Surg Endosc (2013) 27:2886–2893
DOI 10.1007/s00464-013-2849-z

Teaching and training in laparoscopic inguinal hernia repair (TAPP): impact of the learning curve on patient outcome

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Received: 22 November 2012 / Accepted: 16 January 2013 / Published online: 23 February 2013

Abstract
Background On the basis of lower incidence of postoperative pain and faster recovery compared with open techniques, the laparoscopic transabdominal preperitoneal patch plastic (TAPP) technique was established as a leading mode of inguinal hernia repair. In contrast to open hernia repairs, which are well integrated in the training of young surgeons, TAPP is still considered a more difficult surgical procedure, raising the questions of how to include this technique in trainee programs and how to provide appropriate training.
Methods Out of 15,101 TAPP procedures performed in our department between 1993 and 2007, we analyzed 254 operations that occurred from April 2004 to February 2007 by young trainees (between the second and fourth years of surgical training). The analysis compared the trainees' TAPP operations with 3,200 TAPP procedures performed by experienced surgeons in the same time period, and with the first 254 TAPP operations in our department performed by pioneers who introduced this technique in 1993.
Results In the 254 operations performed by young trainees, the mean operation time was 59 min, the morbidity rate was 3.2 %, and the recurrence rate was 0.4 %. Compared to experienced surgeons, we found no significant difference in recurrence rate and morbidity. For operation time, however, the young trainees demonstrated a learning curve with continuous improvement until the end of the study period approaching expert level. Pioneers also demonstrated a clear learning curve in operation time and additionally also regarding morbidity and recurrence rate.
Conclusions Our study demonstrates that the TAPP learning curve of young trainees is only related to operation time. Therefore, TAPP is a safe and reproducible technique when performed by young trainees under the supervision of experienced laparoscopic surgeons. With an adequate program, the technique can be learned quickly, skillfully, and safely when a standardized technique is used. It should be included as a fundamental part of state-of-the-art trainee programs.

Keywords Inguinal hernia · Laparoscopic hernia repair · Laparoscopy · Learning curve · Training laparoscopic skills

Twenty years after the advent of transabdominal preperitoneal patch plasty [1] and total extraperitoneal plasty [2], both techniques are accepted as therapeutic modalities in inguinal hernia repair worldwide. Currently, in Germany, out of 177,000 hernia repairs performed in hospitals, 48.2 % are done laparoscopically or endoscopically (TAPP [transabdominal preperitoneal] 30 %, TEP [totally extraperitoneal] 18.2 %) [3]. According to the guidelines of the European Hernia Society (EHS) [4] and International Endohernia Society (IEHS) [5], both new techniques are advantageous regarding all pain-associated parameters when compared to open surgery. Correspondingly, the guidelines recommend laparoscopic hernia repair to be the first choice treatment in those patients

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where a quick postoperative recovery is particularly important (grade A). Furthermore, the guidelines postulate that from a socio-economic perspective an endoscopic procedure must be proposed for the active working population, especially for bilateral hernias (grade A). In addition, a recently published study demonstrated that in patients having a low pain threshold, which are operated with an open mesh technique their risk for developing chronic pain is about 2.5-fold higher compared to the laparoscopic repair [6].

Despite these proven benefits of the new, revolutionary technique, there is an insufficient implementation of the guidelines in the clinical routine of most of the countries. Underlying reasons that are discussed include the technical difficulty of laparoscopic surgery as well as the lack of structured training programs.

The aim of this study was to investigate what can be achieved by the laparoscopic hernia repair; the extent and the duration of the learning curve; and how education can be improved.

Materials and methods

In 1993, the first laparoscopic inguinal hernia repair (TAPP) in the Department of General Surgery of the Marienhospital Stuttgart (on average 3,500–3,600 patients operated on yearly) was done by the chief surgeon in a patient who experienced recurrence after open surgery. The operation was performed after studying the literature and attending a live demonstration. As a result of a previous bad experience, the patient did not want to undergo open surgery again, and thus the patient gave fully informed consent to be the first in the new technique. The operation lasted 2.5 h, but the operation and postoperative course were uncomplicated.

From this time on, all patients were prospectively recorded and entered into a database. Furthermore, the patients were included in a follow-up program which comprised a specific postoperative hernia consultation after 4 weeks and again after 1, 2, 5, and 10 years. Follow-up ranged from 1 to 176 months. Around 90 % of the patients were examined clinically at least once after discharge, most of them during the first year after surgery. After 5 years, the follow-up rate declined to less than 55 %.

The data were analyzed at regular intervals, so that insufficient results were immediately recognized and the operative technique could be improved accordingly. Eighty-seven percent of recurrences ($n = 92$) after TAPP were reoperated by TAPP; thus, it was possible to exactly diagnose the causes for the recurrence. For example, in the pioneering time of the new technology, the whole pelvic floor was not completely dissected (missing defects), the mesh was far too small (8 × 12 cm), and the mesh was slit. This led to an increased recurrence rate in the beginning. Furthermore, when changing to a nonslit mesh, initially the parietalization was insufficiently done, which also led to a higher recurrence rate. Moreover, a heavy-weight mesh was implanted during the first years (leading to more pain and more seroma), too many clips were used (>6) (leading to more pain), and the peritoneum was not closed by suture (leading to more pain). The results of the first experiences in TAPP, which explored individual learning curves without our own previous or institutional experience, were published several years ago [7]. Meanwhile, the operative technique has been completely standardized. A detailed description of the current technique of TAPP has been recently published [8]. The acceptance of the new method was so high that not only more patients, but also increasingly more difficult cases, could be treated with this new technique. Whereas in 1993 only 35.6 % (180 of 505) of the patients in our surgical department were operated on laparoscopically, during the next year this percentage increased to 73.6 % (502 of 682); in 1995 the percentage reached 87.7 % (711 of 811), and in the year after that 97.6 % (1,014 of 1,034). Since 1997, the number of inguinal hernia repairs has ranged 1,100–1,200 per year, among them consistently >98 % TAPP.

After the TAPP technique had been established and standardized by the chief surgeon and four attending surgeons (consultants) in 1996, the first resident performed a laparoscopic hernia repair. Since that year, the percentage of operations conducted by young trainees has been increasing (Fig. 1).

Initially, residents were introduced to TAPP in their last trainee year, but since 2004, young trainees begin laparoscopic hernia repair in their second or third year of surgical training. Before they can complete their own first complete operations, young trainees need to meet the following requirements: total awareness of the laparoscopic anatomy and the main parts of the operations and their pitfalls; at least 50 camera assistances at TAPP procedures; at least 20

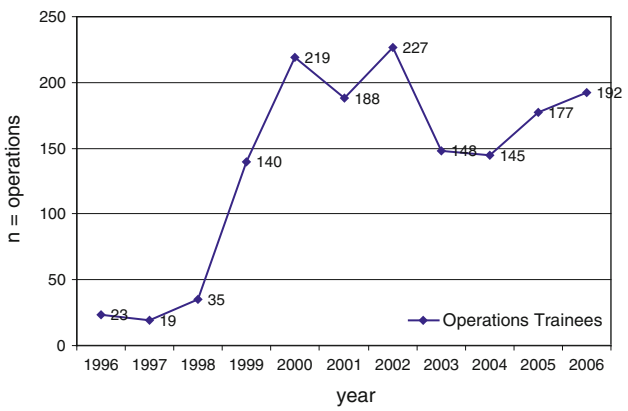

Fig. 1 Percentage of TAPP performed by trainees

laparoscopic cholecystectomies; and the capability of performing parts of the operation.

All the operations performed by young trainees are guided by an experienced laparoscopic surgeon at the camera. Some of the tapes of the trainees operations are later analyzed and critically observed by the team in order to faster realize further progress and improvement.

The present study evaluates TAPP training on the basis of a prospective documentation. It was designed to examine the feasibility and to evaluate the surgical outcome of TAPP performed by young trainees—that is, the learning curve when doing TAPP in a hospital in which laparoscopic inguinal hernia repair is established, fully standardized, and integrated in clinical routine. These results were compared to the outcome of patients who were operated by the attending surgeons who had introduced the laparoscopic technique.

Statistical analysis of the evaluated data was performed with the Student's *t* test and the Qui-Quadrat test. The level of significance was set at $p < 0.05$.

Results

Between 1993 and 2007 a total of 15,101 laparoscopic inguinal hernia repairs were performed in the Department of General and Visceral Surgery, Marienhospital Stuttgart, which was primarily not focused on hernia repair but rather on performing all types of abdominal surgery except transplantation. The team consisted of the chief surgeon, 5 attending surgeons, and 12 residents, including 5 young trainees.

The study period for trainee performance lasted from April 2004 to February 2007. During this time, 254 TAPPs were performed by five young trainees in their second or third year of surgical training; during this time, 3,200 TAPPs were performed by 12 experienced colleagues. The study period for the pioneer's performance lasted from April 1993 until February 1994. During this period, the four pioneers introduced this technique and performed 254 TAPP procedures. The characteristics of these study groups and the distribution of the hernia anatomy are listed in Tables 1 and 2 and compared with the whole inguinal hernia patient group operated on at the same institution.

In the 254 operations performed by young trainees, the mean operation time was 59 min. The morbidity rate was 3.2 % (eight patients), the recurrence rate was at 0.4 % (one medial recurrence). We compared these findings to those for 2,580 patients with 3,200 primary hernias that were operated on by experienced surgeons during the same time period between April 2004 and February 2007 in our department. We found no significant difference in recurrence rate when

Table 1 Study group characteristics

Patient characteristics	Trainee (04/2004–02/2007)	Expert (04/2004–02/2007)	Pioneer (04/1993–02/1994)	Total (04/1993–12/2007)
Patients, *n*	236	2,580	212	12,221
Hernias, *n*	254	3,200	254	15,101
Men, *n*	212	2,370	193	10,334
Women, *n*	24	210	19	1,887
Age, years, median (range)	55.5 (17–92)	57.5 (17–100)	55.0 (18–86)	58.8 (17–100)
Body mass index, kg/m^2, median (range)	26.8 (17–42)	26.2 (17–42)	24.4 (18–38)	26.2 (17–42)
Operation time, min, mean	59	46	60	42

Table 2 Distribution of the hernias according to the Nyhus classification

Nyhus classification criterion	Trainee (04/2004–02/2007)	Expert (04/2004–02/2007)	Pioneer (04/1993–02/1994)	Total (04/1993–12/2007)
2 (indirect, posterior wall intact)	83 (32.7 %)	942 (29.4 %)	109 (42.9 %)	3,852 (25.5 %)
3a (direct)	96 (37.8 %)	1,050 (32.8 %)	87 (34.3 %)	4,893 (32.4 %)
3b (indirect, posterior wall defect)	57 (22.4 %)	582 (18.2 %)	7 (2.8 %)	3,086 (20.4 %)
3c (femoral)	6 (2.4 %)	37 (1.2 %)	2 (0.8 %)	318 (2.1 %)
4 (recurrence hernia)	5 (2.0 %)	337 (10.5 %)	36 (14.2 %)	2,006 (13.3 %)
Combined	6 (2.4 %)	214 (6.7 %)	13 (5.1 %)	886 (5.9 %)
Not classified	1 (0.4 %)	48 (1.5 %)	0 (0 %)	60 (0.4 %)

Table 3 Comparison of overall results for the three groups

Characteristics	Trainee (04/2004–02/2007)	Expert (04/2004–02/2007)	Pioneer (04/1993–02/1994)
Morbidity (%)	3.2 %	2.2 %	14.4 %
Recurrence rate (%)	0.4 %	0.3 %	5.9 %
Operation time, min, mean	59	46	60

Table 4 Overview of overall complications

Characteristics	Trainee (04/2004–02/2007)	Expert (04/2004–02/2007)	Pioneer (04/1993–02/1994)
Intraoperative complications[a]	0 (0 %)	1 (0.03 %)	3 (1.2 %)
Orchitis	1 (0.4 %)	4 (0.1 %)	1 (0.4 %)
Chronic pain	1 (0.4 %)	17 (0.5 %)	0 (0 %)
Lesion nerves (Nervus cutaneus femoris lateralis)	1 (0.4 %)	5 (0.2 %)	4 (1.6 %)
Other	2 (0.8 %)	26 (0.8 %)	20 (7.9 %)
Total	8 (3.2 %)	70 (2.2 %)	37 (14.4 %)

[a] Severe intraoperative bleeding

we assessed the operated patients (0.4 % in the trainees vs. 0.3 % in the experts; $p = 0.825$). Concerning the morbidity rate, we found a slightly but not significantly higher rate in the patients operated on by young trainees. The young trainees' cases had a morbidity rate of 3.2 %, and the morbidity in the patients operated by experts was at 2.2 % ($p = 0.321$; Tables 3, 4).

The young trainees needed significantly more operating time—a mean of 59 min, versus 46 min ($p < 0.001$) in the expert group (Table 3). However, when we compared the mean operation time of the trainees and the pioneers, we found no significant difference in the length of the operations (59 min for the trainees vs. 60 min for the pioneers, $p = 0.603$). Both groups demonstrated a learning curve. The pioneers started with a mean operation time of 78 min in their first 50 operations and the trainees with 67 min. The pioneers decreased it to 58 min and the trainees to 51 min in the last 50 operations of the study period (Fig. 2).

Concerning morbidity, the trainees demonstrated good results right from the beginning, in contrast to the pioneers. The young trainees had a significant lower morbidity rate, 3.2 versus 14.4 % ($p < 0.001$) in the pioneer group. The same goes for the recurrence rate. The trainees achieved a low median recurrence rate of 0.4 %, whereas the pioneers started in their first 50 operations with a median recurrence rate of 12 % and an overall median recurrence rate of 5.9 %. In total, the trainees had a significant lower recurrence rate ($p < 0.001$). In contrast to the trainees' operations, the pioneers had a steep learning curve for the morbidity and recurrence rate (Figs. 3, 4).

Looking at the learning curve of the pioneers, we found a decrease in morbidity, recurrence rate, and mean operation time in their first 200 operations. The trainees demonstrated a continuous improvement over the whole study period with 254 operations. After the first 200 operations, the pioneers moved on to more difficult hernia cases, which again led to an increase in morbidity, recurrence rate, and mean operation time, whereas the trainees continued to operate on the easier cases until the end of the study period.

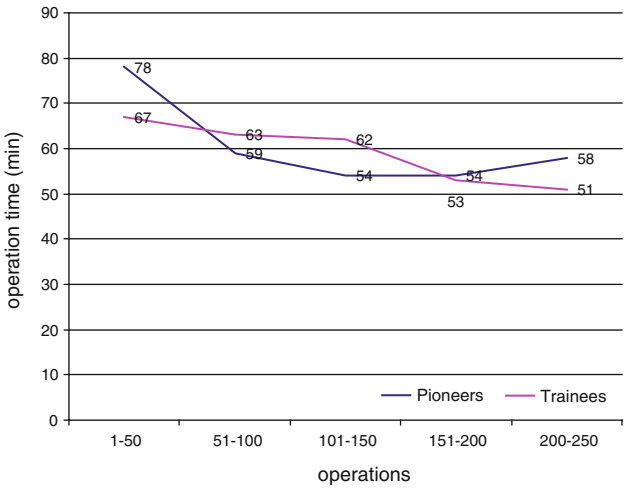

Fig. 2 Development of the operation time

Discussion

The results of the large prospective clinical trial realized in the database of Marienhospital Stuttgart, with its experience of more than 15,000 patients, prove that laparoscopic inguinal hernia repair using the TAPP technique can be performed safely and effectively as a routine intervention

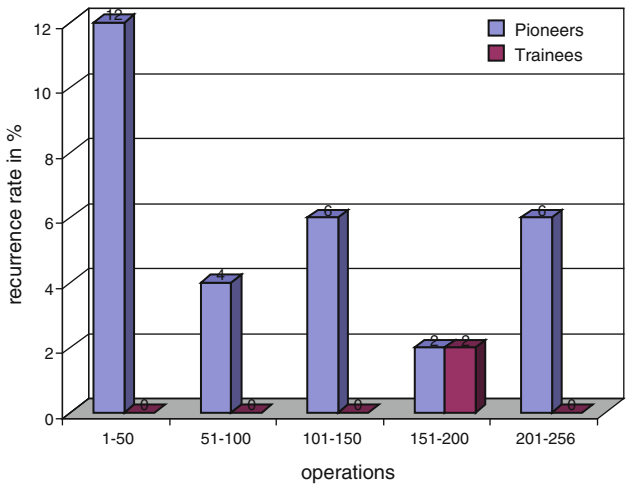

Fig. 3 Development of the recurrence rate comparing pioneers' and trainees' first TAPP operations

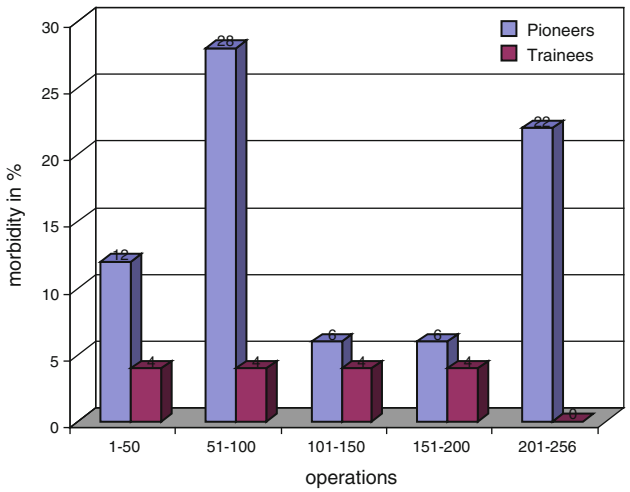

Fig. 4 Development of the morbidity comparing pioneers' and trainees' first TAPP operations

even in a nonspecialized general surgical department of a community hospital. According to our experience, the prerequisite for the demonstrated good results in over 15,000 patients who underwent surgery in a 15 year period by a total of 23 surgeons is a strict standardization of operating technique and continuous quality control. Moreover, well-structured training plays a key role to achieve an optimal result. The study demonstrated clearly that TAPP is not just a surgery for specialists but also for young surgeons in training, who can achieve excellent results.

Stylopoulos et al. [9] concluded, in accordance with the long-term outcomes of their huge study population, that from a societal perspective, laparoscopic hernia repair is a cost-effective approach and is associated with higher quality-of-life benefits at lower cost. The authors postulated that greater efforts to make laparoscopic herniorrhaphy easier to perform could ultimately reduce health care costs. Accordingly, education is of primary importance in this process. In the literature, we found several articles that described education and how to overcome the learning curve in inguinal hernia repair. Some studies evaluated the learning curve by studying the operation time [10–15], conversion rate [10, 11, 13, 16, 17], or number of recurrences [10, 11, 16–20]. According to these studies, between 20 and 240 procedures are required for the learning curve to reduce operation time, morbidity, and recurrence rate to a stable level in line with experienced surgeons. The cause for the large differences in the number of operations necessary to become familiar with the new technique lies in the remarkable heterogeneity of these studies. Many factors may influence the learning curve, including previous individual and institutional experiences in surgery, and specifically in the laparoscopic technique. Furthermore, the number of hernia repairs performed per year may be important, as may be the selection of patients for laparoscopy, the details of the technique, and the training. In this context, it is important to differentiate between the learning curve of established surgeons when learning a new technique and the learning curve of young surgeons working in a hospital where TAPP already has been fully standardized and is performed as a daily routine procedure.

Our results clearly demonstrate that the four senior surgeons who had started laparoscopic inguinal hernia repair in 1993 had needed significantly more operations to decrease morbidity and recurrence rate down to today's standard level than did the five trainees. Moreover, the total morbidity in the patients operated on by the trainees was significantly lower than those operated on by the pioneers, which amounted to a level of 3–4 % already in their first lot of operations (operations 1–50). Even more strikingly, in the patients operated on by the trainees, we observed a recurrence rate that was less than 1 % even from the beginning. Accordingly, our overall results achieved by the 23 individual surgeons included in the hernia program demonstrate that it is just the operation time that demonstrates a significant learning curve. Operation time is longer when performed by less experienced surgeons or trainees, but this does not influence long-term results, and the trainees demonstrated a continuous improvement in terms of the operation time.

One study reported a recurrence rate of 14.3 % in patients operated on by less experienced surgeons (level 1, >10 procedures performed), but 2.4 % for experienced surgeons (level 3, >25 hernia repairs) [21]. A large randomized clinical trial reporting long-term results of 1,183 patients operated on in seven surgical centers by a total of 12 TAPP surgeons found the recurrence rate at the different hospitals to range between 5 and 13 % and for the

individual surgeons 0–23 % [22]. A further large randomized controlled trial [23] including 12 hospitals and 22 TEP surgeons demonstrated a 5 year recurrence rate ranging from 0 to 32 % for the individual surgeons and 0 and 13.5 % for the different hospitals. These extremely large differences in the quality between hospitals and individual surgeons who had taken part in the above-mentioned studies, as well as the higher morbidity and recurrence rates published in the literature demonstrating a steep learning curve when starting to perform laparoscopic inguinal hernia repair [12, 15, 16, 19], are in contrast to the outcomes of our presented study.

The 23 surgeons in our study demonstrated relatively uniform results in terms of morbidity and recurrence rate, regardless of their personal experience (number of operations performed). Thus, in the context of our experience, the term *learning curve* no longer necessarily implies more patient complications; it suggests longer operation times. The key point to achieve this goal is education and learning in a center where laparoscopic inguinal hernia repair is well standardized and completely integrated into daily routine work. Meanwhile, many centers perform excellent laparoscopic hernia repair. In this context, autodidactic learning—as it was used in the early 1990s and which had produced a steep learning curve—can no longer be recommended.

In our department, with its complete standardization of TAPP, a gradually increasing number of younger surgeons and trainees are able to become familiar with the new technique. Several reasons can be listed as an explanation for the good results achieved by young surgeons and trainees in our setting. First, the requirement for young trainees to be included in the hernia program was to guide the camera at least 50 times. Second, they were required to already have some experience with laparoscopic operations (25 laparoscopic cholecystectomies). Third, all operations were done under the guidance of experienced surgeons; thus, many pitfalls and intraoperative problems could be anticipated and possible complications prevented. Finally, our strictly standardized technique made it easier for young trainees to become familiar with the laparoscopic anatomy and the operative strategy.

In a similar study regarding the TEP technique, Haidenberg et al. [18] came to the same conclusion. They demonstrated that under structured guidance by an experienced endoscopic surgeon, young trainees benefit from the knowledge of the more senior surgeon. The experience and knowledge that the more experienced surgeons gained when establishing the new surgical technique can be passed on, thus avoiding typical possible problems in operations performed by the trainees. In accordance with Miserez et al. [24], we advocate a stepwise learning of TAPP. This saves time and is more relaxing for both the trainer and the trainee. In our experience, it is best to start with intra-abdominal suture closure of the peritoneum because there is no danger to the patient. The next step is the opening of the peritoneum, then dissecting the medial compartment, mesh placement and glue fixation, and last, dissecting the hernia sac (most difficult and dangerous). In order to learn more easily and effectively, video recordings of the trainee operation should be created and analyzed in the clinical rounds afterward.

In the discussion about making the operation more acceptable, operating time is an important issue, as is shortening the learning curve. A trainee will need more than 30 min solely to perform suturing the peritoneum for the first time. Considering the economic situation of most hospitals, such long operation times are hard for management to bear. Furthermore, as a result of current restrictions on resident duty hours and the huge increase in bureaucratic obligations, trainees spend less and less time in the operating theater. Thus, there is an urgent need to organize training more efficiently. In this context, training surgeons outside the operating room with simulation-based strategies (computer, video, model) is gaining increasingly more importance [25–30]. Several studies have demonstrated that trainees who practice laparoscopic skills in a simulated environment demonstrate improvement of those skills when tested in the same environment, but Zendejas et al. [31] were the first to demonstrate that a simulation-based mastery learning decreased operating time, improved trainee performance, and decreased intra- and postoperative complications after laparoscopic inguinal hernia repair. Skills training consisted of supervised practice sessions using the Guildford MATTU TEP hernia model [32] and standard laparoscopic equipment. A similar model was developed in our department in cooperation with the company Karl Storz, allowing model simulation training of four steps of TAPP: opening the peritoneum, placing the

Fig. 5 The hernia model is placed in a quite normal laparoscopic box trainer and closed by a textile membrane that simulates the peritoneum

Fig. 6 The inside of the model illustrates in an anatomically accurate manner the pelvic floor for placement of a mesh 10 × 15 cm in size. The important structures (vessels, nerves) are roughly marked

mesh, and fixing and suturing closed the peritoneum (Figs. 5, 6).

In summary, laparoscopic hernia repair is a well-accepted technique in inguinal hernia repair that has significant benefits regarding all pain-associated parameters when compared to open surgery. Moreover, we demonstrated that laparoscopic hernia repair is a safe and promising method even if performed by young trainees. Laparoscopic hernia repair should therefore be an elementary part of the trainee program. Under the precondition that TAPP is well established in the clinic, that the operative technique is strictly standardized, and that there is a well-structured educational program, *learning curve* does not necessarily have to mean higher complication rates and recurrence rates. The depth of experience presented in this study demonstrates that the learning curve can be reduced to the operating time. In order to shorten the operating time and thereby make the surgery more efficient, model simulation training is strongly recommended.

Disclosures Drs. Bökeler, Schwarz, Bittner, Zacheja, and Smaxwil have no conflicts of interest or financial ties to disclose.

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