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ARAŞTIRMA / RESEARCH

Cumulative sum analysis of the learning curve for laparoscopic complete mesocolic excision with central vascular ligation for right sided colon cancer

Sağ kolon tümörlerinde laparoskopik komplet mezokolik eksizyon ve santral vasküler ligasyon öğrenme eğrisi için kümülatif toplam analizi

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Abstract

Purpose: Every procedure, no matter how difficult, has a learning curve. However, no one discusses the learning curve for simple operations. This idea constantly comes up when there is a demanding surgical method that challenges habits. The aim of this study is to use cumulative sum analysis to estimate the learning curve of the demanding laparoscopic complete mesocolic excision+central vascular ligation technique for right sided colon cancer.

Materials and Methods: This retrospective study involved patients older than 18 years and with right-sided colon cancer admitted to Ankara University School of Medicine, Department of General Surgery between January 2015 and June 2022. The cumulative sum (CUSUM) chart based on operation duration and quantity of lymph nodes harvested was utilized to determine the learning curve.

Results: 53 patients included in this study. CUSUM analysis based on operation duration showed that Surgeon had passed the learning phase and was considered proficient after 21 cases. And the CUSUM analysis based on the lymph nodes harvested revealed that surgeon gained proficiency in 25th case. In terms of demographic, oncological, and operative data, there was no difference between the the groups defined by the phases according to the CUSUM analysis based on both operation duration and lymph node count.

Conclusion: Surgeons can become familiar with laparoscopic complete mesocolic excision for right sided colon cancer and perform it after approximately 21 to 25 operations.

Keywords:. Complete mesocolic excision, laparoscopy, learning curve, CUSUM

Öz

Amaç: Her prosedürün, ne kadar zor olursa olsun, bir öğrenme eğrisi vardır. Ancak, hiç kimse basit işlemler için öğrenme eğrisinden bahsetmez. Bu kavram alışkanlıklara meydan okuyan zorlu bir cerrahi yöntem söz konusu olduğunda karşımıza çıkar. Bu çalışmanın amacı, sağ taraflı kolon kanseri için zorlayıcı bir yöntem olan laparoskopik komplet mezokolik eksizyon ve santral vasküler ligasyon tekniğinin kümülatif toplam analizi ile öğrenme eğrisinin belirlenmesidir.

Gereç ve Yöntem: Bu retrospektif çalışmada Ocak 2015-Haziran 2022 tarihleri arasında Ankara Üniversitesi Tıp Fakültesi Genel Cerrahi Anabilim Dalı'na başvuran 18 yaşından büyük sağ kolon kanserli hastalar dahil edilmiştir. Ameliyat süresi ve lenf nodu miktarına göre kümülatif toplam (CUSUM) analizi kullanılarak öğrenme eğrisi belirlenmiştir.

Bulgular: 53 hasta çalışmaya dahil edildi. Operasyon süresine göre yapılan CUSUM analizi, cerrahın 21 vakadan sonra öğrenme aşamasını geçtiğini ve yeterlik kazandığını göstermiştir. Lenf nodlarına göre yapılan CUSUM analizi ise cerrahın 25. vakada yeterlik kazandığını ortaya koymuştur. CUSUM analizlerine göre yeterlik öncesi ve sorası fazlardaki hastaların karşılaştırılmasında demografik, onkolojik ve operasyonel veriler açısından fark bulunamamıştır.

Sonuç: Cerrahlar sağ kolon kanseri için laparoskopik komplet mezokolik eksizyon prosedürünü yaklaşık 21 ile 25 vaka sonrasında rahatlıkla yapabilirler.

Anahtar kelimeler: Komplet mezokolik eksizyon, laparoskopi, öğrenme eğrisi, CUSUM

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INTRODUCTION

Dissection along the embryological planes between fascial layers, as well as appropriate lymph node harvesting, appear to be crucial oncological concepts in both colon and rectal cancer surgeries. Heald originally articulated these concepts for rectal cancer surgery, and successful oncological outcomes were obtained[1]. Employing the same principles, Hohenberger et al. described the complete mesocolic excision (CME)-central vascular ligation (CVL) procedure for treating right-sided colon cancer, and demonstrated that it reduces the local recurrence and improves survival[2,3].

The CME-CVL method was developed primarily for open surgery. Despite the fact that it is a difficult method that necessitates dissection of the superior mesenteric vessels, it has been gradually performed laparoscopically as surgeons gain experience in conducting minimally invasive colorectal surgery. Opponents, on the other hand, argue that the risk of significant vascular injury is quite high as compared to conventional right hemicolectomy, and this could lead to serious consequences[4]. Regardless of these opinions, it is becoming increasingly popular in terms of satisfying general oncological principles and offering an uniform surgical method.

This technique, like many surgical techniques, has a learning curve. The learning curve has been defined simply as "The time and/or number of procedures required for an average surgeon to be able to conduct a procedure independently with a reasonable outcome"[5]. In other words, the learning curve is used to estimate the number of cases required to be proficient in a surgical method. Several studies has demonstrated taht varying number of cases ranged between 17 to 33 were needed to gain proficiency[6-8].

The aim of this study is to use cumulative sum analysis to estimate the learning curve of the demanding laparoscopic CME+CVL technique for right sided colon cancer and to guide novice surgeons who want to start utilizing this technique. And it was hypothesized that a surgeon experienced in laparoscopic colorectal surgery gain proficiency in this technique in a shorter period.

MATERIALS AND METHODS

Study design and population

The study was approved by the Ethics Committee of the Ankara University School of Medicine (approval number: i07-455-22). This was a single-center retrospective cross-sectional observational study and involved patients older than 18 years and with right-sided colon cancer admitted to Ankara University School of Medicine, Department of General Surgery between January 2015 and June 2022.

All of the patients who had undergone elective laparoscopic right hemicolectomy with complete mesocolic excision and central vascular ligation, and operated by a single surgeon (CA) were included in the study. The technique for laparoscopic right hemicolectomy with CME-CVL was previously described in detail[9]. Patients who underwent multiple organ resection, and those who converted to open surgery were excluded.

Outcomes

Data regarding the patients' demographics, body-mass index (BMI), American Society of Anesthesiologists (ASA) score, previous abdominal surgery, operation duration, tumor localization, tumor diameter, and total lymph nodes harvested were prospectively obtained from hospital database. The American Joint Committee on Cancer staging system (8th edition) was used for the pathologic staging of the cases[10].

Learning curve evaluation

It is important to complete a particular number of cases in order to learn and master any surgical procedure. This is known as the learning curve. The cumulative sum (CUSUM) analysis was used to determine the learning curve in this study. The CUSUM generates a graph by the cumulative sum (running total) of the difference between each value and the mean of all values in a group of values. It detects minor deviations from the mean value in a process. Therefore, it is used in learning curve analysis.[11] If "μ" is accepted as the mean value, it is calculated with the $CUSUM_n=\sum_{i=1}^{n}(xi-\mu)$ formula.

In this study, after sorting the cases from oldest to newest, learning curves were generated using the CUSUM formula based on the operation duration and the quantity of lymph nodes harvested, separately. Furthermore, the learning curve is modeled as a 2nd order polynomial. The number of cases required to gain proficiency was determined as the point at which the slope of the polynomial becomes more horizontal and coincides with the highest peak in the CUSUM dot plot[8,12].

Statistical analysis

Examinations of normal distribution assumptions for continuous variables were assessed with the Shapiro-Wilk test. Categorical data were presented as number (n) and percentage (%), and continuous data as median with range values. Associations between phase groups (phase 1 and phase 2) and age, body mass index, operation duration, tumor diameter, and total harvested lymph node were evaluated using the Mann Whitney U test.

The Pearson's χ^2 or Fisher's exact tests were used for comparing categorical variables such as gender, ASA score, previous surgical history, tumor location, and T stage, where appropriate. P values less than 0.05 were considered statistically significant. All statistical analyses were performed in RStudio statistical software, version 1.3.1093 (Rstudio, Inc., Boston, MA, USA).

RESULTS

A total of 57 patients underwent laparoscopic right hemicolectomy with CME-CVL during the study period. Four patients were excluded form the study: Two patients were converted to open due to adhesions and tumor infiltration, and the other 2 underwent multiple organ resection. The total number of patients in the final research cohort was 53. The median age was 67 (32-88) years old, and 33 (62.3%) patients were male. There were 56.6% tumors in cecum, 28.3% in ascending colon, and 15.1% in hepatic flexure. Median operation duration was 222.5 (90-450) minutes, and median number of harvested lymph nodes was 27 (9-55). Most of the patients had T3 tumors (Table1).

CUSUM chart based on the operation duration, and learning curve generated as a 2nd order polinomial with an equation of "$CUSUM_{OD}$ = -85.23+22.096*case number-0.431*case number^2" (R^2 was 0.699) was shown in Figure 1. As shown in the figure, the point where the slope was less steep and coincided the first peak in the dot plot was the 21st case. Surgeon had passed the learning phase (phase1) and was considered proficient after 21 cases.

Table 1. The demographics, and clinical and tumoral characteristics of the patients

Characteristics	
Age (years)	67 (range, 32–88)
Male gender, n (%)	33 (62.3%)
ASA score, n (%)	
1–2	39 (73.6%)
3–4	14 (26.4%)
Body mass index (kg/m^2)	26.7 (range, 20.5–37.9)
Previous surgical history, n (%)	16 (30.2%)
Tumor location, n (%)	
Caecum	30 (56.6%)
Ascending colon	15 (28.3%)
Flexura	8 (15.1%)
Operation duration (min)	222.5 (range, 90–450)
Tumor diameter (cm)	4 (range, 1–10)
Total number of lymph node	27 (range, 9–85)
T stage, n (%)	
Tis	4 (7.5%)
T1	5 (9.4%)
T2	3 (5.7%)
T3	33 (62.3%)
T4	8 (15.1%)

ASA, American Society of Anesthesiologists

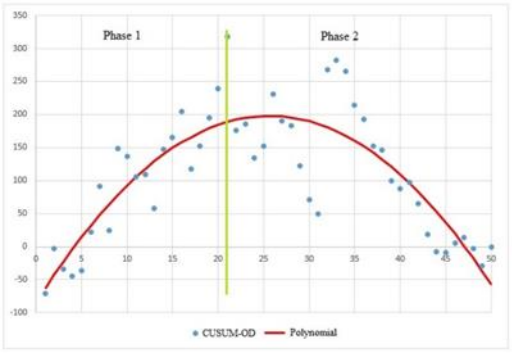

Figure 1. CUSUM chart based on operation duration.

The green line shows the case number which the surgeon gained proficiency.

As detailed in Table. 1, there were no differences regarding age, sex, ASA score, BMI, previous abdominal surgery, tumor location, tumor diameter, harvested lymph nodes, and T stage when Phase 1 and 2 cases were compared. Although the median operation duration in phase 2 was 35 minutes shorter, the difference was also not statistically significant. CUSUM chart based on the harvested lymph node count, and learning curve generated as a 2nd order polinomial with an equation of "$CUSUM_{LN}$ = -88.195+5.833*case number-0.073*case number^2" (R^2 was 0.646) was shown in Figure 2. Regarding harvested lymph nodes, surgeon had passed the phase and was considered proficient after 25 cases.

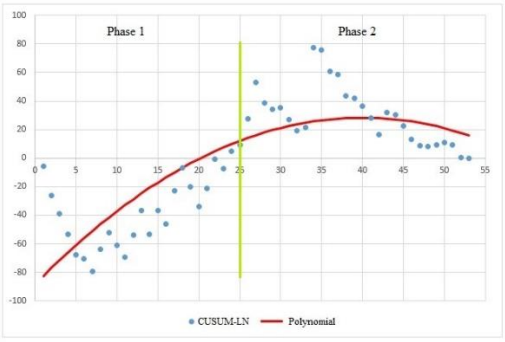

Figure 2. CUSUM chart based on quantity of lymph nodes harvested.

The green line shows the case number which the surgeon gained proficiency.

As detailed in Table. 2, there were also no differences regarding age, sex, ASA score, BMI, previous abdominal surgery, operation duration, tumor location, tumor diameter, harvested lymph nodes, and T stage when Phase 1 and 2 cases were compared.

Table 2. Comparison of the groups regarding CUSUM analysis based on operation duration

	Phase 1 (n = 21)	**Phase 2 (n = 29)**	***p* value**
Age (years)	67 (range, 39–80)	66 (range, 32–88)	0.530
Male gender, n (%)	15 (71.4%)	16 (55.2%)	0.242
ASA score 3–4, n (%)	4 (19.0%)	10 (34.5%)	0.230
Body mass index (kg/m^2)	26.2 (range, 20.7–37.4)	26.7 (range, 20.5–37.9)	0.699
Previous surgical history, n (%)	7 (33.3%)	9 (31.0%)	0.863
Tumor location, n (%)			0.800
Caecum	12 (57.1%)	16 (55.2%)	
Ascending colon	5 (23.8%)	9 (31.0%)	
Flexura	4 (19.0%)	4 (13.8%)	
Operation duration (min)	250 (range, 145–355)	215 (range, 90–450)	0.123
Tumor diameter (cm)	4.5 (range, 1.8–10)	4 (range, 1–9.5)	0.784
Total number of lymph node	27 (range, 13–53)	28 (range, 15–85)	0.608
T stage, n (%)			0.070
Tis	1 (4.8%)	2 (6.9%)	
T1	0 (0%)	5 (17.2%)	
T2	1 (4.8%)	2 (6.9%)	
T3	18 (85.7%)	14 (48.3%)	
T4	1 (4.8%)	6 (20.7%)	

ASA, American Society of Anesthesiologists

Table 3. Comparison of the groups regarding CUSUM analysis based on quantity of lymph nodes harvested

	Phase 1 (n = 25)	Phase 2 (n = 28)	*p* value
Age (years)	67 (range, 39–80)	67 (range, 32–88)	0.579
Male gender, n (%)	18 (72.0%)	15 (53.6%)	0.167
ASA score 3–4, n (%)	4 (16.0%)	10 (35.7%)	0.104
Body mass index (kg/m^2)	27.6 (range, 20.7–37.4)	26.6 (range, 20.5–37.9)	0.956
Previous surgical history, n (%)	7 (28.0%)	9 (32.1%)	0.743
Tumor location, n (%)			0.806
Caecum	15 (60.0%)	15 (53.6%)	
Ascending colon	6 (24.0%)	9 (32.1%)	
Flexura	4 (16.0%)	4 (14.3%)	
Operation duration (min)	245 (range, 90–355)	215 (range, 170–450)	0.399
Tumor diameter (cm)	4.5 (range, 1.8–10)	4 (range, 1–9.5)	0.905
Total number of lymph node	24 (range, 9–53)	27.5 (range, 15–85)	0.857
T stage, n (%)			0.070
Tis	2 (8.0%)	2 (7.1%)	
T1	0 (0%)	5 (17.9%)	
T2	1 (4.0%)	2 (7.1%)	
T3	20 (80.0%)	13 (46.4%)	
T4	2 (8.0%)	6 (21.4%)	

ASA, American Society of Anesthesiologists

DISCUSSION

Every procedure, no matter how difficult, has a learning curve. However, no one discusses the learning curve for simple operations. This idea constantly comes up when there is a demanding surgical method that challenges habits. For years, conventional right colonic surgery was regarded to be the easiest location among colon cancer procedures, and even when laparoscopic surgery for colon cancer became widespread, it was thought to be one of the first operations conducted for novice surgeons to learn laparoscopic colonic surgery[13]. However, with Hohenberger's concept of CME+CVL and the unstoppable popularity of laparoscopy, laparoscopic right sided colon cancer surgery has become the most difficult colon cancer surgery. This naturally resulted in a significant number of opponents, and as it should, the concept of the learning curve has gained prominence for this technique.

In this study, two variables that might objectively demonstrate the surgeon's ability are discussed: operation duration and quantity of lymph nodes harvested. When these two datasets were analyzed individually using the CUSUM formula, it was discovered that the surgeon gained proficiency in the 21st case regarding operation duration and in the 25th case regarding lymph node harvested. A recent research which analyzes 3 surgeons operation durations by CUSUM chart has demonstrated that peak of the learning curve for the first surgeon was 17th case while it was 27th case for the 3rd surgeon. This was a multidimensional study of the learning curve for laparoscopic CME-CVL and reported that an experienced minimally invasive colorectal surgeon acquires proficiency after performing 24–33 cases[8]. In another study, according to the learning curve analysis of the cases of a novice surgeon based on the operation duration, it was determined that the number of cases in which he gained competence for laparoscopic right hemicolectomy was 25[7].

This study discovered an intriguing finding: the number of cases necessary to become competent in robotic surgery was 16, implying a substantially faster learning curve. In their study which involved learning cuve analysis based on lymph node harvesting, Kutlu et al. stated that 25 cases are required for competence in laparoscopic CME-CVL[6]. Taking all of these research into account, it is clear that the shortest learning curve was observed in this study, particularly in analyses based on operation duration. This is because the surgeon in this study was working in a fully-equipped, well-organized center, was an experienced laparoscopic surgeon, and had earned adequate expertise in laparoscopic conventional right colon surgery and open CME-CVL technique before attempting the laparoscopic CME-CVL.

Of course, variances in learning curves among surgeons should be expected[11]. Because many factors influence the learning curve. These include things like current technology, guidelines, and the presence of a community working to develop the technique. Furthermore, the fact that the surgeon works in a well-organized and properly equipped facility, as well as working with a skilled surgical team, can be considered crucial[14]. Talent, knowledge of anatomy, attitude, motivation and previous experience of the surgeon, and the ability to learn new skills affect the learning process[11,15].

In terms of demographic, oncological, and operative data, there was no difference between the the groups defined by the phases according to the CUSUM analysis based on the operation duration. The lack of difference between the groups implies that the cases were homogeneously distributed. At the beginning of the learning curve, the number of lymph nodes harvested is expected to be lower, and the operation duration is predicted to be longer. As previously stated in the study, the surgeon's experience in both laparoscopic abdominal surgery and open right hemicolectomy with CME-CVL caused him to be meticulous in lymph node harvesting, and thus the average lymph node numbers of the groups were high in accordance with oncological principles and inevitably similar. Furthermore, although not statistically significant, it was considered that operation durations were reduced by more than 30 minutes on average, which was crucial in daily practice.

The limitations of this study include its retrospective and single-center design, as well as data from cases of a single surgeon. On the other hand, because the learning curve analysis was performed not only based on the operation duration, but also on oncological data such as the number of lymph nodes, a more accurate analysis was expected.

To summarize, it is undeniable that a specific number of cases are required to gain proficiency for demanding operations such as laparoscopic right hemicolectomy with CME-CVL. Although there are numerous factors that influence learning, learning curve analyses can be useful for inexperienced surgeons. According to this study, the laparoscopic CME-CVL for right sided colon cancer learning curve is shorter for experienced surgeons.

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Author Contributions: Concept/Design : MAK; Data acquisition: MAK; Data analysis and interpretation: MAK; Drafting manuscript: MAK; Critical revision of manuscript: MAK; Final approval and accountability: MAK; Technical or material support: MAK; Supervision: MAK; Securing funding (if available): n/a.
Ethical Approval: For this study, ethical approval was obtained from the Human Research Ethics Committee of Ankara University with the decision dated 15.08.2022 and numbered IO7-455-22.
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