Learning curve of trainees performing laparoscopic appendectomy- a register-based study

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Research Article

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Abstract

Background

Appendectomy is one of the first procedures that surgical trainees are expected to manage alone. The purpose of this study was to analyse the learning curve of a cohort of surgical trainees and to explore the association between trainee surgeon volume and complication rate.

Method

The study was based on a cohort extracted from the local appendectomy register at Södersjukhuset (*transl.* South Hospital), Stockholm. The register includes patient characteristics, surgical method, operation time, and 30-day complications. First-year surgical trainees attending the hospital's trainee programme were included and followed over five years of training. Trainees who had performed less than ten procedures during the period of the study were excluded. The learning curve was described using moving average of order ten for each trainee, studying the trend in operation time with increasing volume. The cumulative sum technique was used to chart changes in complication rates of the trainees.

Results

586 procedures performed by 9 surgical trainees were included, of which 97.6% were performed laparoscopically. A plateau in operation time on the learning curve was reached at 60 procedures. For three of the trainees, the 30-day complication rate decreased after completing the learning curve, whereas for two others it increased. In a multivariate analysis, operation times differed more between the trainees than it did between procedures performed early or late in the programme. Shortest versus longest mean operation time (41 min versus 89 min).

Conclusion

At least 60 procedures are required to reach sufficient proficiency in appendectomy. This highlights the importance of meticulous selection of surgical trainees, structure of training programmes, feedback, and assessment.

Background

Acute appendicitis is one of the most common causes of acute lower abdominal pain among patients attending the emergency department. The overall lifetime risk for appendicitis is around 7% with no difference between the sexes. Since the middle of the 19th century, the primary method of treatment has been surgical removal of the appendix. The recommended first line treatment is still surgery, though nowadays this is usually carried out laparoscopically (1, 2). Traditionally, this is the first abdominal

procedure that surgical trainees are expected to accomplish early on in their journey to becoming an independent surgeon. To guarantee patient safety, it is important to identify the surgical volume required to reach skills high enough to perform an appendectomy, and to gain better understanding of factors that influence the learning process. Furthermore, defining the learning curve for laparoscopic appendectomy in the Swedish setting may also reveal areas in the surgical training system that need improvement. Practising in a simulation-based environment has been shown to be helpful (3–7). However, there will always be a gap between virtual reality-based training and the operating theatre. A number of previous studies (8–10) have been conducted on smaller cohorts of patients and surgeons under training, showing that operation times decrease, reaching a plateau after around 20–30 procedures (11). A recent study on a larger cohort of 1173 patients undergoing laparoscopic appendectomy showed that there was no significant difference between surgical trainees and senior colleagues regarding operation time, length of stay, and complications (12). However, we do not know whether these studies are valid in the Swedish setting. The surgical training of trainees in Sweden differs slightly from other European countries and in the US, since trainees are expected to carry out this procedure unsupervised at a relatively early stage in their career. Laparoscopic appendectomy is one of the first abdominal procedures that the first-year trainee is expected to manage alone out-of-hours. Furthermore, there is no final examination before completing general surgery residency in Sweden, and no nationally adopted department-based tool for assessing technical skill. This register-based study aimed to define the learning curve for laparoscopic appendectomy in a group of Swedish general surgery trainees and to assess any relationship between surgeon volume and clinical outcome of appendicitis.

Methods

The study was based on a cohort extracted from a local appendectomy register and assembled between 01-12-2015 and 31-12-2020. It was approved by the Swedish Ethics Review Authority (2019–05976). The register covers all patients > aged 9 years with acute appendicitis admitted from the emergency department for further treatment at Södersjukhuset in Stockholm. Data from appendectomies were collected from the surgical planning software (Orbit 5, Evry) and transferred to a database. The register was validated through a retrospective review of the medical records.

All procedures coded “JEA00” and “JEA01” (ICD-10 classification for appendectomy and laparoscopic appendectomy) were identified. All patients with a diagnosis of acute appendicitis operated on by a surgical trainee as primary surgeon were considered eligible for inclusion. Surgical trainees, who had carried out less than 10 procedures during the study period were excluded.

Definition of Complications

A bleeding complication was defined as bleeding that required follow-up, additional haemoglobin testing, radiology, or reoperation. Postoperative mechanical ileus was defined as a condition requiring oral contrast and or surgery. Postoperative paralytic ileus was defined as absence of bowel movements longer than expected and verified radiologically or clinically. A surgical site infection was defined as a wound

complication needing additional or prolonged antibiotics, or wound debridement. Intra-abdominal abscess was defined as an abscess verified with radiology, with or without percutaneous drainage. Other complications such as urinary tract infection and wound dehiscence were registered based on the judgement of the reviewers.

The trainees evaluated were selected by identifying those who carried out their first appendectomy during the period of the study. These nine trainees were followed during their five-year residency period. The accumulated number of procedures carried out by the trainee was defined as surgeon volume. The main outcome was operation time. Postoperative complication rates were also analysed.

Surgical technique

The routine surgical technique for laparoscopic appendectomy at Södersjukhuset is diathermy hooking plus stapling of the appendix base. Intraoperative antibiotic prophylaxis is generally given. To begin with, surgery is performed by a trainee as primary surgeon with the assistance of a senior colleague holding the camera. When considered capable, the trainee performs the procedure independently, though there is always a senior surgeon who can be called in for assistance.

Statistical analysis

We used a moving average of order 10 to build learning curves for each trainee and to study how the trend in operation time followed increase in experience.

The cumulative sum (CUSUM) technique was used to chart changes in the complication rates of the trainees. The CUSUM technique uses a sequential probability ratio test recognising the importance of time as a “hidden variable” in clinical studies and thus avoiding the statistical problems associated with repeated significance testing (13). Moreover, the CUSUM technique detects clusters of surgical failures during the patient care process rather than after an arbitrary unit of time, thus alerting the trainee to suboptimal performance. In this study, CUSUM was defined as- S_n ($S_{n+1} = \max(0, S_n + x_i, x_0)$) in which x_i 1 for “failure” (complication) and x_i 0 for “success” (no complication), whereas x_0 is the reference or target value. In this study, x_0 for the conversion rate was set at 0.05, indicating that the target complication rate was 5%. When plotting outcomes on the CUSUM curve (Fig. 2), the slope of the curve reveals trend in performance relative to the target complication rate. A positive slope implies that the target is not being met, a negative slope implies that the target has been exceeded, while a level slope indicates that the target is being met and maintained. We used classification trees to identify factors associated with operation time and to stratify groups of patients with similar operation times. We used the CHAID algorithm to build the tree (14). A chi-squared automatic interaction detection (CHAID) analysis starts with all data in one group. The test then finds the factor split that leads to the strongest association with the main outcome: operation time (continuous). Nine possible independent factors were chosen (Table 1). The resulting groups were split until one of the following stop criteria was reached: tree depth

was limited to three levels, no groups with less than 15 patients were formed, and no split with a Bonferroni adjustment of less than 0.05 was executed.

Statistical analyses were carried out in SPSS version 27 and R Core Team (2020)

Results

Nine surgical trainees performed 586 procedures as primary surgeon. Laparoscopic appendectomy was performed in 97.6% of procedures. In Fig. 1, the learning curve is seen to reach a plateau phase in operation time after approximately 60 procedures. Table 1 shows the tree analysis of exposure variables associated with operation time. The factor with the strongest impact was the pervading technical performance of the individual surgical trainee. This factor was stronger than the accumulated experience of the whole group. In Fig. 2, for the trainees in Nodes 1 and 2, the second strongest factor influencing operation time was perforation of the appendix, while for those in Node 3 the second strongest influencing factor was accumulated experience. This shows that the factor with strongest impact on operation time is the technical skill of the trainee and not the case complexity, comorbidity, time of day, or time elapsed since the previous procedure.

In Fig. 3, the CUSUM-analysis of complications, most of the trainees were found to have more complications during the first half of the learning curve whereafter rates gradually decreased. However, two trainees continued to have high complications rates throughout the training period. Complication rates for appendectomy are low (about 5%) (15, 16). From the local appendectomy register the complication rate was 6.6% for laparoscopic appendectomy and 10.5% for open appendectomy.

Discussion

The present study shows that our surgical trainees needed approximately 60 procedures before reaching a plateau phase in operation time. Although individual variation was large during the learning phase, after 60 procedures times became more congruent. The estimated surgical volume required to acquire proficiency in this study is higher than in other international studies (17). This may be because the Swedish way of training surgeons is structurally different to other countries. At an early stage in the programme, the trainee is left to begin the procedure in theatre on his/her own, though active or passive help will probably be asked for before finishing the case. Already during their first year of training, on-call trainees are relied upon to perform emergency appendectomy alone and out-of-hours. This differs from other countries where a senior colleague is always present during the procedure. This could affect the learning curve in Sweden in that more procedures are necessary for the trainee to become safe and autonomous, whereas close supervision, as in other European countries, promotes rapid development.

It is hard to draw definite conclusions from these data since the extent of guidance the trainee received was not registered. At the time this study was carried out, there was no systematic evaluation tool to

objectively test the trainees' readiness. It is possible that such a tool would have revealed those trainees left without supervision too early.

In the present study, we characterised the learning curve for surgical trainees in Stockholm, Sweden. The learning curve was found to be slightly longer than reported in studies from other countries. This was probably due to structural differences in the training programme. None of the trainees in the present study had access to a virtual reality simulation centre or wet lab before operating in the theatre. However, the strength of this study is that all nine trainees had the same experience of surgery from the start since they all took part in the same training programme at the same surgical department. The slightly higher complication rate during the learning phase could indicate that the trainees were left unattended too early since accumulated volume and case complexity took second place of factors with strongest influence. More active guidance and supervision would theoretically have reduced the impact of case complexity on outcome.

A limitation of this study is that the extent of guidance during the early phase of the learning curve was not registered. The trainees were registered as primarily responsible for the procedures, but presumably several cases required some degree of assistance from a senior colleague during the learning curve. A trainee with a steep learning curve could be assumed to have reached autonomy earlier, which may have influenced the complication rate. Another factor that might have influenced the complication rate is the operation time *per se*. It is known that the risk for complications increases if the operation time is long. On the other hand, complication rates may be moderated by the fact that trainees are usually assisted by a senior colleague in the early learning phase.

In general, with this form of study design it is hard to control for all confounding factors. However, we believe that our large sample size provides some balance.

Conclusion

In conclusion, it is most important to have a well-defined structure for training junior surgeons in the operating theatre. The factor having greatest impact on operation time and complication rate was the technical performance of the individual trainee. This study highlights the fact that individual surgical training, even for less complex procedures, is likely to improve the patient's outcome. How to train junior surgeons and continuously evaluate their surgical performance remains a great challenge, and this is an obvious target for improving patient safety. Apparently, the adage "see one, do one, teach one..." needs updating.

Abbreviations

ICD

International classification of diseases

CUSUM

Cumulative sum
CHIAD
Chi-Square Automatic Interaction Detector
SPSS
Statistical Package for the Social Sciences
MA
Moving average

Declarations

Ethics approval and consent to participate

The study was approved by the Swedish Ethics Review Authority (2019-05976). Written information about the register was given to the patients.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

NY contributed to the design of the work, interpretation of data and major contributor in writing the manuscript.

LB created the patient register, collected the data, validated the register, and helped revising the manuscript.

GS collected the data, contributed to the conception and design of the work, interpretation of data and substantively revised the manuscript.

HPJ contributed to the statistical design, carried out the analysis of the data and drafted the manuscript. All authors read and approved the final manuscript.

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References

1. Di Saverio S, Podda M, De Simone B, Ceresoli M, Augustin G, Gori A, et al. Diagnosis and treatment of acute appendicitis: 2020 update of the WSES Jerusalem guidelines. *World J Emerg Surg.* 2020;15(1):27.
2. Lin KB, Lai KR, Yang NP, Chan CL, Liu YH, Pan RH, et al. Epidemiology and socioeconomic features of appendicitis in Taiwan: a 12-year population-based study. *World J Emerg Surg.* 2015;10:42.
3. Ahlberg G, Enochsson L, Gallagher AG, Hedman L, Hogman C, McClusky DA 3. Proficiency-based virtual reality training significantly reduces the error rate for residents during their first 10 laparoscopic cholecystectomies. *American journal of surgery.* 2007;193(6):797–804. rd, et al.
4. Ahlberg L, Weurlander M, Hedman L, Nisel H, Lindqvist PG, Fellander-Tsai L, et al. Individualized feedback during simulated laparoscopic training: a mixed methods study. *International journal of medical education.* 2015;6:93–100.
5. Ahlberg L, Hedman L, Nisell H, Fellander-Tsai L, Enochsson L. Simulator training and non-technical factors improve laparoscopic performance among OBGYN trainees. *Acta obstetrica et gynecologica Scandinavica.* 2013;92(10):1194–201.
6. Hagelsteen K, Sevonius D, Bergenfelz A, Ekelund M. Simball Box for Laparoscopic Training With Advanced 4D Motion Analysis of Skills. *Surg Innov.* 2016;23(3):309–16.
7. Hagelsteen K, Langegard A, Lantz A, Ekelund M, Anderberg M, Bergenfelz A. Faster acquisition of laparoscopic skills in virtual reality with haptic feedback and 3D vision. *Minimally invasive therapy & allied technologies: MITAT : official journal of the Society for Minimally Invasive Therapy.* 2017;26(5):269–77.
8. Man E, Nemeth T, Geczi T, Simonka Z, Lazar G. Learning curve after rapid introduction of laparoscopic appendectomy: are there any risks in surgical resident participation? *World J Emerg Surg.* 2016;11:17.
9. Kim SY, Hong SG, Roh HR, Park SB, Kim YH, Chae GB. Learning curve for a laparoscopic appendectomy by a surgical trainee. *J Korean Soc Coloproctol.* 2010;26(5):324–8.
10. Lopez LC, Murgueitio NC, Castrillon CED, Pinzon F, Molina GR. Experience and Learning Curve of Laparoscopic Appendectomy and Cholecystectomy of General Surgery Residents in a Latin American Hospital. *Universitas Medica.* 2019;60(2).
11. Lin YY, Shabbir A, So JB. Laparoscopic appendectomy by residents: evaluating outcomes and learning curve. *Surg Endosc.* 2010;24(1):125–30.
12. Ussia A, Vaccari S, Gallo G, Grossi U, Ussia R, Sartarelli L, et al. Laparoscopic appendectomy as an index procedure for surgical trainees: clinical outcomes and learning curve. *Updates Surg.* 2021.

13. GV K. An exploratory technique for investigating large quantities of categorical data. *J R Stat Soc.* 1980;1980;29: 119–127.
14. Bilen K, Ponzer S, Ottosson C, Castren M, Pettersson H. Deliberate self-harm patients in the emergency department: who will repeat and who will not? Validation and development of clinical decision rules. *Emerg Med J.* 2013;30(8):650–6.
15. de Wijkerslooth EML, van den Boom AL, Wijnhoven BPL. Disease burden of appendectomy for appendicitis: a population-based cohort study. *Surg Endosc.* 2020;34(1):116–25.
16. Bos C, Doumouras AG, Akhtar-Danesh GG, Flageole H, Hong D. A population-based cohort examining factors affecting all-cause morbidity and cost after pediatric appendectomy: Does annual adult procedure volume matter? *American journal of surgery.* 2019;218(3):619–23.
17. Neugebauer E, Troidl H, Kum CK, Eypasch E, Miserez M, Paul A. The E.A.E.S. Consensus Development Conferences on laparoscopic cholecystectomy, appendectomy, and hernia repair. Consensus statements–September 1994. The Educational Committee of the European Association for Endoscopic Surgery. *Surg Endosc.* 1995;9(5):550 – 63.

Tables

Table 1

		Mean	Standard Deviation	Count	n %
Age		33	19		
	<18			179	30.4%
	19-30			128	21.8%
	31-45			135	23.0%
	46-65			94	16.0%
	>65			51	8.7%
Gender	Female			263	44.9%
	Male			322	54.9%
ASA-class	1			331	56.5%
	2			209	35.7%
	3			21	3.6%
	Missing			25	4.3%
Trainees	Trainee 1			82	14.0%
	Trainee 2			56	9.6%
	Trainee 3			98	16.7%
	Trainee 4			56	9.6%
	Trainee 5			90	15.4%
	Trainee 6			35	6.0%
	Trainee 7			55	9.4%
	Trainee 8			44	7.5%

	Trainee 9	70	11.9%
Operation approach	Laparoscopic	572	97.6%
	Open	14	2.4%
Perforation	No	400	68.3%
	Yes	186	31.7%
Cumulative number of procedures performed	<10	90	15.4%
	11-20	90	15.4%
	21-30	90	15.4%
	31-40	85	14.5%
	41-50	74	12.6%
	>51	157	26.9%
Time (days) from last operation	<15	426	73.8%
	16-30	76	13.2%
	31-45	23	4.0%
	46-60	21	3.6%
	>61	31	5.4%

Figures

Figure 1

Change in operation time (MA10 moving averages, order 10) according to each trainee, as well as mean operation time. The graph shows a decrease in mean operation time with increasing surgeon volume. Large differences between trainees can be seen.

Figure 2

Operation time was associated with trainee performing the procedure (irrespective of surgeon volume), appendix perforation and cumulative number of procedures. Shortest operation times (mean 40.6 minutes) were found for trainees 3,5 and 9 after they had carried out more than 30 procedures without perforation. In contrast, the longest operation times (mean 80.9 minutes) were found among trainees 2,4,8 with perforation. Operation time was not related to time elapsed since previous procedure performed, ASA, gender, laparoscopic or open appendectomy, or age.

Figure 3

Complications according to trainee (CUSUM analysis). The graph shows differences between complications according to trainee. No falling trend with number of procedures is seen for trainees 3 and 5.