The importance of simulation training in pediatric surgery

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1. INRODUCTION

1.1. Special challenges of pediatric laparoscopic interventions

The number of advanced endoscopic surgical interventions is continuously increasing worldwide. Nonetheless, pediatric surgery (surgery on newborns and infants) faces special challenges, including the use of special surgical instruments and limited interventions due to a smaller workspace, while the safety of surgical interventions plays a particularly large role with children. Accordingly, development of pediatric minimally invasive techniques has been somewhat slower than with adult approaches. Another feature of pediatric surgery is that it is not typically divided into subspecialities; therefore, every pediatric surgeon is expected to be familiar with numerous types of surgical interventions. Before conducting any demanding/advanced task, pediatric residents and junior pediatric surgeons need to gain experience with simpler laparoscopic techniques.

1.2. Examples of pediatric laparoscopic interventions (of basic and higher level of difficulty)

Inguinal hernia is one of the most common congenital pathologies in pediatric surgery. Unlike in adults, inguinal hernias are mostly indirect in nature in the pediatric population; therefore, the use of meshes – which are usually preferred in adult general surgery – is not appropriate here. Various laparoscopic herniorrhaphy techniques arose from the late 1990s. Of the laparoscopic hernia operations, 3-suture purse-string and (particularly) the percutaneous internal ring suturing (PIRS) are the most widely used approaches due to their relatively easy implementation. Studying the learning curves and determining the minimum number of surgeries needed for pediatric surgeons to perform interventions these successfully is crucial when introducing these interventions in a paediatric surgery department.

Duodenal atresia is a rare paediatric pathology, but duodeno-duodostomy remains to be one of the most challenging laparoscopic tasks performed on neonates. During duodenal atresia repair, restoration of the continuity of the passage is based on anastomoses between the duodenal stumps or the duodenum and jejunum (depending on the localization of the defect) and special care must be taken so as to prevent biliary complications (i.e. lesions of the papilla of Vater). The most frequent postoperative complications include stenosis or insufficiency of the anastomosis and pouchitis (in the case of duodenojejunostomy). To overcome these difficulties and also those originating from the disproportionate calibres of the atretic duodenal stumps, Kimura described the diamond-shaped technique. The laparoscopic version

of duodeno-duodenal anastomosis was first described in 2001 by Bax et al. with an approach based on the same principles as those of the open version of diamond-shaped anastomosis (described by Kimura).

1.3. Training approaches in laparoscopy. Measures of efficacy.

Given the special technical skills required during conduction of laparoscopic procedures and the specificities of pediatric surgery, it is essential to learn and repetitively practice both basic and advanced laparoscopic techniques before performing them in the clinical practice. Although dry lab training is an essential step during the course of laparoscopic training process, sessions involving the use of animal organs *ex vivo* ("wet lab") or surgical procedures on anaesthetized animals ("vet lab") provide more realistic circumstances and simulate human surgical procedures remarkably better. Although numerous authors have described the superiority of *in vivo* animal models over dry or wet lab approaches, animal surgeries are greatly limited in many countries out of ethical considerations. Among the animals used for surgical training, lapine and porcine models appear to be the most popular, although rat, dog and sheep models have also been described among the potential solutions. For simulation of pediatric surgical procedures, the rabbit probably seems to be the most suitable model animal due to similarity to newborns in anatomy and size and for financial considerations and veterinary viewpoints. The number of *in vivo* training models of duodeno-duodostomy involving lapascopy, however, are limited. Furthermore, there is a lack of generally accepted criteria by which a trainee could be considered suitable to perform this procedure on humans.

1.4 Measures of efficacy for laparoscopic interventions in laboratory and clinical settings

During laparoscopic dry/wet/vet lab trainings, technical development can relatively easily be characterized by optimal operating time and criterium-based execution of the actual task. The success of the laparoscopic surgical intervention and low peri- and postoperative complication rate(s) are, however, the most evident and clinically most relevant measures of success when human (and in particular pediatric) surgeries are concerned. Here, similarly to vet lab trainings, the most frequently used assessment tools for laparoscopic performance include Visual Analogue Scale, global rating scales and task-specific checklists. Global Operative Assessment of Laparoscopic Skills (GOALS) score and its specific modifications (e.g. the GOALS groin hernia score) have been proven the most feasible methods in both simulation settings and human operating theatres.

2. MAIN GOALS OF THE STUDIES

- Since treating duodenal atresia is a highly demanding task in pediatric practice, we aimed to establish a clinically relevant *in vivo* rabbit model of duodenal atresia (involving diamond-shaped anastomosis) by which the technical skill of laparoscopic anastomosis suturing can be acquired in preclinical settings. The feasibility of this model was tested by means of sophisticated quantification methods.
- Since repetitive training is a crucial step during the learning process of any laparoscopic intervention, we tested how a standardized dry lab training session influences future skill development using the rabbit ("vet lab") model of duodenal atresia noted above as a test operation.
- Using this experience with learning curves of vet lab laparoscopic duodenal atresia surgery, we also wished to define criteria enabling trainees to perform the same laparoscopic intervention in clinical settings. To this end, we analysed objective and semiquantitative indices of improvement in skill development related to this rather demanding laparoscopic diamond-shaped anastomosis model.
- Since knowledge of the minimum number of operations enabling pediatric surgeons to perform successful interventions is crucial in clinical settings, we aimed to assess the characteristics of the learning process of two inguinal hernia operations (the PIRS and 3-port inguinal hernia techniques) during their introduction in clinical pediatric surgery units.

3. MATERIALS AND METHODS

3.1. Methods for the rabbit model of duodenal atresia (Study 1)

3.1.1. Participants

A total of 15 laparoscopic trainees were recruited and allotted into one or the other of two groups. A beginner group (n=8) consisted of medical doctors soon after graduation without any previous laparoscopic experience. This group underwent at least twelve hours of laparoscopic training with the same supervisor based on a modified, previously validated inanimate assessment method known as the McGill Inanimate System for Training and Evaluation of Laparoscopic Skills (MISTELS). An advanced group (n=7) comprised pediatric surgery fellows with previous laparoscopic experience of at least 25 human cases (e.g. appendectomy, varicocelectomy or herniorrhaphy).

3.1.2. Method of test operation

An optic port was inserted through the umbilical region of the rabbit followed by symmetrical placement of two working ports bilaterally. A jejunal segment was selected and suspended to the abdominal wall. A proximal transverse enterotomy and a distal longitudinal one were made in the selected bowel segment to simulate the atretic stumps.

3.1.3. Video recording and segmentation

Each video segment of the net anastomosis procedure was saved separately, encoded with randomly generated numbers, shared using secure cloud storage and used for analysis. The duration of the segments was recorded. Each segment was assessed by four experts in a randomized, blinded fashion (see later).

3.1.3. Assessments and parameters examined

- Surgical time: the time interval between the proximal opening of the bowel segment and the last surgical knot.
- Quality of the anastomosis: luminal passage and macroscopic leakage of the anastomosis were assessed after the animals were sacrificed by pressing the luminal content through the anastomosis.
- Video recordings were assessed in a blinded fashion by fellow surgeon experts in laparoscopy using the GOALS score (which is based a 1-5-point scale) and includes the following domains: (1) depth perception, (2) bimanual dexterity, (3) efficiency, (4) tissue handling and (5) overall competency.
- Participants' feedback: a 1–5-scale questionnaire was used for the following parameters: (1) working space, (2) workflow, (3) level of self-confidence and (4) level of self-achievement.

3.2. Methods for the clinical study on PIRS (Study 2)

3.2.1. Participants and patient selection

This retrospective study was approved by the local scientific ethics committee of the University of Minho (reference number: SECVS 133/2014). All staff members involved in the programme were consultants with basic training as pediatric surgeons with different skill levels in laparoscopic surgery. All children referred for surgical repair of indirect inguinal hernia (at any age) or communicating hydrocele (over two years old) were included between June 2011 and November 2016 at the Department of Pediatric Surgery, Braga Hospital. Patients with hernias other than indirect inguinal hernia were excluded. Demographic data and

clinical details were gathered, including gender, age, diagnosis (hernia vs. communicating hydrocele), pre- vs. perioperative laterality match, identification of silent patent *processus vaginalis*, conversion to open repair, ipsilateral recurrence and metachronous contralateral hernia, perioperative complications reported by the surgical team.

3.2.2. Assessments of learning curves for PIRS

Five staff surgeons who adopted PIRS as the technique of choice with a minimum operation number of 35 were selected. During repair of inguinal hernia and communicating hydrocele with the PIRS method, each intervention was considered as a single procedure, independently of being unilateral or bilateral repair. During the analysis, individual operation times were measured and rates of perioperative/postoperative complications, ipsilateral recurrence as well as conversion to open repair were calculated.

3.3. Methods for the clinical study on the "3-port approach to inguinal hernia" (Study 3)

3.3.1. Participants and patient selection

In our retrospective study, we included patients operated on with the laparoscopic 3-port technique at the Pediatric Surgery Unit, Department of Pediatrics, University of Szeged, between November 2015 and July 2020 (ethical licence number: 87/2017-SZTE). A total of 112 patients were operated on by eight surgeons at our unit, but since only three of them had performed a large number of interventions, the results for surgery time for these three colleagues were included in the analysis. Since the minimum number of operations was 17 among them, learning curves for these surgeons were analysed during this preliminary period.

3.3.2. Assessments of learning curves for the "3-port approach to inguinal hernia"

In the case of the 3-port technique, three staff surgeons with a minimum operation number of 17 were selected. All laparoscopic inguinal hernia and communicating hydrocele procedures were included, with each intervention being considered as a single procedure independently of being unilateral or bilateral repair. During the analysis, individual operation times were measured and rates of perioperative/postoperative complications, ipsilateral recurrence as well as conversion to open repair were calculated.

4. RESULTS

4.1. Results of the vet lab (duodenal atresia) study

All of the participants succeeded in completing all eight of the test operations without any major complications; therefore, all of the overall 120 surgical interventions were included in the analysis.

4.1.1. Surgical time

The duration of the first two operations was significantly lower in the advanced than in the beginner group. In the beginner group, the operative time fell from 170.9±11.6 to 107.1±11.4 min (37.4%) versus a drop from 124.9±15.6 to 61.8±5.1 min (a 50.5% decrease) in the advanced group. Nevertheless, a significant difference persisted even during the sixth and eighth operations. This parameter showed a continuous decrease in both groups, and, as a result of their steep reduction in operation time, the beginner group reaching the values of the advanced group in the middle of the study. In the sixth and eighth operations, the advanced group again performed the task faster.

4.1.2. Anastomosis quality

As evidenced by a relatively rapid reduction in the occurrence of leakage, the overall surgical performance showed a dramatic improvement in both groups. Specifically, 5/8 of anastomoses showed leakage in the beginner group, and this decreased to zero after the fifth intervention. In the advanced group, the anastomosis leakage rate was smaller than in the beginner group as early as from the first to the third surgery; the difference achieved significance at the first two time points of the studies only.

4.1.3. Expert opinion (GOALS)

Values for this score displayed a similar trend of improvement during the course of the learning process, with the values only being significantly different at a few time points (i.e. at the second, seventh and eighth time points) of the study. This score showed significant improvement in the advanced group at each time point. In the beginner group, however, this progress started later (being confined to the second part of the study). Since the GOALS score comprises five evaluation criteria, the relative contribution of these elements can also be included in the analysis when the key determinants of the inter-group differences are in focus.

4.1.4. Participant feedback

All of the self-reflective parameters improved over time, and no significant differences were in evidence between the groups. As compared to the baseline, the advanced group expressed

earlier satisfaction with its own performance (workflow) (after the third operation), whereas this occurred later in the beginner group.

4.2. Learning curves during clinical introduction of the PIRS techniques (Study 2)

Surgery times showed surprisingly high individual variability over time, with bilateral cases usually associated with long durations of surgery. Since we could not detect a statistically significant improvement in individual operation times during the time frame under examination (35 operations), the mean values of individual operation durations were also calculated. As regards the entire study period, mean surgical time (including only unilateral cases) was 38.5 minutes (ranging from 10 to 90 minutes) and did not differ significantly between the five surgeons recruited in this study.

The complication rates were as follows: perioperative complications: 2.3%, postoperative complications: 2.6%, ipsilateral recurrence: 1.5% and conversion to open repair: 0.9%.

4.3. Results of the clinical study on the "3-port approach to inguinal hernia" (Study 3)

Individual operation time did not show significant improvement in this study and was greatly influenced by the uni-/bilateral nature of the surgical intervention. However, we found significantly shorter surgical durations in the case of one of the surgeons as compared with his colleagues. The average surgical time was 41.3 minutes (ranging from 15 to 115 minutes) with this technique. Conversion to open surgery (due to technical difficulties) was associated with longer operation durations.

The complication rates were as follows: perioperative complications: 0%, postoperative complications: 0%, ipsilateral recurrence: 0.9% and conversion to open repair: 1.8%.

5. DISCUSSION

5.1. Assessment of laparoscopic performance in an animal model of duodenal atresia using multiple modalities

Laparoscopic duodenal atresia repair is still one of the most challenging tasks in pediatric surgery. The performance of this relatively demanding surgery, however, greatly improves over a period of nearly a decade at a given surgical unit. This observation underlines the importance of repetitive performance of highly challenging interventions, which was also highlighted in guidelines issued by members of the European Society of Pediatric Endoscopic

Surgeons, which recommend at least 10–20 hours of dry lab training and a minimum of ten hours of animal model-based training to gain expertise before performing human surgeries. The superiority of *in vivo* models over *ex vivo* ones was concluded by Kirlum et al. in a rabbit model of an intestinal biopsy showing a slower learning process, but a markedly better final performance in the *in vivo* group.

Related to the special dimensions of pediatric surgery, we chose a model relevant in size, space and technical challenges involved in suturing. As regards complex approaches to laparoscopic duodenal atresia repair, only one previous *in vivo* study on rabbits was reported with feasibility tested on the basis of a single surgical intervention. Here, the characteristics of the model were assessed based on an analysis of individual learning curves and a comparison of performance of two trainee groups with the aim of showing a threshold expertise, thus making the same procedure possible in clinical practice. Apart from providing a novel training model, probably another novelty of our present study is that the analysis was based on simultaneous consideration of multiple perspectives.

Surgery time is one of the most objective and easily accessible indices of performance, which was found to be similar to those in clinical practice for laparoscopic diamond-shaped anastomosis. Owing to a standardized, structured MISTELS-based training in our study, the beginner group only completed the tasks more slowly than the clinically experienced advanced group in the first few test operations. However, probably the most important and clinically most relevant measure of technical achievement is the success of the intervention (here, anastomosis quality refers to the passage and water tightness of an anastomosis). This is a binary parameter specific to the actual model. The fact that this desired outcome was reached relatively early in both groups shows (1) the efficacy of the dry lab laparoscopic training of the beginner group and (2) the feasibility of the present *in vivo* rabbit model.

In addition to the parameters noted above, we also used other methods, thus enjoying the advantage of including several aspects of surgical performance when challenging laparoscopic tasks are evaluated. The GOALS score appears to be an appropriate approach for both basic and complex interventions. It enables assessors not only to classify surgeons based on their technical performance, but also to compare advancement in different training groups. We observed significant improvement in both groups as regards the GOALS score, but a statistically significant difference between the study groups was only observed at a few time points in the learning. This underlines the efficacy of standardized laboratory (e.g. MISTELS) training, enabling beginners to show similar results to those of more experienced colleagues

during the test operation. Bansal et al. also used operation time and anastomosis quality to compare the performance of beginner and trained residents after a laparoscopic training using five test operations in an *ex vivo* model of gastrojejunostomy. In their model, gradual improvements were found in all parameters, with a minor and gradually vanishing initial difference between the two groups over time. When the transferability of lab training findings to clinical situations is considered, the GOALS score may also represent a good tool to assess the efficacy of laparoscopy. In another study by Bansal et al., a five-day (wet lab) laparoscopic training programme for cholecystectomy resulted in marked differences in clinical performance of the same operation. In our study, a clinical "test operation" could not be conducted to assess the transferability of our findings, but this could be a highly important aspect of future studies.

Interestingly, certain trials found no significant improvement in participant performance at a certain stage after repeatedly conducting the same type of laparoscopic procedure. The same was demonstrated by Bin Fu B et al. with an *in vivo* pyeloplasty in a porcine model, where a stationary phase was reached in the learning process after the fifth operation. However, surgery duration showed further improvement in our study, while leakage rate and GOALS score values indicated a lower degree of improvement between the fifth and eight surgeries. This suggests that a minimum number of laboratory surgeries is definitely needed (which also happen to be five) in the present diamond-shaped anastomosis model, but any further skill development should most probably be monitored under clinical conditions. Our findings are also supported by results from participant feedback forms which are regarded as important tools to gain insights into personal or self-assessment. The feedback questionnaire used in our study showed that both groups found the task similarly challenging at different stages of the study, with the values gradually increasing in parallel with the improvement in technical skills (as indicated by the GOALS score). Self-reflective parameters (particularly workflow and self-confidence) also showed significant improvement as of the fifth surgery (as compared to the baseline).

5.2. Assessment of performance during laparoscopic hernia operations in children

In our clinical studies of minimally invasive inguinal hernia repair, surgery time and intraoperative complication (including conversion) rate were chosen to assess among the clinically most relevant parameters. Similarly to other types of laparoscopic interventions, these parameters of hernia surgeries are not expected to be significantly different from those of the open approach and based on the literature data, superiority of neither the open nor the

laparoscopic approach can be stated (if all of the clinical aspects are considered). Therefore, benefits of laparoscopic and open hernia surgeries should be considered simultaneously, and decisions should be made on an individual basis (including adequate indication and appropriate patient selection), also taking the surgeon's concerns into account.

In both of our laparoscopic hernia repair studies, surgery time approximated the values of open procedures, but the continuous improvement in surgical times shown by others in parallel with the increase in the number of surgical interventions was not observed with either of the procedures here. Probably a longer follow-up period would be required to identify such a phenomenon. It appears that open inguinal surgeries associated with various aspects of surgical challenges (patient age and possible obesity, as well as hernia hose quality and scarring to surrounding formulas) can cause great variance in surgical time, while laparoscopic interventions involve the use of similar technical steps and show more uniform anatomical conditions. It is also noteworthy that the inevitably more time-consuming bilateral analysis interventions have also been included in the analysis.

The intraoperative complication rate is also definitely related to the technical skill level of the surgeon during the learning process. In the case of PIRS, injury to the epigastric artery or femoral vein is the most common surgical complication. According to a large study, the vascular injury rate with PIRS varies between 2.3 and 3.6%, while it is very low (typically zero) with the 3-port technique. The present PIRS approach is a slight modification of the original one as it is performed completely extraperitoneally, and, since it leaves no gap above the funiculus, the recurrence rate is also expected to be low. In our study, the number of complications during PIRS surgeries showed a decreasing trend during the learning process, as no surgical conversion or surgical injury occurred after the 35^{th} surgery. As for the 3-port technique, the reason for more efficient prevention of vascular and ductal injuries is probably the lifting of the peritoneum, which is routinely done with this approach. It should be mentioned that PIRS surgeries also have advantages, which lie in their lower degree of invasiveness and better cosmesis as well as usually requiring shorter mean surgical time. Certainly, a direct comparison of these procedures is difficult because the length of surgery is influenced decisively by the child's gender and age and whether the hernia is bilateral. This assumption may also be supported by a previous paper involving the 3-port technique, whereas the surgical times were reported to be similar to ours (the average surgical time for boys was 28 minutes for unilateral hernia and 23 minutes for girls, and the average was 40 minutes for boys and 30 minutes for girls for bilateral surgeries.

It appears that adequate indication and appropriate patient selection greatly influence both surgery time and the intraoperative complication rate, particularly at the beginning of the learning process. As regards surgical indication, we intended to conduct an appropriate patient selection in both studies, simultaneously also taking parental needs into account. It should be noted, however, that older children and primarily girls were recruited at the beginning of the learning process in both studies. In the case of the PIRS study, the proportion of operated boys reached the expected gender ratio (which is known from open surgery data) in the last third of the study period. With the 3-port technique, one of the surgical conversions at the beginning of the learning curve was most probably also attributable to the young age of the operated infant and therefore represented a mismatch between the actual surgical skill of the surgeon and the challenge of the anatomical size. With the same type of operation, later operations were successfully conducted without any major intraoperative complications irrespectively of the young age of the infants.

Intraoperative diagnosis of silent contralateral hernias is an important non-technical skill during laparoscopic hernia operations, and one of the most prominent advantages of the laparoscopic surgeries also lies in the potential to detect contralateral patent *processus vaginalis* intraoperatively. According to the literature on open surgeries, asymptomatic contralateral hernias are mostly explored in infant girls, and the overall incidence of asymptomatic hernias was found to be 6–7.3%. During laparoscopy, a routine search is always performed to detect open contralateral inguinal ring, and its incidence is reported to be approximately 30%; however, this was somewhat lower in our studies (~17% with PIRS and ~23% with the 3-port study). Since this is technically easier to perform than the originally operated (manifest hernia) site, we believe that closure of the contralateral open inguinal rings may also provide an optimal opportunity for less trained pediatric surgeons to master the steps in the surgery during PIRS operations (by becoming a performing surgeon temporarily).

Cosmesis is also an important benefit of laparoscopic hernia surgery. In this respect, open surgery leaves no visible scar either, and minimally invasive techniques also cause only very small scar formation. In the case of PIRS, only a tiny, mostly completely invisible umbilical wound is expected, whereas the 3-port technique leaves only two 3-mm scars along the umbilicus. While the 3-port technique is associated with standard laparoscopic wounding, the technical skill of the pediatric surgeon performing PIRS may influence final cosmesis because the need for additional instruments may require additional incisions.

Postoperative recurrence at the operated site is also a crucial issue due to surgical inexperience, use of absorbable suture materials and peritoneal defects not being closed sufficiently. The incidence was found to be 0–4.2% for laparoscopic surgeries and 0.68–4% for open hernia surgeries. Postoperative recurrences (within <2 years) in the PIRS group were also observed in girls where the gap below the ligamentum rotundum was most probably not resolved. For this reason, great emphasis was placed on the dissection of the peritoneum above the ligament and its complete closure. The procedure was similar among boys, where the entire peritoneum was dissected, thus avoiding a recurrence gap at the edge of the inguinal ring. This reduced the recurrence rate seen with the original PIRS technique; however, longer surgical time was required, which was accompanied by a greater risk of injury to surrounding arteries. Nevertheless, even in the case of large defects in infants, the gapless technique appeared to be effective as no recurrence was found in the PIRS group when operating on this kind of defect. One child had recurrent ipsilateral hernia after the 3-port technique (0.7%), which falls within the lower value range of both laparoscopic and open postoperative recurrence rates.

5.3. Conclusions to be drawn from the studies

Although surgical time is of great importance in clinical practice, achievement during a learning process should most probably be related to the reduction of complications related to surgery (both in the short and long run). As for surgery time, preclinical and clinical studies provided somewhat different findings in our studies. During the learning process in the vet lab study, a significant improvement was observed in the surgical times after the fifth operation, whereas this significant improvement could not be detected during human studies (involving 17 and 35 operations). One of the possible explanations is that the animal model was based on repetitions of the same surgical tasks, whereas clinical situations are inevitably more diverse and complicated. Furthermore, non-uniform factors (stress, and different anatomy and size) and non-technical skills (e.g. effectiveness of teamwork) may also critically influence surgery time, but, according to our present findings, these factors do not seem to reduce the ultimate success of surgical performance.

In our vet lab study, development of laparoscopic skills was assessed using the GOALS score, and this approach seems to be applicable to establishing a benchmark that allows pediatric trainees to further develop their skills in a clinical setting. The potential use of GOALS and other scores is most probably greatly limited when performance of surgeons should be compared in clinical settings during a learning process. This is partially due to lack of time

and resources, but, on the other hand, clinical surgeons already have a certain degree of prior laparoscopic skills and their performance improvement may not be quantified by the same means. It is reasonable to assume that the learning process for a newly introduced procedure is typically not based on development of merely new technical skills, but more likely on knowledge and understanding of the steps in the new procedures to be adopted. Analysis of video recordings and online video-based telemedicine/telesurgery approaches may, however, have great potential in skill development. Scoring systems can also be used to provide objective criteria to define further necessary steps of improvement during telesurgery approaches (a visiting professorship with potential real-time scoring) and certainly also for retrospective self-assessment.

Although the time of surgery is important for patient safety (e.g. from an anaesthetic point of view), it is not in itself a suitable way to characterise the learning process, as the process of successful surgery consists of optimizing technical skills (also described by GOALS score). Their success can be characterised by firstly achieving the planned surgical outcome and avoiding intra- and late operative complications, as it will eventually manifest in improvement in surgical time.

6. SUMMARY OF NEW FINDINGS

1. We successfully developed and validated a new laparoscopic duodenal atresia training approach (diamond-shaped anastomosis) in rabbits. As shown by quantitative means of assessment during the learning process, the model represents a sufficiently high-degree and clinically relevant *in vivo* laparoscopic suturing challenge. Using this approach, the most important basic characteristics of laparoscopic surgery-related learning processes (time, success/outcome and technical improvement) can be assessed.
2. The GOALS score represents an excellent assessment tool to detect technical improvements in this “vet lab” training model. Among the domains of the GOALS score system, depth perception, tissue handling and efficiency score values reach the major degree of improvement during this laparoscopic suturing approach.
3. A minimum number of necessary repetitions can also be defined in this model, since anastomosis quality (the indicator of success of this surgery type) reaches its optimal value and GOALS shows no considerable further improvement after the fifth surgery.

4. Performance of participants undergoing standardized and structured basic laparoscopic skill training reached the levels of experienced, but non-uniformly trained residents, using diamond-shaped anastomosis surgery as a technically challenging test operation. This manifests in similarly ideal anastomosis quality as well as approximated values of GOALS score and surgery time.

5. In our pediatric laparoscopic hernia studies involving the PIRS and the 3-port hernia techniques, surgery time did not show significant improvement during the time frames under examination (35 and 17 operations, respectively), but remarkably low intraoperative and early postoperative complication rates were achieved. Our data suggest the superior relevance/importance of complication rate over surgery time to ascertain achievement (reflecting improved technical performance) if novel hernia operation techniques are introduced at pediatric surgery units.

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LIST OF FULL PAPERS RELATING TO THE SUBJECT OF THE THESIS

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