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ARTICLE

The transferability of the minimal invasive surgeon's skills to open surgery

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ABSTRACT

Background: Robot-assisted laparoscopic surgery has gained popularity, which has contributed to a decrease in the number of open procedures. Hence a growing concern regarding the ability of laparoscopically trained surgeons to perform open surgery (e.g. due to bleeding complications) has been raised. The aim of the study was to investigate the ability of conversion to open surgery following exclusively robotic or laparoscopic training.

Methods: Thirty-six medical students were randomized into three groups: Open surgery, laparoscopy, and robot-assisted laparoscopy. All underwent intensive simulation training in the allocated surgical modality. Subsequently, all study subjects performed an open bowel anastomosis in a pig model where anastomoses were tested for resistance to pressure and leak as a surrogate marker of surgical quality.

Results: The primary endpoint was the surgical quality of an open surgery model assessed as, leak pressure, which was 80.01 ± 36.16 mmHg in the laparoscopic training group, 106.57 ± 23.03 mmHg in the robotic training group, and 133.65 ± 18.32 mmHg in the open surgery training group (mean, SD). We found that there were no significant differences between the open surgery training group and the robotic training group whereas a significant difference was found when comparing laparoscopic and open surgery training groups in favor of open procedure training ($p < 0.001$).

Conclusion: In a surrogate open surgery model based on bowel anastomosis, we found that skills acquired through practice on robotic simulation platforms were not significantly worse when compared to skills acquired through training in open surgery, whereas skills acquired from laparoscopic training were significantly poorer when compared to open surgery practice.

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Introduction

The use of minimally invasive surgical techniques is associated with a reduced complication rate, improved visualization of structures, decreased blood loss, decreased postoperative pain, and faster recovery compared to open surgical procedures [1]. These benefits have driven a dramatic increase in the utilization of the minimal invasive approach. The initial focus was on classic laparoscopy, but within the last decades, the focus has turned towards robot-assisted laparoscopic surgery [2]. With the introduction of minimally invasive surgery, the number of open procedures continues to decline [3]. The small fraction of general surgeons, urologists and gynecologists that are converting from exclusively open surgical procedures to robotic surgery, carry with them a broad surgical experience in case of conversion to open surgery. On the contrary, newly trained- and laparoscopic-trained surgeons have minimal invasive surgery as their primary skill and less or no training in open surgery. Technical skills in open surgery are crucial when a minimal invasive procedure cannot be safely or effectively completed and conversion to an open procedure is required.

In the nature of robotic-assisted surgery lies handling of instruments, visualization and the use of an assistant, which resembles open procedures far more than laparoscopic surgery. This is supported by studies showing that open surgical skills transfer to robotic skills [4]. However, data supporting the transfer of skills acquired during robotic surgery to open surgery, are lacking.

The aim of this study was to investigate whether conversion to open surgery is easier for a robotically trained surgeon compared to a laparoscopic-trained surgeon. The hypothesis was that increased use of robotic surgery could be an advantage compared to conventional laparoscopy, concerning the conversion to open surgery increasing patient safety.

Methods

Medical students with limited or no previous experience with minimally invasive surgery or simulation were recruited from

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Aarhus University Hospital. Recruitment was based on a notice posted on online platforms aiming at surgically interested medical students at Aarhus University. Applicants were asked to complete an electronic form, including the level of education, gaming/music/sports experience and experience with surgical simulation. Exclusion criteria consisted of any formal training with robotic simulation, laparoscopic simulation experience greater than 10 hours of clinical experience with robotic or laparoscopic techniques. Study subjects self-reported their demographics and experiences.

Study subjects consenting to participate in the study were randomized into three groups stratified on gender: laparoscopic, open surgery and robotic training, using REDcap software (Vanderbilt University, Nashville, TN, USA). They completed a baseline assessment (pretraining test) in the surgical modality for which they were randomized.

Pretraining test

Laparoscopy group: Peg transfer task (Fundamentals of Laparoscopic Surgery Program, Los Angeles, CA): Six plastic triangular pegs were individually grasped from the left side of the pegboard with a Maryland grasper in the left hand, transferred mid-air to a Maryland grasper in the right hand, and re-positioned on the right side of the pegboard. In a similar fashion the students transferred the pegs back to the left side of the pegboard.

Open surgery group: A low fidelity simulator for knot tying. The students performed a knot tie using the 2-1-1 technique, two stitches and then again a knot. The knots were tested for resistance. If a knot slipped, the task had to be repeated. The test was passed when the knots were done accurately, adding the time of the failed trials to the total time.

Robotic group: Seaspikes 1 exercise (dV-Trainer): Coloured virtual rings were individually grasped and placed onto the matching coloured cones. Measured in Mimic dV-trainer motion metrics automatically recorded by the Mimic dVtrainer.

Training period

Immediately after baseline performance, study subjects underwent training in the modality to which they were randomized. All study subjects received oral and video instructions on how to perform a standardized hand-sewn, laparoscopic, and robotic porcine intestinal anastomosis. Training consisted of supervised and formalized training in sutured small bowel anastomosis by the allocated surgical modality.

Fresh fragments of the porcine small intestine (10 cm) were harvested, irrigated, and frozen until the start of the experiment. Bisected segments were aligned and an end-to-end anastomosis was completed using a seromuscular stitching technique with a running 4-0 monofilament suture. In the case of suture breakage, the study subject was provided with an additional suture. This model had previously been described as a useful surgical simulation model for bowel anastomosis [5].

Stations

The hand-sewn station was supplied with forceps and a standard needle holder. The laparoscopic station consisted of a laparoscopic training box, a 10-mm, 0° digital laparoscopic camera (Karl-Storz, Tuttlingen, Germany) with the light source set at 60% intensity, a monitor and laparoscopic needle drivers. The robotic station consisted of the da Vinci surgical robot system (Intuitive) supplied with a Maryland and a grasper. The groups repeated the procedure repetitive 90 min every week for 6 weeks.

Posttraining test

At the end of the training period, the study subjects repeated the assessment in the surgical modality they were trained, similar to the baseline assessment.

Final study test

For the final study test, study subjects performed a final exam on a euthanized pig, consisting of a small bowel end-to-end anastomosis using the hand-sewn technique. Procedure time was registered and following the procedure, intestines were harvested, and leak pressure tested. Leak pressure was assessed by occluding the bowel 3 cm from the anastomosis. The other end of the intestinal lumen was attached to a tube connected to a 1 liter water bag.

The pressure was gradually increased by raising the water bag. When a leak in the suture line was observed, the height of the bag was registered and the pressure calculated, using (height*water density*Earth's gravity = pascal). Insufficient suture lines were registered with a leak pressure of zero.

Statistical analysis

Statistical analysis was performed using (Medcalc, version 19.6.4). Parametric data were presented as means with 95% confidence intervals if not stated otherwise. In-group comparison was performed using paired *t*-test for normally distributed data and tested using the Shapiro-Wilk test. Between-group analyses were performed using generalized linear model ANOVA with leak pressure as the dependent variable and surgical modality as independent variables. The level of statistical significance was set at $p < 0.05$.

Results

A total of 36 study subjects were enrolled in the study and randomized to one of the three study groups (Figure 1). There was no significant demographic difference between the three groups (see Table 1). One participant did not show up to the first training session and was subsequently excluded from the study. All other study subjects completed

Table 1. Demographics of participants.

	Laparoscopic training group ($N = 12$)	Open surgery training group ($N = 11$)	Robotic training group ($N = 12$)
Female (*N* %)	7 (58.3)	6 (54.5)	7 (58.3)
Mean age (years)	25	26	25
Played musical instrument (*N*, mean years)	5 (11.3)	0	2 (14.0)
Played organized sports (*N*, mean years)	4 (6.0)	6 (4.9)	3 (6.7)
Experience with video games (*N*, mean hours per week)	7 (2.9)	5 (3.5)	5 (2.1)
Prior laparoscopic simulator experience (*N*, mean total experience time (h))	3 (5.0)	1 (2.0)	1 (4.0)
Prior robotic simulator experience	0	0	0

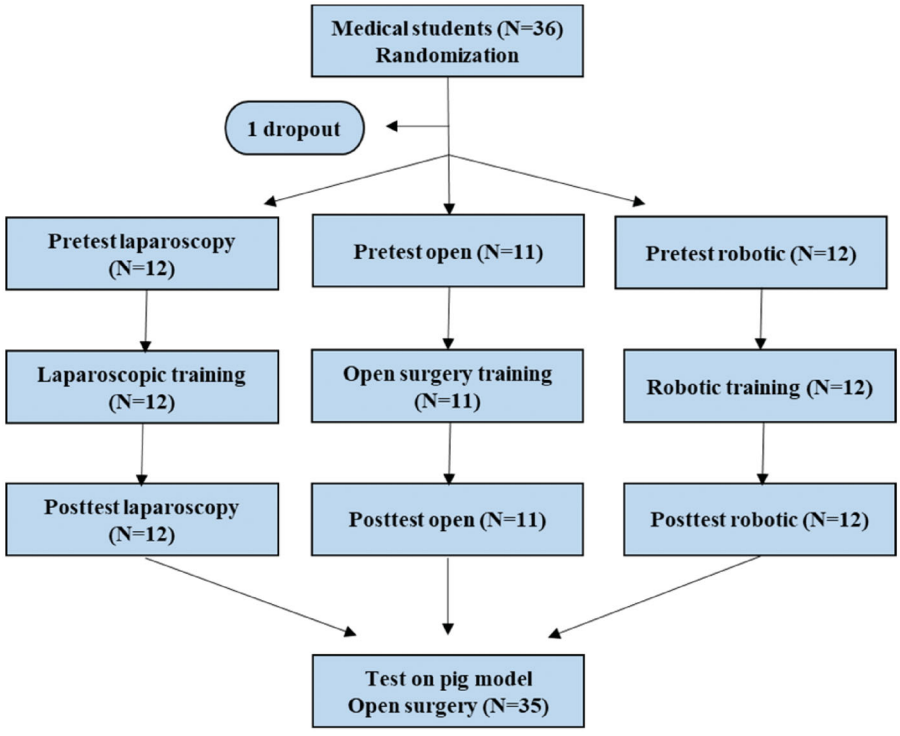

Figure 1. Study flow diagram. Medical students with no previous surgical experience were randomized into three groups. All underwent simulation training in the allocated surgical modality for 6 weeks. Following the training period, all performed an open bowel anastomosis in a pig model where anastomoses were tested as a surrogate marker of surgical quality, Aarhus University Hospital.

the training program lasting for 6 weeks (9 h) (Figure 2). As a measure of technical improvement, time consumption during test procedures was significantly decreased in the laparoscopic trained and open surgical trained groups from 6.96 (5.04–8.88) min to 2.07 (1.56–2.58) min and from 7.46 (5.08–9.84) min to 1.96 (1.33–2.58) min ($p = 0.004$ for both groups). Technical improvement was demonstrated in the robotic surgery trained group with a significant increase in MScore from 60.83 (49.73–71.94) points to 87.91 (85.38–90.44) points ($p < 0.0001$).

The mean leak pressure ± CI was 80.01 ± 36.16 mmHg in the laparoscopic training group, 106.57 ± 23.03 mmHg in the robotic training group and 133.65 ± 18.32 mmHg in the open surgery group. When comparing groups for this final study test, the open surgery training group had a statistically higher mean leak pressure of the anastomosis compared to the laparoscopic training group ($p < 0.001$). There was no significant difference between the open- and the robotic training group (Figure 3).

Regarding personal characteristics, neither music instruments, nor sports experience influenced study subjects' performance significantly in the final test. The subjects who self-reported experience with video games (gamers), however, showed increased leak pressure/reduced operating time compared to non-gamers when comparing the study subjects in the final study test: 136.51 (113.32–159.70) mmHg and 99.01 (74.90–123.11) mmHg, respectively ($p = 0.04$).

Discussion

When a minimally invasive procedure cannot safely or effectively be completed, the strategy is often to convert to an open procedure. The skills, experience, and confidence to complete an open procedure are therefore necessary. In this study, we investigated if simulation training improved the surgical skills in three different surgical modalities using fresh tissue models to mimic the clinical setting. We modified a

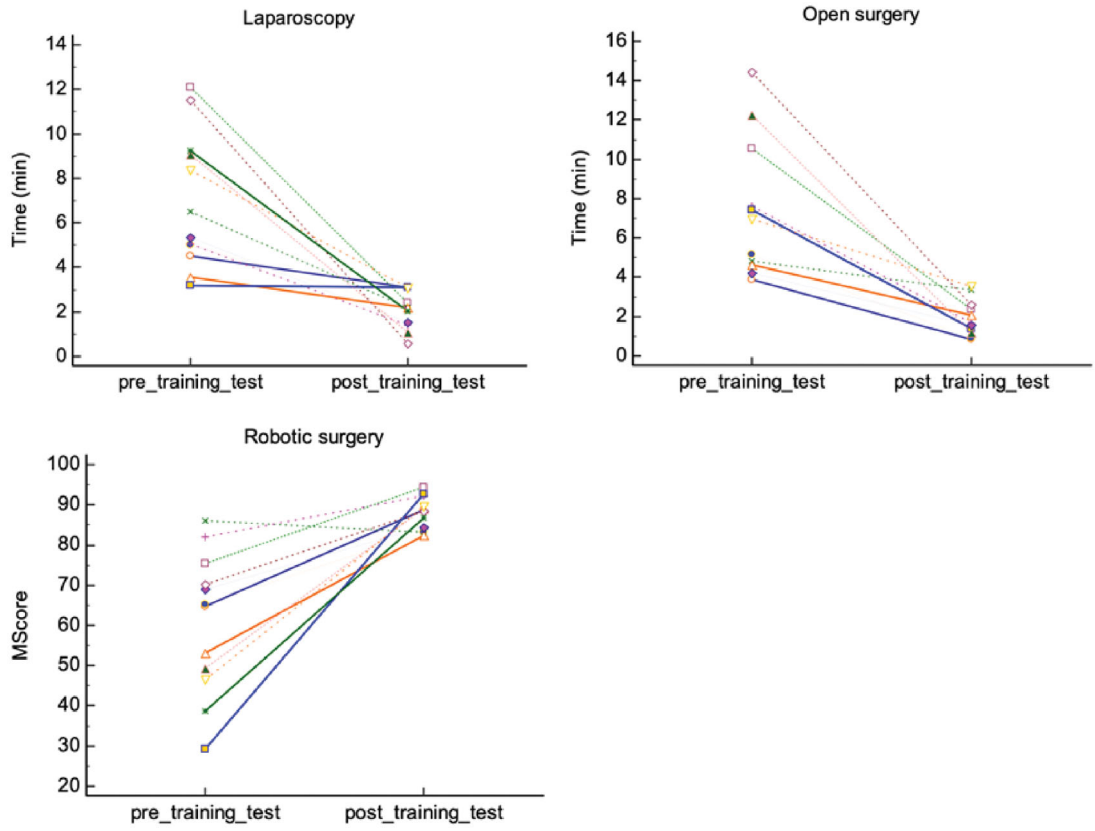

Figure 2. In-group comparisons of technical improvement after 6 weeks of training. A high test score in a robotic post-training test equals a higher skill level. A lower score in laparoscopic and open surgery post-training tests equals a higher skill level.

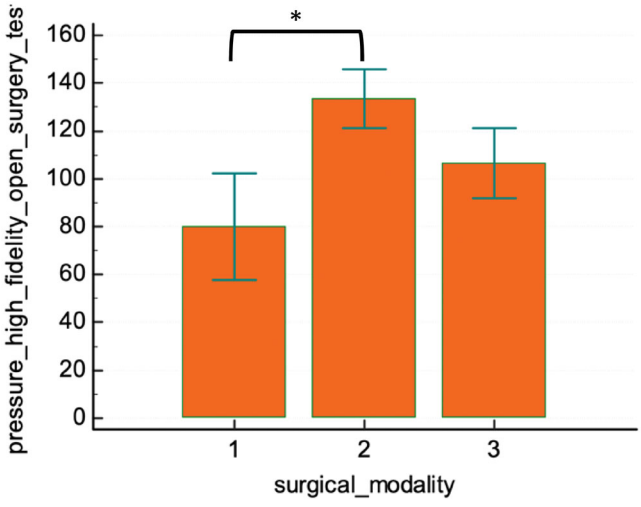

Figure 3. Final study test: Leak pressure test on pig model open anastomosis. 1 (Laparoscopy), 2 (open surgery), 3 (robotic surgery) * Significant difference.

simulation model previously used as a training model for both open surgeries [5,6], robotic [7] and laparoscopic simulation [7,8]. Previous studies have demonstrated the efficacy of simulation-based training in improving trainees' basic skills [9–13]. A complex reconstructive procedure, like a robotic-sutured intestinal anastomosis, can be reproduced successfully by residents [14].

We expect that the results translate into improved performance in a clinical setting. A systematic review performed by Dawe et al. evaluated 27 randomized clinical trials and 7 non-randomized comparative studies, showing that structured simulation training improves performance in a patient setting [15].

In our study, we found that robotic surgery resembles open procedures more than laparoscopic surgery does. Thus the question arises to which extent robotic and open surgery skills are interchangeable. It is unclear how robotic surgery skills will transfer when the strategy is to convert to an open procedure. The study gives us reason to think that the robotically trained surgeon will be better prepared for a conversion maneuver compared to the laparoscopic-trained surgeon. Future studies are warranted evaluating the outcome of clinical conversions focusing on the surgeon's surgical experience.

The increased use of minimally invasive procedures and fewer open surgical procedures could be an issue for residents' ability to convert [3]. Preferring robotic surgery in favor of laparoscopic surgery, supplemented with simulation training in open surgery, maybe one way to ease conversion to open surgery.

In the present study, we found a positive association between video game experience, male gender and performance in the final study test. This could partly be due to gender-specific interests, such as gaming. The previous video gaming experience has been shown beneficial for learning surgical psychomotor skills [16–19]. Studies also suggest that the observed differences could be due to gender-related differences in learning preferences [20]. In contrast, neither

musical instruments nor sports experience showed an effect on performance in the present study. This corresponds to the results, in robotic surgery, found in the study by Kowalewski et al. [17].

Our study brings evidence related to the transfer of skills from minimally invasive surgery to open surgery skills. The major limitation consists of the small sample size and the limited number of exercises. As a potential solution for some limitations that may have affected the outcomes, we added the open surgery group as a training arm to the study. The capacity was limited to one daVinci surgical robot, hence individual training. The two other groups, open and laparoscopic, had simulation training platforms and could undergo training in small groups. We designed the study with one final test, limiting the study to this end-point. Optimally we would include sharp and blunt dissection, the use of diathermy and hemostasis techniques. The bowel anastomosis exercise as a test is well-used and acknowledged as a good evaluation method for technical surgical skills [14,21]. We wanted a model suitable for achieving competencies in basic surgery skills in the time available (6 weeks) in surgically inexperienced study subjects. Performing the intestinal suture line with robotic assistance and as well as for laparoscopic approach is one of the more difficult exercises and in our pilot study, it took the 6-weeks training period for the laparoscopic trained study subjects to achieve a plateau of skills in the procedure. By using this anastomosis model we aimed to have an indicator for surgical skills even though we are aware of its inadequacy regarding covering all relevant skills within the surgery.

Furthermore, it would be relevant to examine the transfer of surgical skills to surgical residents for the fact that they are the new young surgeons who could benefit from the research in this field. Our study subjects are medical students with no prior surgical experience. By using surgical residents, variability would increase and thereby increase the sample size considerably and we would not be able to complete the study under our conditions.

The training consisted of repeated sessions with a fixed time for each session and no continuous evaluation. This could be considered a limitation of the study, but evaluating an improvement in technical skills over a training period would not be feasible, due to study logistics. Although the learning curves may differ between the surgical modalities this was not the scope of the present study.

In our study, training in robotic surgery seems to transfer skills to an extension to open surgery as we see no significant difference in performance in open surgery between these two groups. The results of this study have a clinical impact being useful for the new generation of surgeons, initially trained in robotic surgery.

Conclusion

In a surrogate open surgery model based on bowel anastomosis, we found that skills acquired through practice on robotic simulation platforms were not significantly worse when compared to skills acquired through training in open surgery, whereas skills acquired from laparoscopic training were significantly poorer when compared to open surgery practice.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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