



# Laparoscopic Sleeve Gastrectomy Learning Curve: Clinical and Economical Impact

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## Abstract

**Background** The results in the literature regarding the learning curve (LC) of laparoscopic sleeve gastrectomy (LSG) are scarce and non-definitive. The purpose of the study was to evaluate the correlation between the LSG learning curve and intraoperative parameter variation, postoperative morbidity, weight loss results, and economic impact.

**Methods** The first 99 obese patients undergoing LSG surgery by the same surgeon from March 2013 to April 2016 were included in the present study. Patients were equally distributed among three groups (A, B, C) based on case sequence.

**Results** The three study groups were homogeneous with respect to age, BMI, gender, and comorbidities. There was a significant reduction in operative time among the groups ( $p < 0.00001$ ), with a difference of approximately 40 min between the first and third groups. The decrease in operative time was associated with a decrease in the number of stapler firings used per LSG. Conversely, there was no statistical correlation between intraoperative blood loss, intraoperative complications, or weight loss 1-year postsurgery and the LSG learning curve. In addition, the increase in experience with LSG was also associated with a significant reduction ( $p < 0.00001$ ) in the length of hospital stay. With respect to postoperative complications, a statistically significant difference was recorded between groups B and C ( $p = 0.02$ ). Finally, a patient undergoing surgery at the end of the LC had an estimated reduction in economic impact of approximately 2700 Euros compared with a patient undergoing surgery at the beginning of the LC.

**Conclusion** Approximately 60 cases are required to reach proficiency in reducing postoperative complications and costs of LSG.

**Keywords** Learning curve · Laparoscopic sleeve gastrectomy · Proficiency · Staple firings · Operative time · Length of hospital stay

## Introduction

During the last decade, laparoscopic sleeve gastrectomy (LSG) has become the most-performed bariatric procedure worldwide [1]. LSG success among the bariatric community is due not only to its proven effectiveness in treating obesity and related comorbidities in the short and long terms but

also because it is considered less technically demanding compared with other malabsorptive procedures [2, 3]. Although LSG does not require reconstructive time with the creation of gastrointestinal anastomoses, it nevertheless presents certain fundamental surgical steps that need a certain level of experience in laparoscopic and bariatric surgery to reduce the risk of postoperative complications [4]. Despite these issues, the results presented in the literature regarding the pathway necessary to learn and improve the technique, the so-called learning curve (LC), are scarce and non-definitive [5–9]. This lack of data resonates even more with the increase in global obesity rates and the increasing occurrence of general surgeons performing bariatric surgery. The purpose of the present study was to evaluate the correlation between the LSG learning curve and intraoperative parameter variation, postoperative morbidity, and weight loss results. We also attempted to quantify the economic impact that the evolution of the LC can have on the surgical departments that deal with obese patients.

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## Materials and Methods

The first 99 obese patients undergoing LSG surgery by the same surgeon from March 2013 to April 2016 were included in the present study. All patients underwent surgery at two university hospitals (Hôpital Jean-Verdier and Hôpital Avicenne), located in the suburbs of Paris, France, equipped with a bariatric surgery service of more than 400 procedures/year. Data pertaining to each patient, including demographic, clinical, and operative data, were collected prospectively and analyzed retrospectively. Patients with previous bariatric interventions, previous extensive laparotomic surgery, or follow-up inferior to 1 year, were excluded. During the series, seven patients needed an associated procedure such as cholecystectomy, hiatal hernia repair, or ovariectomy. In these cases, the extra time spent for the concomitant procedure was subtracted from the total operative time. All patients were enrolled, operated on, and followed up by the same surgeon with advanced experience in laparoscopic surgery, but early experience in bariatric surgery. Prior to the start of the present study, the surgeon accomplished a 1-year bariatric surgery fellowship training position at a European center of excellence. Patients underwent an extensive preoperative evaluation including esophago-gastric endoscopy, polysomnography, nutritional, psychiatric, and endocrinological evaluation before being considered for bariatric surgery. Patients with gastroesophageal reflux and difficult-to-control diabetes underwent gastric bypass. The eligibility for surgery was established according to the French High Authority of Health (HAS) and the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) criteria. Patients were equally distributed to three groups (A, B, C) based on case sequence. Primary outcomes included operative time, intraoperative complications, blood loss, and number of staple firings used for the gastric sleeve. Total operative time was recorded as the time between the first skin incision and the end of skin closure. Blood loss was calculated by measuring the volume of blood in the suction at the end of the procedure. Secondary outcomes included the length of hospital stay (LOS), postoperative complications, rehospitalization, and postoperative weight loss. In order to be discharged from the hospital, patient had to fill the following criteria: temperature inferior to 38 °C, no tachycardia, patient's ability to eat, no vomiting, no pain or pain controlled by discontinuing oral treatment (Visual Analogic Scale (VAS): inferior to 3), and independent patient mobilization. Postoperative complications were classified based on the Clavien-Dindo classification [10] and the time of onset (early, during the first postoperative month; or late, after the first postoperative month). Weight loss was expressed as the change in body mass index (BMI), total weight loss (TWL), and percentage of excess weight loss (%EWL), with the calculation of ideal body weight as that equivalent to a BMI of 25 kg/m<sup>2</sup>. Furthermore,

a cost analysis was performed to assess the economic impact of the LSG learning curve. Three parameters were included in this analysis; cost of the surgical materials used to perform the intervention, the employment cost of the operating room, and the cost of the hospital stay. All interventions were performed with the same surgical instruments, and for this reason, the parameter employed to estimate the cost of the materials was the number of stapler recharges used for the gastric resection. The cost of the operating room (OR) was calculated as follows: (Euros for 1 h of OR / 60 min) × total operative time (min). The cost of the hospital stay was calculated by the value of one hospitalization day in our hospital in 2016.

## Surgical Technique and Postoperative Management

The four trocars technique was used. The greater curvature of the stomach was dissected free by dividing the short gastric vessels using a harmonic scalpel, starting at a position opposite to the Crow's foot (approximately 5 cm proximal to the pylorus) and reaching the angle of His. Posterior gastric adhesions were divided when present. Calibration was obtained by passing a 36-Fr gastric bougie, pushed toward and along the lesser curvature, and the stomach was transected with sequential firings of linear green and blue GIA reloads (60-mm Echelon®, Ethicon Endosurgery Cincinnati, OH). To reduce intraoperative bleeding, we waited 20 to 40 s between stapler closure and firing, and the staple line was reinforced by a continuous imbricating running suture using Monocryl™. The resected stomach was extracted from the abdomen into a plastic bag. The staple line was tested with methylene blue pushed in the nasogastric tube: no intraoperative leak was shown. A silicon drain was placed along the SL. To rule out leaks, all patients were double-checked with a methylene blue test and an upper gastrointestinal series during the postoperative period, and if no leakage was detected, an oral fluid diet was started. Postoperative assessments were conducted by the operator at 1, 3, 6, 9, 12, 18, 24, and 36 months postoperatively, and annually thereafter.

## Statistical Analysis

Continuous demographic variables are expressed as the mean ± standard deviation and the range. Categorical variables, in addition to complications, are reported as numbers and percentages. Continuous outcome variables are generally reported as the mean ± standard deviation and the range. Fisher's exact test and a Chi-squared test were used to investigate relationships among categorical variables. Comparison of continuous outcomes among the three groups was carried out by means of parametric and nonparametric testing, as appropriate (analysis of variance (ANOVA); Wilcoxon/Kruskal-Wallis tests). A *p* value < 0.05 was considered statistically significant. Statistical analysis was performed using the

Statistical Package for Social Sciences, version 17 (SPSS, Chicago, IL).

## Results

Preoperative data are reported in Table 1. The study population consisted of 87 females and 12 males, with no statistical differences in terms of age, BMI, gender, or comorbidities found among the groups. As shown in Table 2, there was a constant and significant reduction in operative time among the sequential groups ( $p < 0.00001$ ), with a difference of approximately 40 min between the first and third groups. The decrease in operative time was associated with a decrease in the number of stapler firings used per LSG, which was statistically significant ( $p = 0.008$ ) between groups A and C. Conversely, there was no statistical correlation between intraoperative blood loss and the LSG learning curve ( $p = 0.98$ ). In addition, the increase in experience with LSG was also associated with changes in postoperative protocols, which led to a significant reduction ( $p < 0.00001$ ) in the LOS, with a patient in group C remaining hospitalized on average 2 days less than a patient in group A. Specifically, at postoperative days (POD) 1, 2, and 3, the number of patients that filled the discharge criteria was greater in group C than in the other two groups. At POD 2, respectively, the 39.4% of patients in group A, the 54.5% of patients in group B, and the 72.7% of patients in group C, filled the criteria for the discharge ( $p = 0.02$ ).

No one patient was converted to laparotomy, and the mortality rate was 0%. The rate of intraoperative complications was the same in each group (3%); section of the calibration probe in one patient in group A, a serious bleed of the spleen (445 cc) in one patient in group B, and a serious bleed of the liver (460 cm<sup>3</sup>) in one patient in group C. During the postoperative period, four patients in group A experienced an early complication (12.1%). One patient was reoperated on at POD 1 due to bleeding from the staple line (grade IIIb). A second patient was readmitted to the hospital at POD 6 for fever, and a

CT scan detected a subphrenic collection without leakage of contrast media (grade II). A third patient presented at POD 4 with abdominal pain associated with an increase in C-reactive protein levels and a murky liquid spill from the drain. Once again, no leak was detected by radiological control and repeated methylene blue tests (grade II). A fourth patient was readmitted at POD 7 for diarrhea and vomiting of unknown origin and was discharged after 48 h of hydration (grade I). In group B, a total of 6 patients were rehospitalized for postoperative complications (18.1%). One patient experienced dysphagia due to gastric stenosis 2 months postoperatively (late complication), which was successfully treated by endoscopic dilatation (grade IIIa). A second patient was readmitted at POD 10 for fever and abdominal pain; however, no complications related to the sleeve were detected (grade I). Three patients experienced a temporary food blockage without an organic cause at POD 10, 21, and 29, respectively. In these patients, dysphagia resolved spontaneously following a brief hospitalization and endoscopic evaluation (grade IIIa). Finally, a sixth patient was readmitted at POD 10 with diarrhea and vomiting and following a simple rehydration, the patient was discharged from the hospital (grade I). In group C, neither postoperative complications nor patient readmission were recorded. A statistically significant difference was recorded between groups B and C ( $p = 0.02$ ), while no difference was recorded between the first two groups.

At 1 year after surgery, 100% of patients in group A, 94% of patients in group B, and 97% of patients in group C were available for follow-up. Weight loss results are shown in Table 3. The mean TWL and %EWL at 1 year for the entire study population were  $37 \pm 10.2$  kg and  $70.3 \pm 16.6\%$ , respectively. No statistically significant differences in terms of BMI change, TWL, or %EWL were recorded among the three groups.

The economic impact of the LSG learning curve was calculated based on the 2016 value of stapler recharge, 1 h OR use, and a daily hospital stay, which were 125, 600, and 911 Euros, respectively. Economic data concerning the three

**Table 1** Preoperative data

	Group A	Group B	Group C	<i>p</i> value
Sex (M/F (%))	4/29 (13.8%)	2/31 (6.4%)	6/27 (22.2%)	0.32
Age (years (range))	36.1 ± 11.1 (20–61)	35.9 ± 9.2 (21–58)	35.9 ± 10.7 (17–59)	0.99
Weight (kg (range))	116.5 ± 17.9 (94–191)	118.3 ± 17.1 (93–163)	114.2 ± 20.2 (80–175)	0.65
BMI (kg/m <sup>2</sup> (range))	43.1 ± 7 (36.1–74.6)	42.8 ± 4.9 (35.3–57.1)	41.2 ± 6.1 (35.4 ± 58.6)	0.41
Diabetes ( <i>n</i> )	3	0	3	0.54
OSAS ( <i>n</i> (CPAP))	17 (11)	15 (5)	20 (5)	0.46
Hypertension ( <i>n</i> )	9	8	5	0.46
Dyslipidemia	6	4	3	0.53
Arthrosis	9	0	3	0.01

*BMI*, body mass index; *OSAS*, obstructive sleep apnea syndrome; *CPAP*, continuous positive airway pressure; *N*, number; *kg*, kilogram; *m*<sup>2</sup>, square meter; *M*, male; *F*, female

**Table 2** Operative data

	Group A	Group B	Group C	<i>p</i> value
Operative time (min (range))	108.6 ± 20.2 (85–180)	82 ± 16.1 (50–120)	69 ± 15.7 (49–120)	< 0.00001
Staple firings ( <i>n</i> )	6.1 ± 0.6 (5–8)	6 ± 0.6 (5–7)	5.7 ± 0.5 (5–7)	0.02
Bleeding (cm <sup>3</sup> )	50.9 ± 71.8 (5–390)	50.3 ± 81.4 (5–445)	47.8 ± 96.3 (5–460)	0.5
LOS (days)	5.7 ± 2 (3–14)	4.5 ± 2.1 (2–13)	3.2 ± 0.7 (2–5)	< 0.00001

*min*, minute; *N*, number; *cm*<sup>3</sup>, cubic centimeter

groups are shown in Fig. 1. During the LC, the improvement in the technical skills required to perform LSG reduced the operative time by approximately 40 min, consequently saving 400 Euros/patient. Although statistically significant, the decrease in the number of stapler firings used between groups A and C showed little economic impact (50 Euros). Conversely, the increase in experience during the LSG postoperative period showed a large reduction in hospitalization costs at the end of the series, by an average of 2300 Euros/patient. In summary, a patient undergoing surgery at the end of the LC had an estimated reduction in economic impact of approximately 2700 Euros compared with a patient undergoing surgery at the beginning of the LC.

## Discussion

Completion of the LC of a given intervention occurs when the surgeon is able to standardize the procedure by improving the operative parameters and reducing postoperative

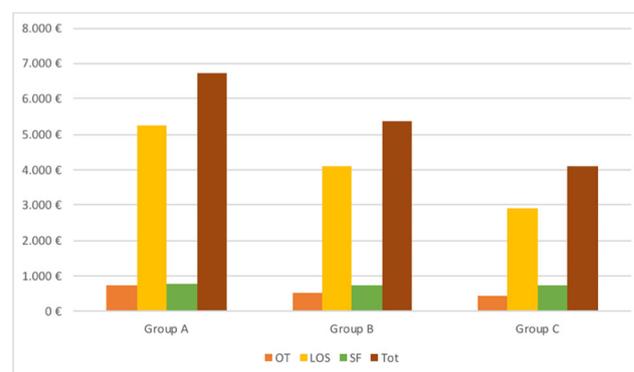
complications. The number of cases needed for each procedure is linked to several factors that are sometimes difficult to quantify, such as the personal skills and experience of the surgeon, adequate training, the hospital case volume, and the availability of a multidisciplinary team and institutional facilities [11]. The concept of an LC in bariatric surgery has been widely discussed for certain procedures such as the gastric bypass, while for others, data in the literature remain scarce [12, 13]. Likely due to the lack of gastrointestinal anastomosis, LSG is considered a relatively simple procedure, and therefore, its results are less influenced by the learning curve. Typically, LSG presents certain technical difficulties such as the detachment of the gastric fundus from the spleen, the dissection of the posterior gastric wall, and the correct section of the stomach, which require a certain level of experience in laparoscopic and bariatric surgery. In the present study, the surgeon was already experienced in advanced laparoscopic bariatric surgery, having completed a full-time 1-year fellowship in a high-volume center of excellence prior to starting the series. Moreover, during the first few cases, the surgeon was supervised by an experienced bariatric surgeon who had performed more than 500 procedures. We agree with other authors that the presence of these two conditions is necessary prior to starting the LC of a procedure such as LSG [5, 6, 8, 14].

The parameters typically used to evaluate the evolution of the LC and the achievement of proficiency in LSG are operative time, postoperative complications, conversion rate,

**Table 3** Weight loss results

	Group A	Group B	Group C	<i>p</i> value
3 months				
TWL	20.8 ± 7.8	21.8 ± 5.9	19.8 ± 6.4	0.5
%EWL	38.5 ± 10.5	40.6 ± 12.1	42.2 ± 16.7	0.5
BMI	35.3 ± 5.1	34.9 ± 5.1	33.6 ± 6.3	0.5
6 months				
TWL	29.3 ± 10.8	30.1 ± 7.6	27.2 ± 8.2	0.5
%EWL	53.3 ± 13.5	55.7 ± 14.8	57.8 ± 18.4	0.5
BMI	32.0 ± 4.5	31.9 ± 4.6	30.7 ± 5.8	0.5
9 months				
TWL	33.8 ± 11.4	34.2 ± 8.3	32.3 ± 8.5	0.6
%EWL	61.7 ± 30.5	62.9 ± 15.4	67.9 ± 18.9	0.3
BMI	30.5 ± 4.1	30.4 ± 4.4	29.1 ± 5.5	0.2
12 months				
TWL	37 ± 12	37.5 ± 9.7	36.5 ± 8.4	0.9
%EWL	67.4 ± 13.4	68.8 ± 17.5	76.6 ± 18.4	0.08
BMI	29.3 ± 3.8	29.3 ± 4.6	27.5 ± 5.1	0.1

TWL, total weight loss; %EWL, % excess weight loss; BMI, body mass index



**Fig. 1** The economic impact of the LSG learning curve (OT, operative time; LOS, length of hospital stay; SF, staple firings; Tot, total)

weight loss, and LOS [5, 8]. Consistent with the data reported in the literature, we found a significant reduction in operative time after the first 33 cases; however, the point of the learning curve from which the operating time no longer showed significant variation came much later, around the 58th procedure [7, 8]. According to Zacharoulis et al., this is likely the point that could be overcome to reach proficiency in LSG [8]. To assess the presence of a correlation between the different steps of LSG and the LC, we also recorded the rate of intraoperative complications, the extent of intraoperative bleeding, and the number of recharges used for gastrectomy. While intraoperative complications and blood loss showed no difference among the three groups, the number of recharges used was significantly decreased in group C. This likely reflected the previous experience of the surgeon in advanced laparoscopic surgery that allowed management of bleeding and intraoperative accidents, even in patients with a high BMI. Conversely, the significant difference in the use of recharges between the first 66 and the remaining patients more accurately reflects the evolution of the LC with respect to a surgical maneuver typical of LSG, such as the longitudinal section of the stomach. Small traction and/or correct positioning of the freed stomach allowed for reduction in the number of recharges without increasing patient risk.

The overall postoperative results of the present study are comparable with LSG data found in the literature [15], with only one patient needing reoperation for bleeding, eight patients experiencing a minor complication and being rehospitalized, and no leaks being recorded. Analysis of the allocation of complications in relation to the LC showed that all postoperative complications occurred in the first two groups, where the number of cases was lower and the operative time longer, the results of which are consistent with previous studies. Birkmeyer et al. showed a direct correlation between the number of operated cases and postoperative morbidity, and similarly, Reames et al. reported a correlation between the reduction in complications during bariatric surgery and the reduction in operating time [14, 16]. With an increase in LSG experience and a decrease in the operative time, adverse events were significantly reduced.

The data in the present study shows that the LC significantly affected the length of hospital stays, with an average reduction of 2 days from the beginning to the end of the series. It is reasonable to suggest that this difference was due to two important issues; the reduction in postoperative complications and the increase in experience in patient management during LSG surgery. As the number of cases increased and the operative time decreased, a greater number of patients filled the discharge criteria more rapidly, probably in relation to earlier mobilization and a better management of postoperative pain. Furthermore, in recent years, increasing data

have been presented in favor of reducing the hospitalization time of bariatric patients [17], and in certain centers, LSG surgery is routinely performed as day surgery [18, 19]. In light of these studies and an increase in fast-track surgery in our department, the LOS was reduced in parallel to the rise in the number of cases performed.

With respect to weight loss, no significant differences were recorded among the three groups during the LC. In particular, the postoperative %EWL of each group 1 year after the surgery was comparable with those reported for LSG in the literature [20, 21]. Casella et al. found similar results, with an overall %EWL of approximately 80% 1 year after LSG and no differences among the three periods of the LC [5], and it was speculated that since the early experiences, LSG was likely performed in an efficient manner. Unfortunately, as shown by other authors, 1 year of follow-up is a very short time in which to draw firm conclusions. Prevot et al. found that following the first 30 cases, the mean %EWL at postoperative 5 years improved significantly, suggesting a direct correlation between the periods of the LC and long-term results [7]. Further studies with larger cohorts and longer follow-up periods are required to better evaluate the effects of the LC on long-term weight loss.

In the present study, we also analyzed the economic impact of the LC of LSG. By influencing the number of recharges, operative time, and LOS, the LC in turn significantly influenced the direct cost of each LSG performed. In particular, a rough estimate demonstrates a reduction in cost of approximately 2700 Euros between surgeries performed at the beginning of the LC and those performed once sufficient proficiency had been reached. Moreover, these results were underestimated, since they did not consider the indirect costs of LSG linked to postoperative morbidity or the rehospitalization rate recorded in groups A and B. Taken together, these results clearly demonstrate that the increase in experience of LSG surgery, not only reduced postoperative morbidity but also the economic impact of patients. Furthermore, it is reasonable to suggest that this reduction in cost should be an incentive for hospitals to invest extensively in intensive fellowship programs for bariatric surgeons and to encourage the practice of mentorship by more experienced surgeons.

The present study presents two important limitations. Firstly, all patients were operated on by the same surgeon, and consequently, the results obtained were strongly influenced by his experience and skill, which unfortunately cannot be quantified. The lack of one or more surgeons with which to compare the results partially removes the possibility of generalizing the data. Secondly, the short follow-up period did not allow us to establish a firm correlation between the LC and long-term results. The weight loss several years after LSG

surgery may be an important indicator of the quality of surgery variation during the LC.

## Conclusion

The results of the present study indicate that LSG surgery is a safe and effective intervention in the hands of a surgeon with experience in advanced laparoscopic surgery following an intensive 1-year fellowship in bariatric surgery. In terms of the LC, data suggest that approximately 30 cases are needed to significantly reduce operative times. Further, an operative series of at least 60 cases is required to significantly reduce the postoperative complications rate and the costs of LSG surgery owing to a reduction in the operative time (with the possibility of increasing the number of operations per day), the LOS, and the direct costs of the surgical materials, without increased patient risk.

## Compliance with Ethical Standards

**Conflict of Interests** The authors declare that they have no conflict of interest.

**Statement of Informed Consent** For this type of study, formal consent is not required.

**Statement of Human Rights** All of the procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional research committee and the 1964 Helsinki.

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