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Comparative outcomes of ERAS and conventional methods in laparoscopic sleeve gastrectomy: a 5-Year prospective cohort study in Saudi Arabia

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Abstract

Background The burden of obesity in Saudi Arabia is partly addressed with Laparoscopic Sleeve Gastrectomy (LSG), a bariatric surgical option, but perioperative complications and prolonged hospital stays persist. Enhanced Recovery After Surgery (ERAS) aims to improve postoperative outcomes.

Objectives To compare the peri-operative LSG outcomes among patients receiving ERAS and conventional bariatric procedures (non-ERAS).

Methods A prospective cohort study design involving patients receiving conventional LSG care (non-ERAS) ($n=50$) and those receiving ERAS protocol ($n=44$) at International Medical Centre, Jeddah, Saudi Arabia. The ERAS protocol consisted of preoperative, intraoperative, and postoperative components, including patient education, fluid management, early mobilization, and pain management. Outcomes were compared between the two groups in terms of length of stay, postoperative ambulation, Clavien-Dindo graded postoperative complications, 30-day readmission, mortality and healthcare costs, followed by a five-year follow-up.

Results In total the number of participants was 94 patients. The ERAS group had a slightly shorter length of stay (2.05 days vs. 2.20 days) and significantly lower healthcare costs (SAR43,337 vs. SAR46,040, $p<0.05$) compared to the non-ERAS group. The ERAS group had a lower incidence of postoperative Clavien-Dindo-graded complications, including wound infection, atelectasis, and pneumonia. The total length of the surgical procedure did not differ significantly ($p<0.05$). Remarkably, 100% of patients in the ERAS group were out-of-bed on postoperative day (POD) zero compared to only 25% in the non-ERAS group. On the day of the operation, a greater percentage of patients in the ERAS group (58%) began oral intake than in the conventional care group (42%). There were no observable statistical differences in analgesic benefits in both groups ($p=0.543$), 6 h after discharge from the post-anaesthesia care unit and at POD 1 ($p=0.08$). At 5-year follow-up, the ERAS group had a better prognosis with fewer complications. At 5-year

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follow-up, a higher percentage of the ERAS group did not report any complication compared to the non-ERAS group (61% vs. 51%).

Conclusion Implementation of ERAS in LSG improved postoperative outcomes, including shorter length of stay, better mobilization, lower healthcare costs, and fewer complications. This demonstrates the effectiveness of ERAS in LSG and provides valuable insights for improving perioperative bariatric care practices.

Keywords ERAS, Laparoscopic sleeve gastrectomy, Perioperative outcomes, Length of hospitalization, Cost-effectiveness

Introduction

Obesity (defined as Body Mass Index ≥ 30 kg/m^2) affects over 2 billion persons worldwide [1], and has an estimated prevalence above the global average in Saudi Arabia [2]. Following the projections of the World Obesity Federation, obesity is predicted to have caused a 4.4% loss in Gross Domestic Product in Saudi Arabia in 2016 and gulped up to 13.6% of all healthcare costs in the Eastern Mediterranean region [2]. The negative effects of obesity on the quality of life and economy have prompted the creation of a wide range of weight-loss treatments, including behavioural, pharmaceutical, and surgical options [3]. Currently, the only treatment that effectively reduces body weight in a noticeable and long-lasting way is bariatric surgery that includes Laparoscopic Sleeve Gastrectomy (LSG) [3–6]. While bariatric surgery is the most successful obesity treatment, it is also the most intrusive because of the perioperative risks associated with the actual procedure, such as recovery after general anaesthesia [7]. Moreover, there have been perioperative safety concerns associated with all bariatric surgeries as they have become increasingly common [8].

Enhanced recovery after surgery (ERAS), was first discussed by Fearon et al. in 2005 [9]. It is a multimodal system that involves all three stages of perioperative care: the preoperative, intraoperative, and postoperative period of surgeries. It integrates evidence-based methods that minimize postoperative complications and accelerate recovery in patients undergoing surgery [8, 9]. ERAS includes patient education, proper fluid management, shorter fasting time, early mobilization, replacing opioids analgesia, and reducing the use of tubes [5, 10, 11].

The long-term treatment of obesity and obesity-related morbidity can be achieved with minimally invasive, safe, and successful bariatric surgery, such as laparoscopic sleeve gastrectomy (LSG) [12, 13]. The deployment of standardised ERAS pathways becomes crucial as the prevalence of LSG continues to rise in Saudi Arabia. However, the paucity of data on the application of ERAS in LSG specifically in Jeddah, Saudi Arabia, underscores the importance of conducting comprehensive research to evaluate its efficacy and outcomes. This project is considered the first to implement ERAS in LSG and to perform a 5-year follow-up in Jeddah-Saudi Arabia. Therefore, this study was geared towards implementing the ERAS protocol among patients undergoing LSG with the goal of improving postoperative outcomes. We further hypothesized that the application of the ERAS project would be pharmacoeconomically viable compared to the conventional LSG.

Methods

Study design

This is an open-label prospective cohort study in which the study population included the ERAS and non-ERAS groups. Initially, LSG was conducted for 4 months duration using conventional bariatric protocol (non-ERAS). Thereafter, the ERAS multidisciplinary team was educated through a series of intensive ERAS training sessions followed by ERAS protocol implementation (ERAS group) for another 4 months.

Study settings/participants

The enrolled study population includes bariatric surgical patients admitted for an elective LSG between 2017 and 2018 in the surgical inpatient ward, surgical clinic, and pre-anaesthesia clinic of the International Medical Centre, Jeddah, Kingdom of Saudi Arabia. The inclusion criteria included adult patients (≥ 18 years) undergoing LSG in the centre. Obese patients with Body Mass Index (BMI) > 35 kg/m^2 having comorbid conditions such as Type 2 diabetes mellitus, hypertension, and obstructive sleep apnoea were included. The exclusion criteria include reoperations (during the same admission or within 30 days), and renal impairment (elevated creatinine level; normal levels: 0.6 to 1.2 mg/dL, in adult males and 0.5 to 1.1 mg/dL in adult females). Patients with cardiac diseases (including, ischemic heart disease, arrhythmia, valvular heart disease) and those with uncontrolled diabetes mellitus (HbA1c values > 9%, NCQA data, Comprehensive Diabetes care, 2008). Patients with anaemia (defined as a haemoglobin level of less than 13 g/dL in men and less than 12 g/dL in women), were also excluded.

Opportunity sampling, in which research participants are chosen according to their availability at the time of study, was used. A total of 50 and 44 patients for the

non-ERAS and ERAS groups respectively, were available for enrolment at the point of the study.

Variables

The ERAS group and the conventional care group were compared with respect to demographics, comorbidities, operating data, postoperative length of stay, 30-day postoperative complications, and 30-day postoperative readmission. The number of nights stayed in the hospital following surgery was denoted as the length of stay (LOS). Clavien-Dindo classification was used to grade the complications.

Implementing ERAS guidelines

ERAS protocol implementation requires a multidisciplinary collaboration between various stakeholders (surgeons, anaesthesiologists, nurses, nutritionists, pharmacists, physical therapists, patient educators, and administrative staff). Rigorous professional education to get all team members well acquainted with the novel care provided in the facility. The anticipated positive outcomes of the ERAS protocol were emphasized and full cooperation, understanding, and adherence to the standards were sought from all personnel. The hospital management assisted in organizing the human and material resources necessary to implement the ERAS protocol. Furthermore, auditing was implemented for monitoring and evaluation purposes on the ERAS protocol compliance level.

The ERAS protocol includes the preoperative, intraoperative, and postoperative phases. The details of the guidelines had been presented elsewhere [5, 8, 10, 11, 14]. However, peculiar synopses relevant to this study are summarized in Table 1.

Statistical analysis

Clinical data was collected by the surgeon and nurses caring for each patient using a predesigned scoresheet which was then transferred into a Microsoft Excel Spreadsheet®. The data was exported to JMP statistical analysis software (version 17) and the outcomes of the ERAS program were compared with those of conventional care (non-ERAS). Kolmogorov–Smirnov test was conducted to check for normality of data. A comparison of outcomes was made using an independent sample *t*-test for normally distributed continuous dependent variables. Mann-Whitney U test was used for non-normally distributed continuous outcomes. Pearson Chi-squared (χ^2) or Fisher's exact tests were used for categorical outcomes. The result was summarized descriptively as frequencies and percentages for categorical variables. Continuous data was presented as mean or median with their respective standard deviation or interquartile range, respectively. Differences were considered significant for *p*-values < 0.05.

Results

Demographic characteristics

A total of 94 patients were recruited into the study. Standard care (non-ERAS) was provided to 50 patients, while the ERAS protocol was implemented in 44 patients. Both cohorts were comparable in terms of age and gender. The majority of the patients belong to the class 3 (≥ 40 Kg/m^2) BMI classification comprising of 19.1% and 34.1% from the non-ERAS and ERAS groups, respectively (Table 3). The remainder constitutes a few patients with Class 1 BMI classification.

Implementation of ERAS protocol

The tripartite multimodal protocol of preoperative, intraoperative, and postoperative components was successfully implemented in all patients belonging to the ERAS group. The implementation rates of the preoperative phase elements were 100% in the ERAS group with a statistically significant difference ($p < 0.001$) compared to those in the non-ERAS group (Table 4). In all the reported intraoperative elements, the rate of implementation of ERAS elements differed significantly across the two groups. However, the implementation of bariatric medication protocol and TAP blockade were not significantly different ($p > 0.05$). While compliance with the ERAS protocol was 100% in the postoperative component, some elements such as mobilization on POD 0 were not optimal (47.7% in the ERAS group), but still statistically significant compared to the conventional group.

It should be noted that there was a substantial decrease in the volume of intraoperative IVF utilized (Table 4). Controlled IVF use was obtained only in 4.5% of the non-ERAS patients which drastically contrasts the ERAS patients where full control of IVF was implemented. Similarly, there was a remarkable difference in the intraoperative and postoperative opioids.

Primary and secondary outcomes

The median length of hospital stay (LOS) was 2.05 in the ERAS group compared to 2.20 days in the non-ERAS care group (Fig. 1). In at least 13 patients in the non-ERAS group the LOS was at least 3 days which is in contrast to the ERAS group where only 4 patients had LOS above the group median. The run chart indicated a consistent trend in the plot pointing to the significance of the ERAS intervention over conventional care in the reduction of LOS (Fig. 2).

The cost of the intervention differed significantly across the two groups (Fig. 3). The ERAS group had a median cost of Saudi Riyal (SAR) 43,337 compared to SAR 46,040 in the non-ERAS group and IQR of SAR10636 and SAR15843, respectively. Considering the 3rd quartiles of the distribution it could be deduced that over 75% of the patients in the ERAS group spent SAR 43,763 compared

Table 1 Summary of enhanced recovery after surgery (ERAS) and conventional care protocols applied in the study

Perioperative phase	ERAS	Non-ERAS
Type of care/ protocol (Nomenclature)	Enhanced Recovery After Surgery (ERAS)	Conventional/standard care (non-ERAS)
Preoperative	Preoperative information, education, and counselling	Basic patient education
	- Carbohydrate loading (2 packs of 237 ml Resource Breeze Tetra Pack) administered 4 h before anaesthesia	- Placebo drink (bottle of water at night and 2–4 h prior to OR) - Discussion on what to expect on OR day and post-op.
	- Smoking cessation plan (at least 4 weeks to surgery) - Nutritional assessment - Preoperative physical activity	- Smoking cessation 4 weeks preoperatively - Nutritionist visit
	- Antipyretic (PO paracetamol 1000 mg, Stat) and analgesic (PO gabapentin 600 mg Stat) < 2 h before the surgery, and antiemetic (IV ondansetron 4 mg Stat)	-No preoperative medications.
	- Diabetes/pre-diabetes screening/test - Screening for risks of hyperglycaemia using the Centre for Disease Control prediabetes screening score - Fasting blood sugar and/or glucose tolerance tests - Referral of patients with evidence of diabetes or prediabetes to the endocrinology clinic	- Glycemic control
Intraoperative	- Normothermia - Bair-Hugger temperature management - Maintain operating room temperature at > 21 °C - Maintain intravenous fluids at operating body temperature	- Active warming - Operating room air conditioning maintained at 18 °C
	- Controlled intraoperative intravenous infusion (IVF) management	- No limitation on Intravenous Infusion (IVF)
	- Avoidance of tubes (nasogastric tubes)	
	- Transversus Abdominus Plane (TAP) block directed for postoperative pain management (POPM) - Standardized anaesthesia protocol (See Table 2)	- Intra-operative abdominal infiltration by 80 cc 0.25% Marcaine - IV Fentanyl 25 mcg PRN (2–3 times) in PACU for breakthrough pain
Postoperative	- POPM: Replace opioids with selective cyclooxygenase-2 inhibitor	- POPM: IV Acetaminophen 1000 mg/6 h around the clock. Not to exceed 4 g/24 h. - Tramadol 50 mg IV PRN q6hrs – moderate to severe pain (VAS 6–10). Use with caution in patients with a seizure history. - IV Ondansetron 4 mg q6 hrs as routine.
	- Early postoperative ambulation on postoperative day zero (POD 0) 4 h after recovery from general anaesthesia	Postoperative Day1 (POD 1) patient education about wound care, precautions, mobilization, spirometer use, anticoagulant, nutritionist visit
	- Adequate patient counselling on hourly postoperative incentive spirometer use	

Stat: immediately, PO: per oral, POD: postoperative day, POM: postoperative medication, PACU: postanesthesia care unit

Table 2 Anesthesia protocol for laparoscopic sleeve gastrectomy

Induction	Maintenance
- IV Fentanyl 100 mcg - IV Propofol titrated dose to attain BIS between 40 to 60 - IV Rocuronium 1 mg/kg (IBW) - Preincision IV Dexamethasone 8 mg (if diabetic or body weight < 100 kg) or 16 mg (if non-diabetic or body weight > 100 kg give 16 mg) - Preincision IV Lidocaine 1.5 mg/kg (IBW) - Preincision IV Ketamine bolus 0.25 mg/kg (IBW)	- Desflurane titrated to keep BIS between 40 and 60 - Rocuronium bolus to keep TOF count 1 - Ondansetron 4 mg IV 30 min (before the end of surgery) - No intraoperative opioids - Dexmedetomidine infusion 0.5- 1 mcg/kg/h (IBW) adapt to HR/MAP - Ketamine infusion 0.125–0.25 mg/kg/h (IBW) (added to dexmedetomidine) - Lidocaine infusion 1.5- 3 mg/kg/h (IBW) added to dexmedetomidine)

IV: Intravenous, BIS: Bispectral Index, TOF: Train of Four ratios, IBW: Ideal Body Weight

Table 3 Demographic description and baseline preoperative body mass index

Variable	Variable	Non-ERAS ($n=50$)	ERAS ($n=44$)	*p*-value
Age (years)*	Age (years)*	34 (12)	36 (12)	0.350[+]
Gender**	Female	31 (62)	27 (61.4)	0.950[‡]
	Male	19 (38)	17 (38.6)	
BMI category**	Class 2 (35 to < 40 Kg/m^2)	9 (19.1)	15 (34.1)	0.106[‡]
	Class 3 (≥ 40 Kg/m^2)	38 (80.9)	29 (65.9)	

* Mean (standard deviation), BMI: Body mass index. **Gender and BMI categories were presented as frequencies with their percentages in parentheses.[+]Independent sample test, [‡]Fisher exact test (cell count < 5)

Table 4 Perioperative components and implementation rates in ERAS and non-ERAS groups

ERAS item, *n* (%)	Non-ERAS ($n=50$)	ERAS group ($n=44$)	*p*-value
Preoperative phase			
Education and counselling	43 (91.49)	44 (100)	0.019[‡]
Preoperative referral (Nutrition)	50 (100)	44 (100)	
Preoperative referral (Endocrine)	33 (66)	44 (100)	< 0.001*
Preoperative referral (Psychiatry)	46 (92)	44 (100)	0.022*
ERAS bag received	0 (0)	44 (100)	< 0.0001[‡]
Preoperativemedication (PO Paracetamol 1 g stat; Gabapentin 600 mg stat)	8 (16)	44 (100)	< 0.0001
Preoperative warming (Normothermia)	7 (14)	44 (100)	< 0.0001*
Preoperative carbohydrate intake (2–4 h before LSG)	0 (0)	44 (100)	< 0.0001*
Preoperative water intake (2–4 h before LSG)	27 (54)	0 (0)	< 0.0001*
Incentive spirometer	6 (12)	44 (100)	< 0.0001*
Physical activity at home	8 (16)	44 (100)	< 0.0001*
Preoperative blood sugar control (Bedside Accu-Chek)	24 (48)	44 (1000	< 0.0001*
Intraoperative phase			
Bair Hugger temperature management, IVF warming	27 (55.1)	44 (100)	< 0.0001
Theatre room temperature > 21 °C	14 (28.6)	44 (100)	< 0.0001
Free use of nasogastric tube	37 (80.4)	0	< 0.0001*
Controlled IVF use	2 (4.5)	44 (100)	< 0.0001*
Bariatric medication protocol	45 (97.8)	44 (100)	0.325
Transversus abdominis plane block	47 (95.92)	44 (100)	0.175*
Intraoperative medication used	49 (100)	0	< 0.0001*
Postoperative phase			
Mobilization on POD 0	11 (22)	21 (47.7)	0.007
Opioid sparing analgesics	0	44 (100)	< 0.0001*

ERAS: Enhanced Recovery After Surgery, ERAS-implemented laparoscopic sleeve gastrectomy, Non-ERAS-implemented laparoscopic sleeve gastrectomy, ‡Pearson χ^2-test, *Fisher exact test (cell count < 5), LSG: Laparoscopic sleeve gastrectomy

to SAR 59,059 in the non-ERAS patients. Similarly, a comparison of the 1st quartile indicated that at least 25% of patients in the ERAS group, spent SAR 3312 compared to SAR 43,216 in the non-ERAS patients. The maximum cost of intervention ever attained during the study by any patient from the ERAS group was SAR 55,792, while in the non-ERAS group up to SAR 90,943 was paid by one patient.

The length of the surgical procedure appeared to be equivalent in both patient groups ($p > 0.05$). With regards to post-operative discharge, none of the patients from the non-ERAS group was discharged on POD 1. Contrarily, there were 36 (81.82%) discharges on POD 1 from the ERAS group (Table 5). This could be directly attributable to insufficient tolerance for a clear liquid diet, insufficient pain management, prolonged observation for obstructive sleep apnoea, and other potential postoperative complications that prolong hospital stay.

On the day of the operation, a greater percentage of patients in the ERAS group (58%) began oral intake than in the standard care group (42%). Also, 100% of patients in the ERAS group were out-of-bed on POD 0 compared to only 25% in the non-ERAS group. However, postoperative nausea and vomiting manifest in both groups on the same day. Even on POD 1 and 2, the prognosis was statistically better in the non-ERAS group compared to the patients on ERAS protocol. Furthermore, the time to first flatus occurred in POD 1 in all ERAS-based patients relative to only 6% in the counter group (Table 5).

There were no observable statistical differences in analgesic benefits in both groups ($p = 0.543$), 6 h after discharge from PACU and at POD 1 ($p = 0.08$). Similarly,

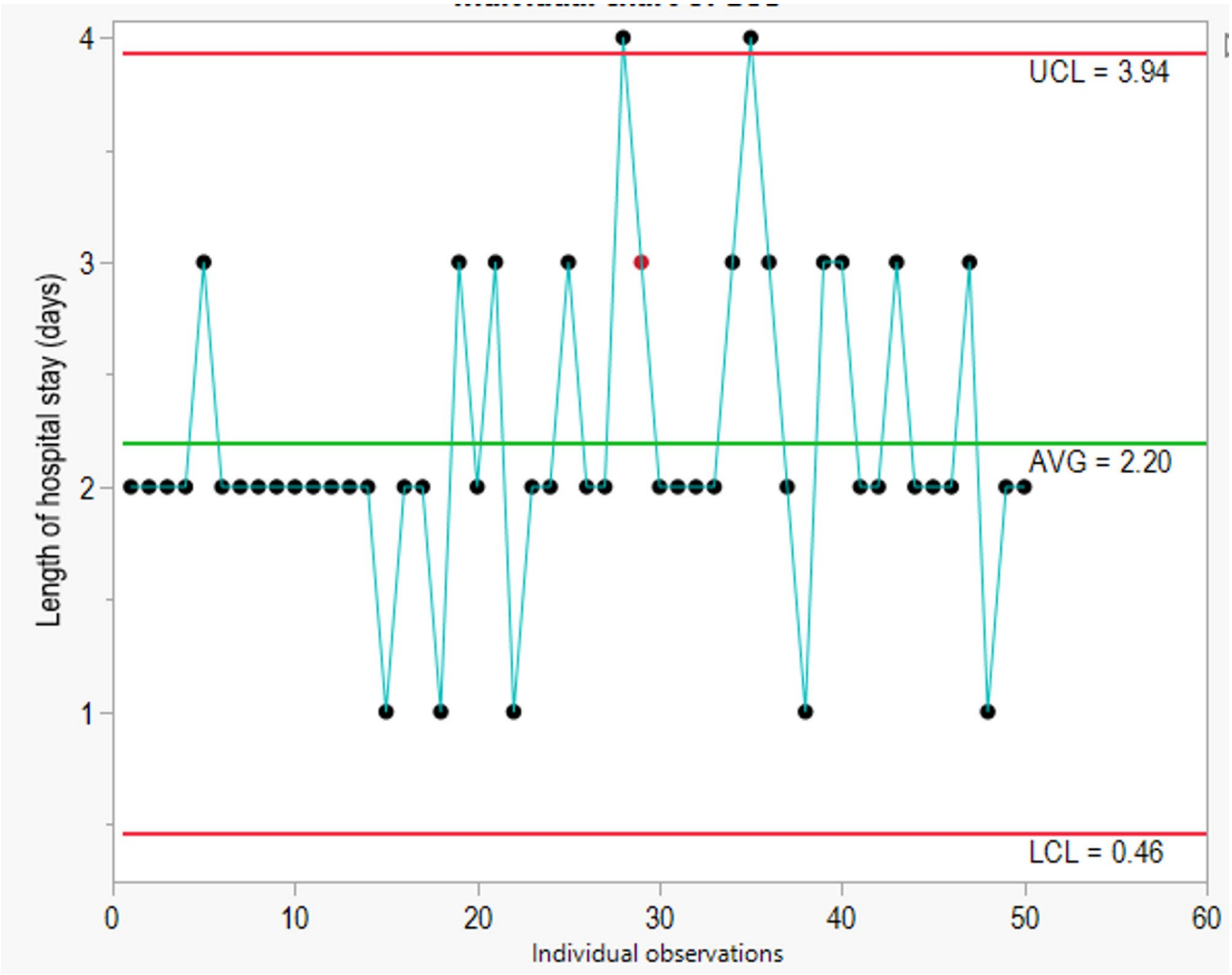

Fig. 1 Run chart indicating the length of hospital stay in the non-ERAS. LCL: Lower control limit, UCL: Upper control limit

the differences in pain scores at POD 1 and 2 were not statistically significant. Thus, the analgesic regimens of the ERAS protocol were not superior to the non-ERAS (Table 6). However, the aversion of possible opioid side effects has obviously manifested as better recovery rates in the ERAS group.

Generally, the ERAS group was associated with a lower incidence of postoperative complications. There were 2 patients with wound infection in both groups. Atelectasis/pneumonia occurred in up to 10 cases in the non-ERAS group but appeared in only 3 patients of the ERAS group. One patient was readmitted in 30 days from the non-ERAS group. In both groups, there were no mortality and no reoperation (Table 7).

After 5 years of follow-up, up to 61% of patients in the ERAS group exhibited a better prognosis with no complications. Conversely, 51% in the non-ERAS group had no complications. Weight regains and reflux occurred in 6 and 10 patients from the ERAS group compared to 5 and 13 in the non-ERAS group, respectively. Combined complications including anaemia/reflux, weight regain/reflux, and weight regain/anaemia occurred more frequently in non-ERAS relative to ERAS patients, (Table 8). Compliance rates to bariatric diet and regular follow-up were similar in both groups, while the ERAS arm displayed statistically significant compliance rates to exercise (Table 9).

Discussion

For the first time, the ERAS protocol was implemented in Jeddah, Kingdom of Saudi Arabia to compare the impact of the fastrack model on outcomes of laparoscopic sleeve gastrectomy against the conventional elective bariatric surgical care. A 5-year follow-up study was also conducted to evaluate long-term prognosis. The ERAS group and the conventional care group were compared with respect to demographics, operating data, postoperative LOS, 30-day postoperative complications, and 30-day postoperative readmissions. Clavien-Dindo classification was used to grade the complications.

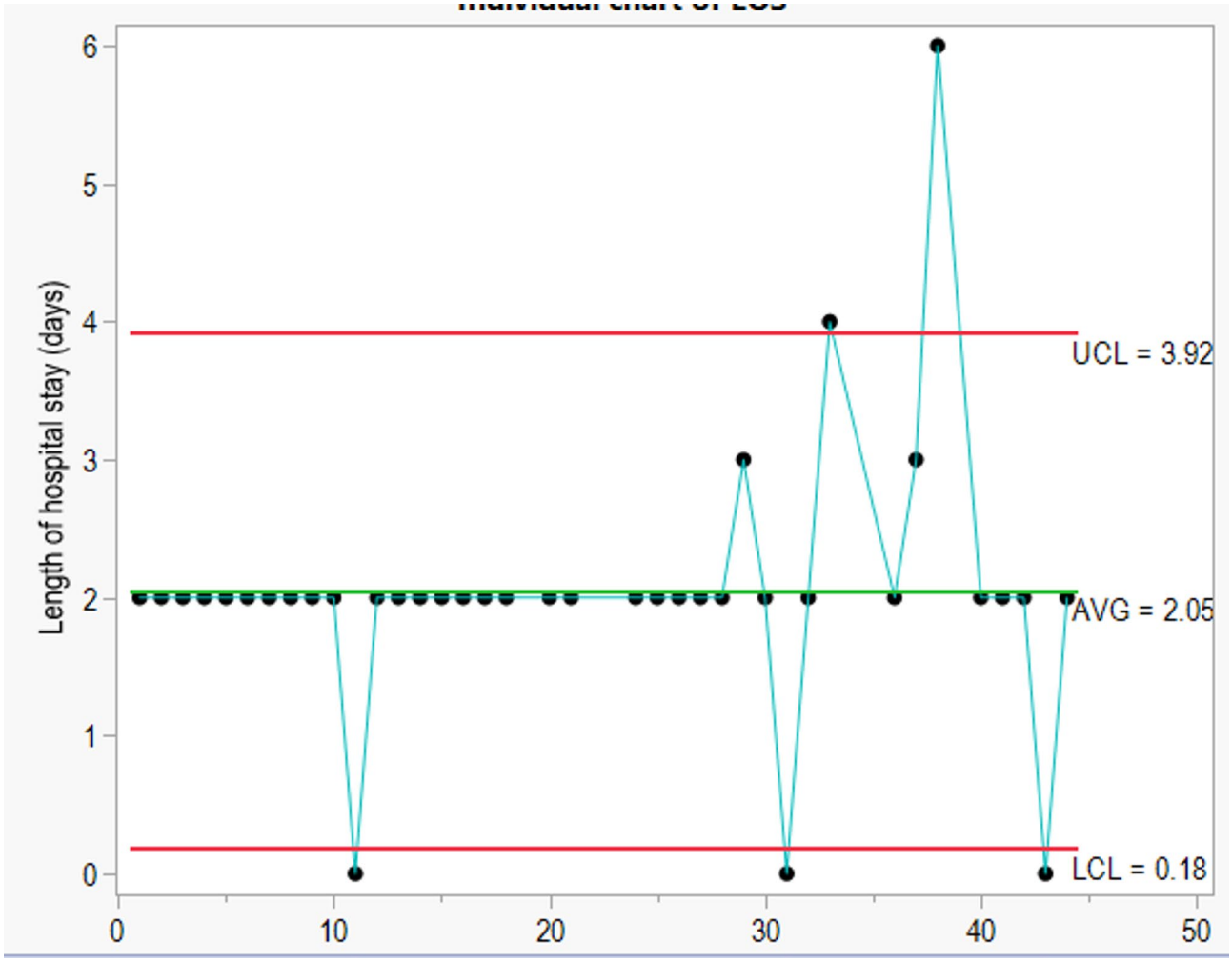

Fig. 2 Run chart indicating the length of hospital stay in the ERAS group. LCL: Lower control limit, UCL: Upper control limit

Our study has indicated that ERAS was associated with 81.82% of discharge at POD 1 compared to zero discharge from the non-ERAS group. Other studies examined the safety of early discharge on POD 1 following bariatric surgery with LSG and found that it was safe and practical without increasing the risk of problems or readmissions, thus corroborating our findings. We discovered that 38 patients began oral intake on POD 0. Despite suboptimal mobilization, all ERAS patients were out-of-bed on POD 0 against 50% in the non-ERAS group, hence corroborating earlier findings byYalcin et al. [8]. Moreover, our findings add to the increasing amount of data demonstrating the safety of ERAS protocols in bariatric surgery. Between the non-ERAS and the ERAS groups, there was a non-significant increase in Clavien-Dindo IIIa or higher complications.

Our study revealed a median length of hospital stay (LOS) was 2.05 in the ERAS group compared to 2.20 days in the non-ERAS care group. In at least 13 patients in the non-ERAS group the LOS was at least 3 days. Moreover, the median cost of the surgical expenditure was SAR 43,337 (IQR: 10636) in the ERAS patients compared to SAR 46,040 (IQR: 15843) in the non-ERAS group. Our study thus aligns with an earlier study conducted by Taylor et al. that reported a LOS-associated decrease in the median cost per bariatric surgical case of over $2500, and an annual net institutional savings of $800,000 [13]. Stone et al. further reported an annual net savings of $400,000 associated with a reduction of LOS by 0.7 days at their medical facility [15].

Enhanced recovery after surgery (ERAS) is an evidenced-based clinical pathway proposed to improve the outcome and accelerate recovery after surgery [8, 9, 14]. The outcomes of these protocols were found to provide shorter hospitalisation, decrease perioperative complications, reduce medical costs, and furnish consistent outcomes [9, 16]. ERAS has been found to reduce major complications after abdominal surgery by about 40%. It also allows for faster patient recovery and reduces the

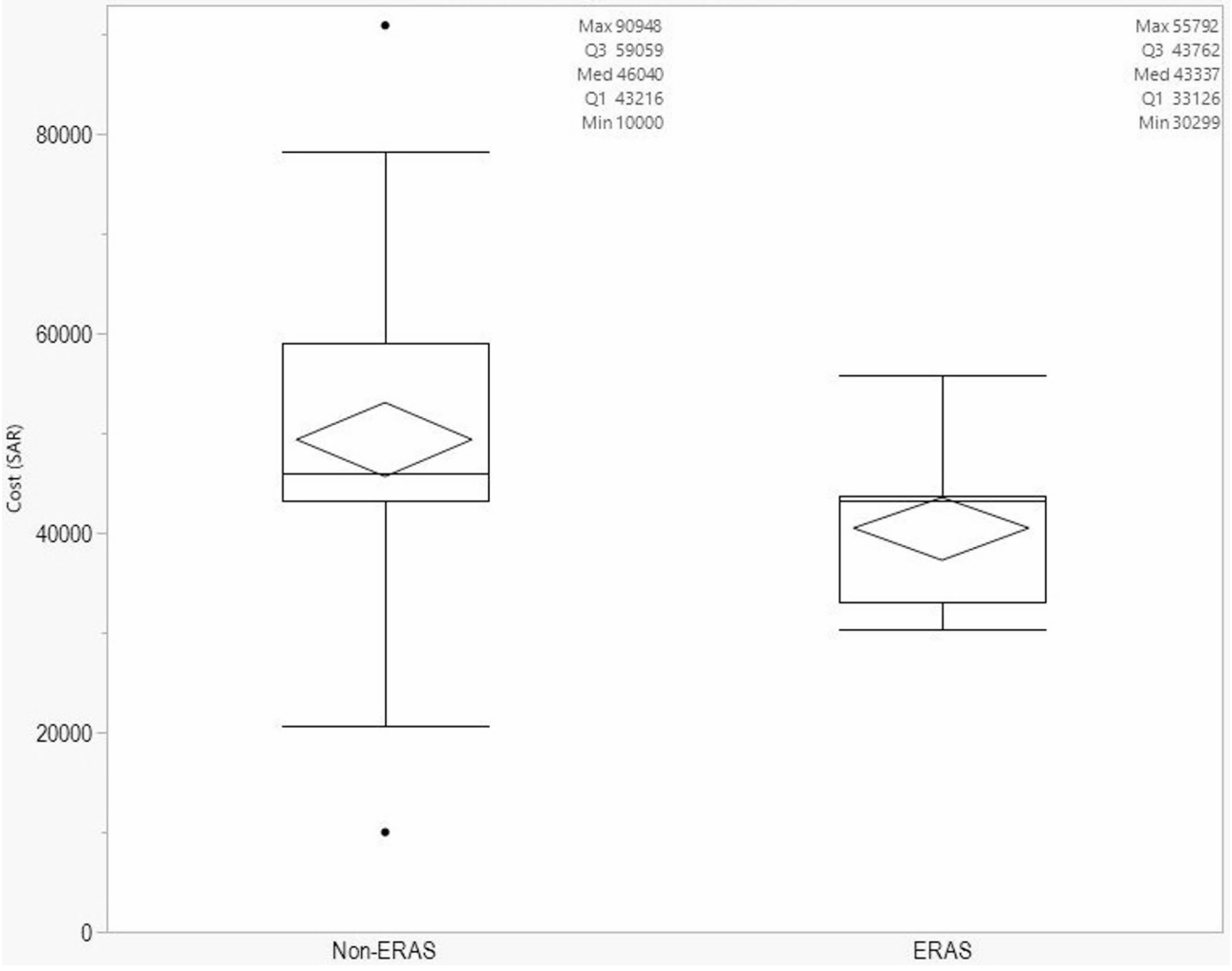

Fig. 3 Comparison of cost distribution of laparoscopic sleeve gastrectomy in the conventional surgical model (non-ERAS) and following implementation of enhanced recovery after surgery (ERAS) protocol. SAR: Saudi Arabia Riyal, Q1: Lower Quartile, Q3: Upper Quartile

Table 5 Postoperative pain outcomes between conventional and ERAS groups

ERAS item, *n* (%)	Non-ERAS (*n* = 50)	ERAS group (*n* = 44)	*p*-value
Total surgical procedure time (hour)	2.14 (0.67)	2.27 (0.52)	> 0.05
Discharge at POD 1	0	36 (81.82)	< 0.0001*
First oral intake			
POD 0	27 (41.54)	38 (58.46)	0.0007‡
POD 1	23 (79.31)	6 (20.69)	
Out-of-bed			
POD 0	25 (50)	44 (100)	< 0.0001*
POD 1	25 (50)	0	< 0.0001
Time to first flatus			
POD 1	3 (6)	44 (100)	< 0.0001*
POD 2	47 (94)	0	< 0.0001*
Postoperative nausea and vomiting			
POD 0	50 (100)	44 (100)	0.05*
POD 1	38 (76)	24 (54.55)	0.029*
POD 2	27 (54)	12 (27.27)	0.008*

ERAS: Enhanced Recovery After Surgery, ERAS-implemented laparoscopic sleeve gastrectomy, non-ERAS-implemented laparoscopic sleeve gastrectomy, Postoperative day, ‡Pearson χ^2 test, *Fisher exact test, LSG: Laparoscopic sleeve gastrectomy, [a]Interquartile range, [b]Mann-Whiteney U test, SAR: Saudi Riyal

Table 6 Comparison of postoperative pain outcomes

Time	Pain score	Non-ERAS (*n* = 50)	ERAS group (*n* = 44)	*p*-value
6 h following discharge from post-anaesthesia care unit	4	2 (4)	5 (11.36)	0.543‡
	5	15 (30)	13 (29.55)	
	6	12 (24)	7 (15.91)	
	7	10 (20)	8 (18.18)	
	8	4 (8)	6 (13.64)	
	9	5 (10)	5 (11.36)	
	10	2 (4)	0	
Postoperative day (POD) 1 at 8 am	1	4 (8)	6 (13.6)	0.081‡
	2	10 (20)	15 (34.09)	
	3	13 (26)	7 (15.910)	
	4	6 (12)	8 (18.18)	
	5	4 (8)	4 (9.09)	
	6	5 (10)	3 (6.82)	
	7	8 (16)	0	
	8	0	1 (1.06)	
Postoperative day (POD) 2 at 8 am	1	18 (36)	28 (63.64)	0.056
	2	23 (46)	12 (27.27)	
	3	8 (16)	3 (6.82)	
	4	1 (2)	1 (2.270)	

ERAS: Enhanced Recovery After Surgery, ERAS-implemented laparoscopic sleeve gastrectomy. Non-ERAS-implemented laparoscopic sleeve gastrectomy, POD: Postoperative day, ‡Pearson χ^2 test, *Fisher exact test, LSG: Laparoscopic sleeve gastrectomy

Table 7 Comparison of postoperative Clavien-Dindo complications 30-days complications, readmission, reoperation, and mortality rate between conventional and ERAS groups

Complication	Non-ERAS (*n* = 50)	ERAS group (*n* = 44)	*p*-value
Deep vein thrombosis	1 (2)	0	0.346*
Atelectasis/Pneumonia	10 (20)	3 (6.82)	0.064*
Pulmonary embolism	0	0	-
Failed weight loss	8 (16)	0	0.006
Reflux	11 (22)	0	0.007
Wound infection	2 (4)	2 (4.55)	0.738*
30-day readmission	1 (2)	0	0.532
Reoperation	0	0	-
Mortality	0	0	-

ERAS: Enhanced Recovery After Surgery, ERAS-implemented laparoscopic sleeve gastrectomy, non-ERAS-implemented laparoscopic sleeve gastrectomy, Postoperative day, ‡Pearson χ^2 test, *Fisher exact test, LSG: Laparoscopic sleeve gastrectomy

Table 8 Comparison of Clavien-Dindo complications 5 years after follow-up

Complication	Non-ERAS (*n* = 50)	ERAS group (*n* = 44)	*p*-value
None	23 (51.11)	27 (61.36)	0.579*
Reflux	13 (28.89)	10 (22.73)	
Combined reflux and anaemia	1 (2.22)	0	
Weight regain	5 (11.11)	6 (13.64)	
Combined weight regain and reflux	2 (4.44)	0	
Combined weight regain and anaemia	1 (2.22)	1 (2.27)	

ERAS: Enhanced Recovery After Surgery, ERAS-implemented laparoscopic sleeve gastrectomy, non-ERAS-implemented laparoscopic sleeve gastrectomy, ‡Pearson χ^2 test, *Fisher exact test, LSG: Laparoscopic sleeve gastrectomy

LOS (length of stay) by about 30% or by more than 2 days after major abdominal surgery [17, 18].

The success of the ERAS group in improving postoperative outcomes could be attributed to the multimodal perioperative strategies. For instance, in the preoperative carbohydrate loading, Smith et al. had earlier found that preoperative administration of carbohydrate treatment reduced LOS when compared with placebo or fasting in patients undergoing elective surgery. Moreover, the lower incidence of postoperative complications could be partially ascribed to the implemented smoking cessation plan. Furthermore, preoperative exercise therapy

Table 9 Comparison of compliance to exercise, diet, and follow-ups after 5 years between conventional and ERAS groups

Compliance	Non-ERAS ($n=50$)	ERAS group ($n=44$)	p-value‡
Exercise	10 (22.22)	18 (40.91)	0.047
Diet	23 (51.11)	30 (68.18)	0.100
Follow-ups	13 (28.89)	21 (47.73)	0.067

‡Pearson χ^2 test, ERAS: Enhanced Recovery After Surgery, ERAS-implemented laparoscopic sleeve gastrectomy, non-ERAS-implemented laparoscopic sleeve gastrectomy

was also found to be effective in decreasing postoperative complications and LOS following abdominal or cardiac surgeries, which also likely impacted the outcomes of the study. Thus, the use of an incentive spirometer was believed to have contributed to postoperative recovery via restoration of lung physiology. Our study was thus supported by Kundra et al. who linked frequent preoperative utilization of spirometer to better postoperative restoration of lung function.

Perioperative hyperglycaemia was associated with adverse outcomes following a general surgery regardless of the history of diabetes mellitus. Literature has also shown that hyperglycaemia doubles the risk of surgical site infection (SSI) [6]. In our study, only 2 patients in the ERAS group (also 2 in the non-ERAS group) developed SSI. This positive outcome was secondary to comprehensive preoperative glycemic control. ERAS patients with evidence of prediabetes were referred to the endocrinology clinic for proper screening, adequate counselling and optimal glycemic control to minimize the risk of SSI.

Administration of paracetamol (1000 mg, PO, STAT) and gabapentin (600 mg, PO, STAT) 2 h before surgery had been anticipated to cause a reduction in postoperative pain and opioid use [5]. However, there were no statistically significant differences between ERAS and non-ERAS in the pain scores 6 h after discharge from PACU ($p=0.543$). Yet, more episodes of nausea were reported in the non-ERAS group, for which ondansetron 4 mg, IV, STAT was added. The minimal side effects of gabapentin and minimal time to reach the peak plasma level (~3 h), made it a useful part of multimodal analgesic therapy resulting in an opioid-sparing effect of up to 60% for a single preoperative dose in 24 h following administration [5, 19, 20].

The pathophysiology of obesity predisposes patients to a greater risk of postoperative morbidity and delayed recovery secondary to venous thromboembolic (VTE) and pulmonary complications [3]. Consequently, early postoperative ambulation constitutes a crucial preventive modality for these complications [21–24]. Thus, the institution of optimal perioperative analgesia regimens has been shown to reduce these complications by strengthening early postoperative ambulation in ERAS-based surgery. Since minimal opioid analgesia is advocated, a multimodal analgesic strategy is recommended for optimal analgesia. In line with this, the Transversus Abdominus Plane (TAP) block (TAP block) provides a safe unfluctuating analgesic effect [25]. A study by McDonnell and colleagues reported highly effective postoperative analgesia after the TAP block in the first 24 h following a major abdominal surgery [26]. By deploying TAP blockage numerous visceral afferent pathways could be blocked to obtain adequate and sustained pain control with little or no need for supplementation with opioid analgesics. Hence, easier mobility and better postoperative prognosis were obtained.

Furthermore, the routine use of nasogastric tubes was completely avoided in the ERAS group. Another greatly enhanced concept in our investigation was goal-directed IV hydration treatment in perioperative care. Conservative IV fluid regimes, which prevent fluid overload with no difference in intraoperative urine output are strongly advised over a liberal approach by evidence-based ERAS guidelines for bariatric surgery. It has been stated that following major abdominal surgery, a goal-directed fluid therapy protocol based on limited intravenous fluid (IVF) administration using various hemodynamic parameters could reduce postoperative morbidity and shorten the LOS. In the ERAS group, a significant reduction in the volume of IVF was recorded relative to the conventional group. The reported resultant effect is the reduction in postoperative ileus [11].

Five years after follow-up, the ERAS group displayed better compliance to exercise than the non-ERAS group ($p<0.05$), while the compliance rates to bariatric diet, and regular follow-up were not statistically appreciable in both groups. This might likely explain the motive for the weight regain in 5 and 6 patients belonging to the non-ERAS and ERAS groups, respectively. It should be highlighted that although lifestyle modifications are advised in all bariatric surgeries, they are challenging to incorporate into conventional care practices and have little long-term effectiveness, mostly because of low adherence [27]. Thus, further efforts are recommended to sustain the long-term clinical effectiveness of ERAS in LSG.

Our findings have suggested that ERAS protocols optimized postoperative care, improved recovery, and reduced some complications. However, their impact on postoperative gastroesophageal reflux disease (GERD) symptoms after LSG remains of significant interest. Our findings suggest that ERAS pathways may exert distinct influences on reflux outcomes compared to conventional postoperative management. Given the underlying findings, we hypothesized ERAS-specific mechanisms to explain this concern. Firstly, the implemented early oral intake protocols emphasize early resumption of oral fluids and nutrition. In the immediate postoperative period following LSG, particularly POD 0 and POD 1, the gastric sleeve is still inflamed and oedematous. Early fluid intake

could likely overpower the lower esophageal sphincter (LES) increasing intragastric pressure, thus promoting gastroesophageal reflux. In contrast, the conventional care typically had delayed oral intake, allowing more time for oedema to subside and the sleeve to adapt, possibly reducing early reflux episodes.

Secondly, accelerated mobilization induces intra-abdominal pressure changes augmenting the risk for reflux. In addition, although the implemented ERAS protocol had prevented thromboembolism, the increased physical activity immediately following LSG could transiently elevate intra-abdominal pressure. This pressure gradient between the abdomen and the thoracic cavity could exacerbate reflux, especially in the highly vulnerable early healing phase. Moreover, ERAS aims to reduce surgical stress through comprehensive care pathways geared towards reducing bariatriac surgical stress. Counterintuitively, the rapid transitions and expectations associated with early mobilization and discharge could induce stress-related alterations in autonomic nervous system function. This could in turn impair gastric motility, thereby promoting reflux. In addition, ERAS protocols discourage routine nasogastric decompression to minimize discomfort and accelerate recovery. However, the absence of gastric decompression may allow accumulation of secretions and gas, leading to gastric overdistension and functional outflow resistance at the gastroesophageal junction, thus promoting reflux.

ERAS promotes multimodal, opioid-sparing analgesia. Reliance on nonsteroidal anti-inflammatory drugs could cause gastric mucosal irritation, possibly compounding reflux symptoms. On the other hand, minimizing opioids use decreases risks of ileus and respiratory depression, it could also remove the LES tone-increasing effect that opioids can exert. Moreover, early postoperative dietary progression might challenge the altered resected gastric anatomy after the LSG. If gastric emptying is not yet fully restored, this could result in stasis, delayed clearance of gastric contents, and a higher risk of reflux into the esophagus. From the foregoing, understanding these ERAS-specific mechanisms is critical because GERD following LSG can significantly impair quality of life and may necessitate further surgical interventions, such as conversion to gastric bypass. Future comprehensive studies tailoring ERAS protocols to better address reflux risks are thus recommended in the centre.

In this cohort study, the ERAS group was associated with zero incidence of 30-day postoperative complications, reoperation, and mortality. However, sequel to the relatively small sample, the detection of subtle differences in outcomes becomes difficult secondary to limited statistical power. Also since the patient had been recruited based on availability at the time of the study, the results could be prone to selection bias. Additionally, early reoperations may underestimate complication rates. However, since no patient in either group had met the criteria (Table 7), there was no any effect on outcomes. Similarly, a 5-year follow-up period requires high patient retention. As a result of the loss to follow-up, the potential of bias was possible because of the propensity of the patient who dropped out to possess different outcomes from those who completed the study. Finally, our study could also be limited from the viewpoint of non-generalizability to other healthcare settings owing to single-centre study bias. Thus, future studies should be directed to address these limitations as well as to evaluate the safety of this protocol in larger cohorts.

Conclusion

Implementation of ERAS in LSG improved postoperative outcomes, including shorter length of stay, better mobilization, lower healthcare costs, and fewer 30-day complications. This demonstrates the effectiveness of ERAS in LSG and provides valuable insights for improving perioperative bariatric care practices. After 5 years, Clavien-Dindo graded complication rates were minimal, although compliance to regular follow-up visits and bariatric diet were not appreciable. This study offers valuable data to improve perioperative care and bariatric surgery management, though larger studies are needed to validate its safety. High-volume facilities should expand this protocol to all bariatric and other surgical specialties.

Abbreviations

BMI	Body Mass Index
ERAS	Enhanced Recovery After Surgery
GERD	Gastroesophageal reflux disease
HbA1c	Hemoglobin A1c
IBW	Ideal Body Weight
IQR	Interquartile range
IV	Intravenous
IVF	Intravenous fluid
LES	Lower esophageal sphincter
LOS	Length of stay
LSG	Laparoscopic Sleeve Gastrectomy
NCQA	National Committee for Quality Assurance
PACU	Postanesthesia care unit
PO	Per oral
POD	Postoperative day
POM	Postoperative medication
SAR	Saudi Arabia Riyal
TAP	Transversus Abdominus Plane
VTE	Venous thromboembolism

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Author contributions

HA, TY, MF, HK, FJ, AS, OD contributed to conceptualization, supervision, project administration, methodology and data analysis. HA, DA, AA, AM, FA, YE, KA, and EM participated in methodology, data curation, and statistical analysis. All named authors involved in the interpretation of results, and in the drafting, writing, editing, proofreading, and approval of the final version of the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study was conducted in full accordance with the ethical principles outlined in the Declaration of Helsinki, as revised in October 2013 (Fortaleza, Brazil). Ethical approval was obtained from the Ethics Committee of the International Medical Centre prior to the initiation of data collection (No. IMC-EC/2019–000). Also, written informed consent was obtained from all participants prior to their inclusion in the study. The objectives, procedures, potential risks, and benefits of the research were clearly explained, and participation was voluntary.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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