SCIENTIFIC PAPER JSLS

How To Reduce the Laparoscopic Colorectal Learning Curve

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ABSTRACT

Background: The laparoscopic approach for colorectal pathologies is becoming more widely used, and surgeons have had to learn how to perform this new technique. The purpose of this work is to study the indicators of the learning curve for laparoscopic colectomy in a community hospital and to find when the group begins to improve.

Methodology: From January 1 2005 to December 31 2012, 313 consecutive laparoscopic colorectal surgeries were performed (105 rectal and 208 colonic) by at least 60% of the same surgical team (6 members) in each operation. We evaluate the learning curve by moving averages and cumulative sums (CUSUM) for different variables related to the surgery outcomes.

Results: Moving average curves for postoperative stay, fasting, and second step analgesia show a stabilizing trend toward improvement as we get more experience. However, intensive care unit stay, number of lymph nodes achieved, and operating time did not show a clear decreasing tendency. CUSUM curves of conversion, specimens <12 lymph nodes, and complications all show a clear turning point marked on all the charts around the procedure 60, accumulating a positive trend toward improvement. The CUSUM curve of the "learning variable" shows this improvement point at procedure 70.

Conclusions: The laparoscopic colectomy learning curve accelerates with a collective team involvement in each procedure. The CUSUM and moving average curves are useful for initial and ongoing monitoring of new surgical procedures. The markers of the learning curve evidenced in our study are the conversion rate, postoperative surgical morbidity, and the number of patients with a lymph node count <12.

What is new in this paper? The significance of this study is the evaluation of the learning curve, in laparoscopic colorectal surgery, of a surgical team in a community hospital, using moving average and CUSUM curves. This study demonstrated that the number of patients needed to achieve skilful practice decreased when there is collective team involvement in each procedure.

Key Words: Colorectal surgery; Laparoscopic; Learning curve.

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DOI: 10.4293/JSLS.2014.00321

INTRODUCTION

Since 1991, when M. Jacobs performed the first laparoscopic colectomy, the laparoscopic approach for colorectal diseases has been widely used; this was largely because different randomized studies showed evidence of both short-term and long-term results comparable to those of conventional open surgery,[1] with a low incidence of tumor implantations at the abdominal wounds.[2] The development of this technique has meant that surgeons have had to learn how to perform this new approach.[3]

The learning curve is defined as the number of cases that a surgeon needs to have in order to perform a procedure with guaranteed results based on comparisons with the results obtained with the previous technique.[4] The most frequently used markers to set the learning curve have been operating time, morbidity, conversion rate, readmission rate, and the number of lymph nodes obtained.[5]

The aim of this work is to study and validate the indicators of the learning curve for laparoscopic colectomy in a community hospital, with a surgical team of 6 members; and to determine how sharing experiences as a group leads to faster improvement, as compared to how they would have improved working independently.

MATERIALS AND METHODS

All the data related to the study were included in a prospective database (ACCESS 2003, Microsoft Corporation, Redmond, Washington) including 130 variables. During the period from January 2005 to December 2012, data from 313 consecutive laparoscopic colorectal surgeries (105 rectal and 208 colon) were included. All the procedures were performed by the same surgical team made up of 6 members, including 3 surgeons with preferential dedication to colorectal disease, trained in European and national centers with teaching accreditation on laparoscopic colorectal surgery. Half the team was present in every surgery and ≥1of the 3 colorectal surgeons. In the first 15 cases, the specialized surgeon was always the primary surgeon, but in later cases, the members of the team shared the task of being the primary surgeon equally. The first assistant held the camera, while the second assistant exposed the operating field by means of graspers. Thus, although there is always a colorectal surgeon in all the operations, he/she was not necessarily the primary surgeon.

The surgical procedure was standardized from the beginning of our series. The right and right-extended colectomy was performed using 4 trocars, medial to lateral mobilization, ligation of the vascular pedicle, double intracorporeal bowel section, intracorporeal anastomosis in most patients, and extraction by suprapubic protected mini-incision. For the left, left-enlarged colectomy, and/or sigmoidectomy, the approach was made using 4 to 5 trocars, medial to lateral mobilization, high division of the vascular pedicle, distal intracorporeal section, externalization of the specimen by suprapubic mini-incision, and intracorporeal anastomosis with endoluminal circular transanal stapler.

The follow-up of the patients was performed according to the guidelines of the European Society of Medical Oncology for those with tumor pathology and every 6 months for 2 years for patients with benign diseases, who were subsequently contacted by telephone at the end of this study.

For the data analysis, we defined the following terms: "conversion" as a laparotomy for any technical gesture apart from extraction; "assisted anastomosis" as one performed extracorporeally; "operating time" as the minutes between the incision and closure; and "second step analgesia" as the need for opiate treatment. We consider global complications to be any major or minor medical or surgical postoperative complication. Major complications were considered to be anastomotic leak, hemoperitoneum, intraperitoneal abscess, sepsis, and pneumonia. Surgical complications were defined as wound infection, anastomotic leak, hemoperitoneum, intraperitoneal abscess, and visceral or urethral injury. Finally, the "learning variable" is defined as the sum of the conversion, the number of patients with lymph nodes <12, and postoperative surgical complications.[6]

We evaluate the learning curve to get moving averages and cumulative sums (CUSUM) for different variables related to the surgery.

The moving average method was used to evaluate continuous variables such as changes in surgical time, postoperative stay, fasting time, the duration of second step analgesia, the need for parenteral nutrition, and the number of lymph nodes obtained.

In this study, the CUSUM type curves were used for dichotomous qualitative variables such as global complications, surgical complications, major surgical complications, wound infection, conversion, and number of lymph nodes obtained <12. CUSUM was defined as $Sn = \Sigma (Xi–X0)$, where Xi is the individual record of the surgical team (0 = success and 1 = failure) and X0 is the error considered to be acceptable for that variable in the procedure.

RESULTS

From January 2005 to December 2012, we performed, after excluding rectal surgery, 208 colon laparoscopic resections **(Figure 1).** The demographic data are summarized in **Table 1** and the surgical results in **Table 2.**

The average age of the patients in the series was 68.4 years (range 18–91 years), 45.7% female and 54.3% male. The most common indication was colon adenocarcinoma in 168 patients (80.8%), followed by diverticulosis in 15 patients (7.2%). Left and sigmoid colon were the most common locations (54.3%) followed by right colon (36.1%). The most frequent anesthetic risk was American Society of Anesthesiology class I–II with 127 patients (61%), whereas 56 patients (26.9%) had had previous abdominal surgery.

Laparoscopic palliative surgery was performed in 10 patients (4.8%), laparoscopic emergency surgery in 7 patients (3.4%), and delayed laparoscopic surgery after endoscopic decompression with stent in 12 patients (5.8%).

Conversion to open surgery was 11.1%, and the primary cause was the inability to continue the procedure be-

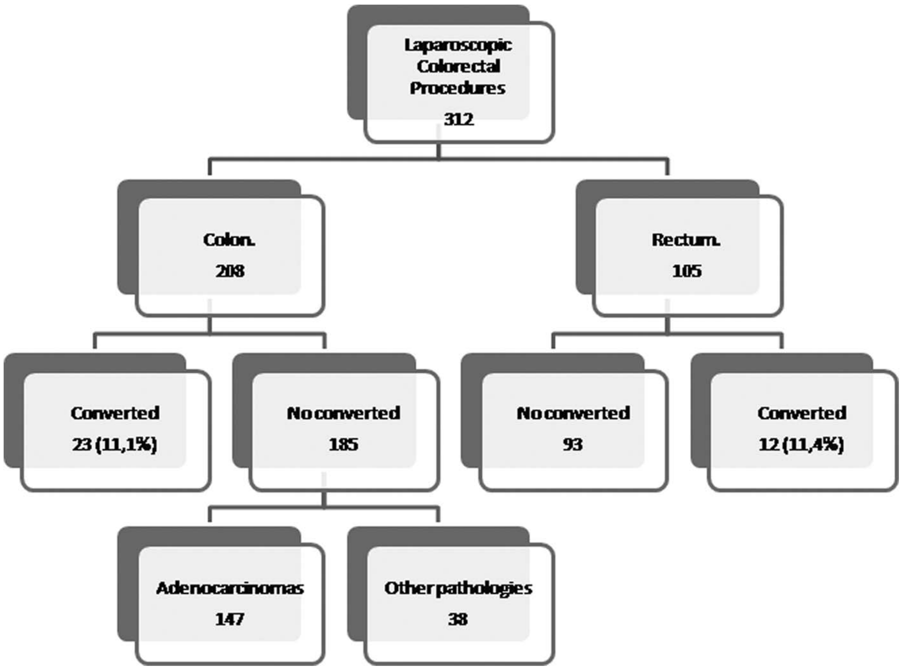

Figure 1. Flow chart of laparoscopic colorectal procedures.

cause of tumor infiltration. Considering conversion as a different surgical technique of laparoscopic surgery, converted patients were excluded, reducing the sample size of the study to 185 laparoscopic patients on which the surgical analysis of the results are based (Table 2). Intestinal anastomoses were assisted in 22 cases (11.9%).

The following median applied: operating time 185 minutes (range 50–330 minutes), postoperative stay 8 days (range 2–63 days), stay in the intensive care unit 1 day (range 1–25 days), number of days fasting was 3.5 (range 1–48 days), and number of days with second stage analgesia 2 (range 1–20 days). Total parenteral nutrition was necessary in 88 patients (48%) with a median of 5 days (range 2–21 day), and 33 patients (18%) required a blood transfusion, with a median of 2 units (range 1–7 units). Medical or surgical complications appeared in 63 patients (34.1%); the complications were major in 29 patients (15.7%), medical in 28 (15.1%), and surgical in 47 (25.4%). The most common medical complication was respiratory infection with 6 patients (3.2%), and the most common surgical complication was wound infection with 26 patients (14.1%).

Twelve patients (6.4%) had anastomotic leak requiring reoperation, 9 patients (4.9%) presented with postoperative abdominal abscesses, and there were 6 patients (3.2%) with hemoperitoneum. A total of 16 patients were reoperated on (8.6%). The global patient mortality was 6 (3.2%), 2 with anastomotic leaks, 1 with iatrogenic duodenal injury, and 3 with respiratory failure.

In patients with colon cancer, the most frequent TNM staging was T3 (50.6%), followed by N0 (59.3%), M0 (92.6%), and the American Joint Committee on Cancer stages 2A (26.1%) and 3B (20.2%).

The median of lymph nodes included in surgical specimens obtained from cancer patients was 21 (range 1–55 nodes), that of the distal margin was 7 cm (range 1–30 cm), and that of the proximal margin was 8 cm (range 1–40 cm). R0 resection was performed in 137 patients (93.2%), R1 in 1 (0.7%), and R2 in 9 (6.1%).

The mean follow-up of patients was 23 months (range 1–110 months). Local recurrences were diagnosed in 10 patients (5.4%), metastatic disease in 16 (8.6%), and the number of postoperative hernia wounds was 11 (5.9%).

Moving average curves **(Figure 2)** for postoperative stay, fasting, and days of second step analgesia show a stabilizing trend toward improvement as we become more experienced. However, the intensive care unit stay, the number of lymph nodes achieved, and the operating time did not show a clear decreasing tendency.

Table 1.
Demographic Data

	Global
Age, yrs, median	68.4
Sex	
Female	95 (45.7)
Male	113 (54.3)
Previous abdominal surgery	56 (26.9)
ASA	
I	35 (16.8)
II	92 (44.2)
III	71 (34.1)
IV	7 (3.4)
Location	
Right colon	75 (36)
Sigma and left colon	117 (56.2)
Transverse colon	16 (7.7)
Pathology	
Adenocarcinoma	168 (80.8)
Diverticulosis	15 (7.2)
Other benign tumors	8 (3.8)
Hartmann reconstruction	4 (1.9)
Perforation	4 (3.8)
Constipation	2 (1)
Other malignant tumors	4 (1.9)
EII (Crohn disease)	3 (1.5)
Previous prosthesis	12 (5.8)
Visceral infiltration	15 (7.2)
Carcinomatosis	1 (0.5)
Metastasis in surgery	7 (3.8)
Palliative	10 (4.8)
Urgency	7 (3.4)
Intracorporeal anastomosis	186 (89.4)
Assisted anastomosis	22 (10.5)
Conversion	23 (11.05)

Abbreviations: ASA, American Society of Anesthesiology class; EII, electrical impedance imaging.
Values are *n* (%) unless otherwise indicated.

Table 2.
Surgical Results

Without conversion	Global, $n = 185$
Surgical time, min	185
Postoperative stay, d	8
Reanimation stay, d	2
Fasting days	3.5
Second stage analgesia, d	2
NPT days	5 (88–48)
Transfusion needed	2 (33–18)
Lymph nodes	21
Oncological resection	
R0	137 (93.2)
R1	1 (0.7)
R2	10 (6.1)
Tumor stage, AJCC, $n = 147$	
0	4 (2.7)
1	19 (12.9)
2A	44 (29.9)
2B	16 (10.8)
2C	1 (0.6)
3A	3 (2)
3B	34 (23.1)
3C	15 (10.2)
4	10 (6.8)
Global complications	63 (34.1)
Medical complications	28 (15.1)
Surgical complications	47 (25.4)
Anastomotic leak	12 (6.4)
Abdominal abscess	9 (4.9)
Hemoperitoneum	6 (3.2)
Visceral and ureteral injury	2 (1.1)
Wound infection	26 (14.1)
Major complications	29 (15.7)
Mortality	6 (3.2)
Reoperations	16 (8.6)

Abbreviation: AJCC, American Joint Committee on Cancer.
Values are *n* or *n* (%).

The CUSUM curves **(Figure 3)** show a trend of failure in the first proceedings, with a clear turning point marked on all the charts around procedures 50 to 70, where the data began to be successful, accumulating a positive trend toward improvement.

The CUSUM curve of the learning variable shows an improvement after 65 patients and then a steady decline of the curve was maintained **(Figure 4),** indicating a high frequency of successful processes and marking the turning point where we begin to improve.

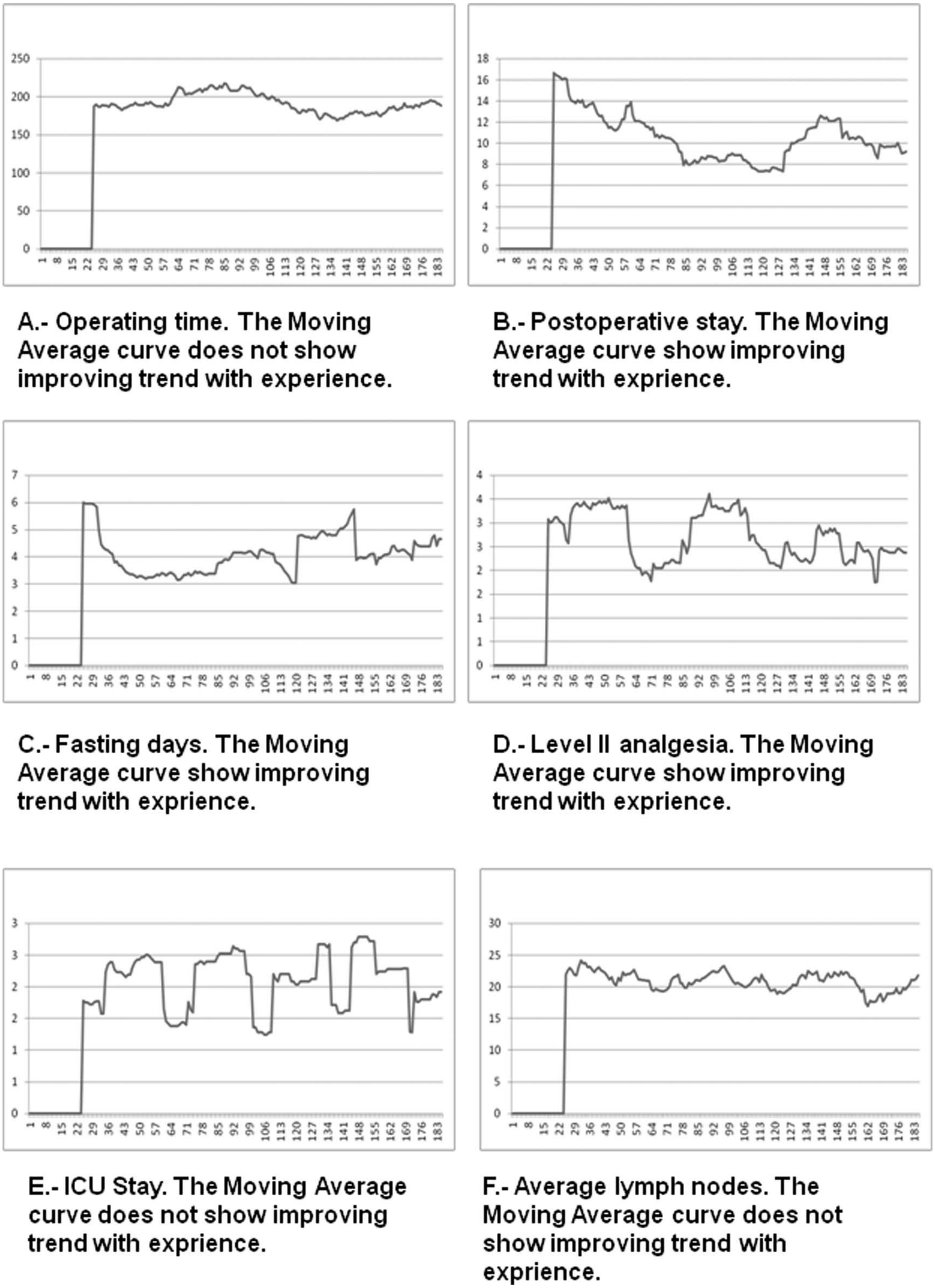

Figure 2. Moving averages: evolution of quantitative variables depending on the number of cases performed. The variables are operating time **(A),** postoperative stay **(B),** fasting days **(C),** level II analgesia **(D),** intensive care unit stay **(E),** and average lymph nodes **(F)**.

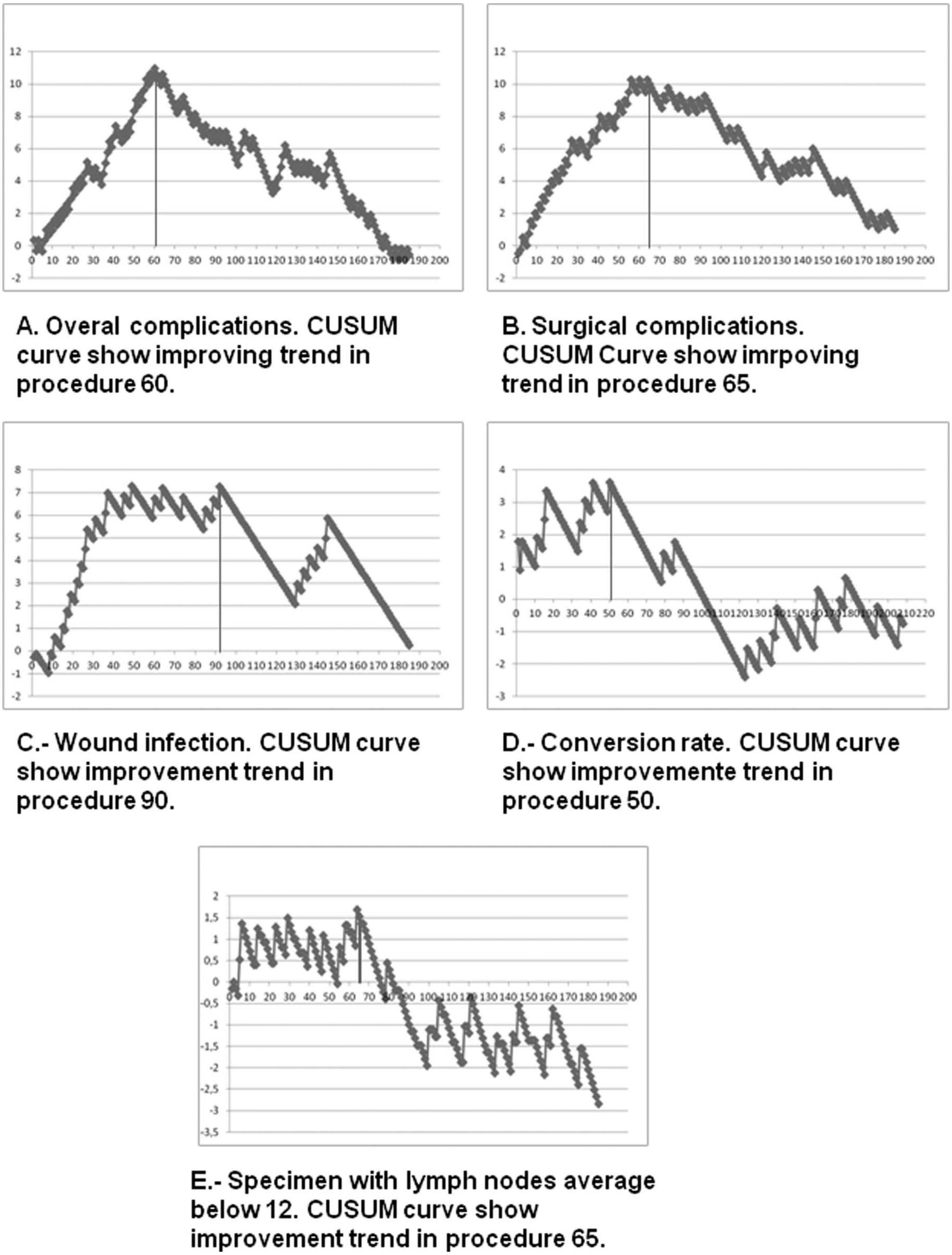

Figure 3. Cumulative sums (CUSUM) for qualitative variables that change with learning. The variables are overall complications **(A),** surgical complications **(B),** wound infection **(C),** conversion rate **(D),** and specimen with lymph nodes average <12 **(E)**.

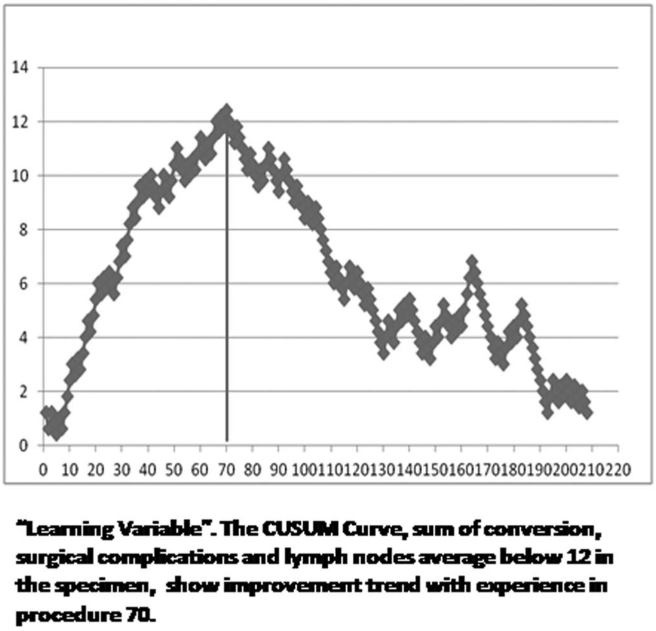

Figure 4. Learning variable: variable defined as the sum of conversion, surgical complications, and patients with node number <12.

DISCUSSION

The laparoscopic colorectal surgery is becoming common because it has demonstrated advantages over conventional surgery. Such advantages are reduced hospital stay, fewer cases of postoperative ileus, and less need for analgesia, all showing proven oncological safety with survival results that are comparable to conventional surgery[7,8] or even better, as shown by recent studies.[9] In our country, it has been estimated that <35% of general surgeons use this type of approach in colorectal surgery,[10] which is why a great number of resident doctors reach the end of their training without having had any experience of laparoscopic colorectal surgery. Thus, they have to gain this experience later in their careers.

There is currently no evidence to support an ideal method for training surgeons in laparoscopic surgery,[11] although there is evidence that in-hospital training stays with experts do improve results[12] and that the progressive introduction of this technique into daily clinical care will encourage formation and shorten the surgeons' learning process.[13,14]

This difficulty is accentuated in community hospitals, where the number of colorectal operations per year is limited. In our case, however, after an initial period in which the technique was introduced by the specialist colorectal surgeons, the entire team is involved in each procedure, with at least 50% of the surgeons working in every procedure, and each of the 6 surgeons doing the same number of cases, sharing experiences and learning under the supervision of the most experienced surgeon.[15] This may mean that, in small hospitals, the collective work of the team in each procedure can reduce the number of patients needed to achieve the necessary skills.[4,16,17]

In 2002, McCulloch et al.[18] suggested that to improve the standards of surgery, learning curves and surgery quality should be measured and controlled through instruments such as the CUSUM plots. The number of operated patients necessary to overcome the learning curve is, in almost every study, based on operating time and the cumulative sum (CUSUM) of the variables that change with learning. But how should those learning variables be determined?

In our series, the moving average of the operating time has not improved as we have gained experience, so this is not a good learning marker for us. Neither are the total parenteral nutrition or the average number of lymph nodes obtained, as the mean has been >12 since the beginning of the study. On the other hand, as can be seen in the graphs, the remaining quantitative variables show a stable tendency toward improvement, in such aspects as postoperative stay, days of fasting, and second step analgesia (Figure 2).

The graphs of CUSUM for qualitative variables indicate an improvement with experience, as evidenced by the decrease in the incidence of the overall complication rate, surgical complications, wound infection, leaks, and conversion, which, in our series, begin to descend between cases 50 and 80 (Figure 3).

Although some investigators proposed 15 patients as a turning point in the learning curve, almost all published series, performed by a single surgeon, established the learning point at 30 patients.[19] In our study, we propose that the surgical team should simultaneously perform all operations, that 3 of them should have prior training in advanced laparoscopic surgery level III from accredited training centers, that they should simultaneously acquire level IV, and that they should be dedicated to colorectal surgery.[6,17] In this way, the primary surgeon's experience is transmitted to the assistants and the collective learning is faster and more efficient.

We believe that initial case selection is a mistake, because excluding patients with diverticulitis, body mass index >30, American Society of Anesthesiology class III-IV, age

>80 years, previous laparotomy, and curative oncological operations, as recommended in the literature,[7,16] would reduce the number of cases performed, and this would make the learning curve much slower. Similarly, to start by performing only benign colon disease operations would increase the rate of left colonic diverticular disease, which requires greater dexterity due to the anatomical breakdown of the area.[5,20] In our study, as in those published by other investigators,[5,16] performing all kinds of procedures without case selection of cases has made the series homogeneous from the beginning, with a higher volume of patients and, thus, greater speed in acquiring the necessary skills has been achieved, shortening the learning curve without worsening the oncological quality of the resections.

Our series coincides with other published works, achieving improvements in conversion rates, postoperative morbidity, reoperations, hospital stay, and analgesic requirements; but, in contrast to the literature, we did not improve operating time, number of lymph nodes obtained, or the number of R0 resections, which were optimal from the beginning.[4,8,20]

The reduction in operating time, taken as indicative of the turning point in the learning curve in other published studies,[4,21] has not been, however, a good marker in our study, as it remains virtually unchanged from the beginning. This fact is attributable to the decrease in the conversion rate, completing more complicated laparoscopic procedures as we gain in experience and reliability.[5,20,22] Surgical time tends to decline during the first cases, stabilizing as we gain in experience.

The most common cause of conversion is the tumor stage (T),[8] followed by previous abdominal surgery and intraoperative complications.[22] Other factors are age, the patient's body mass index, and the surgeon's experience. In our study, we observed a progressive decrease in the conversion rate once the learning curve had been passed in case 50,[4,8,20] although there are publications in which this decline cannot be appreciated after 300 procedures.[14]

Many studies support the theory that conversion directly affects the worsening of the short- and long-term results.[7,23] However, our results do not show evidence of worse short-term results in converted patients, as has already been demonstrated.[24] This may indicate that the conversion has been done in time without increasing morbidity and that the conversion has not been an urgent laparotomy caused by an intraoperative complication.[16] The lower disease-free period in converted patients in the long-term follow-up reflects the fact that the stage of the tumor (T) directly influences the conversion more than the surgeon's experience does.[8,22]

The creation of the learning variable, the sum of the conversion, the surgical complications, and the number of patients with lymph nodes <2 (Figure 4), is based on the variables that have improved with experience, as shown in the graphs, indicating the moment where our group starts to improve, and therefore marks the point of surpassing the learning curve.[6,17] Other variables used by other investigators, such as blood loss or operating time,[12,14] did not change during the study and are, therefore, not good indicators in our experience. This improvement point is defined, in our series, by this learning variable, at patient 70 for the entire surgical team (Figure 4), a far cry from the 180 we should have to operate on to complete the learning curve (30 patients × 6 surgeons) according to other investigators.[19]

In our study, postoperative morbidity and reoperation rate, as in other publications, have improved significantly after overcoming the learning curve, with less medical and surgical morbidity.[25] However, other investigators, such as Li et al.,[14] only saw improvement in intraoperative variables, and not in postoperative morbidity.

This study has been developed prospectively, allowing us a continuous self-assessment of morbidity, leading to the modification of certain technical aspects that resulted in immediate significant improvements. It was in this way that we corrected, during the study, the surgical management of the extraction wound by changing gloves, systematically every hour, before and after performing a mini-laparotomy, thus significantly lowering the wound infection rate.

The improvement obtained in hospital stay, analgesic requirements, and postoperative total parenteral nutrition is also reflected in previous studies,[19,25] but these variables are not included in the learning variable, as we believe that its reduction may be due to the gradual application and implementation of the pseudomultimodal resuscitation described by Kehlet and Wilmore,[26] rather than through the debugging of the surgical technique itself.[25]

The number of lymph nodes currently included in the surgical specimen is the most important prognostic factor for colorectal carcinoma. Some publications showed that survival is not only linked to the number of lymph nodes with metastases, but also to the number of lymph nodes obtained and the integrity of the mesocolic fascia.[27,28]

The guidelines of the American Joint Committee on Cancer have therefore set the minimum number of lymph nodes in the surgical specimen at 12 for correct tumor staging.[29] In our study, all surgical specimens were examined by the same pathologist, allowing us to assess the quality of our oncological resection, without any variation in the number of lymph nodes between different pathologists. We therefore obtain, from the very beginning, a lymph node average far superior to that recommended by the American Joint Committee on Cancer (mean >20). This fact indicates that the mesocolic tumor excision was correct at the start of our learning curve, unlike other published series.[4] Nevertheless, we did include the number of patients with <12 lymph nodes in the learning variable, as the CUSUM curve began to descend from patient 70 (Figure 3). Similarly, the percentage of R0 resections did not change significantly throughout our study.[30]

This confirms that, with proper training and prior laparoscopic experience, it is not necessary to exclude cancer cases with a curative intention at the beginning of the learning curve, because the quality of the surgical oncology specimen may be optimal, even in early cases.

CONCLUSIONS

Oncological laparoscopic colectomy can be safely done by groups of surgeons with experience in other laparoscopic procedures, and learning can be accelerated by means of a team working together in each procedure. We believe that self-evaluation with CUSUM type curves and moving average is a useful tool for the initial and ongoing monitoring of the implementation of these new procedures in surgery, and that they may be good markers for evaluating the formation of our resident doctors. These markers of the learning curve are, in our opinion, the conversion rate, postoperative morbidity, and the number of patients with a lymph node count <12, but not, by contrast, the surgical time or the global number of lymph nodes.

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