOIHR were invited per email. Inclusion criteria was extensive experience in performing (more than 1000 surgical procedures) and/or researching the open inguinal hernia repair (more than 5 papers). Participants were excluded when they did not complete the survey. After confirmation of participation, an instruction letter was sent, including their login credentials to a website where they could view the stepwise description of the LOIHR, the step-by-step video-demonstration, and the OCHRA-checklist. The experts were then requested to assess the stepwise description and the OCHRA-checklist by rating statements. This study has been reported in line with the STROCSS criteria.[21]

Rating of statements

Three categories of statements were made; 1. accuracy of the LOIHR stepwise description, 2. accuracy of the LOIHR OCHRA-checklist, and 3. usefulness of the LOIHR OCHRA-checklist. First, the accuracy of the LOIHR stepwise description was rated using eight statements regarding the procedure (steps, substeps and hazards). The statements regarding the accuracy of the stepwise description included two control statements ('*Steps of the open inguinal hernia repair are missing*' and '*Hazards of the open inguinal hernia repair are missing*'). Second, the accuracy of the OCHRA-checklist was rated using seven statements. Third, the usefulness of the OCHRA-checklist for surgical training and assessment of medical students, residents, and experts was rated using six statements. All the statements were rated on a 5-point Likert-scale, varying from 1 = totally disagree to 5 = totally agree, with 3 = neutral.

Statistical analysis

The median and interquartile ranges (IQR) of the rated statements were analyzed due to the skewness of the data. One-sample Wilcoxon signed-rank test was used to compare the median of the statements to the neutral value of 3. A *p*-value of $<.05$ was considered statistically significant.

Cronbach's α was used to determine the internal consistency of each category: accuracy of the stepwise description (8 items), the accuracy of the OCHRA-checklist (7 items), and usefulness of the OCHRA-checklist (6 items). A Cronbach's α from .70 to .95 indicated an acceptable internal consistency.[22] The analyses were performed using SPSS® version 24.0 (IBM, Armonk, New York, USA).

RESULTS

Ten surgeons from seven different countries and three different continents participated in this study (**Table 1**). The average age of the expert surgeons was 55 years old (range 37 to 69). Eight expert surgeons had more than 20 years of post-residency experience, one surgeon had 10 – 20 years, and one surgeon had up to 10 years of post-residency experience. Five of the ten experts have performed individually more than 3000 open inguinal hernia repairs and have published individually more than 50 hernia-related papers.

Table 1. Demographics expert surgeons

		Expert surgeons (n=10)
Age (median; range)		55 (37 – 69)
Sex (%)	Female	2
	Male	8
How many years of surgical experience (postgraduate) do you have? (n)	< 10	1
	10 to 20	1
	> 20	8
What is the total amount of open inguinal hernia repairs performed in your clinic annually? (n)	< 200	2
	200 - 400	4
	400 - 600	1
	> 600	3
What is the total amount of open inguinal hernia repairs performed personally by you in a year? (n)	< 100	4
	100 - 200	5
	> 300	1
What is the total amount of open inguinal hernia repairs performed personally by you in total? (n)	> 100	1
	> 1.000	3
	> 3.000	2
	> 6.000	1
	> 10.000	2
	Unknown	1
What is the total amount of laparoscopic inguinal hernia repairs performed personally by you in a year? (n)	< 100	8
	100 - 200	1
	> 300	1
How many hernia-related papers did you publish in total? (n)	< 25	1
	> 25	3
	> 50	3
	> 75	2
	Unknown	1

10

The accuracy of the LOIHR stepwise description, as shown in **Table 2**, was rated statistically significantly higher than the neutral value of 3 (median 4.75 [5.00 – 4.00], Z=2.60, p=.009) with an internal consistency of Cronbach's α=.787. The individual statements regarding the accuracy of the stepwise description were all rated statistically significantly higher than the neutral value of 3, including statements regarding steps, substeps, and hazards. The abovementioned control statements were not statistically significantly different compared to the neutral value of 3. Furthermore, the statement "The step-by-step description of the open inguinal hernia repair is a complete representation of the actual surgery" was also not rated statistically significantly different than the neutral value of 3 (median 4.00 [5.00 – 2.75], Z=1.29, p=.196).

Table 2. Statements regarding the accuracy of the stepwise LOIHR description

	median	**IQR**	***p*-value** *
Accuracy of the stepwise description (Cronbach alfa = .787)	4.75	5.00 – 4.00	.009†
The steps in the open inguinal hernia repair are correct	5.00	5.00 – 4.00	.023†
The steps in the open inguinal hernia repair are in the correct order	5.00	5.00 – 5.00	.003†
Steps of the open inguinal hernia repair are missing	2.00	2.50 – 1.00	.084
The hazards that are encountered during the surgery are correct	5.00	5.00 – 3.75	.012†
The hazards are encountered in the steps where they have been described	4.50	5.00 – 3.00	.021†
Hazards of the open inguinal hernia repair are missing	2.50	4.00 – 1.00	.194
The step-by-step description of the open inguinal hernia repair is a complete representation of the actual surgery	4.00	5.00 – 2.75	.196
The step-by-step description is a good basis for the OCHRA assessment	5.00	5.00 – 4.00	.009†

IQR interquartile range (Q3 – Q1); *analyzed using one-sample Wilcoxon signed-rank test, compared to a neutral value of 3; † statistically significant

The accuracy of the LOIHR OCHRA-checklist, as shown in **Table 3**, was rated statistically significantly higher than the neutral value of 3 (median 5.00 [5.00 – 4.00], Z=2.63, p=.009), with an internal consistency of Cronbach's α=.960. The individual statements in this category were all rated statistically significantly higher than the neutral value of 3.

Table 3. Statements regarding the accuracy and usefulness of the OCHRA-checklist

	median	IQR	*p*-value*
Accuracy (Cronbach alfa = .960)	5.00	5.00 – 4.00	.009†
The OCHRA checklist assesses the open inguinal hernia repair specifically	5.00	5.00 – 4.00	.009†
The OCHRA checklist assesses the hazards occurring during the open inguinal hernia repair adequately	4.50	5.00 – 4.00	.010†
The OCHRA checklist is a useful tool to assess open inguinal hernia repair	5.00	5.00 – 4.00	.007†
An assessment based on the distinction between procedural and executional errors is good	4.50	5.00 – 3.00	.021†
An assessment based on consequential and inconsequential errors is good	5.00	5.00 – 3.75	.012†
The OCHRA being derived from the step-by-step description provides a complete assessment of the open inguinal hernia repair	4.50	5.00 – 3.75	.015†
The OCHRA provides an objective assessment of the surgery	4.50	5.00 – 3.75	.050†
Usefulness (Cronbach alfa = .886)	4.00	5.00 – 4.00	.032†
The OCHRA checklist is useful for the assessment of surgeons	4.00	4.25 – 2.00	.357
The OCHRA checklist is useful for the assessment of surgical residents	4.50	5.00 – 4.00	.010†
The OCHRA checklist is useful for the assessment of medical students	4.50	5.00 – 1.75	.261
The OCHRA checklist is useful to monitor and analyze the proficiency-gain of a surgical resident	4.00	4.25 – 3.00	.033†
The OCHRA checklist is useful to monitor and analyze the proficiency of a surgeon	4.00	4.00 – 3.00	.187
The OCHRA checklist is useful in the training of a surgical resident	5.00	5.00 – 4.00	.009†

IQR interquartile range (Q3 – Q1); *analyzed using one-sample Wilcoxon signed-rank test, compared to a neutral value of 3; † statistically significant

The category regarding the usefulness of the LOIHR OCHRA-checklist for training and assessment, as shown in **Table 3**, was rated statistically significantly higher than the neutral value of 3 (median 4.00 [5.00 – 4.00], Z=2.15, p=.032), with an internal consistency of Cronbach's α=.866. For surgical residents, the usefulness of the OCHRA-checklist for training (median 5.00 [5.00 – 4.00], Z=2.63, p=.009), assessment (median 4.50 [5.00 – 4.00], Z=2.57, p=.010), and monitoring of proficiency gain (median 4.00 [4.25 – 3.00], Z=2.13, p=.033) were rated statistically significant higher than the neutral value of 3. The LOIHR OCHRA-checklist was found not to be useful for the assessment of medical students (median 4.50 [5.00 – 1.75], Z=1.12, p=.261), or expert surgeons (median 4.00 [4.25 – 2.00], Z=1.31, p=.357).

DISCUSSION

The step-by-step framework is a theoretical model to break down surgical procedures into steps and substeps in a standardized manner. In this study, a stepwise description of the LOIHR was constructed in a relatively short time using the step-by-step framework. The expert hernia surgeons highly rated the accuracy of the LOIHR stepwise description. Subsequently, an OCHRA-checklist was composed using the LOIHR stepwise description. This LOIHR OCHRA-checklist was found to be accurate and useful for surgical training, assessment, and monitoring of proficiency gain, particularly for surgical residents.

Stepwise description

Previous studies described other methods to segment surgical procedures into steps and substeps, for example using hierarchical task analysis (HTA) based on historical technical protocols,[2, 5-6] experts or expert panels,[7-9] or HTA performed by research groups.[3, 14] These methods might result in a potentially more detailed description of surgical procedures, but these methods can be time-consuming and logistically challenging. For example, Sarker et al. described an open inguinal hernia repair description using textbooks, articles, and video-analyses of the surgical procedure to draft an initial surgical procedure description.[10] Additionally, an anesthetic expert and a scrub nurse task analysis was performed and combined with this initial description. Finally, expert surgeons refined the surgical procedure description. In comparison to our LOIHR stepwise description, the open inguinal hernia repair description of Sarker et al. consisted of at least 16 tasks (equivalent to steps) in contrast to 6 steps in our LOIHR stepwise description, while the content and order of steps were similar in both descriptions.[10]

OCHRA-checklist

The developed LOIHR OCHRA-checklist was assessed to be useful by the surgical hernia experts, particularly for the training, assessment, and monitoring of the proficiency gain of surgical residents. The expert surgeons assessed the LOIHR OCHRA-checklist not to be useful for surgeons, this is in contrast to the extensive use of the OCHRA-checklists in surgeons for the assessment of laparoscopic surgeries[3, 9, 23] and monitoring of proficiency gains.[14] In those studies, the OCHRA-checklist was found to provide surgeons objective and complete assessment of their surgical performance.[3, 12]

A possible explanation that our developed OCHRA-checklist was not found to be useful for surgeons might be due to that our stepwise description and subsequently, developed OCHRA-checklist described a standard approach to perform the LOIHR. Actual surgeries in patients can have variations in anatomy and pathology. In this study, we chose to exclude these variations to provide a basic outlay of the surgical procedure for inexperienced surgical residents. The addition of these variations might enhance the OCHRA-checklist usefulness for surgeons. Furthermore, experienced surgeons perform parts of a surgical procedure semi-automatically without conscious awareness.[4] When expert surgeons are asked to explain the execution of a surgical procedure in detail, it appears considerably tricky for them to identify the decisive moments.[24] The integration of which steps do and do not require conscious awareness, as in a cognitive task analysis (CTA),[25] may also make the OCHRA-checklist more suitable for surgeons.

The expert surgeons highly rated the usefulness for the monitoring of proficiency gain in surgical residents, comparable to a previous study in surgeons.[14] As the OCHRA-checklist allows supervisors to assess a surgical trainee per step of a procedure, insight will be established in which steps need more attention and the proficiency gain can be monitored.

Limitations

We acknowledge that the absence of an expert panel can be a potential weakness of the step-by-step framework, which may lead to a less detailed stepwise description. Nonetheless, the step-by-step framework provides a clear method to segment all surgical procedures in a standardized, comprehensive and time-efficient manner into steps, substeps and to identify hazards. The great advantage of the step-by-step framework is that more surgical procedures can be segmented efficiently, which may facilitate the implementation of the OCHRA-checklist more widely. A second limitation in our study was the use of a static simulation model to demonstrate a standardized LOIHR for an indirect hernia. This simulation model did not include any anatomical and pathological variations, such as adhesions due to previous surgeries, obesity, or sliding hernia.

Future perspectives

The OCHRA checklist could be used for feedback to facilitate the learning curve. Based on the checklist, the proficiency of the resident can be evaluated and measured over time. The supervisor can decide to include more difficult cases over time and continue to assess the proficiency with the OCHRA method.

To further improve the stepwise descriptions and associated OCHRA-checklists, a system could be developed to continuously integrate clinically encountered anatomical and pathological variations of the patient during the surgical procedure. This system could also use clinical postoperative patient outcomes to improve the hazards in the stepwise description and OCHRA-checklist. If the postoperative adverse events were caused during surgery, these could be implemented as new hazards. In previous studies, the OCHRA was considered to be useful to pinpoint the potential hazard zones for a specific error.[8, 12, 26]

Finally, further research is needed to determine the actual usefulness and compliance of the OCHRA-checklist in the operating room with surgical trainees and their supervisors. Also, research concerning the comparison of the effects, usefulness, and compliance between the OCHRA-checklist and other surgical assessment tools, such as the Objective Structured Assessment of Technical Skills (OSATS) or the Surgical Quality Assurance (SQA) should be carried out.[27-28] We are testing this hypothesis in a next study.

CONCLUSIONS

In summary, the step-by-step framework was used to construct a stepwise description for the open inguinal hernia repair and OCHRA-checklist. The international experts highly rated the accuracy of the stepwise description, and the accuracy and usefulness of the OCHRA-checklist. The OCHRA-checklist was found to be particularly useful for surgical residents in terms of training, assessment, and monitoring of proficiency gain.

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11

GLOBAL VERSUS TASK-SPECIFIC POST-OPERATIVE FEEDBACK IN SURGICAL PROCEDURE LEARNING

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ABSTRACT

Background

Task-specific checklists and global rating scales are both recommended assessment tools to provide constructive feedback on surgical performance. This study evaluated the most effective feedback tool by comparing the effects of the Observational Clinical Human Reliability Analysis (OCHRA) and Objective Structured Assessment of Technical Skills (OSATS) on surgical performance in relation to visual-spatial ability of the learners.

Methods

In a randomized controlled trial, medical students were allocated to either OCHRA (n=25) or OSATS (n=25) feedback group. Visual-spatial ability was measured by a Mental Rotation Test (MRT). Participants performed an open inguinal hernia repair procedure on a simulation model twice. Feedback was provided after the first procedure. Improvement in performance was evaluated blindly using a global rating scale (performance score) and hand-motion analysis (time and path length).

Results

Mean improvement in performance score was not significantly different between the OCHRA and OSATS feedback groups ($p = .100$). However, mean improvement in time (371.0 ± 223.4 vs. 274.6 ± 341.6; $p = .027$) and path length (53.5±42.4 vs. 34.7±39.0; $p = .046$) was significantly greater in the OCHRA feedback group. When stratified by MRT scores, the greater improvement in time ($p = .032$) and path length ($p = .053$) was observed only among individuals with low visual-spatial abilities.

Conclusions

A task-specific (OCHRA) feedback is more effective in improving surgical skills in terms of time and path length in novices as compared to a global rating scale (OSATS). The effects of a task-specific feedback are present mostly in individuals with lower visual spatial abilities.

INTRODUCTION

Feedback has long been recognized for its positive effect in surgical knowledge and skills training.[1] It has been shown to be crucial in technical skill development as it increases motivation, prevents incorrect actions and reinforces correct actions.[2-3] Feedback can be provided based on direct observation of technical skills.[4] Within the surgical field, different observational assessment tools are available.[5] Assessment tools assess surgical performance on competences, skills, or surgical specific items on a checklist. These tools can be used as a media for feedback to provide information regarding a trainee's performance in order to improve on specific items that are being assessed.[1, 5] Two main types of assessment tools can be recognized: global rating scale which rate general surgical skills and are applicable to all surgical procedures, or procedure specific checklists.[5] In both categories, many tools have been developed and validated.[4-5]

A commonly used and generally accepted as 'gold standard' assessment tool is Objective Structured Assessment of Technical Skills (OSATS), a global rating scale introduced by Martin and colleagues, for assessing technical skills of an entire surgical procedure.[5-6] OSATS is a reliable, validated tool that assesses seven competencies on a 5-point Likert scale.[6] It is feasible and effective in assessment of surgical skills of trainees in the operating room.[7]

While global rating scales such as the OSATS are easy in use, these scales can be imprecise.[4] A task-specific method may provide more concise and precise feedback.[4] A task-specific technical skills assessment method is the Observational Clinical Human Reliability Analysis (OCHRA).[8] An OCHRA checklist assesses in a stepwise manner whether a substep was correct or incorrect.[8] Both OSATS and OCHRA assessment tools have shown to be valid for providing constructive feedback.[4, 7] However, according to constructive alignment theory, the OCHRA feedback might be more effective when the surgical procedure is also learnt in a stepwise manner.[9]

Although the validity of OSATS and OCHRA is demonstrated, these assessment tools are still based on individual judgments, which are inevitably associated with subjectivity.[10] Quantifying measures of technical skills may potentially mitigate this subjectivity. For open surgery, different motion tracking devices are described to measure either hand or instrument movements.[11-14] The outcomes of time to complete a task and total path length can differentiate between novices and experts.[13-15]

Additionally, the effect of feedback in relation to visual-spatial ability, as another determining factor for technical skills development, is unrecognized. Visual-spatial ability is defined as the ability that allows individuals to construct visual-spatial, e.g. three-dimensional (3D) mental representations of 2D images and to mentally manipulate these representations.[16-17] This ability determines how well individuals are able to translate the acquired anatomical knowledge into clinical and surgical practice. Consequently, visual-spatial ability determines how well surgical residents are able to understand and perform spatially complex procedures. The positive association between visual-spatial ability and acquisition of surgical skills, including quality of hand motion, has been observed especially in the early phases of surgical training.[15, 18-20] Moreover, visual-spatial ability can have a modifying effect on outcomes. Individuals with lower visual-spatial abilities tend to perform worse than individuals with high visual-spatial abilities on acquisition of anatomical knowledge and surgical skills. However with supportive instructional methods and deliberate practice and feedback, they are able to achieve comparable level of competency.[15, 21-23]

The aim of this study was to investigate whether a task-specific, stepwise feedback checklist (OCHRA) leads to a greater improvement in performance of a surgical procedure compared to a global rating scale method (OSATS) in terms of improvement of overall performance score, time to complete task and total path length. These outcomes were also evaluated in relation to learners' visual-spatial ability.

METHODS

Study design and population

A randomized controlled trial was conducted at the Leiden University Medical Center, the Netherlands. Participants were medical students and were novices to most any type of surgical procedures. Only right-handed students were included as left-handed novice students may have difficulties with the surgical instruments.[24] Participation was voluntary and written consent was obtained from all participants. The study protocol was approved by the Netherlands Association for Medical Education (NVMO) Ethical Review Board (NERB dossier number: 1013) (**Figure 1**).

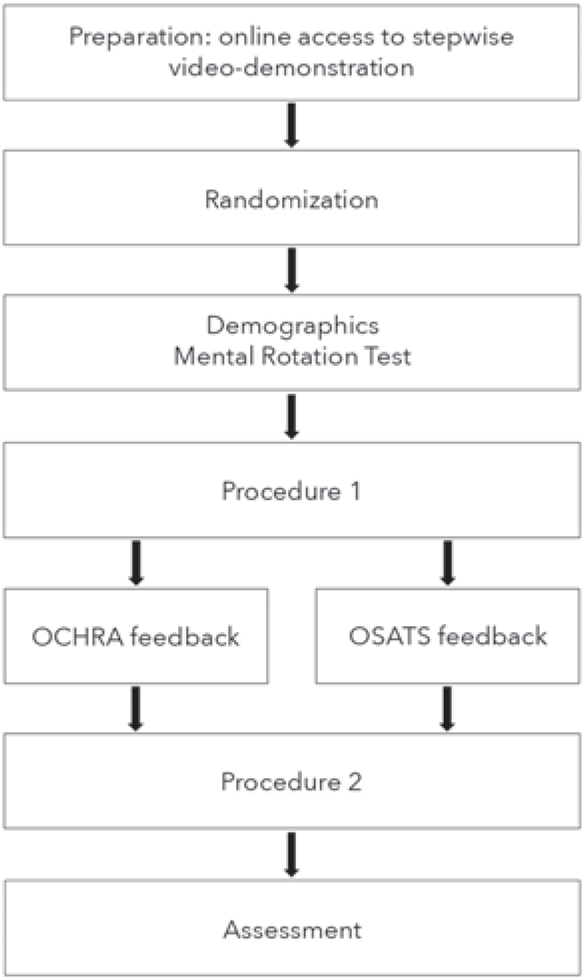

Figure 1. Flowchart of study design

Randomization

Participants were randomly allocated to either OCHRA feedback (n = 25) or OSATS feedback group (n = 25) using an Excel Random Group Generator.

Surgical procedure

The Lichtenstein open inguinal hernia repair was chosen as procedure containing multiple surgical steps and because of its spatial complexity that requires a certain level of surgical anatomical knowledge and visual-spatial ability of the learner. The first part of the surgery, until resecting the hernia sac, requires solely basic surgical skills like incising, dissecting and ligating. The second part, the placement and fixation of the mesh, is more complex. Each participant performed the Lichtenstein open inguinal hernia repair two times on a validated simulation model.[25] Participants were given access to the online course one week before the experiment in order to prepare for the experiment. The course consisted of three components: an introductory description included text and figures regarding the surgical anatomy, a stepwise textual description and video demonstration of the procedure on the identical model used during the experiment (**Appendix A**).[26] The video demonstration depicted all important steps that need to be undertaken during surgery. Video was accompanied with auditory explanation. Participants were able to retrieve the materials as many times as they wanted and were able to it on their own pace.

On the day of experiment, participants were given 30 minutes to complete each procedure.[27] The second procedure was performed directly after the provided feedback on the first procedure. Both procedures were recorded on video for blinded assessment. Participants were wearing a right-hand glove for the recording of motion by a motion tracking device (PST Base, PS-Tech B.V., Amsterdam, The Netherlands).

Demographic questionnaire

The questionnaire was administered prior to the experiment to account for factors that could possibly influence the performance. In a previous study, the time students studied for the open inguinal hernia repair with the use of a video-demonstration, had a significant modifying effect on surgical performance.[27] Therefore, study time was included in the questionnaire and was accounted for in the data analysis.

Visual-spatial ability

Visual-spatial ability was measured by the Mental Rotation Test (MRT) prior to the experiment. MRT is a validated 24-item psychometric test and the golden standard in assessing visual-spatial ability in anatomical and surgical education.[19, 28-30] Participants were given 10 minutes to complete the test. The maximum possible score for the test was 24 points.

Interventions

In the OCHRA feedback group, post-operative feedback was provided using OCHRA. The OCHRA checklist is a reliable and valid instrument that has been successfully used in assessment of performance in various surgical procedures.[8, 31-33] It is a procedure specific step-by-step skills assessment checklist that is characterized by a breakdown of a procedure into tasks.[26] Each step is assessed for being performed correctly and if errors are being made during the particular step. Provided feedback was based on the evaluation of each performed procedural step (**Appendix I**). If a particular step was performed incorrectly, the error was discussed and a proper execution of the step was explained. No points or final scores were awarded for the performance.

In the OSATS feedback group, post-operative feedback was provided immediately after performing the first procedure using the OSATS assessment tool (**Appendix J**). OSATS is a seven-item global rating scale that focuses on the following overall competencies: (1) respect for tissue, (2) time and motion, (3) instrument handling, (4) knowledge of instruments, (5) use of assistance, (6) flow of operation and (7) knowledge of procedure.[6] The tool has been previously validated in a wide range of surgical procedures and disciplines with reasonable index of reliability.[6, 34-35]

Provided feedback was based on the evaluation of each of the seven competencies in the exact order of OSATS. Suboptimal performance and errors made within a competence were discussed based on an example followed by an explanation for the improvement. No points or final scores were awarded for the performance to avoid any bias that could be introduced by grading the performance during the feedback phase.

In both groups, feedback was provided immediately after performing the first procedure. The total feedback time was held constant in both conditions and was approximately about ten minutes. Feedback was provided by one of the two researchers who were trained in providing both types of feedback in the context of this experiment. Care was taken to ensure that the feedback was complete and that participants were able to ask questions and verify whether they understood the information properly.

Performance score

Video-recorded procedures were assessed blindly by two independent researchers using OSATS, as the most common assessment tool for surgical performance. A minimum of 1 and a maximum of 5 points could be awarded for each of the seven competences. A maximum possible performance score for each procedure was 35 points. Both researchers were trained in assessment of recorded procedures. Training was facilitated by a surgeon who is an expert in this field. It included a comprehensive study of the procedure using the provided study material followed by execution of the procedure on the model themselves. After that, researchers were trained in assessment until they got sufficiently familiar with all aspects of OSATS. The actual assessment of recorded procedures was performed independently. In case of discrepancies, consensus was reached by re-evaluating the procedure. Additionally, five percent of procedures were randomly selected and assessed by the expert to detect any discrepancies in scoring. No differences in ratings were identified.

Motion tracking

Motion tracking analysis was performed using a combination of a commercially available optical tracker system (PST Base, PS-Tech B.V., Amsterdam, The Netherlands) and a customized glove for the dominant right hand. This could track 6 degrees of freedom position in Cartesian coordinates (X, Y and Z axis) at a rate of 30 samples per second. Time to complete the task and path length were measured. These have shown to be excellent markers of surgical performance.[11, 36-38] Since not all participants were able to complete the procedure within 30 minutes, the completion of the step of hernia sac removal was chosen as the endpoint for the outcomes of motion tracking analysis.

Outcomes

The study outcomes were defined as the differences in mean improvement in performance score (as measured by the OSATS assessment tool; time (in seconds) and path length (in meters) between the 1st and the 2nd procedure between two groups. Outcomes were stratified by MRT scores. Individuals who scored below the mean, were assigned to the MRT-low group (n = 22). Students who scored above the mean, were assigned to the MRT-high group (n = 28).

Statistical analysis

Due to the novelty of this study, no previous data was available to calculate the sample size. A sample size of 50 participants was assumed to be appropriate. Participants' baseline characteristics were summarized using descriptive statistics. Differences in baseline measurements were assessed with an independent *t*-test for differences in means and c^2 test for differences in proportions. The differences in mean performance scores of the first procedure between groups were assessed with an independent *t*-test. The improvement between second and first procedure within a group was assessed with a paired *t*-test. The difference in mean improvement (∆) in performance scores between second and first procedure between groups were assessed with a one-way ANCOVA. ∆Performance score was included as dependent variable, intervention group and study time as fixed factor (0-1 vs. 1-2 vs. 2-3 hours), and performance score on the first procedure and MRT score as covariates. Additionally, the outcomes were stratified by MRT score to evaluate the effect of intervention for different levels of visual-spatial ability. The analyses were repeated for mean improvement in time (∆ time) and path length (∆ path length). Partial Eta Squared was calculated and used as an effect size (0.2 = small effect, 0.5 = moderate effect 0.8 = large effect). Analyses were performed using SPSS statistical software package version 25.0 for Windows (IBM Corp., Armonk, NY). Statistical significance was determined at the level of $p < .05$.

RESULTS

A total of 50 medical students was included. There were no significant differences between groups on baseline characteristics, as shown in **Table 1**.

Table 1. Baseline characteristics of the included participants

Characteristic	OCHRA feedback (n = 25)	OSATS feedback (n = 25)	*p*-value
Sex, n (%)			
Male	10 (40)	13 (52)	.571
Female	15 (60)	12 (48)	
Age, mean (±SD), in years	21.5 (2.2)	21.2 (1.9)	.537
Study phase, n (%)			
Bachelor students	15 (60)	14 (56)	.302
Master students	10 (40)	11 (44)	
Time spent studying online course, n (%)			
0 – 1 hours	8 (32)	5 (20)	.288
1 – 2 hours	16 (64)	16 (64)	
2 – 3 hours	1 (4)	4 (16)	
I liked the way the hernia repair was taught, median [IQR] †	8.0 [7.0 – 9.0]	7.0 [6.5 – 8.7]	.104
I felt prepared after completing the online course, mean (±SD) †	6.3 (1.2)	6.1 (2.1)	.679
Times seen open inguinal hernia repair surgery in real life, median [IQR]	0.0 [0.0 – 0.5]	0.0 [0.0 – 0.5]	.984
Other sources used to study, n (%)			
Not used	16 (64)	11 (44)	.256
Yes	9 (36)	14 (56)	
Time spent studying other sources, n (%)			
0 – 1 hours	8 (88.9)	13 (92.9)	1.00
1 – 2 hours	1 (11.1)	1 (7.1)	
Hours of sleep last night, median [IQR]	7.0 [6.0 – 8.0]	8.0 [7.0 – 8.0]	.471
Alcohol consumption last night, median [IQR]	0.0 [0.0 – 0.8]	0.0 [0.0 – 0.0]	.402
Coffee consumption before surgical performance, median [IQR]	1.0 [0.0 – 1.0]	0.5 [0.0 – 1.0]	.879
Other circumstances that could have affected the surgical performance, n (%)	18 (72)	22 (88)	.289
Not used	7 (28)	3 (12)	
Yes			
Mental Rotation Test score, mean (±SD)	16.4 (5.5)	16.7 (4.9)	.872

OCHRA, Observational Clinical Human Reliability Analysis; OSATS, Objective Structured Assessment of Technical Skills; n, number of participants; SD, standard deviation; IQR, interquartile range; † rated on a 10-point scale from 'not at all' to 'completely'

Both groups improved significantly in terms of total OSATS score, time and path length between the first and second time of performing the procedure (**Table 2**). Since not all participants were able to complete the procedure within 30 minutes, the completion of the step of hernia sac removal was chosen as the endpoint for the outcome measures time (s) and path length (m). This step was performed by 42 (84%) of participants. Path length data of 5 of the participants was lacking due to technical issues.

The mean improvement in performance scores was not significantly different between two groups (β = 2.1; 95% IC [-0.41; -4.5]; η2 = 0.06; p = .100). However, the mean improvement in time (β = -139.4; 95% CI [-.262.5; -16.5]; η2 = 0.13; p = .027) and in path length (β = -21.2; 95% CI [-41.9; -0.5]; η2 = 0,13; p = .046) was significantly greater in the OCHRA feedback group.

Table 2. Differences in performance scores, time and path length between two interventions.

	OCHRA feedback	OSATS feedback	*p*-value
Performance score	n = 25	n = 25	
1st procedure	17.4 ± 3.1	17.4 ± 3.8	.935
2nd procedure	23.5 ± 5.4	21.8 ± 4.9	
Δ	6.2 ± 3.5*	4.4 ± 4.7*	.100 †
Time (sec)	n = 20	n = 22	
1st procedure	1239.6 ± 274.8	1300.4 ± 382.3	.561
2nd procedure	868.6 ± 151.6	1025.7 ± 286.4	
Δ	371.0 ± 223.4*	274.6 ± 341.6*	.027 †
Path length (m)	n = 19	n = 18	
1st procedure	168.4 ± 61.5	168.9 ± 39.6	.977
2nd procedure	112.4 ± 36.2	134.2 ± 36.3	
Δ	53.5 ± 42.4*	34.7 ± 39.0*	.046 †

Δ = delta, difference between 2nd and 1st procedure; sec, seconds; m, meters. * $p < 0.001$ paired t-test; † Differences assessed with ANCOVA.

Effect of visual-spatial ability

When outcomes were stratified by MRT scores, the greater improvement in time in the OCHRA feedback group was observed only among individuals with lower visual-spatial abilities (β = -220.2; 95% CI [-418.4; -22,1]; η2 = 0.26; p = .032) (Figure 2). As shown in Figure 3, a similar trajectory was observed for the improvement in path length. However, this difference did not reach the significance level (β = -28.2; 95% CI [-56.8; 0.42]; η2 = 0.24; p = .053). Regardless of intervention, MRT scores were significantly associated with mean improvement in time (β = -14.17; 95% CI [-26.9; -2.6]; η2 = 0.14; *p* = .019), but not in path length (β = -0.74; 95% CI [-2.8; 1.3]; η2 = 0.01; *p* = .469) and OSATS scores (β = 0.05; 95% CI [-0.2;0.3]; η2 = 0.004; p = .670).

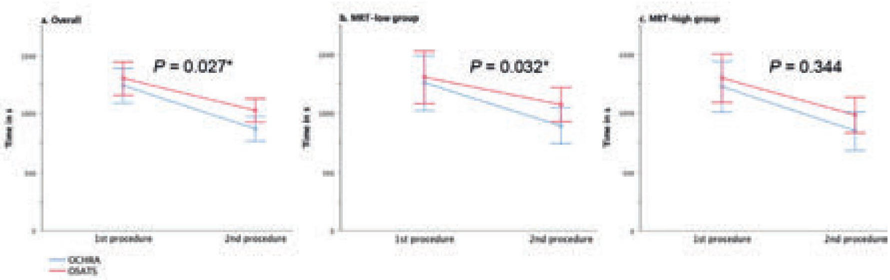

Figure 2. Differences in Δtime (s) between OCHRA feedback and OSATS feedback groups: (a) overall; (b) MRT-low group, and (c) MRT- high group; p < .05.

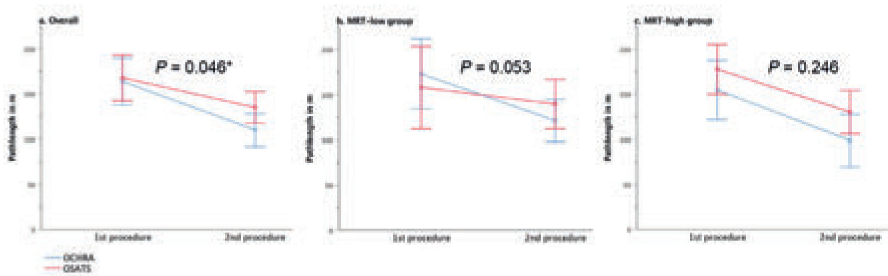

Figure 3. Differences in Δpath length (mm) between OCHRA feedback and OSATS feedback group: (a) overall; (b) MRT-low group, and (c) MRT-high group; p < .05.

DISCUSSION

The aim of this study was to investigate if a task-specific, stepwise feedback checklist (OCHRA) leads to a greater improvement in surgical performance compared to a global rating scale feedback method (OSATS). The outcomes were evaluated in relation to visual-spatial ability. The mean improvement in performance scores was not significantly different between the OCHRA and OSATS feedback groups. However, the OCHRA feedback showed a significant improvement on performance in terms of time and path length, as measured by the hand-motion analysis system. The effects of OCHRA feedback were mainly present among individuals with lower visual-spatial abilities.

The observed effectiveness of OCHRA feedback on surgical performance in a simplified hernia repair model, as a more precise and concise approach, is supported by the instructional alignment theory.[39] When training and assessment methods are aligned, the effects of instruction are up to four times greater than in non-aligned methods.[39] In the current study, participants prepared for the open inguinal hernia repair procedure using a stepwise video-demonstration. As OCHRA feedback was based on the evaluation of the subsequent surgical steps, instead of competencies as part of the OSATS feedback, a greater alignment between learning and feedback could be achieved. Although this did not result in a difference in outcome in terms of the surgical scores, differences were found for the time and path length. In this study, most participants could not finish the entire surgical procedure within the 30-minute timeframe. Possibly differences in surgical scores would have been found if students did complete the entire surgical procedure. Additionally, the value of a checklist (OCHRA) and global rating scale (OSATS) assessments may depend on the level of learners' experience.[40] Global rating scales have been reported to be more useful for learners with higher levels of expertise, while checklists may be more useful for novice learners, such as the participants in this study.[40-41]

The observed modifying effect of visual-spatial ability on time and path length leads to important considerations. First, the findings are in line with previous research reporting positive association between visual-spatial ability and hand motion.[15, 42-45] However, by treating visual-spatial ability as a possible effect modifier, this study showed that this association was only present for individuals with lower levels of visual-spatial ability. This effect, also referred to as aptitude-treatment effect,[46-47] has been repeatedly observed in the research field of anatomical education.[21-23, 46] Therefore, it is instrumental to consider possible modifying effects of visual-spatial ability on outcomes when designing new research. Second, the observed differences could be explained by the cognitive load theory.[48] Students with lower visual-spatial abilities are in general less effective in processing new spatial information in their working memory than students with higher visual-spatial abilities. However, in contrast to a global approach, the information from a task-specific stepwise feedback, building up on an already existing step-wise schema of a surgical procedure, could have decreased the cognitive load.48 Subsequently, more working memory capacity could be created in order to process new procedural skills among low performing individuals. This emphasizes the importance of an aptitude-based approach in learning and teaching surgical technical skills to novices. Lastly, the effect of visual-spatial ability on OSATS scores was found to be not significant. This could be due to the inability of most participants to complete the entire procedure within the given timeframe.

OSATS was used both as intervention and assessment scoring tool in this study. The rationale behind the choice to use the OSATS as assessment scoring tool is that OSATS is considered to be the 'gold standard' assessment tool for surgical performance and one of the few actually used in residency training and research.[5, 15] In the Netherlands, OSATS is incorporated within the surgical residency training.[49] Secondly, in a systematic review comparing checklist with global rating scales as assessment tools, reported that global rating scales might being be better in capturing nuanced elements of expertise.[40] Other assessment tools for surgical performance, such as the recently reported Surgical Quality Assurance (SQA) could have been an option, and perhaps would have found differences in surgical performance.[50]

The timing of feedback is still on debate. Xeroulis et al. distinguished feedback provided during the task (concurrent feedback) and feedback upon completing the task (summary feedback).[3] The latter was found to be superior for learning basic surgical skills, however, Al Fayyad et al. found the opposite. In their study, concurrent (immediate) feedback was perceived as superior in learning basic surgical skills compared to summary (delayed) feedback.[51] In our study, summary feedback was chosen as the students operated on a simulation model without the risk of doing any harm. In an actual patient, a trainee needs guidance from a surgeon using concurrent feedback in order to avoid harmful errors.

Limitations

This study has several limitations. First, the sample size could not be calculated beforehand due to the novelty of the study aim and design. Although it was sufficient to reveal significant differences in terms of time and path length, the sample size could have been too small to detect significant differences in OSATS scores. Second, not all participants were able to complete the procedure within given 30 minutes. As the step of hernia sac removal was reached by most participants, it was used as the endpoint to ensure a justified comparison in terms of time and path length. Allowing participants to complete the entire procedure would have provided a better display of their performance. Third, the participants were medical students with low and slightly various levels of anatomical knowledge and technical skills, including suturing. Due to random allocation, these differences are expected to have little to no effect on outcomes. Additionally, the mean improvement in outcome measures was chosen instead of the absolute scores to account for those differences. Another limitation is the possible inability to generalize the conclusions to left-handed students, as this study only included right-handed students. Furthermore, these findings cannot be generalized to other procedures outside of IH repair. Last, the effect of OCHRA feedback was evaluated in a simulated environment. This study should be repeated among surgical residents with higher levels of anatomical knowledge and technical skills in a clinical setting on multiple procedures.

The findings of this study have implications for both practice and research. In this study, the open inguinal hernia repair was chosen as an exemplary procedure. It is unknown whether an inguinal hernia repair simulation is ideally suited to detect differences in outcome studying different ways of feedback. The implementation of structured, stepwise feedback, that is aligned with the learning activities, should be considered especially in the early phases of surgical training. The aligned stepwise instruction using stepwise video-demonstrations and procedure-specific OCHRA checklist assessment can be transferred to other surgical procedures. The stepwise segmentation of a surgical procedure can be made using the step-by-step framework.[26] This stepwise description of a surgical procedure can then be used to create a procedure-specific OCHRA checklist. Moreover, an aptitude-based approach in teaching and learning of surgical procedural skills could be of benefit for individuals with lower visual-spatial abilities. As demonstrated, it is crucial to consider the modifying effect of visual-spatial ability on surgical outcomes when setting up new research. In fact, when overall outcomes are not evaluated for different levels of visual-spatial abilities, the real differences may remain unrevealed.

CONCLUSIONS

A task-specific, stepwise feedback checklist (OCHRA), proves to be more effective in improving surgical skills, in terms of time and path length, among surgical novices as compared to a global rating scale feedback (OSATS). The effects of a task-specific feedback are present mostly in individuals with lower visual spatial abilities.

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GENERAL DISCUSSION

The master-apprentice model in which residents were taught in a "see one, do one, teach one" model has been proved to be inefficient and inadequate.[1] A more efficient method to learn surgical procedures is needed in times of a changing learner's climate in light of medico-legal facets, duty hour restrictions and digitalization. This thesis analyzed the effects of making learning more efficient by structuring surgical procedure learning on three learning levels: learning by observing, learning by doing, and learning by reflection.

CONCLUSIONS

Our step-by-step framework was developed to segment surgical procedures in a standardized manner. The framework was found to be precise, useful and applicable to segment surgical procedures. This framework may facilitate learning, communication and assessment. In a meta-analysis, video-based learning of a surgical procedure was found to be superior to conventional ways of learning (books and lectures). When comparing segmented stepwise video-demonstrations of surgical procedures to continuous learning, segmented learning led to fewer procedural errors and lower experienced extraneous cognitive load. An online video-based surgical education platform that uses the step-by-step framework helped to increase the feeling of preparedness significantly in medical students. The platform was found to be comprehensible, useful and highly satisfactory. In comparison to a control group, the platform improved the test scores and self-reported surgical knowledge in medical students.

A European survey showed that surgical residents prefer to practice either on simulation or cadaveric models. Clearly, there is a need for more extensive practice before entering the operating room (OR). However, simulation training is often provided as a one-time event.[2] Therefore, we developed a low-cost synthetic open inguinal hernia repair simulation model as possible solution for a time- and place-independent simulation training option. This model was found to be particularly useful for the training of surgical residents.

As alignment of the different learning phases improves surgical procedure learning, feedback should also be organized in a segmented manner. To develop a segmented stepwise surgical procedure-specific assessment tool, first a stepwise description of the procedure must be made. The stepwise surgical procedure-specific assessment tool developed using the step-by-step framework was found to be accurate and useful, in particular for training, assessment and monitoring proficiency gain of surgical residents. In comparing the surgical procedure-specific assessment tool (OCHRA) to an Objective Structured Assessments of Technical Skills (OSATS, global rating scale), the OCHRA feedback was more effective in improving surgical performance (time and path length).

PRACTICAL IMPLICATIONS

In the metaphor of learning how to drive a car, first knowledge on different functions of the car needs to be presented to the driver: how to steer, accelerate, brake, and so on. Then, a simple to complex approach is used to first practice in a safe environment, for example on an empty parking lot. Afterwards the student is allowed on the roads within a town. When the student is more capable, an attempt is made to go to the highway. In learning a surgical procedure, it sometimes feels as if the trainee starts out on the highway. Full speed ahead without the knowledge or abilities to perform at the required level of complexity.

As with driving, surgical training needs to be learned in a more structured manner. The simple to complex approach should be used to first learn basic surgical procedures and practice these in a safe environment, e.g. on a simulation model. Any lacking basic surgical skills as knotting and suturing should be practiced. Afterwards, the surgical procedure can be performed in the OR under strict supervision with feedback. Feedback and reflection enforce improvement.

When learning a surgical procedure, it is essential to learn the standard way first as a standard set of steps to go through. To stay in the metaphor – driving on the open roads before indulging into hairpin loops in the mountains. It is paramount to give residents knowledge of standard ways of performing. Afterwards they can be exposed to deviations from the standard, such as patient-, disease- or surgeon preference related variations. With increasing competence, they can proceed to more complex procedures.

This thesis focused on the effects of structured learning of surgical procedures to be more efficient using the cognitive theory of multimedia learning and the segmentation principle. First, the managing of cognitive load is discussed. Afterwards, the structured learning on three levels is reviewed: learning by observing, by doing, and by reflecting. Finally, the integration of all the phases is discussed.

Managing cognitive load

The most important limitation in training is the capacity to understand information. For processing new information, the intrinsic, extraneous and germane cognitive load are crucial.[3-4] Intrinsic and extraneous cognitive load should be as low as possible, to provide opportunity for germane load.

Extraneous cognitive load is lowered by learning a surgical procedure in a segmented form, and thus leaving more space for germane cognitive load.[5] Surgical trainees have therefore more cognitive capacity available to construct cognitive schemas and improve surgical performance.[6] The segmentation in our studies was done using the step-by-step framework. Question remains whether segmentation using other definitions for steps and substeps, such as hazards, or even segmenting using time as cut off points, instead of the step-by-step framework would give the same results. While segmentation based on anatomy and separate goals during surgery feels intuitive as anatomy is crucial for a surgeon, further research should be conducted to other types of segmentation such as the risk of phase-related, specific complications.

Intrinsic cognitive load arises from the complexity of a task. This load is dependent on learners' prior knowledge and experience. Consequently, this cognitive load can only be altered by changing the complexity of the task or the knowledge levels of the trainees.[3] The intrinsic cognitive load of the surgical procedure should be lowered by starting with learning and practicing the standard surgical procedure without the addition of any variations. When the resident is more competent, variations such as patient- or disease-related can be added.

Learning by observing

Learning by observing can be achieved in various ways. In our studies video-based learning was used, which proved better than books in our systematic review and was preferred by the residents in our survey. Other modalities to learn surgical procedures by observing are available such as augmented reality (AR), virtual reality (VR) or live surgeries. Major advantage of live surgeries is the possibility for interaction between the surgeon and the viewers. The viewers can ask the surgeon questions, and the surgeon can quiz the viewers. However, an advantage of video-based learning is its flexibility in use, especially if it is available online on demand. This facilitates the “just-in-time” learning strategy of students as it allows education independent of time, place and pace.[7-8] Important is that available online material should be peer-reviewed by experts to avoid misinforming the trainees.[9-14]

Video-based and VR learning offers the possibility for interactive learning by implementing quizzes to test the trainees’ knowledge, especially in a stepwise manner. Further, video-based learning may facilitate blended learning or a flipped-classroom model. In blended educational programs, online and face-to-face learning is combined. The trainee acquires knowledge online and can apply this knowledge during face-to-face learning. In addition, the traditional classroom interactions are offered online and live: student-student and student-teacher interactions.[15] In the ‘flipped-classroom’, trainees develop knowledge or skills using videos or other online learning resources prior to a lecture or class session which leads to more active learning during the class session.[16]

As many training modalities for learning by observing are available, further comparative research should be performed to analyze which method is superior for different learning goals.

Learning by doing

Our survey among European residents revealed that they want to practice their surgical procedures on simulation or cadaveric models. Several studies have proven the positive effects of simulation training, [17-18] however, its implementation into the residents’ curriculum remains challenging.[2, 19] Different methods of simulation training are available such as human and animal cadaver training, training using a box trainer, VR or AR training and training on a synthetic model. Often, simulation training is unstructured or provided as ‘one-time’ events at courses.[2] Perhaps the widespread implementation of simulation models is also hampered as these can be expensive and time- and place-dependent. This is not in line with the just-in-time learning principle.[7] To overcome the cost aspect, we developed a low-cost synthetic inguinal hernia model that can be used time- and place-independently.

Times are evolving and many new modalities are arising and improving. The arrival of new VR and AR devices such as the Oculus Quest, Google Glass and HoloLens provide an opportunity to practice time- and place-independently. Studies showed that VR and AR improved the speed of acquiring surgical skills, the ability to perform a procedure accurately and hand-eye coordination.[20-21] VR and AR also provide the opportunity to practice open surgery. As a simulation model can never fully mimic a real patient, further research is needed to analyze the transfer of surgical knowledge and skills from simulator to operating room in terms of surgical performance and outcomes. The research should focus on the new AR and VR devices as on synthetic models. Secondly, the effects of implementing surgical simulation models into the curriculum – as a necessity before performing the surgical procedure on a patient in the OR – should be further researched.

Learning by reflecting

Feedback has been recognized for its positive effect in surgical training.[22] Feedback can be provided using assessment tools, such as OSATS or OCHRA. Other assessment tools are also available such as the task-specific Surgical Quality Assurance (SQA) or Direct Observation of Procedural Skills (DOPS; an assessment of a practical procedure on a patient, from start to finish).[23-24] These assessment tools can be used as guidance to determine entrustable professional activities (EPAs) for surgical procedures,[25-26] or even for certain steps within a surgical procedure. As a trainer, it is extremely helpful to know the entrusted tasks of a trainee. This leaves space to focus on the skills and certain surgical steps of tasks a trainee is not entrusted. This is especially important as time in the OR is limited. In surgical curricula, the effects of approving certain surgical steps for residents should be further investigated.

The assessment tools can be used to provide feedback immediate (during) or delayed (after) the surgical procedure.[27-28] Immediate feedback is warranted when operating on an actual patient, since the trainee needs to be corrected immediately, while on the other hand feedback can be delivered immediate or delayed in a simulated setting. Notably, we believe that stepwise feedback is most important to preserve the alignment between stepwise observing, doing and reflecting of the surgical procedure, and thus increasing the effect of the training. Further research is needed to evaluate in which conditions the immediate or the delayed feedback is superior.

Technical innovations offer possibilities for flexibility to learn and receive feedback. Video recorded surgical procedures can be used for delayed feedback from a trainer,[29] or perhaps in the future from an artificial intelligence system that can recognize if surgical errors are made. Motion tracking devices might facilitate video recordings for determining errors. In addition, live video feed can be used for immediate feedback. This feedback can be provided by experts from all over the world. This has been demonstrated by using Google Glass or HoloLens for real-time consultation with a live feed of the surgical view.[30-32] The effects of the new technical innovations for assessment and feedback on surgical performance should be further researched. Furthermore, the development of artificial intelligence for assessment and feedback also should be evaluated.

STRENGTHS AND LIMITATIONS

The topic of this thesis is relevant as the surgical residents' learning climate is changing due to less time in the OR and the general feeling that it is better not to 'practice' on patients. Therefore, more efficient methods to learn surgical procedures are needed. The strengths of this thesis are its potential applicability for surgical procedure education in all surgical disciplines, ranging from general surgery, gynecology or ophthalmology. The developed and evaluated step-by-step framework is as a conceptual construct useful for any surgical procedure in all disciplines. Therefore, the findings from this thesis are universally applicable. The second strength is the use of multiple studies to evaluate the effects of the segmentation principle. Its effects have been investigated in studies comparing segmentation to continuous learning, as well as the integration of segmentation within an online video-based surgical education platform.

The limitations of this thesis are the generalizability of the findings. First, the comparative studies have been conducted with either high school students or medical students. Further research should be done on the effectiveness for residents. Secondly, the studies in this thesis used the open inguinal hernia repair as an example surgical procedure. We chose this surgical procedure as it is a complex, multiple steps surgical procedure that we could evaluate on the synthetic open inguinal hernia repair simulation model. Despite the conceptual construct of the step-by-step framework and the addition of open small bowel resection beside the open inguinal hernia repair to validate the step-by-step framework, the generalizability of the results to other surgical procedures is compromised. Further studies to compare segmented stepwise to continuous learning should be conducted in different surgical procedures.

INTEGRATING THE PHASES

Modern surgical learning is forced to be more efficient and effective. In this thesis, structure is presented to facilitate this process. This structure is three-dimensional. First, the phases of learning should be structured in order to facilitate learning: observing, doing and reflecting. Secondly, the content of these phases should also be structured in a stepwise manner and aligned between the different phases. The continued alignment between the phases will create a framework for the trainee. Thirdly, the surgical curriculum should be structured in which a resident learns simple surgical procedures first and continues to more complex surgical procedures only when proven capable.

In an ideal surgical training world, trainees should observe the surgical procedure in a stepwise manner – either live or video-based. Then, trainees should practice the procedure in the same stepwise manner in a safe environment with preferably self-reflection and receiving feedback, as on a simulation model. When proven capable, possibly after passing a certain bar, the trainee can perform the surgical procedure in the operating room under strict supervision. During the procedure, the trainee should receive stepwise feedback to improve his or her surgical performance further. This cycle of observing, doing and reflecting should be repeated in the training from simple to complex surgical procedures. Ultimately, the cycle continues during one's career for lifelong learning. Implementation of these three structures would improve surgical procedure learning.

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SUMMARY

NEDERLANDSE SAMENVATTING

This thesis analyzed the effects of structuring the learning of surgical procedures on efficiency. The studies included in this thesis were categorized into one of three parts: learning by observing, learning by doing, and learning by reflection.

Learning by observing

A method to structure surgical procedure learning is segmentation, to create a step-by-step description. Many methods of structuring complex tasks, and even surgical procedures are available, however, these are procedure specific and time consuming. First, a method to segment in a standardized manner was evaluated. Then, traditional and video-based learning methods were compared in a meta-analysis. Afterwards, the effects of segmented stepwise learning were compared to continuous learning. Finally, the effects of an online surgical education platform that uses segmented stepwise learning were analyzed.

In **Chapter 2**, the validity of a new universal step-by-step framework to standardize segmentation of surgical procedures into steps and substeps is researched among an international surgical expert panel (n=20). The general definitions of a step and substep make the framework applicable for all surgical procedures. The substep is based on anatomy, and a step is a bounded element of a surgical procedure with a certain goal. The step-by-step framework was found to be a precise, useful and applicable method to segment surgical procedures into stepwise descriptions. The step-by-step framework may facilitate learning, communication and assessment.

In **Chapter 3**, a systematic review and meta-analysis compared traditional (reading and lectures) versus video-based methods for more efficient learning of a surgical procedure. This showed that video-based learning of a surgical procedure was superior to conventional ways of learning.

Chapter 4 was the first study that compared segmented stepwise surgical procedure learning to continuous learning in a simulated setting. High school students were taught relevant anatomy of the Lichtenstein open inguinal hernia repair in either a segmented (n=112) or a continuous manner (n=108). The students were quizzed on their anatomical knowledge. This study revealed that continuous learning was superior to stepwise learning for these students. A possible explanation is that the participants in the segmented condition were too novice to comprehend the study material.

In **Chapter 5**, the second study to compare segmented versus continuous learning is discussed. Medical students learned the Lichtenstein open inguinal hernia repair in either a segmented (n=23) or a continuous manner (n=20). Then, the students had to demonstrate the surgical procedure on a simulation model which was assessed using the Observational Clinical Human Reliability Analysis (OCHRA) checklist. The stepwise learning group made fewer procedural errors and experienced lower extraneous cognitive load compared to continuous learning.

Chapter 6 is the first chapter to review the effects of an online surgical education platform (Incision Academy) that uses the segmentation principle (the step-by-step framework) amongst medical students in their surgical clerkship. This showed that medical students used the platform primarily during clerkship and not during the preparatory course. During the clerkship, the feeling of preparedness increased significantly. The students found the online surgical education platform comprehensible, useful and highly satisfactory.

Chapter 7 is the second study to compare the use of an online surgical education platform (Incision Academy) that uses the segmentation principle. Medical students with voluntary access to the online video-based surgical education platform (n=88) and a control group (n=91) were included. An evaluation among medical students with access to the platform and their supervisors found the platform to be a valuable addition to the current surgical curriculum. It improved their test scores and self-reported surgical knowledge. Students felt better prepared and more able to find the information necessary to complete the clerkship compared to the control group.

Learning by doing

Simulation training is proven to have positive effects. Yet, it is often provided unstructured or as a 'one-time' event.[1-2] In this part, the preferred learning methods of surgical residents were investigated. Then, a low-cost synthetic open inguinal hernia repair simulation model is presented as possible solution for a time- and place-independent simulation training option.

In **Chapter 8**, a European survey among surgical residents (n=323) showed that residents prefer to study through lectures or video-demonstrations or want to practice either on simulation or cadaveric models. Clearly, there is a need for more extensive practice before entering the OR.

In **Chapter 9,** we developed an open inguinal hernia repair simulation model which was found to be useful by 66 surgical residents and ten international expert surgeons. It was found to be particularly useful for the training of surgical residents.

Learning by reflecting

Learning a surgical procedure is better when all phases of learning are aligned. Therefore, in investigating whether segmented learning is more efficient compared to continuous learning, the assessment and feedback should also be provided in a segmented stepwise manner. A stepwise description of the surgical procedure must be created to develop a stepwise surgical procedure-specific assessment tool.[3] The existing surgical procedure-specific assessment tools use extensive, time-consuming and logistically-challenging methods to construct such a stepwise description of the surgical procedure.[4-8] In this part, the accuracy and usefulness of a stepwise surgical procedure-specific assessment tool developed using the step-by-step framework is reviewed. Secondly, the segmented stepwise feedback method is compared to a global rating scale.

In **Chapter 10**, an Observational Clinical Human Reliability Analysis (OCHRA) checklist was developed based on stepwise description created using the step-by-step framework. Ten expert surgeons evaluated this OCHRA checklist to be accurate and useful, in particular for training, assessment and monitoring proficiency gain of surgical residents.

In **Chapter 11**, the commonly used Objective Structured Assessments of Technical Skills (OSATS) was compared to OCHRA. Medical students were randomized to OCHRA (n=25) or OSATS (n=25) feedback group. OCHRA feedback (task-specific) was more effective in improving surgical performance (time and path length) as compared to OSATS (global rating scale).

In **Chapter 12**, a general discussion of the findings of this thesis and the future perspectives were presented.

In dit proefschrift wordt het gestructureerd leren van chirurgische procedures geanalyseerd. De onderzoeken in dit proefschrift zijn in drie delen onderverdeeld: leren door te observeren, te doen en te reflecteren.

Leren door te observeren

Een methode om chirurgische procedures te structureren is opdelen in stukken (segmentatie), die een stapsgewijze beschrijving impliceert. Er zijn veel methoden beschikbaar voor het segmenteren van complexe taken en zelfs van chirurgische procedures, echter deze methodes zijn deze procedure-specifiek en daarmee tijdrovend. In deel 1 van dit proefschrift wordt eerst een methode om chirurgische procedures op een gestandaardiseerde manier te segmenteren geëvalueerd. Vervolgens worden traditionele en video-gebaseerde leermethoden in een meta-analyse met elkaar vergeleken. Daarna worden de effecten van gesegmenteerd stapsgewijs leren met continu leren vergeleken. Ten slotte worden de effecten geanalyseerd van een online chirurgisch onderwijsplatform dat van gesegmenteerd stapsgewijs leren gebruik maakt.

In **hoofdstuk 2** wordt een nieuw universeel stapsgewijs opgebouwd model gepresenteerd om de segmentatie van chirurgische procedures in stappen en substappen op een gestandaardiseerde wijze te beschrijven. Met een internationaal chirurgisch expertpanel (n=20) wordt de validiteit van het model onderzocht. De algemene definities van een stap en substap maken het model generiek toepasbaar op alle chirurgische ingrepen. De substap is gebaseerd op een anatomische structuur en een stap is een afgebakend onderdeel van een chirurgische ingreep met een duidelijk doel. Het stapsgewijs opgebouwde model blijkt een nauwkeurige en bruikbare methode te zijn om chirurgische procedures in stapsgewijze beschrijvingen te segmenteren. Het stapsgewijze model kan het chirurgisch leren, de communicatie en de beoordeling vergemakkelijken.

In **hoofdstuk 3** worden traditionele (lezen en colleges) versus video-gebaseerde methoden voor leren van een chirurgische ingreep in een systematische review en meta-analyse vergeleken. Hieruit blijkt dat video-gebaseerd leren van een chirurgische ingreep superieur is aan de traditionele manieren van leren.

In **hoofdstuk 4** wordt de eerste studie gepresenteerd waarbij gesegmenteerd stapsgewijs leren van chirurgische procedures met continu leren wordt vergeleken. Middelbare scholieren leren relevante anatomie van de Lichtenstein open liesbreukreparatie op een gesegmenteerde (n = 112) of een continue manier (n = 108). Vervolgens wordt hun anatomische kennis getoetst. Uit dit onderzoek blijkt dat voor deze scholieren continu leren superieur is aan stapsgewijs leren. Een mogelijke verklaring is dat de deelnemers in de groep met segmentatie jonger zijn en daardoor te onervaren om het studiemateriaal goed te begrijpen.

In **hoofdstuk 5** wordt in een tweede studie gesegmenteerd leren vergeleken met continu leren. Geneeskundestudenten leren de Lichtenstein open liesbreukreparatie op een gesegmenteerde (n=23) of een continue manier (n=20). Vervolgens moeten de studenten de chirurgische procedure uitvoeren op een simulatiemodel. Achteraf wordt de uitgevoerde procedure met behulp van de checklist Observational Clinical Human Reliability Analysis (OCHRA) beoordeeld. De studenten uit de gesegmenteerde groep maken minder procedurele fouten en ervaren een lagere externe cognitieve belasting in vergelijking met studenten van de continue groep.

In **hoofdstuk 6** wordt het eerste artikel gepresenteerd, waarin effecten worden geanalyseerd van een online chirurgisch video-gebaseerd onderwijsplatform dat gebruik maakt van het stapsgewijs opgebouwd model (Incision Academy). Dit wordt onder geneeskundestudenten tijdens hun chirurgische coschap onderzocht. Hieruit blijkt dat geneeskundestudenten het platform vooral tijdens het coschap gebruikten en niet tijdens de voorbereidende cursus direct voorafgaand aan het coschap. Tijdens het coschap voelen studenten zich aanzienlijk beter voorbereid. De studenten vinden het online chirurgische onderwijsplatform nuttig en de cursussen begrijpelijk en waardevol.

In **hoofdstuk 7** wordt de tweede studie gepresenteerd, waarin het gebruik van het online chirurgisch opleidingsplatform onderzocht wordt. Geneeskundestudenten met toegang tot het platform (n=88) en een controlegroep zonder toegang (n=90) worden geïncludeerd. Uit een evaluatie onder geneeskundestudenten met toegang tot het platform en hun begeleiders blijkt het platform een waardevolle aanvulling op het huidige chirurgische curriculum. De groep met toegang scoren hoger op de testen en op hun zelf-gerapporteerde chirurgische kennis. Studenten voelen zich beter voorbereid en beter in staat om de informatie voor hun coschap te vinden in vergelijking met de controlegroep.

Leren door te doen

Uit de literatuur blijkt dat simulatietraining positieve effecten heeft. Toch wordt simulatietraining vaak ongestructureerd of als een incidentele gebeurtenis aangeboden.[1-2] In deel 2 van het proefschrift worden de voorkeursleermethoden van arts-assistenten chirurgie onderzocht. Vervolgens wordt een goedkoop synthetisch simulatiemodel voor open liesbreukherstel gepresenteerd als mogelijke optie voor tijd- en plaats aan elkaar vast onafhankelijke simulatietraining.

In **hoofdstuk 8** wordt een survey onder Europese arts-assistenten chirurgie (n=323) gepresenteerd waarin aangetoond wordt dat arts-assistenten liever studeren door middel van colleges of videodemonstraties of door te oefenen op simulatie- of kadavermodellen. Er is duidelijk meer behoefte aan oefenen voordat de operatiekamer wordt betreden.

In **hoofdstuk 9** wordt een nieuw simulatiemodel voor het herstellen van een open liesbreuk beschreven. Door 66 arts-assistenten chirurgie en tien internationale expert chirurgen wordt dit model waardevol gevonden voor training. Het blijkt met name nuttig te zijn voor de opleiding van chirurgische arts-assistenten.

Leren door te reflecteren

Het leren van een chirurgische ingreep is efficiënter wanneer alle leerfasen op elkaar zijn afgestemd. Daarom moet bij het onderzoeken of gesegmenteerd leren efficiënter is dan continu leren de beoordeling en feedback ook gesegmenteerd worden aangeboden. Voor het ontwikkelen van een stapsgewijs procedure-specifiek beoordelingsinstrument moet eerst een stapsgewijze beschrijving van de chirurgische procedure gemaakt worden.[3] De bestaande methoden voor het maken van dergelijke stapsgewijze beschrijvingen van chirurgische procedures zijn tijdrovend en logistiek uitdagend.[4-8] In deel 3 van het proefschrift wordt als alternatief het stapsgewijze model voor het ontwikkelen van een stapsgewijze beschrijving van een chirurgische procedure en vervolgens voor het ontwikkelen van een procedure-specifieke beoordelingsinstrument gebruikt. Ten tweede, wordt de feedback met dit stapsgewijze beoordelingsinstrument met een bestaand globaal beoordelingsinstrument vergeleken.

In **hoofdstuk 10** wordt eerst een stapsgewijze chirurgische procedure beschrijving met het stapsgewijze model gemaakt. Vervolgens wordt op basis van de stapsgewijze operatiebeschrijving een Observational Clinical Human Reliability Analysis (OCHRA) checklist ontwikkeld. Tien internationale expert chirurgen beoordelen deze OCHRA-checklist als nauwkeurig en nuttig voor de beoordeling en monitoring van de training van arts-assistenten chirurgie.

In **hoofdstuk 11** wordt de veelgebruikte Objective Structured Assessments of Technical Skills (OSATS) vergeleken met de OCHRA. Geneeskundestudenten worden gerandomiseerd in een OCHRA (n=25) of OSATS (n=25) feedbackgroep. In vergelijking met OSATS is OCHRA-feedback effectiever in het verbeteren van de chirurgische prestaties gedefinieerd als vermindering van tijd en verkorting van de pad lengte.

In **hoofdstuk 12** is een algemene bespreking van de bevindingen van dit proefschrift en de toekomstperspectieven gepresenteerd.

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APPENDICES

LIST OF PUBLICATIONS
LIST OF CONTRIBUTING AUTHORS
DANKWOORD
PHD PORTFOLIO
CURRICULUM VITAE

APPENDIX A. STEPWISE DESCRIPTION LICHTENSTEIN OPEN INGUINAL HERNIA REPAIR

Step	Substep (structure)	Action	Specification
1. External oblique aponeurosis exposure	Skin	Incise	Incise the skin for a length of approximately 5 cm in the line between anterior superior iliac spine to the pubic tubercle.
	Subcutaneous tissue	Incise	Incise the subcutaneous tissue until Scarpa's fascia is reached.
			HAZARD Superficial epigastric vessels damage During the incision of the subcutaneous tissue caution should be taken for the superficial epigastric vessels.
	Superficial epigastric vessels	Transect	Transect the superficial epigastric vessels in order to prevent postoperative hemorrhage.
	Scarpa's fascia	Incise	Incise Scarpa's fascia to expose the fat tissue overlying the external oblique aponeurosis.
	Subcutaneous tissue	Incise	Incise the subcutaneous tissue overlying the external oblique aponeurosis to expose it.
2. Inguinal canal exposure	External oblique aponeurosis	Identify	Identify the external oblique aponeurosis as a white plane with oblique fibers.
		Incise	Incise the aponeurosis of the external oblique muscle in the direction of the fibers. Extend the incision towards the external inguinal ring medially.
			HAZARD - The ilioinguinal nerve damage The ilioinguinal nerve on top of the spermatic cord should be identified to avoid injuring it.
		Dissect	Dissect the external oblique aponeurosis by developing the plane between the aponeurosis of the external oblique muscle and the internal oblique muscle caudally, while avoiding the ilioinguinal nerve.
3. Spermatic cord mobilization	Spermatic cord	Isolate	Isolate the spermatic cord completely from the floor of the inguinal canal, the transverse fascia and the pubic bone.
		Encircle	Encircle the spermatic cord with a penrose drain.
4. Hernia sac removal	Hernia sac	Identify	Identify the hernia sac.
		Remove	Remove the hernia sac by first rotating the hernia sac around its own axis. Then the hernia sac is transected after clamping and tying the rotated hernia sac.

Step	Substep (structure)	Action	Specification
5. Mesh placement	Inguinal ligament	Expose	Expose the inguinal ligament which is the lower edge of the inguinal canal.
	Mesh	Trim	Trim the mesh to fit the inguinal canal.
		Fixate - medial	Fixate the mesh medially to the distal anterior rectus sheath with 2 cm overlap over the pubic bone.
			HAZARD - Pubic periosteum damage During medial fixation of the mesh to the anterior rectus sheath, care should be taken not to include the pubic periosteum in this suture as this may result in chronic pain.
		Fixate - caudal	Fixate caudally by continuing with a running suture on the lower edge of the inguinal ligament to the level of the internal inguinal ring. Do not continue this suture beyond the lateral border of the internal inguinal ring.
			HAZARD - Femoral vessels and nerve damage During the caudal fixation, avoid damaging the femoral vessels and nerve which run just underneath the inguinal ligament. Therefore, only small bites of the lower edge of the inguinal ligament (1-2 mm) should be taken.
		Trim	Trim the mesh from lateral to medial until the medial border of the internal inguinal ring, creating two tails. The superior tail is approximately 2/3 of the width of the mesh and the inferior tail is approximately 1/3.
		Position	Position the mesh under the spermatic cord, and subsequently maneuver the spermatic cord between the two tails. Then, pass the superior tail over the inferior tail to create a prosthetic internal inguinal ring.
		Fixate	Fixate both tails with a single non-absorbable suture to the inguinal ligament.
		Position	Position the tails of the mesh under the external oblique aponeurosis laterally and cranially.
		Fixate - cranial	Fixate the superior margin of the mesh with one or two interrupted absorbable sutures to the aponeurosis of the internal oblique muscle, while avoiding the iliohypogastric nerve.
			HAZARD - Iliohypogastric nerve damage Avoid damage or entrapment of the iliohypogastric nerve, preferably by identification. Make a transverse suture rather than a longitudinal suture, as this minimizes the risk of nerve entrapment. If necessary a separate cut can be made into the mesh to free the iliohypogastric nerve. If the nerve cannot be freed from the mesh, transect this nerve and bury the iliohypogastric nerve in the oblique internal muscle.

Step	Substep (structure)	Action	Specification
6. Wound closure	External oblique aponeurosis	Close	Close the aponeurosis of the external oblique muscle, creating a new external ring.
	Scarpa's fascia	Close	Close Scarpa's fascia.
	Skin	Close	Close the skin.

APPENDIX B. STEPWISE DESCRIPTION OPEN SMALL BOWEL RESECTION

Step	Substep (structure)	Action	Specification
1. Abdominal cavity approach	A. Skin	Incise	Incise the skin in the midline from the umbilicus to the pubic bone.
			TIP Incision scarring To minimize postoperative scarring, the skin incision is placed preferably over old incision scars.
	B. Subcutaneous tissue	Incise	Incise the subcutaneous tissue until the linea alba is encountered.
	C. Linea alba	Incise	Incise the linea alba.
			TIP - Linea alba Identification of the linea alba, is facilitated by equal lateral traction on the skin and subcutaneous tissue. The linea alba is formed by fusion of contralateral aponeuroses of the abdominal muscles, therefore it can be identified by looking for a white line of crossing fibers.
	D. Peritoneum	Identify	Identify the peritoneum as a thin smooth layer usually with the presence of preperitoneal fat.
		Lift	Lift the peritoneum to prevent damage to the intraperitoneal organs.
		Incise	Incise the peritoneum with scissors and be careful not to damage the posteriorly-lying intraperitoneal organs.
			TIP - Peritoneal opening Opening of the peritoneum should be performed in a section without prior surgery. Here the chances of adhesions will be small and the risk of intraperitoneal organ injury minimized.

Step	Substep (structure)	Action	Specification
2. Mesentery transection	A. Bowel	Identify	Identify the transection site. Important is (1) if the bowel looks well vascularized, (2) the two ends can be brought together tension free, and (3) if the lumen sizes are comparable.
			TIP - Lumen size difference If the difference in size is too big to correct during suturing you can choose to either go for an End to Side or Side to Side anastomosis, or enlarge one end by cutting in an oblique way from the antimesenteric to the mesenteric side until it matches the other lumen. Another option is to make a dorsal slit on the antimesenteric side of the part with the smallest lumen.
	B. Visceral peritoneum	Incise	Incise the visceral peritoneum covering the mesentery, from the determined sites to central in a V-shape.
			TIP - Location intestinal branches. Intestinal branches can be located with transillumination and after the incision of the peritoneum.
	C. Mesentery	Transect	Transect the mesentery, including intestinal branches, in the same line as the visceral peritoneum incisions, starting at the level of the bowel wall.
3. Small bowel resection	A. Bowel	Position	Position non-crushing clamps on the bowel, proximal and distal from the determined sites, to prevent leakage of bowel contents in the abdominal cavity.
			Hazard - Clamp placement The clamp is solely placed on the bowel and not on the mesentery as this may compromise the vascularization of the bowel.
		Transect	Transect the bowel at the determined sites.

Step	Substep (structure)	Action	Specification
4. Small bowel anastomosis	A. Bowel corner mesenteric side	Close	Suture the first mesenteric corner with a double-armed suture through all layers from inside to outside and the second stitch with the same needle from outside to inside in the mesenteric corner of the opposite lumen using a monofilament slow absorbable thread. Knot the suture but do not cut it.
	B. Bowel	Close	Continue suturing the posterior side of the anastomosis with this needle with an inside-outside-outside-inside technique. Use a continuous one layer technique with small parts of the mucosa and slightly larger parts of the seromuscular layer. Distance between the stitches should be around 3- 5 millimeter. The last stich should end on the outside.
			TIP - Bowel turning If the other corner is reached at the mesenteric side, it is easiest to turn the bowel by turning the two clamps in such way that allows the surgeon to suture again towards him/her.
	C. Bowel corner anti-mesenteric side	Close	After reaching the anti-mesenteric site of the posterior wall, switch to the other needle. The first stich should be made with the backhand from inside to outside. After this stich, the anterior site of the anastomosis can be closed from the mesenteric to the anti-mesenteric site. Finalize the sutures at the anti-mesenteric site with an adequate knot.
			TIP - Two-layer anastomosing If a two-layer anastomosis is preferred the second layer is usually knotted with parts from the seromuscular layer only and using monofilament slowly absorbable thread.
	D. Mesentery	Close	Close the mesentery after removal of the non-crushing clamps with standing absorbable sutures to prevent herniation of the bowel

Step	Substep (structure)	Action	Specification
5. Abdominal wall closure	A. Linea alba	Approximate	Approximate the linea alba with slowly absorbable sutures with maximal steps of 1 cm at the time. Approximate the edges, but do not squeeze to prevent necrosis of the fascia.
			HAZARD - Fascial necrosis While during closure of the fascia the sutures are tied too firmly, this will lead to necrosis. Note, a wound heals between the sutures. Sutures are placed to approximate the tissue and promote healing.
	B. Skin	Close	Close the skin with running subcuticular absorbable monofilament sutures.
			TIP - Peritonitis In case of peritonitis or higher risk of wound infection, the skin may be closed with standing non-absorbable monofilament sutures or skin staples.

APPENDIX C. SEARCH STRATEGY

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('education'/mj OR 'continuing education'/mj OR curriculum/mj OR 'curriculum development'/mj OR 'doctoral education'/mj OR 'education program'/mj OR 'educational technology'/mj OR 'medical education'/mj/exp OR 'postdoctoral education'/mj OR 'postgraduate education'/mj OR Teaching/mj OR learning/mj OR 'learning curve'/mj OR (((education* OR curriculum* OR training OR instruction* OR learning OR trainee* OR Internship OR intern OR interns OR Residenc*) NEAR/3 (surg* OR medical* OR intervention* OR procedur* OR preoperati* OR pre-operati*))):ti) AND ('surgery'/exp OR 'surgical training'/de OR 'operating room'/de OR surgeon/de OR (surger* OR surgical* OR operating OR operati* OR intraoperati*):ab,ti) AND ('controlled study'/exp OR 'clinical trial'/exp OR 'comparative study'/exp OR 'Program Evaluation'/de OR (controlled OR random* OR trial OR comparative OR (Program* NEAR/3 Evaluat*)):ab,ti) NOT ([Conference Abstract]/lim OR [Letter]/lim OR [Note]/lim OR [Editorial]/lim) AND [english]/lim

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(*education/ OR *General Surgery/ed OR * Surgical Procedures, Operative/ed or *exp Education, Professional/ or *Curriculum/ or *Schools, Medical/ or *exp Teaching/ or *learning/ or *learning curve/ OR (((education* OR curriculum* OR training OR instruction* OR learning OR trainee* OR Internship OR intern OR interns OR Residenc*) ADJ3 (surg* OR medical* OR intervention* OR procedur* OR preoperati* OR pre-operati*))).ti.) AND (exp Surgical Procedures, Operative/ OR Operating Rooms/ OR surgeons/ OR (surger* OR surgical* OR operating OR operati* OR intraoperati*).ab,ti.) AND (Controlled Before-After Studies/ OR exp clinical trial/ OR comparative study/ OR exp Program Evaluation/ OR (controlled OR random* OR trial OR comparative OR (Program* ADJ3 Evaluat*)).ab,ti.) NOT (letter OR news OR comment OR editorial OR congresses OR abstracts).pt. AND english.la.

Cochrane CENTRAL

((((education* OR curriculum* OR training OR instruction* OR learning OR trainee* OR Internship OR intern OR interns OR Residenc*) NEAR/3 (surg* OR medical* OR intervention* OR procedur* OR preoperati* OR pre-operati*))):ti) AND ((surger* OR surgical* OR operating OR operati* OR intraoperati*):ab,ti)

APPENDIX D. MODIFIED KIRKPATRICK'S MODEL

Level 1	Reaction – subjective evaluation	*Participants opinion/satisfaction on content, quality, utility of the new teaching method. Participants perception of learning*
Level 2	Learning – changes of knowledge and/or skills	Acquisition of knowledge and/or skills, measured outside the operating room, before or after surgery *Objectively evaluated outcomes of acquired procedural knowledge on paper*
Level 3	Behavioral change-transfer of learning to the workplace	Improvement of surgical performance, measured in the operating room *Objectively evaluated outcomes of acquired procedural knowledge in the operating room on a patient*
Level 4A	Results – changes in professional practice	Wider changes in the organization or delivery of care, attributable to an educational program
Level 4B	Results – benefits to patients	Improvement of surgical result and patient outcomes

APPENDIX E. CHARACTERISTICS OF INCLUDED STUDIES

Author	Study design	Participants	N	Type of Procedure	Intervention, technology	Video type	Segmented continuous	/Feature intervention	Duration	Control(s), technology	Duration	Assessment method
Amer et al., 2017[17]	RCT, posttest only	Medical students	100	Carpal tunnel release	Carpal tunnel surgery application, 3D simulated step by step tutorial, smartphone	Animation	Segmented	Interactive	3 times 6.3 min in one sitting	Audio dubbed slide show, projector screen	3 times 7.4 minutes in one sitting	21-item MCQ knowledge test
Friedl et al., 2006[18]	RCT, pre-and posttest	Residents	126	Aortic valve replacement	Multimedia e-learning, procedures edited into key procedural	Live + animation	Continuous	Non – interactive	1 day, unlimited access	2D pictures, print medium	1 day, unlimited access	20-item MCQ knowledge test z
Harzif et al., 2018[19]	RCT, pre-and posttest	Residents	14	Hysterectomy	e-learning module, instructional video edited into key procedural steps	Animation	Segmented	Non-interactive	1 day	Lectures	1 day	35-item MCQ knowledge test
Hearty et al., 2013[20]	RCT, posttest only	Residents	28	Closed reduction and percutaneous pinning of a pediatric extension-type supracondylar humeral fracture	E-learning module, it shows entire procedure by separating it into components based on key parts of the procedure, computer	Animation + live	Segmented	Non-interactive	Unlimited	Textbook, print medium	Unlimited	60 -item MCQ knowledge test
Norris et al., 2020[21]	RCT, posttest only	Residents	24	Laparoscopic salpingoophorectomy	Instructional video, procedures edited into key procedural steps	Animation + live	Continuous	Non-interactive	1 week, unlimited access	Print medium	1 week, unlimited access	10-item MCQ knowledge test
Plana et al., 2019[22]	RCT, pre-and posttest	Medical students	35	Complete unilateral cleft repair	3D digital simulation	Animation	Continuous	Interactive, user can manipulate digital images	20 minutes	Textbook chapter, print medium	20 minutes	10-item marking knowledge test
Shariff et al., 2015[23]	RCT, pre-and posttest	Residents	43	Open anterior resection	Multimedia e-learning, procedures edited into key procedural steps	Live	Segmented	Non-interactive	30 days Unlimited access	Interactive lectures, surgeon Slide show, projector screen	1 study day	30-item knowledge test, with 20 MCQ and 10 open questions

N = number of participants; RCT = randomized controlled trial; 3D = three-dimensional; 2D = two-dimensional

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APPENDIX F. QUESTIONNAIRE

[1] Number participant?

[2] What is your gender? Circle your answer.

Male Female

[3] What is your age?

[4] In which class are you?

[5] Did you watch hernia introduction video? Yes No

[6] Did you watch the hernia procedure video? Yes No

[7] How much time did you spent studying the inguinal hernia repair website? Circle your answer.

0 - 1 hour 1 - 2 hours 2 - 3 hours 3 - 4 hours more than 4 hours

[8] Did your teacher gave additional lessons about the inguinal hernia? Circle your answer.

Yes No

[9] If your answer to question 6 was "Yes", please answer this question. How much time did your teacher spent on the additional lessons about the inguinal hernia? Circle your answer.

0 - 1 hour 1 - 2 hours 2 - 3 hours 3 - 4 hours more than 4 hours

All of the following 5 questions refer to the online course that just finished. Please take your time to read each of the questions carefully and respond to each of the questions on the presented scale from 0 to 10, in which ‘0’ indicates not at all the case and ‘10’ indicates completely the case). Circle your answer.

[1] The content of this online course was very complex.

0	1	2	3	4	5	6	7	8	9	10
Not at all										Completely

[2] In this online course, complex terms were mentioned.

0	1	2	3	4	5	6	7	8	9	10
Not at all										Completely

[3] I invested a high mental effort in this online course.

0	1	2	3	4	5	6	7	8	9	10
Not at all										Completely

[4] The explanations and instructions in this online course were very unclear

0	1	2	3	4	5	6	7	8	9	10
Not at all										Completely

[5] This online course really enhanced my understanding of the content that was covered.

0	1	2	3	4	5	6	7	8	9	10
Not at all										Completely

APPENDIX G. APPENDIX F. FIDELITY RATING SCALE

Model
This simulation model provides a realistic representation of the abdominal layers
This simulation model provides a realistic representation of the inguinal canal
This simulation model provides a realistic representation of the spermatic cord
This simulation model provides a realistic representation of the nerves
This simulation model provides a realistic representation of the hazards during the surgery
The general performance using this simulator was close in comparison to my general performance in the clinical settings
Equipment
On this simulation model, I could demonstrate the precise movements of the open inguinal hernia repair
I could use all tools/equipment required to perform this procedure in a manner which is close in comparison to the real procedure (OR)
Fixating the mesh was accurate on this simulation model
Psychological
While performing the procedure on the simulation model, it felt like I was doing the procedure on a patient
I felt comfortable performing the procedure
The feel of the equipment made me feel as if I were actually doing the real procedure (in OR)
My experience with the simulation model seemed (overall) consistent with my real-world experiences

APPENDIX H. USEFULNESS RATING SCALE

The open inguinal hernia simulation felt model …
… teaches the importance of performing the open inguinal hernia repair
… teaches the importance of placing a tension-free mesh
… is a useful tool to learn open inguinal hernia repair surgery
… is useful for training of experts
… is useful for training of surgical residents
… is useful for training of medical students

APPENDIX I. OCHRA CHECKLIST LICHTENSTEIN OPEN INGUINAL HERNIA REPAIR

Surgical steps			Performed correctly?	Procedural error	Executional error	Consequential?
Step	Substep	Action				
1. External oblique apo-neurosis exposure	A. Skin	1. Incise				HAZARD - Iliohypogastric nerve damage
	B. Sub-cutaneous tissue	1. Incise				HAZARD - Superficial epigastric vessels damage
	C. Superficial epigastric vein	1. Transect				
	D. Scarpa's fascia	1. Incise				
	E. Sub-cutaneous tissue					
2. Inguinal canal exposure	A. External oblique apo-neurosis	1. Identify				
		2. Incise				HAZARD - Ilioinguinal nerve damage
		3. Dissect				
3. Spermatic cord mob-ilization	A. Spermatic cord	1. Isolate				HAZARD - Genital branch of genitofemoral nerve
		2. Encircle				
4. Hernia sac resection	A. Hernia sac	1. Identify				
		2. Remove				
5. Mesh placement	A. Inguinal canal	1. Expose				
	B. Mesh	1. Trim mesh				
		2. Position mesh parallel to inguinal ligament				

Surgical steps Step	 Substep	 Action	Performed correctly?	Procedural error	Executional error	Consequential?
		3. Fixate - medial to rectus sheath				HAZARD - Pubic periosteum damage
		4. Fixate - caudal to inguinal ligament				HAZARD - Femoral vessels and nerve damage
		5. Split - superior 2/3 inferior 1/3				
		6. Position - folding tails correctly				
		7. Fixate - lateral				HAZARD - prosthetic inguinal ring too wide or too small
		8. Trim mesh laterally				
		9. Position mesh under apo-neurosis				
		10. Fixate - cranial to internal oblique muscle				HAZARD - Iliohypogastric nerve damage
6. Wound closure	A. External oblique apo-neurosis	1. Close				
	B. Scarpa's fascia	1. Close				
	C. Skin	1. Close				

APPENDIX J. OSATS CHECKLIST

Respect for tissue	1 Frequently used unnecessary force on tissue or caused damage by inappropriate use of instruments	2	3 Careful handling of tissue but occasionally caused inadvertent damage	4	5 Consistently handled tissues appropriately with minimal damage
Time and motion	1 Many unnecessary moves	2	3 Efficient time/motion but some unnecessary moves	4	5 Economy of movement and maximum efficiency
Instrument handling	1 Repeatedly makes tentative or awkward moves with instruments	2	3 Competent use of instruments although occasionally appeared stiff or awkward	4	5 Fluid moves with instruments and no awkwardness
Knowledge of instruments	1 Frequently asked for the wrong instrument or used an inappropriate instrument	2	3 Knew the names of most instruments and used appropriate instrument for the task	4	5 Obviously familiar with the instruments required and their names
Use of assistance	1 Consistently placed assistants poorly or failed to use assistants	2	3 Good use of assistants most of the time	4	5 Strategically used assistant to the best advantage at all times

Flow of operation and forward planning	1 Frequently stopped operating or needed to discuss next move	2	3 Demonstrated ability for forward planning with steady progression of operative procedure	4	5 Obviously planned course of operation with effortless flow from one move to the next
Knowledge of specific procedure	1 Deficient knowledge. Needed specific instruction at most operative steps	2	3 Knew all important aspects of the operation	4	5 Demonstrated familiarity with all aspects of the operation

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PHD PORTFOLIO

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PhD period: 2016 – 2021

PhD training	**Year**	**EC**
Courses		
Scientific Integrity	2017	0.3
Advanced Trauma Life Support	2017	2.0
Back to Basics (course on reconstructive surgery)	2018	1.0
Basis Kwalificatie Onderwijs	2021	5.0
Scientific presentations		
Kirurgisk Høstmøte, Oslo	2016	2.0
Global Health Partnerships: Innovations in Surgery, Education and Research, Dublin	2016	2.0
Symposium innovaties in plastisch chirurgisch leren, Amsterdam	2017	2.0
European Society of Surgical Research Congress, Amsterdam	2017	2.0
Congress of the European Hernia Society (3x), Hamburg	2019	6.0
NVvH Chirurgendagen, Veldhoven	2019	2.0
Conferences		
Symposium Global Surgery: One World, One Standard of Care, Amsterdam	2018	1.0
European Society of Cataract & Refractive Surgery, Amsterdam	2021	1.0
Other		
Organizing Symposium innovaties in plastisch chirurgisch leren, Amsterdam	2017	2.0
REPAIR Research meetings	2016 - 2020	2.0
Total		30.3

CURRICULUM VITAE

Tahmina Nazari was born on February 6, 1989, in Kabul, Afghanistan. After fleeing the country, she and her family finally settled in the beautiful village of Baarn. She attended secondary school at Het Baarnsch Lyceum and graduated in 2007. Subsequently, she studied medicine at VU Medical Center Amsterdam and graduated in 2014. After graduation, she started as a content creator at medical startup Incision Academy that focuses on surgical training. Immediately her enthusiasm was raised for surgical education and the idea for research in this area was born. She started her Ph.D. research on this topic in 2016 under the supervision of prof. dr. J.F. Lange and prof. dr. J.J.G. van Merriënboer. She examined whether segmentation improved the learning of surgical procedures, which resulted in this thesis. From September 2017 until September 2018, she worked as a surgical resident at the Department of Surgery at Amstelland Ziekenhuis, Amstelveen. Since April 2020, Tahmina started her residency at the Department of Ophthalmology at University Medical Center Utrecht. Together with her husband, she lives in Amsterdam.