Original Investigations

Significant improvement of laparoscopic knotting time in medical students through manual training with potential cost savings in laparoscopy - an observational study
Findeklee et al. Laparoscopic simulation training could safe costs

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Abstract
Objectives: Laparoscopy is a standard procedure in operative gynaecology, but laparoscopic simulator training for novices/junior surgeons is not well-established so far. The aim of our study was to demonstrate that a laparoscopic knot course for young surgeons can significantly shorten the knotting time and to perform a countervalue calculation for the clinic`s costs.
Materials and Methods: This is an observational study with exercises on a laparoscopic box trainer as part of the practical clerkship in gynaecology and obstetrics between 07.10.2019-31.01.2020. At the beginning and at the end of the exercises, the participants made a laparoscopic knot and the difference in knotting time (Δt in s) was measured.
Results: 88 medical students needed an average of 247.1 s for the first laparoscopic knot at the beginning of the course and an average of 45.43 s for the second at the end of the course. This means an average shortening of the knotting time by 201.67 s or 81.6% (p=0.02). Calculating costs of an average of 40 € to 50 € for an operation minute would mean a cost saving of at least 120 € to 150 € for a partial node.
Conclusion: Young surgeons can significantly improve their operative skills in a short time with the aid of surgical simulation training. Such training on the simulator can be beneficial for the clinics by reducing the operating time if the basics such as sewing and instrument guidance are learned on the simulator. We therefore opt for obligatory implementing operative simulation training in medical education.
Keywords: Laparoscopy-laparoscopic knotting-surgery simulator-equivalent calculation

Introduction

Minimally invasive endoscopic surgery is now considered a standard procedure in many surgical fields, especially in gynaecology and urology, because it is associated with shorter convalescence and an improved cosmetic result. At the same time, it is characterized by a low peri- and postoperative complication rate [1]. However, this depends less on the technical equipment in the operating room than on the training status of the surgeon [2].

According to Gallagher and Satava, laparoscopic surgeons can be divided into novices, juniors and experts with regard to their training status. Novices have performed less than 10 operations, juniors 10-100 and experts performed more than 100 operations [3]. Laparoscopic surgery is sometimes characterized by relatively flat learning curves. The partially complex surgical steps such as the laparoscopic knot should therefore not primarily be learned and practiced on humans. On the other hand, it seems to be essential to familiarize young doctors and possibly also medical students with the laparoscopic approach and to allow them practicing the laparoscopic steps in order to be able to generate enough young surgeons in the future. For reaching this goal, various surgical simulators have been developed over the past few years. With the help of simulators, surgical skills can be practiced without endangering the patient [4]. Unfortunately, training on surgical simulators has so far not been part of student teaching or medical training in operative subjects. Therefore, surgical training on simulators has so far been sporadic and not standardized [5].

The aim of our study was to measure the influence of manual training on the knotting time of medical students as part of the practical clerkship in gynaecology and obstetrics. We utilized a classic box trainer working with a tablet camera and carried out manual exercises in a defined sequence. Figure 1 shows the box trainer.

Materials and Methods

It is an observational study on medical students as part of the practical clerkship in gynaecology and obstetrics in the winter semester 2019/2020. Study period was from 07.10.2019 to 31.01.2020.

The training protocol was as follows: There was one tutor (study doctor with experience in laparoscopic surgery) for a group of six to eight students. At the beginning of the course, the course participants were asked to perform a laparoscopic knot with a wrapping on a self-developed laparoscopy simulator including a box trainer and a tablet camera. This wrapping and the functionality of the instruments were explained to the students in advance. After the students had briefly familiarized themselves with the instruments, they started with their partial node. The knotting time in seconds was measured by the study doctor. For this first part of the training with knotting after instruction by the doctor all in all 30 minutes were calculated.

The following second training step lasted 30 minutes. Here, the students carried out hand-eye coordination exercises with one and two arms and skill training according to a defined protocol. This protocol included picking up tacks with a pair of pliers in the box trainer, threading beads onto a stick and running a ring over a splint without touching it using a laparoscopic needle holder.

Subsequently, clamping a needle in the correct way was demonstrated and the looping for the knot was repeated. The students were now asked to carry out different kinds of seams (interrupted suture, continuous rows of seams). The seams were secured with a double-strand knot and a counter-rotating single knot. This third training session also took 30 minutes. The respective seams and knots were made with braided and thin monofilament threads, so that the students could also develop a feeling for different thread sizes and threads.

Finally, in the last 30 minutes of the knotting training, the students were asked to perform a laparoscopic knot on the simulator again. The study doctor measured the knot time in seconds for a second time. The difference between the mean node time of the first and last

laparoscopic node (Δt) was measured. At the end, every student gained a feed-back by the study doctor.
The training with the four modules, each 30 minutes long, lasted a total of two hours. The course of the laparoscopic knotting training is summarized in figure 2.

Statistical Analysis
The study goal should be to show that the second node after the simulator training is faster compared with the first node before the simulator training. In addition, the paired t-test was used to check whether there was a significant difference between the mean knotting time of the first endoscopic node (t1) and the mean knotting time of the second laparoscopic node (t2) (significance level $p < 0.05$).

Informed consent and ethics
All study participants did sign an informed consent form for further processing the obtained data anonymously before participating in the training course. We did contact the local institutional review board to ask for an ethics vote for the study, but this was not required for the study since it was a regular course belonging to the practical clerkship in gynaecology and obstetrics within the student curriculum.

Results
Between 07.10.2019 and 31.01.2020, a total of 88 medical students took part in the laparoscopic node course with the laparoscopy simulator. The mean duration of the first laparoscopic knot at the beginning of the course was 247.1 s (minimum 45 s, maximum 1 290 s, range 1 245 s). An average of 45.43 s (minimum 7 s, maximum 280 s, range 273 s) was required for the second laparoscopic knot at the end of the course. This means a shortening of the knotting time by 201.67 s or 81.6% due to the learning success with the help of the course (see table 1). The difference between the mean first knotting time and the mean second knotting time (Δt) proved to be statistically significant in the paired t-test ($p = 0.02$). Calculating costs of an average of 40 € to 50 € for an operation minute would mean a cost saving of 120 € to 150 €.

Discussion
Our study shows that medical students can significantly reduce their knotting time by an average of 81.6% after attending a laparoscopic knotting course on the laparoscopy simulator, performing skill exercises and demonstrating and explaining the knotting technique. In this specific case, the clinic could save 120 € to 150 € for each laparoscopic partial node performed if one node had calculated costs of 40 € to 50 € per minute of surgery time, which seems realistic with regard to the published literature [6].
Whereas laparoscopic surgery in general possesses a low operative complication rate it is obvious that the expertise increases with the surgeon`s experience. From an ethical point of view, it is actually not correct to demand for scientific evidence of an economic benefit for the clinic before implementing laparoscopic simulation courses into specialist training for medical doctors. In our eyes, it does not appear ethically responsible to carry out complex surgical interventions in humans with the risk of serious complications without having practiced the individual surgical steps beforehand. Even if there are no complications intraoperatively (e.g. an organ injury), the longer duration of the operation with longer anaesthesia can pose a risk to the patient, especially in the case of pre-existing diseases. There is evidence that complication rates are directly related to surgical duration in gynaecological surgery [7]. As laparoscopic simulator training enables a significant shortening of surgical partial steps like knotting it also has the potential of reducing operative complication rates. Since longer anaesthesia also means an increase in costs for the clinic, this examples stresses how closely linked the medical and economic consequences of longer operation times are. In

the same context it has to be stressed that ethical and economic aspects are no contradictions. Resources in every health care system are limited - hence a responsible use of health care resources (e.g. operating time) is an important aspect to share health care resources with as much patients as possible.

Comparable to the pilot training that has been established for decades, there are currently numerous simulators for laparoscopic operations available with which comparable successes have been demonstrated with respect to the learning curves [8-10]. However, training on the simulator in the surgical curriculum - in contrast to pilot training - is not intended for surgeons. In contrast to pilots, the costs must also be borne by the trainee her- or himself. Hospital providers often argue that they cannot cover the costs of surgical skill training on the simulator, because a countervalue calculation cannot be directly derived. In addition, up to now there is insufficient data on whether both, surgery time as the most cost-intensive factor and the operative complication rate, can be reduced by surgeons trained on the simulator, so that ultimately patients, hospital operators and young surgeons could benefit from the simulated training [3; 11].

Our study provides new data on this issue. So we were able to measure a significant reduction in knotting time through structured simulator-based training. This could result in potential savings in the three-digit Euro range for each laparoscopic partial node. A countervalue calculation also has to consider the exact costs of simulation training. At the same time, it must be emphasized that the costs of structured laparoscopic knotting training on the operation simulator are very low. The technical equipment with box trainer and tablet camera amounts to less than € 1,500 (box trainer 280 €, tablet camera approximately 200 €, laparoscopic instruments including needle holder, grasping forceps and scissors approximately 1000 €). The costs of the suture material are about 250 € per package including 36 pieces. Suture material and endoscopic instruments are also available in every clinic. It is difficult to calculate the costs for the tutor because the study doctor is employed at the clinic and can take the course during working time. There was no necessity for an additional salary. The training programme for all 88 participants at our institution incurred costs of approximately 2,250 €. Fortunately, the technical equipment is re-usable for future trainings. Calculating the operating costs with 50 € per minute, this would mean that the simulator training would have paid for itself if all participants together could reduce the knotting time by at least 45 minutes. The effect of our training was a total reduction in knotting time of about 296 minutes. We therefore recommend our training concept based on our experience, as it is financially worthwhile. Our training concept also allows a variety of other exercises relevant to the operating room, e.g. of spatial imagination within the laparoscopic site or hand-eye coordination.

However, a decrease in the rate of operative complications with the help of simulator training cannot be derived from our study. However, if we regard the handling of the instruments by the students before and after the course, it does not seem to be hard to imagine a potential for reduced surgical complications due to an increase in confidence utilizing laparoscopy instruments. For example, after the training, the seam pad possessing a toughness comparable to that of intestinal tissue, showed significantly fewer tears of the monofilament threads. Perhaps, this could result in a lower rate of anastomotic leakage in the case of surgical interventions on the intestine.

There are several other studies demonstrating that laparoscopic techniques like knotting or sutures can be learned with the aid of simulation courses also by novices [12-15]. In contrast to the other authors, we have introduced the laparoscopic simulation training into the gynaecological practical clerkship with the chance of observing a significant higher number of participants and did compare the time saving of laparoscopic knotting time with a potential saving in operation costs. Our study results therefore provide new arguments for young surgeons as well as medical faculties and teaching hospitals to make laparoscopic simulation

courses an obligatory part of medical training or to have the course costs reimbursed by the employer.

Although surgical simulators are not a new invention, they are still not very widespread, because of the reasons mentioned above. Basically, animal models as well as self-made plastic simulators without material from living beings can be used for practicing surgical interventions [16]. From an ethical point of view, simulators made of non-biological material should be preferred. In addition, they offer the opportunity to practice surgical steps repetitively without time or space restrictions.

Laparoscopy simulators have been successfully evaluated in the past. Among other things, it could be shown that repetitive training has a greater influence on the success of learning the endoscopic knot than talent factors such as manual work or the desire to work in a surgical subject in the future [17]. In addition, Ghesquière et al. and Madec et al. showed that surgical simulators are a suitable instrument to teach surgeons the suitable laparoscopic technique [18; 19]. However, disadvantages of these studies are the relatively small number of participants and their monocentric character.

Our observational study also has some limitations we are aware of. With 88 students, the number of participants is limited and does comprise just one centre. The examined laparoscopic node represents only a partial step of a minimally invasive surgical intervention. It is not possible to infer the improvement in the time required for the entire operative procedure. Besides, there was no further analysis of the characteristics of the students. For example, it could be that a disproportionately large number of students have already worked in a surgical field and therefore had easier access to the laparoscopic node. On the other hand, the talent factor argument was already invalidated by our publication from 2019 [17]. It should also be considered that the number of participants in our study is distinctly higher than the previous publications that have dealt with this topic. Additionally, we are aware that the long-term retention of technical skills acquired during simulation training is a problem. For improving retention of skills, further regular training sessions are recommended and necessary. This circumstance also has to be factored in the cost analysis. Fortunately, repetitive training at an existing simulator is possible without obstacles and does not provide additional costs. Just the costs for the suture of about 250 € per package including 36 pieces have to be estimated. A pragmatic solution could be seen in the utilization of expired sutures. Furthermore, it has to be taken into account that different health care systems in different countries may go along with different health care costs including the costs for operating time. For example, a literature review performed by Chen et al. revealed differences by a factor of 2 in operating costs in the different regions of the world (operating room costs per minute differing from $13.90 in the region Europe, Middle East and Africa to $24.83 in the region North and South America) [20]. Perhaps, this could lower the economic efficacy of simulation training in other countries independent from the ethical point of view.

In our opinion, the special finding of our observational study is that it is not just demonstrating a significant shortening of the time for a laparoscopic knot performed by inexperienced surgeons, but also provides a countervalue calculation for the potentially saving of operation costs. If one assumes that a total laparoscopic hysterectomy requires at least two laparoscopic knots, this operation alone could save the clinic 250 € to 300 € with the aid of surgical skill training. For urogynaecological interventions with a mesh insert, this saving could be increased to 700 € to 1,000 €. This could create an argumentation basis for the assumption of costs for operative simulation training by the hospital authorities, from which doctors and patients would ultimately benefit. The fact that students regularly do not perform laparoscopic knots in real life may limit the impact of our findings. Nevertheless, the students from today are the doctors of tomorrow and also students during practical clerkship do assistance in the operating room with the opportunity of benefiting from the acquired practical skills.

The lesson we learned from our laparoscopic training course is that it will be a mandatory component of the practical clerkship in the subject gynaecology and obstetrics at our faculty. Additionally, the simulator is used by young residents of our clinic. It is imperative to carry out the practical exercises on the simulator under supervision before an operation can be performed in the operating room. Furthermore, the surgical and the urological clinic at our university are planning to implement a similar surgical skills training based on the positive experience we have gained with our course.
Finally, our study could help to further support the spread of operative simulation training, both in the context of training young surgeons and in the curriculum for teaching medical students at the universities.

Conclusion
Young surgeons can significantly improve their operative skills in a short time with the aid of surgical simulation training. Such training on the simulator can be beneficial for the clinics by reducing the operating time if the basics such as sewing and instrument guidance are learned on the simulator. We therefore opt for implementing operative simulation training in medical education.

Conflict of interest
The authors declare no conflict of interest.
The authors confirm that they have had full control of all primary data and that they agree to allow the journal to review their data if requested.

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Table 1. Comparison of node times before and after the course

Criteria	Knotting time t 1	Knotting time t 2
median	247.1 s	45.43 s
minimum	45 s	7 s
maximum	1 290 s	280 s
range	1 245 s	273 s
total	21 745 s	3 998 s

figure 1: structure of the laparoscopy simulator

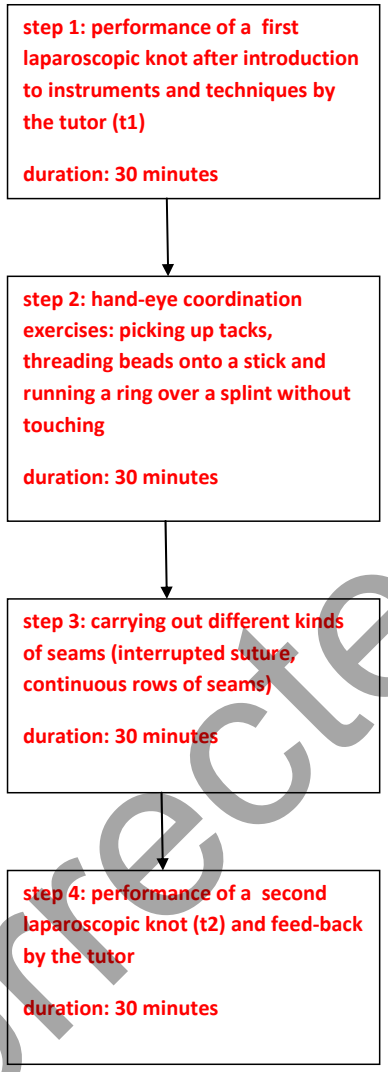

figure 2: course of the laparoscopic knotting training