Evaluation of the Learning Curve and Complications Related to Hand-Assisted Laparoscopic Appendectomy in Children with Acute Appendicitis

Mehrdad Hosseinpour[1] Masoud Nazem[1] Borzoo Khaledifar[2]*

[1]Pediatric surgery department, Medical University of Isfahan, Isfahan, Iran.
[2]Pediatric surgery department, Medical University of Shahrekord, Shahrekord, Iran.

*Address for Corresponder: Dr Borzoo Khaledifar, Pediatric surgery department, Medical University of Shahrekord, Shahrekord, Iran
(email: dr.borzookhaledifar@yahoo.com)

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Abstract

Introduction: Previous studies have shown that according to the learning curve, one's knowledge and skills increase with experience and repetition. However, no studies have yet proved that the learning curve can be generalized to medical procedures. Therefore, this study aimed to evaluate the learning curve and complications of hand assisted laparoscopic appendectomy (HALA) in children with acute appendicitis.
Materials and Methods: In a prospective randomized study in 2016, ninety patients aged 8-16 years were selected for appendectomy. The participants were then consecutively divided into three groups according to admission time. The first, second, and third groups were operated on by an attending pediatric surgeon, an attending pediatric surgeon and a pediatric surgical fellow (a surgeon who is studying the subspecialty of pediatric surgery) and in the third group only a pediatric surgical fellow, respectively. For each surgery, duration of surgery and hospitalization was determined and recorded, and the time trend of surgery was determined and compared in all three groups using the learning curve.
Results: The mean duration of surgery of the groups operated on by an attending, an attending and a fellow, and a fellow alone was 38.7±12.8, 46.9±8.8 and 48.5±11.3 respectively, with a significant difference among the three groups (p=0.002). During the surgery, duration of surgery in the fellow and attending group and the fellow group decreased over time.
Conclusion: The learning curve can be generalized to medical procedures and experiences. Duration of appendectomy for fellows can decrease over time as they become more skilled. Usually after performing 30 surgeries and gaining experience, fellows will be able to perform appendectomy nearly as fast as attending surgeons. In the meantime, the root causes of the fluctuations observed during surgery should be scientifically examined and resolved.

Keywords

- Learning Curve
- Hand Assisted
- Laparoscopic Appendectomy

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Introduction

A learning curve is a graphical representation of the changing rate of learning for an activity or a tool. The learning curve theory, as one of the important concepts of learning, is based on the principle that the amount of time required to complete a given task will be less each time the task is undertaken. In fact, changes in one's mastery over a given task resulting from performing it many times is called the learning curve.[1] Horizontal and vertical axes of this curve represent the number of times a given task is performed and the level of mastery, respectively.[2] By plotting the learning curve, it can be evaluated whether or not a clinical skill is repeated in a standard number of times.[3]

The learning curve was first described in 1885 by Hermann Ebbinghaus (1850-1909), a psychologist from Germany who was among the first scientists who studied memory experimentally and is famous for discovering the forgetting curve and the learning curve. By studying the collective behavior of human beings, Ebbinghaus proposed a model which explains the way one forgets the information, data, and educational materials they have learned. In a study that topics from different areas of knowledge were provided to the target group, Ebbinghaus evaluated the process of remembering the unrelated content. According to this curve, at the moment of zero when the content is presented to a person, he/she hears it in full and seemingly learns. After 19 minutes, only about 57% of the content remains in their mind. What remains in the mind 44 minutes and 2 days after the learning is less than 50% and about 25%, respectively. This 25% will be transferred to the long memory and one's mind is always ready to recall it. However, this type of forgetting does not mean that the whole content disappears from the mind, but forgotten issues get lost amidst the everyday complicated teachings of a human. To avoid forgetting the learned content, Ebbinghaus proposed that review and recall should be done in a way that changes the forgetting curve and converts the content into the long-term memory at a higher level. According to Ebbinghaus, the learned material must be reviewed at specified intervals, so that the forgetting curve changes into a straight line as quick as possible. As a result, one will always remember more of what learned.

To determine an objective criterion indicating the sufficiency of the number of times a given task is repeated, the level of proficiency in each repetition of that task can be recorded and evaluated. The learning curve can be used for simple tasks such as memorizing a word [4], moderate tasks such as establishing an intravenous line [5] and complex tasks such as cystoscopy [6] or laparoscopy. The learning curve is based on Benner's Theory of Novice to Expert, according to which repetition of performing a given task gradually increases the pervasive clinical proficiency.[7] Straightness of the learning curve line, achieving a certain level of proficiency (e.g. 75%) and achievement of a certain percentage of learners to the desired level of proficiency are the most common methods of standardization using the learning curve. The standards obtained from the first two methods are criterion-based with low flexibility. The standards resulting from the latter, that is the percentile of proficient learners, make it possible to take into account different condition of the education system and learners. The desired percentage of proficiency can be determined based on factors such as the sensitivity of the task, duration of the course, continuation or discontinuation of education, and education level of learners.[8] By plotting the learning curve, a standard can be set for the number of times a clinical task should be repeated. Using this method, Gitman et al. proposed that six times of repeating cystoscopy is required to achieve proficiency in this regard. Grant et al. also stated that, depending on the previous skill of doctors, the number of times required to acquire proficiency in laparoscopy ranges between 2 and 7.

The efficiency and reliability of laparoscopic appendectomy procedure are widely being accepted, and benefits of this procedure in terms of rapid recovery, reduced postoperative pain, and reduced risk of infection have been proven.[9, 10]

In pediatric surgery, this treatment is considered a basic need which has increased in recent years with a significant increase in the number of patients with a diagnosis of acute appendicitis, especially among children. Hence, the number of Hand-Assisted Laparoscopic Appendectomy has also set to rise. Due to the increasing trend of performing

this laparoscopic procedure, it seems necessary to study its safety and evaluate the learning curve of this technique. [11] Based on the literature review, few studies have been conducted on the plotting and evaluation of the learning curve in laparoscopic appendectomy. Therefore, the present research aims to evaluate the learning curve for Hand-Assisted Laparoscopic Appendectomy in children with acute appendicitis.

Materials and methods

The present research was a prospective randomized study which was carried out at Al-Zahra and Imam Hossein hospitals of Isfahan in 2016. The statistical population included fellow of Pediatric Surgery and patients with acute appendicitis undergoing Hand-Assisted Laparoscopic Appendectomy. It was decided that subjects be excluded from the study in the event of complications during surgery, any change in the technique of surgery and anesthesia, patient death during the surgery and the need for additional surgical procedures.

In this study, 90 patients undergoing appendectomy who met the inclusion criteria were randomly assigned to three groups of 30. Appendectomy was performed on patients in the first, second, third groups by an attending surgeon, an attending surgeon and a fellow of Pediatric Surgery, and a fellow of Pediatric Surgery alone, respectively.

The cases admitted for an appendectomy in 30 consecutive days (one case in each group per day) underwent the surgery by one of the groups listed above. Surgery duration, duration of hospitalization, and postoperative complications were recorded in special forms. Surgery duration was measured from the induction of anesthesia until the end of the last suture and duration of hospitalization was determined based on the time recorded for patient admission and discharge in the medical records.

Demographic information including age, gender, and clinical symptoms was also recorded in special forms. Then, in order to predict the learning curve, the three groups were compared with each other in terms of surgery duration using the moving average method.

The obtained data were analyzed using the t-test, one-way ANOVA. (analysis of variance) with repeated measures and Chi-square in SPSS-24.

Results

In this study, 90 patients undergoing appendectomy who met the inclusion criteria were randomly assigned to three groups of 30. Appendectomy was performed on patients in the first, second and third groups by an attending physician, an attending surgeon along with a fellow of pediatric surgery and a fellow of pediatric surgery alone, respectively.

The mean age of patients was 10.3±2.9. In addition, 19 (21.1%) of our patients were aged under 8, 47 (52.2%) were 8-12 years old and 24 (26.7%) of patients were aged 13-16 years. In terms of gender, 55 patients (61.1%) were male and 35 of them (38.9%) were female. The most common symptom seen in our patients was abdominal pain. **Table 1** shows the distribution of demographic variables of patients in the three experimental groups. According to this table, there was no significant difference between the three groups in terms of age, gender and clinical symptoms (P>0.05).

Table 1: Distribution of demographic variables of patients in this study

Variable		Surgeon			P-value
		Attending surgeon	Attending surgeon and fellow of Pediatric surgery	fellow of Pediatric surgery	
Mean age (years)		11.3±2	9.3±6.1	10.2±2	0.06
Gender	Male	19 (63.3%)	18 (60%)	18 (60%)	0.95
	Female	11 (36.7%)	12 (40%)	12 (40%)	
Clinical symptoms	Abdominal pain	27 (90%)	26 (86.7%)	23 (76.7%)	0.33
	Nausea and vomiting	21 (70%)	22 (73.3%)	24 (80%)	0.66
	Anorexia	21 (70%)	20 (66.7%)	18 (60%)	0.71
	Fever	12 (40%)	16 (53.3%)	18 (60%)	0.29
	Agitation	2 (6.7%)	8 (26.7%)	7 (23.3%)	0.11

Mean surgery duration in the three groups was 38.12±7.8, 46.9±8.8, and 48.511.3 minutes, respectively; which shows a significant difference between them (P=0.002). Scheffe post hoc test showed that there is a significant difference between Group 1 (an attending physician) and Group 2 (an attending physician and a fellow) (P=0.024) and also between Group 1 and Group 3 (a fellow alone) (P=0.005); but such a difference was not found between Group 2 and Group 3 (P=0.85) **Figure 1**.

depicts the distribution of surgery duration in each of the three experimental groups. As shown in this figure, the range of surgery duration was narrower in patients whose surgeon was an attending physician. However, surgery duration was slightly long in one of the patients in this group probably due to the problems during the operation. The range of surgery duration was wider in patients in Group 2 (an attending surgeon and a fellow of pediatric surgery) and Group 3 (a fellow alone).

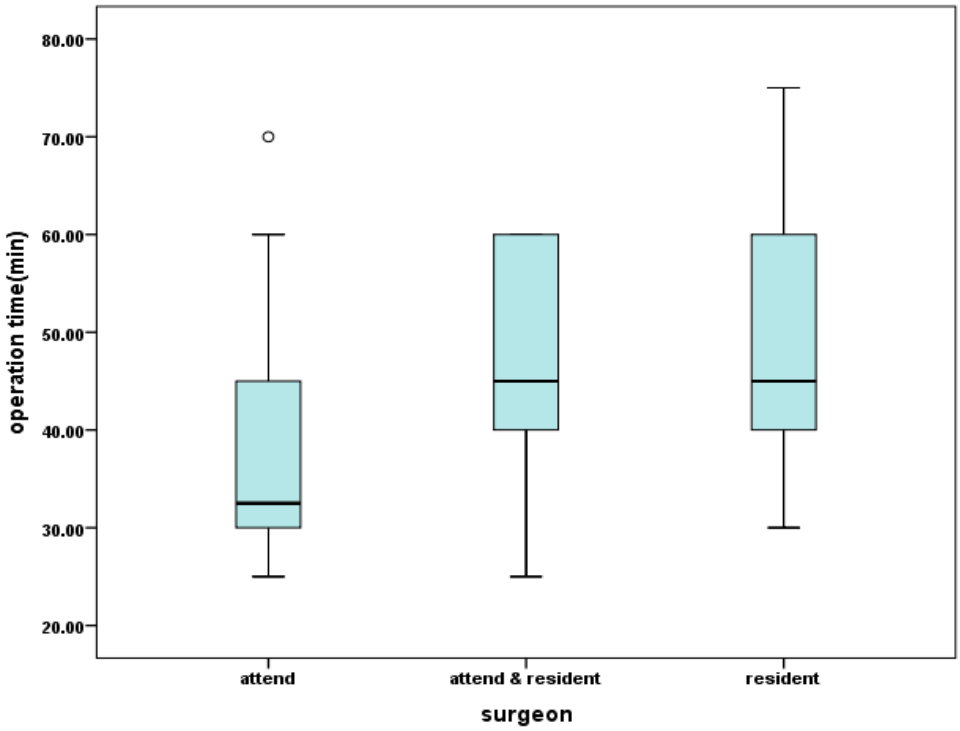

Figure 1: Median, range, and percentile (25% and 75%) of surgery duration in the three experimental group

In **Figure 2**, surgery duration in groups 1, 2, and 3 from the first patient up to the last (thirtieth) patient has been shown. According to this figure, surgery duration was swaying in all three groups. Nevertheless, a tangible reduction was observed in patients whose surgeon was a fellow, while no significant change was found in the other two groups. Analysis of variance with repeated measures also indicated that changes in surgery duration in Group 3 (a fellow alone) were significantly different from the first patient until the last one (P<0.001), while such significant changes were not observed in the two other groups (P=0.12, P=0.64). The results of this test also suggested that patient's age had a significant impact on changes of surgery duration (P=0.001) but gender was not significantly effective in this regard.

The mean duration of hospitalization for all patients was 2±1.85 days with a range of 1-15 days. This figure was obtained 2.03±1.1, 1.7±1.1, and 2.27±2.8 for groups 1, 2, 3, respectively. In this regard, no significant difference was found between the three groups (P=0.5).

Table 2 shows the mean surgery and hospitalization duration based on demographic variables of patients. According to this table, there is a significant difference between age groups in terms of surgery and hospitalization duration. The results of Pearson test indicated that there is a significant direct correlation between age and surgery duration (P<0.001).

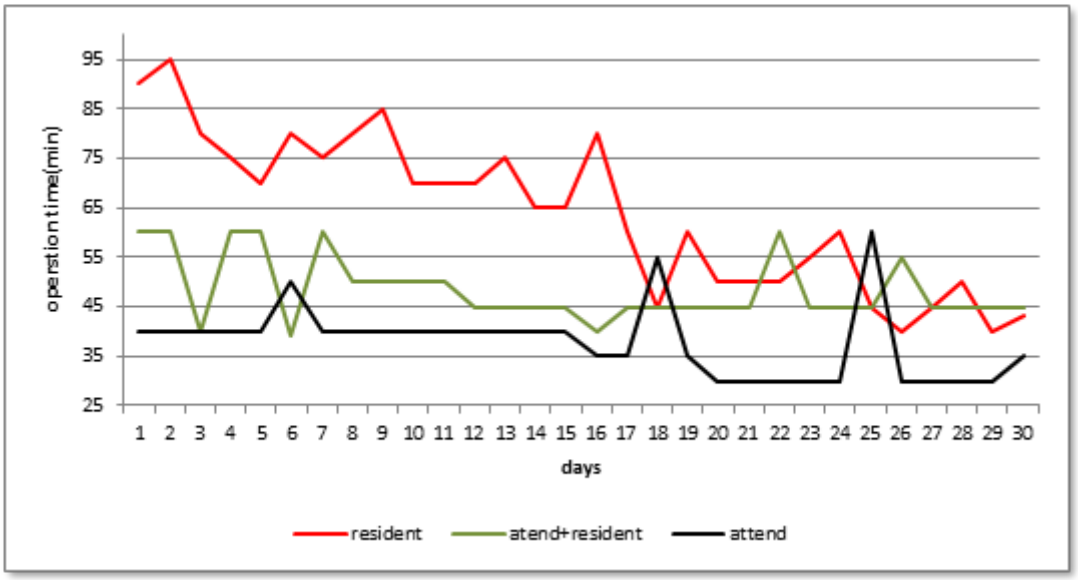

Figure 2: **Changes of surgery duration in the three experimental groups**

Table 2: **The mean and standard deviation of surgery and hospitalization duration based on demographic variables**

Variable		Surgery duration (minute)		Duration of hospitalization (day)	
		Mean	P-value	Mean	P-value
Age group	Under 8	39.8±41.08	<0.001	1.0±18.39	<0.001
	8-13	42.10±3.8		1.0±5.71	
	13-16	52.12±8.9		3.2±52.9	
Gender	Male	43.11±36.8	0.2	2.2±09.16	0.56
	Female	46.12±71.2		1.1±86.24	

It is noteworthy that no case of postoperative complications such as enterocutaneous fistula, wound infection, prolonged ileus, intra-abdominal abscess and postoperative intestinal obstruction was observed in patients in this study.

Discussion

Several studies and experiences have shown that the speed of performing any given task increases as it is repeated and practiced over and over. Scientifically, the increased speed and reduced time of performing a given task have been demonstrated in the learning curve. Although diagnostic-therapeutic procedures are applicable to this model[6], they ebb and flow over time because of complications and adverse events during the surgical procedures. However, acquisition of experience and expertise in medical activities, especially surgeries, must be somehow measurable. Hence, the present research aimed to evaluate the learning curve and complications related to Hand-Assisted Laparoscopic Appendectomy in children with acute appendicitis.

According to the study results, a significant difference existed between the three groups in terms of the mean duration of surgery, as the surgeries performed by an attending surgeon lasted shorter than the two other groups. In a study conducted by Kim et al. (2010), preliminary data, histologic diagnosis, surgery duration, the number of cases leading to complications, and duration of hospitalization related to 53 patients undergoing an open appendectomy and 50 patients undergoing laparoscopic appendectomy were evaluated retrospectively. In addition, the learning curve for laparoscopic appendectomy was studied. Their findings indicated that there was no significant difference between the two surgical methods in terms of surgery duration and frequency of postoperative complications. Patients in the laparoscopic appendectomy group were divided into two subgroups of having undergone surgery before the learning curve and after the learning curve. The

mean surgery duration for these two subgroups was 45.25 and 66.83 minutes, respectively; which suggested a significant difference. Nonetheless, no significant difference was found between them in the frequency of postoperative complications. In their study, in addition to stating that laparoscopic appendectomy is as safe as open appendectomy, it was concluded that the learning curve for laparoscopic appendectomy was equal to 30 cases.[12] Liao et al. in 2013 compared 30 patients undergoing laparoscopic appendectomy with 30 patients who had previously undergone open appendectomy in terms of surgery duration, the number of consultations, the interval between surgery and onset of oral feeding, duration of hospitalization and postoperative complications. Their findings showed that laparoscopic surgery duration reduces after operating on only 10 patients; yet the conventional surgery duration was achieved after 30 cases of surgery.[13] In a study conducted by Lin et al. (2010), a number of patients undergoing laparoscopic appendectomy by 6 surgical residents were evaluated to determine the effect of experience on their learning curve. For this purpose, patients were assigned to 2 groups; the first group consisted of the first 20 patients undergoing surgery and the second group included the next 20 patients who were operated on by a resident. In total, 306 patients were included in the study. The mean surgery duration for all patients was 83.8 minutes. In their study, 14.6% of laparoscopic surgeries were coverted to open surgery. The mean surgery duration and frequency of postoperative complications showed a significant reduction with increasing experience of residents. However, such reduction was not observed in duration of hospitalization.[14] Jaffer et al. in 2008 conducted a study on 40 patients undergoing laparoscopic appendectomy using the CUSUM graphic model and showed that the learning curve for laparoscopic appendectomy is equal to 20 cases.[11]

Although few studies have been conducted about the effect of learning curve on increasing the proficiency and experience of medical residents, the results of the present study showed that repetition of appendectomy helps them to perform it easier and faster. According to the study findings, the mean surgery duration in Group 1 and Group 3 was different from each other by half an hour on the first days of our study; however it reduced to less than 10 minutes at the end. This suggests that the learning curve is applicable to medical and surgical experience. Nevertheless, patient age was an effective factor in surgery duration in this study and time independently caused a reduction in surgery duration. Another noteworthy point is that fluctuations in surgery duration over time can be due to human error which results in complications during the surgery. Therefore, it is necessary to carefully evaluate these fluctuations in the learning curve, and if they account for more than 25% of cases[8], some revisions should be made to the training course of medical residents. In the present study, out of the 30 cases of an appendectomy that was performed during 30 consecutive days, these fluctuations were observed in 12 (40%) of cases, but surgery duration followed a decreasing trend.

Based on the study findings, surgery duration was acceptable during the 30 days of experiment with an increase in all three groups in some days. This is probably due to factors such as abnormalities and adverse events during surgery and errors in the operation room facilities and equipment.

The results also indicated that there was no significant difference between the three experimental groups regarding the duration of hospitalization. In addition, no case of postoperative complications was observed in patients. This also implies that appendectomies performed by residents are based on scientific principles and similar to operations conducted by attending surgeons. On the other hand, although surgeries in Group 3 were independently performed by residents, an attending physician was fully supervising them to take the necessary measures in the case of any adverse event.

Conclusion

According to the study findings, it can be concluded that the learning curve can be generalized to medical teachings and experiences, and duration of appendectomy conducted by residents reduces by acquiring more proficiency over time. It has been shown that 30 cases of appendectomy are enough for residents to achieve the proficiency to perform this surgery in a time close to that of their professors. However, considering the fluctuations observed

in surgery duration in this study, it is necessary to scientifically investigate the reasons for these fluctuations in order to make the necessary revisions to the education system.

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