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ORIGINAL ARTICLE

Laparoscopic versus open incisional hernia repair: a retrospective cohort study with costs analysis on 269 patients

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Abstract
Purpose To compare clinical outcomes and institutional costs of elective laparoscopic and open incisional hernia mesh repairs and to identify independent predictors of prolonged operative time and hospital length of stay (LOS).
Methods Retrospective observational cohort study on 269 consecutive patients who underwent elective incisional hernia mesh repair, laparoscopic group ($N = 94$) and open group ($N = 175$), between May 2004 and July 2014.
Results Operative time was shorter in the laparoscopic versus open group ($p < 0.0001$). Perioperative morbidity and mortality were similar in the two groups. Patients in the laparoscopic group were discharged a median of 2 days earlier ($p < 0.0001$). At a median follow-up over 50 months, no difference in hernia recurrence was detected between the groups. In laparoscopic group total institutional costs were lower ($p = 0.02$). At Cox regression analysis adjusted for potential confounders, large wall defect (W3) and higher operative risk (ASA score 3–4) were associated with prolonged operative time, while midline hernia site was associated with increased hospital LOS. Open surgical approach was associated with prolongation of both operative time and LOS.
Conclusions Laparoscopic approach may be considered safely to all patients for incisional hernia repair, regardless of patients' characteristics (age, gender, BMI, ASA score, comorbidities) and size of the wall defect (W2-3), with the advantage of shorter operating time and hospital LOS that yields reduced total institutional costs. Patients with higher ASA score and large hernia defects are at risk of prolonged operative time, while an open approach is associated with longer duration of surgical operation and hospital LOS.

Keywords Incisional hernia · Herniorrhaphy · Surgical mesh · Laparoscopic surgery · Cost and cost analysis · Cohort study

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Introduction

Incisional hernias are one of the most common complications after abdominal surgery and occur in up to 20% of patients following a midline laparotomy. [1]. Since the first report by Le Blanc in 1992, laparoscopic mesh repair has been proposed as a safe alternative approach to open mesh repair offering to the patients reduced local infection rates and hospital length of stay (LOS). [2]. Recently, indications to laparoscopic incisional hernia repair have been extended to recurrent incisional hernias as well as repairs in elderly and obese patients [3].

The balance between economic resources, demand, and performance of health facilities played an increasingly important role in the last few years, both for the redistribution of economic resources in public as well as private systems and in the search for cost-effective health actions. Few studies, however, have focused on the impact of the laparoscopic versus open incisional hernia repair on both hospital and health care system costs. In randomized trials including economic analysis, the laparoscopic repair was associated with a three- to ninefold increase of the total "*costs of surgical operation*" compared to the open repair, although the shorter hospital LOS after the laparoscopic operation may render this technique cost-efficient. [4–6].

There is evidence in the literature showing that patients with multiple, recurrent, and larger hernias are more likely to require longer operative times and hospital LOS when treated by a laparoscopic approach [7]. Therefore, investigating factors affecting the duration of operative time and hospital LOS may help to refine patients' selection criteria and indications to laparoscopic repair to the benefit of cost-effectiveness.

The aim of this study was twofold: (1) to compare clinical outcomes and institutional costs of elective laparoscopic and open incisional hernia mesh repairs and (2) to identify independent predictors of prolonged operative time and hospital length of stay in patients undergoing elective incisional hernia mesh repair.

Methods

This is a retrospective cohort study on all consecutive patients who underwent elective incisional hernia mesh repair between May 2004 and July 2014 at the Department of Surgery of the S. Anna University Hospital in Ferrara, Italy.

All patients undergoing an emergency incisional hernia repair or with primary ventral hernia were excluded from this study.

The primary objective of the study was to compare clinical outcomes and institutional costs in patients undergoing laparoscopic and open incisional hernia repairs, while the secondary objective was to identify independent factors associated with prolonged operating times and hospital LOS in patients submitted to elective incisional hernia repair.

Patients were divided into two groups according to the surgical approach elected for incisional hernia repair, laparoscopic (laparoscopic group) or open (open group).

Patient demographic and baseline characteristics (Body Mass Index—BMI, American Society of Anaesthesiology—ASA score, comorbidities, previous surgery); intraoperative data (operative time, degree of adhesions according to Zuhlke classification [8], conversion rate to open, type of mesh); hernia site and type; perioperative complications; reoperations; hospital LOS; and post-operative recurrence were reviewed and recorded in an electronic database. Hernia type was defined according to the European Hernia Society (EHS) classification [9]. Post-operative complications were divided according to the Clavien-Dindo classification in minor (Clavien-Dindo I–II) and major (Clavien-Dindo III–IV) complications [10].

For the institutional cost analysis, the hospitalization and operation costs were considered for each patient. The hospitalization cost was determined analysing the hospital LOS and the intensive care unit (ICU) LOS, considering overall ward (€ 1319.00) and ICU (€ 2318.00) fees per day at our institution. To compute the operation cost, all surgical disposable instruments, mesh employed, and the operating room time (€ 40.00/min) per patient were considered.

The same surgeons (GS, CVF, GV) and anaesthesiology teams performed all operations. Patients were transferred to the ward at the end of the surgical procedure or admitted to the ICU if mechanical ventilation was required.

The open repair was performed according to the standardized technique described by Stoppa and subsequently modified by Rives [11]. A polypropylene light mesh was generally employed for the repair, while partially absorbable or composite light mesh was preferred whenever the peritoneum could not be fully reconstructed. In patients with associated intraperitoneal procedures or enterotomies, ePTFE (in-lay technique) or biologic mesh was used, respectively.

One or two suction drains were placed between the mesh and the rectus muscles, except in small hernias (W1).

Laparoscopic incisional hernia repair

Pneumoperitoneum was established with a Veress needle in the left subcostal space. The first trocar was placed laterally by "open-laparoscopy", selecting the side and site on the abdominal wall allowing the greatest distance from the hernia defect. A 30° laparoscope was always used to provide an optimal intraoperative view of the peritoneal cavity. Two additional trocars (5 or 12 mm) were placed on the same side of the abdomen; for large size defects, two to three trocars (5 or 12 mm) were placed on the opposite side to fix the mesh to the anterior abdominal wall.

Adhesiolysis was performed by blunt and sharp dissection employing bipolar scissors for haemostasis. The entire defect was exposed as well as the surrounding surface of the anterior abdominal wall in order to allow a 4–5 cm mesh overlap. The hernia sac was not removed. The mesh was rolled and introduced in the abdominal cavity via a 12-mm trocar and then unrolled. Initially the mesh was fixed with four trans-parietal cardinal stitches and then tacks were fired to obtain a complete 4–5 cm mesh overlap beyond the edges of the fascial defect. The mesh was fixed by two crowns of titanium (Pro-Tack®, Covidien), absorbable (Absorbatack®, Covidien; SorbaFix®, Bard; SecureStrap®, Ethicon) or non-absorbable (PermaFix®, Bard) tacks. Absorbable tacks were used always with titanium or non-absorbable tacks.

The outer crown was placed at least 1 cm away from the mesh border while the inner crown was positioned 1–2 cm inside from the outer crown. After mesh fixation was completed the trans-parietal stitches were removed. No drainage was ever used.

The follow-up was by standardized telephone interview with a surgical resident (AD, ST) and consisted of four simple questions investigating the presence of persistent abdominal pain, mass, bulging, constipation, and cosmetic concerns after the surgical hernia repair. All patients revealing any of the above-mentioned problems were then invited for a visit with no charge in the outpatient clinic. Patients who had been visited by a surgeon for any abdominal complaint after the hernia repair were also invited. Diagnostic imaging studies (parietal ultrasound or abdominal computed tomography scanning) were then requested after the outpatient visit if deemed necessary.

Compliance with ethical standards

This study granted an exception by the Ethical Committee for Human Subject Research at the S. Anna University Hospital. All patients provided a written informed consent for the surgical operation.

Statistical analysis

Data are expressed as median (interquartile range—IQR 25–75) according to the distribution, which was evaluated by the Shapiro–Wilk test. Categorical data are presented as number (%). Data were analysed using the Chi square and Mann–Whitney tests to compare percentages and non-parametric data, respectively. Kaplan–Meier method was used for analysis of duration of the surgical operation and hospital LOS and log-rank test was employed to compare operative time and hospital LOS of patients between groups [12].

We assessed by univariate analysis the association between characteristics of patients, wall defect, surgical approach and prolonged operative time and hospital LOS. As the endpoints of interest, we adopted time to the end of surgical procedure and hospital discharge to evaluate the association with prolonged operative time and hospital LOS, respectively. For the time to event analyses, patients were censored at the time of end of surgical procedure and hospital discharge. We then calculated multivariate Cox regression analyses adjusted for potential confounders to assess independent predictors of increased operative time and hospital LOS. Of note, hazard ratios (HRs) <1 correspond to an association of the factor with an increased duration of the operation and prolonged hospital LOS, while HRs >1 correspond to shorter operation and earlier discharge. Seven patients with both midline and lateral hernias were excluded from the risk analysis. Significance was considered for values of $p < 0.05$. Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp. Armonk, NY: IBM Corp.).

This report complies with the reporting standards established by STROBE guidelines for reporting observational studies [13].

Results

Between May 2004 and July 2014, 269 patients underwent elective incisional hernia mesh repair at the Department of Surgery of the S. Anna University Hospital in Ferrara, Italy.

One hundred seventy-five (65.1%) patients underwent open repair (open group) and 94 (34.9%) laparoscopic repair (laparoscopic group).

The demographics and baseline characteristics of the patients are illustrated in Table 1. The two groups were comparable regarding age, gender distribution, BMI, and ASA score. A higher prevalence of pre-operative chronic renal insufficiency was present among patients undergoing an open repair versus laparoscopic repair ($p = 0.019$). In the open group the previous operation was mostly an open colorectal resection, while laparoscopic or open cholecystectomy and open colorectal resection prevailed in the laparoscopic group (Table 1).

The classification of incisional hernias and adhesions and the type of mesh employed for repair are detailed in Table 2. No difference was found in the site of incisional hernias (i.e. midline, lateral or both) ($p = 0.139$), with a prevalence of midline umbilical wall defects in the laparoscopic group and midline infra-umbilical and suprapubic hernias in the open group ($p < 0.0001$). Subcostal defects were more frequent in the laparoscopic group ($p < 0.002$). Small defects (W1) were prevalent in the open group, whereas large defects (W3) were mainly represented in the laparoscopic group ($p < 0.0001$). The two groups were well balanced regarding the severity of adhesions according to the Zuhlke scoring system ($p = 0.229$). Partially absorbable or composite mesh and polypropylene light mesh were more frequently adopted in the laparoscopic and open group, respectively ($p < 0.0001$). In the open group, ePTFE (in-lay technique) was adopted in two patients with associated intraperitoneal procedures and in three patients, in the early phase of the study, because the peritoneum could not be reconstructed. The midline was approximated in the great majority of cases.

Intra- and postoperative outcomes and variables are summarized in Table 3. The operative time was shorter in the laparoscopic group versus open group ($p < 0.0001$). Intra- and postoperative complications and recurrence rate were similar in the two groups; in particular, no difference was detected in the rate of bowel perforation. One patient

Table 1 Demographic data and baseline characteristics

	Laparoscopic group ($N = 94$)	Open group ($N = 175$)	p
Gender			0.076
Male	48 (51.1%)	72 (41.1%)	
Female	46 (48.9%)	103 (58.9%)	
Age (years)	64 (56–71%)	66 (59–74%)	0.091
Body Mass Index[a] (Kg/m^2)			0.071
<25	11 (17.8%)	24 (30.0%)	
25–29.9	34 (54.8%)	29 (36.3%)	
≥30	17 (27.4%)	27 (33.7%)	
American Society of Anaesthesiologists score[b]			0.436
1–2	41 (57.8%)	50 (50.5%)	
3–4	30 (42.2%)	49 (49.5%)	
Diabetes [N(%)]	6 (6.4%)	12 (6.9%)	0.552
Chronic obstructive pulmonary disease	2 (2.1%)	13 (7.4%)	0.057
Chronic renal insufficiency	0	9 (5.1%)	0.019
Chronic ischemic heart disease	5 (5.3%)	10 (5.7%)	0.567
Chronic hepatic disease	3 (3.2%)	7 (4.0%)	0.515
Oral anticoagulation therapy	2 (2.1%)	1 (0.6%)	0.280
Previous surgery[c]			<0.0001
Laparoscopic colorectal resection	5 (7.0%)	3 (2.4%)	
Open colorectal resection	16 (22.5%)	67 (54.0%)	
Laparoscopic cholecystectomy	15 (21.2%)	7 (5.7%)	
Open cholecystectomy	11 (15.5%)	5 (4.0%)	
Other	24 (33.8%)	42 (33.9%)	

[a] Body Mass Index was not available in 127 (47.2%) patients: 32 (34.0%) patients in the laparoscopic group and 95 (54.3%) in the open group

[b] American Society of Anaesthesiologists score was not available in 99 (36.8%) patients: 23 (24.5%) patients of laparoscopic group and in 76 (43.4%) patients of open group

[c] Data of previous surgery were not available in 74 (27.5%) patients: 23 (24.5%) patients in the laparoscopic group and 51 (29.1%) in the open group

(laparoscopic group) was admitted to the ICU postoperatively; the ICU LOS was 4 days. Patients in laparoscopic group were discharged a median of 2 days earlier ($p < 0.0001$). No difference between the laparoscopic group and the open group was detected in the median length of follow-up ($p = 0.151$), which exceeded 50 months. Twenty-six patients were evaluated in the clinic after standardized telephone interview, 15 in the laparoscopic group and 11 in the open group. Of all invited patients, only five did not accept to be visited. Sixteen (17%) patients were lost to follow-up in the laparoscopic group as opposed to 17 (9.7%) in the open group ($p = 0.18$). Therefore, 246 patients were interviewed, 78 in the laparoscopic group and 168 in the open group.

The costs for the laparoscopic group and open group are compared in Table 4. The costs of operation were higher for laparoscopic group opposed to open group ($p = 0.025$), but the cost of hospitalization was reduced ($p < 0.0001$). The total costs for the institution were lower in the laparoscopic group versus open group ($p = 0.023$).

The regression analysis to investigate factors associated with prolonged operative time is illustrated in Table 5. Unadjusted Cox regression analysis showed an association between open approach and prolonged operative time ($p < 0.0001$). After adjusting for potential confounders, ASA score 3–4 ($p = 0.010$), wall defect width >10 cm (W3) ($p = 0.006$), and open approach ($p = 0.001$) were significantly associated with prolonged operative time.

The regression analysis to investigate factors associated to prolonged hospital LOS is detailed in Table 6. Unadjusted Cox regression analysis demonstrated that age 65–75 years ($p = 0.020$) and >75 ($p = 0.031$), ASA score 3–4 ($p = 0.008$), presence of chronic renal insufficiency ($p = 0.010$) and chronic ischemic heart disease ($p = 0.018$), and open approach ($p < 0.001$) were significantly associated with prolonged hospital LOS. However, after adjusting for potential confounders only the open approach ($p = 0.004$) was significantly associated with prolonged hospital LOS.

Seven patients who had both midline and lateral hernias were excluded from both the risk analysis.

Table 2 Classification of incisional hernias and adhesions and type of mesh

	Laparoscopic group ($N = 94$)	Open group ($N = 175$)	p
EHS Incisional hernia classification			
Hernia localisation[a]			
Midline hernias	$N = 88$	$N = 154$	<0.0001
M1 (subxiphoidal)	11 (12.5%)	26 (16.9%)	
M2 (epigastric)	4 (4.5%)	10 (6.5%)	
M3 (umbilical)	70 (79.5%)	80 (52.0%)	
M4 (infraumbilical)	2 (2.3%)	23 (14.9%)	
M5 (suprapubic)	1 (1.2%)	15 (9.7%)	
Lateral hernias	$N = 9$	$N = 25$	0.002
L1 (subcostal)	7 (77.8%)	3 (12.0%)	
L2 (flank)	1 (11.1%)	6 (24.0%)	
L3 (iliac)	0	14 (56.0%)	
L4 (lumbar)	1 (11.1%)	2 (8.0%)	
Width of wall defect[b]	$N = 93$	$N = 129$	<0.0001
W1 (< 4 cm)	4 (4.3%)	33 (25.6%)	
W2 (4–10 cm)	30 (32.3%)	49 (38.0%)	
W3 (≥ 10 cm)	59 (63.4%)	47 (36.4%)	
Recurrent incisional hernia [N (%)]	5 (5.3%)	16 (9.1%)	0.344
Zuhlke score of adhesions[c] [N (%)]	$N = 94$	$N = 107$	0.229
0	9 (9.6%)	17 (15.9%)	
1	11 (11.7%)	7 (6.5%)	
2	14 (14.9%)	18 (16.8%)	
3	36 (38.3%)	30 (28.1%)	
4	24 (25.5%)	35 (32.7%)	
Type of mesh[d]	$N = 94$	$N = 148$	<0.0001
Partially absorbable and composite light meshes	82 (87.2%)	65 (43.9%)	
Polypropylene light meshes	1 (1.1%)	77 (52.0%)	
ePTFE meshes	10 (10.6%)	5 (3.4%)	
Biologic meshes	1 (1.1%)	1 (0.7%)	

[a] Three patients in the laparoscopic group and four patients in the open group had a midline hernia associated with a lateral hernia

[b] Data of width (W) of wall defect classification were not available in 47 (17.5%) patients: 1 (1.1%) patient in the laparoscopic group and 46 (26.3%) in the open group

[c] Data of Zuhlke score of adhesions were not available in 68 (38.9%) patients of the open group

[d] Data of type of mesh were not available in 27 (15.4%) patients of the open group

Discussion

This retrospective cohort study shows that elective laparoscopic incisional hernia repair compared to the open approach significantly reduced both length of operative time and hospital stay as well as total institutional costs, with no increase in post-operative morbidity and mortality. At a median follow-up over 50 months, hernia recurrence rates were similar in the two groups. Large defects (>10 cm) and higher preoperative risk (ASA score 3–4) were independently associated with prolonged operative time, while being operated on by open approach was significantly associated with both prolonged operative time and hospital LOS.

A systematic review with meta-analysis of randomized trials ($N = 887$) comparing laparoscopic and open techniques for ventral and incisional hernia repairs showed no difference in hernia recurrence; the laparoscopic approach was associated with increased incidence of enterotomies, decreased risk of local infection, and a reduced hospital LOS, considering 5-day minimum LOS trials only [2].

More recently, Awaiz et al. reported a systematic review with meta-analyses of randomized trials ($N = 751$) including incisional hernia only [14]; open repair was associated with a reduction in bowel complications, while laparoscopic repair with less wound infections [15–17].

We detected no difference in postoperative admission to ICU, ICU LOS, perioperative morbidity, and mortality, but

Table 3 Intra- and postoperative outcomes and variables

	Laparoscopic group ($N = 94$)	Open group ($N = 175$)	p
Operative time (min)	138 (90–170)	148 (115–205)	0.001
Intraoperative complications			
Bowel perforation	1 (1.0%)	4 (2.3%)	0.661
Conversion to open surgery	4 (4.2%)	–	
Postoperative complications[a]			0.440
No complications	91 (96.8%)	161 (92%)	
Minor (I–II)	1 (1.0%)	4 (2.3%)	
Major (III–IV)	2 (2.1%)	8 (4.6%)	
Death (V)	0	2 (1.1%)	
Re-intervention	1 (1.0%)	10 (5.7%)	0.057
Hospital length of stay (days)	3 (3–4)	5 (4–8)	<0.0001
Follow-up (months)	50.5 (27.0–79.8)	57.0 (35.0–81.3)	0.151
Recurrence of incisional hernia	8 (8.5%)	21 (12.0%)	0.415
Interval to recurrence[b](months)	27.0 (17.3–41.0)	19.0 (9.0–31.0)	0.313

[a] Clavien-Dindo Classification

[b] The recurrence interval time was not available in two patients of open approach group

Table 4 Direct costs of incisional hernia repair (euro)

	Laparoscopic group ($N = 94$)	Open group ($N = 175$)	p
Costs of operation	7315.35 (5593.58–8615.20)	6298.00 (4600.00–8698.00)	0.025
Materials[a]	1952.95 (1477.75–2520.80)	298.00 (298.00–490.00)	<0.0001
Operating room	5460.00 (3600.00–6800.00)	5740.00 (4400.00–8050.00)	0.046
Costs of hospitalization	3957.00 (3957.00–5276.00)	6595.00 (5276.00–10,552.00)	<0.0001
Total institutional costs	11,300.00 (9860.00–1,4481.23)	12,974.00 (9932.00–18,088.00)	0.023

[a] Laparoscopic disposable instruments and meshes

there was a tendency toward more reoperation among patients operated via an open approach ($p = 0.057$). Notably, only one enterotomy occurred in the laparoscopic group and the rate of enterotomies did not differ significantly between groups.

In our study, including a large control group ($N = 175$), there was no difference in recurrence between laparoscopic and open repairs [8 (8.5%) vs. 21 (12.0%), $p = 0.415$], at a follow-up over 50 months with 23 patients (8.5%) lost to follow-up. However, only patients with possible signs or symptoms of recurrence by telephone interview, or seen by a surgeon postoperatively for abdominal complaints, were examined and abdominal imaging was selectively requested.

Size of the defect has been shown to predict the risk of recurrence by Moreno-Egea et al. in a prospective study [18]. Defect closure of large hernias treated by laparoscopy has been recently proposed in order to reduce the rate of seroma formation, recurrence, and bulging at the hernia site [19]. In our series, we have never closed the defect in laparoscopic repairs. Our practice is to consider an open approach for very large defects (>15 cm), eventually treated by component separation reconstruction [20].

The laparoscopic approach reduced operative time and hospital LOS

Although defects size was larger in the laparoscopic group as compared to open group, we identified that the operative time was a median of 10 min shorter in the laparoscopic group ($p = 0.001$). Olmi et al. reported a 90-min mean difference, with a mean operative time of about 1 h ($p < 0.05$) and a mean defect diameter of approximately 10 cm ($p = 0.75$) for laparoscopic incisional hernia versus open repair [4]. However, about two-thirds of our patients in the laparoscopic group had a ≥10-cm hernia diameter (W3) which may partly account for our longer duration of the laparoscopic repair [median 138 (90–170) min]. By contrast, a difference in operative time has not been detected by other investigators, although a small defect size (2.5–6.9 cm) characterized these studies [21–23].

We detected a 2-day shorter hospital LOS in the laparoscopic versus open group (3 vs. 5, $p < 0.0001$), which is consistent with some Authors [4, 21], but not with others [22–25]. In the absence of predefined, standardized, and universally accepted criteria for hospital discharge it is very difficult to compare such an outcome between studies,

Table 5 Association between characteristics of patients, wall defect, and surgical approach, and prolonged operative time according Cox regression analysis adjusted for potential confounders

	Prolonged operative time			
	Unadjusted model		Full adjusted model	
	Crude hazard ratio (95% CI)	*p*	Adjusted Hazard ratio (95% CI)	*p*
Gender (ref: female)				
Male	1.08 (0.84–1.38)	0.571	1.11 (0.73–1.69)	0.632
Age (ref: <65 years.)				
65–75	0.97 (0.74–1.27)	0.820	1.24 (0.78–1.96)	0.360
>75	1.05 (0.73–1.52)	0.795	1.81 (0.89–3.69)	0.102
Body Mass Index (ref: <25 kg/m^2)				
25–29.9	0.98 (0.64–1.51)	0.937	1.19 (0.72–1.96)	0.504
≥ 30	1.07 (0.67–1.71)	0.766	1.81 (1.01–3.24)	0.047
American Society of Anaesthesiologists score (ref: 1–2)				
3–4	0.78 (0.57–1.07)	0.126	0.55 (0.35–0.87)	0.010
Site of incisional hernia (ref: lateral)				
Midline	0.77 (0.51–1.17)	0.220	0.87 (0.41–1.84)	0.707
Hernia close to bony structures (ref: absence)				
Presence	0.91 (0.67–1.25)	0.573	0.96 (0.56–1.64)	0.890
Width of wall defect (ref: W1 < 4 cm)				
W2 (4–10 cm)	0.76 (0.51–1.16)	0.202	0.57 (0.31–1.06)	0.074
W3 (>10 cm)	0.69 (0.46–1.02)	0.060	0.44 (0.25–0.79)	0.006
Surgical approach (ref: laparoscopic)				
Open	0.59 (0.45–0.78)	<0.0001	0.47 (0.31–0.73)	0.001

which is largely influenced by local practice and patient expectation as well as lack of blindness. Our hospital serves also a wide rural area; therefore, environmental and socio-economical issues may have influenced LOS. It should be kept in mind, however, that this series does not include primary ventral hernias but incisional hernias only and almost 40% of patients in the open group had a large defect (W3). Finally, Colavita et al. recently compared laparoscopic and open ventral hernia repairs with mesh in the United States using the Nationwide Inpatient Sample (NIS), representing about 20% of all inpatient encounters in the United States, and open repair was associated with a mean hospital LOS of 5.2 days [5].

What does really affect operative time and hospital LOS?

We analysed which factors were associated with the risk of a prolonged operative time and, after adjusting for potential confounders, a >10 cm width of the defect (W3), higher ASA score (3–4), and an open surgical approach were significantly associated as opposed to age, gender, BMI, and site of the hernia. A midline defect and open surgical approach were the only factors associated with prolonged hospital LOS on multivariate analysis. Butler et al., retrospectively investigating patient- and hernia-related factors ($N = 91$) that correlate with operative times and LOS after laparoscopic ventral hernia repair, found that larger mesh size (>300 cm^2) independently predicted longer operative time (>120 min) and prolonged LOS (>1 day). Longer operative time was associated with prolonged LOS, while recurrent hernia or multiple defects was associated to longer operative time [7]. Of note, however, as opposed to Butler et al., we investigated only patients undergoing incisional hernia repairs, excluding patients with primary ventral hernias.

The laparoscopic approach decreased direct costs

In our study, the higher costs of the operations for laparoscopic repair than for open repair (median + € 1017.35 per patient) were counterbalanced by reduced costs of hospitalization (median − € 2638.00 per patient) and, therefore, the total facility costs were less in the laparoscopic group (median – € 1674.00 per patient € 11,300.00 vs. € 12,974.00, $p = 0.023$). It should be noted that a reduction in direct costs for patients in the laparoscopic group was achieved despite large defects (W3), requiring larger prosthesis to be repaired, were prevalent in this group as opposed to the open group (Table 4). This initial finding of a cost-reducing strategy is important for further analysis focused on possible social cost-effectiveness and in the perspective of a balance between technical innovation and economic sustainability of optimal health care.

Table 6 Association between characteristics of patients, wall defect, and surgical approach, and hospital length of stay according to Cox regression analysis adjusted for potential confounders

	Prolonged hospital length of stay			
	Unadjusted model		Full adjusted model	
	Crude hazard ratio (95% CI)	p	Adjusted hazard ratio (95% CI)	p
Gender (ref: female)				
Male	0.97 (0.76–1.24)	0.789	0.85 (0.55–1.29)	0.432
Age (ref: <65 years.)				
65–75	0.73 (0.55–0.95)	0.020	0.84 (0.51–1.39)	0.502
>75	0.67 (0.47–0.97)	0.031	0.64 (0.31–1.31)	0.219
Body Mass Index (ref: <25 kg/m^2)				
25–29.9	1.05 (0.68–1.62)	0.817	0.96 (0.55–1.66)	0.870
≥30	0.90 (0.56–1.44)	0.663	0.92 (0.50–1.69)	0.786
American Society of Anaesthesiologists score (ref: 1–2)				
3–4	0.66 (0.48–0.90)	0.008	0.78 (0.48–1.25)	0.299
Diabetes (ref: absence)				
Presence	0.88 (0.54–1.43)	0.605	1.10 (0.48–2.51)	0.823
Chronic obstructive pulmonary disease (ref: absence)				
Presence	0.66 (0.38–1.16)	0.150	0.54 (0.16–1.78)	0.308
Chronic renal insufficiency (ref: absence)				
Presence	0.41 (0.21–0.81)	0.010	0.80 (0.26–2.44)	0.695
Chronic ischemic heart disease (ref: absence)				
Presence	0.51 (0.30–0.89)	0.018	0.87 (0.35–2.17)	0.771
Chronic hepatic disease (ref: absence)				
Presence	0.81 (0.41–1.57)	0.523	1.16 (0.29–4.73)	0.833
Oral anticoagulation therapy (ref: absence)				
Presence	0.37 (0.91–1.50)	0.164	0.46 (0.05–4.08)	0.487
Site of incisional hernia (ref: lateral)				
Midline	0.93 (0.63–1.39)	0.738	0.45 (0.2–0.98)	0.045
Hernia close to bony structures (ref: absence)				
Presence	0.82 (0.60–1.12)	0.208	0.68 (0.38–1.24)	0.210
Width of wall defect (ref: W1 < 4 cm)				
W2 (4–10 cm)	0.86 (0.58–1.27)	0.434	0.68 (0.37–1.25)	0.214
W3 (>10 cm)	0.83 (0.57–1.22)	0.342	0.77 (0.40–1.49)	0.443
Surgical approach (ref: laparoscopic)				
Open	0.45 (0.34–0.59)	<0.0001	0.48 (0.29–0.79)	0.004

About a decade ago, using prospectively collected administrative data, Earle et al. reported that laparoscopic ($N = 268$) compared to open ($N = 158$) incisional hernia repair shows shorter LOS, longer operating room time, higher supply costs (\$2237 ± \$71 vs. \$664 ± \$113, $p < 0.001$), and similar total hospital cost (\$6396 ± \$477 vs. \$7197 ± \$1819, $p = 0.59$) as well as number and cost of post-operative hospital encounters [26].

In Italy, Olmi et al. comparing direct costs in laparoscopic ($N = 85$) and open ($N = 85$) incisional hernia repair found that the laparoscopic approach was more expensive (mean + €1600.00 per patient), but the shorter hospitalization reduced such a cost (mean − € 2000.00 per patient) and, therefore, total costs were similar (mean − € 400.00 per patient) [4].

Finally, more recently Colavita et al. compared laparoscopic and open mesh ventral hernia repairs in the United States using the Nationwide Inpatient Sample [5]. Open repair was associated with more emergent admissions, higher complication and mortality rates, and longer hospital LOS (mean 5.2 days). The total charge was less after laparoscopic repair (mean − \$9761 per patient) and all outcome differences remained significant after controlling for confounding variables with multivariate regression.

Strengths and limitation of the study

This is one of the largest single-centre studies evaluating the direct costs of laparoscopic repair versus open repair for incisional hernias. In addition, the study population was more homogeneous with respect to the abdominal defects (e.g. size, site) and peritoneal adhesions, comprising only patients undergoing elective surgical repair of incisional hernias rather than ventral hernias (i.e. primary and incisional hernias). Also, a single surgical team including three surgeons (GS, CVF, GV) adopting a standardized surgical technique at the same hospital performed all the surgical operations in both groups, which reduced biases and allowed to better evaluate the real impact of the surgical approach. Finally, a long-term follow-up was conducted which allowed determining the efficacy of the procedure in term of recurrence.

However, some limitations also exist. This is a retrospective study and, therefore, caution should be exercised while interpreting the results. The selection of patients into the treatment groups is a potential bias. The different distribution of previous incisions between study groups, as well as larger defects in the laparoscopic versus open group, may have affected clinical and economic outcomes. Due to the retrospective design of our study, we could not collect and analyse indirect costs and prospective follow-up could not be performed, which may have increased the lost to follow-up rate. We did not perform diagnostic imaging studies in all patients postoperatively, follow up was by telephone interview and only patiens presenting signs or symptoms of recurrence were seen and visited.

Conclusion

Elective laparoscopic and open incisional hernia repair seem to produce similar rates of complications and recurrences; the laparoscopic technique is more expensive in the operating theatre but the longer LOS with the open approach counterbalanced this cost, making the latter procedure more expensive in the end. Large defect size (>10 cm) and high preoperative risk (ASA score 3–4) were independently associated with prolonged operative time, while adopting an open rather than laparoscopic technique was significantly associated with both prolonged operative time and hospital LOS. These data suggest that a laparoscopic approach may be considered for all patients for incisional hernia repair, regardless of patients' characteristics (age, gender, BMI, ASA score, comorbidities) and size of the wall defect (W2, W3). Very large defects, however, require open technique to reconstruct the abdominal wall, eventually by component separation [20].

Authors' contributions Study conception and design: GS, MP, CVF. Acquisition of data: ADT, ST. Analysis and interpretation of data: GS, ADT, MP, PC, GV, PMF, CVF. Drafting of manuscript: ADT, CVF. Critical revision of the article: GS, MP, ST, PC, GV, PMF. Final approval of the article: GS, ADT, MP, ST, PC, GV, PMF, CVF. Statistical analysis: MP

Compliance with ethical standards

Conflict of interest GS, ADT, MP, ST, PC, GV, PMF, and CVF declare no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and later amendments or comparable ethical standards. For this type of study formal consent is not required.

Human and animal rights This study granted an exception by the Ethical Committee for Human Subject Research at the S. Anna University Hospital

Informed consent All patients provided a written informed consent for the surgical operation.

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