Hernia (2016) 20:399–404
DOI 10.1007/s10029-016-1465-y

ORIGINAL ARTICLE

Perioperative outcomes and costs of laparoscopic versus open inguinal hernia repair

C. Tadaki[1] · D. Lomelin[2] · A. Simorov[2] · R. Jones[3] · M. Humphreys[4] · M. daSilva[4] · S. Choudhury[4] · V. Shostrom[5] · E. Boilesen[5] · V. Kothari[2] · D. Oleynikov[2] · M. Goede[2]

Received: 16 December 2014 / Accepted: 25 January 2016 / Published online: 13 February 2016

Abstract
Purpose Studies comparing laparoscopic (LIHR) vs. open inguinal hernia repair (OIHR) have shown similar recurrence rates but have disagreed on perioperative outcomes and costs. The aim of this study is to compare laparoscopic vs. open outcomes and costs.
Methods The National Surgical Quality Improvement Program (NSQIP) was used to compare durations of surgery, anesthesia time, and length of stay (LOS). The University HealthSystem Consortium (UHC) was used to review the cost and complications between approaches. Patients were matched on demographics, year of procedure and surgical approach between datasets for statistical analysis.
Results A sample of 5468 patients undergoing OIHR ($N = 4{,}693$) or LIHR ($N = 775$) was selected from UHC from 2008–2011. An identical number of patients from NSQIP were matched to those from UHC resulting in a total of 10,936 records. LIHR patients had shorter duration of wait from admission to operation ($p < 0.05$). Conversely, LIHR patients had longer operating time ($p < 0.05$), duration of anesthesia ($p < 0.05$), and time in the operating room ($p < 0.05$).Overall complication rate was higher in open (3.1 vs. 1.8 %, $p < 0.05$). Cost favored open over LIHR ($4360 vs $5105). The cost discrepancy mainly stemmed from LIHR supplies ($1448 vs. $340; $p < 0.05$) and OR services ($1380 vs. $1080; $p < 0.05$).
Conclusion This study demonstrates the LOS and perioperative outcomes were superior in the LIHR group; however, the overall cost was higher due to the supplies. Advancement in technology, surgeons' skill level and preference of supplies are all factors in decreasing the overall cost of LIHR.

Keywords Inguinal hernia · Laparoscopy · Cost · NSQIP · UHC · Comparative

Introduction

Inguinal hernia repair (IHR) is one of the most common operations performed by general surgeons with over 600,000 performed in the USA [1, 2] and roughly 20 million performed globally each year [3, 4]. The first reported laparoscopic IHR (LIHR) was performed by Ger in 1988; significant improvement in technology and technique has increased its use, but controversy in the USA has stifled its adoption [5–7].

The argument against laparoscopic repair centers on increased recurrence rate, post-operative complications, and cost. The inguinal hernia repair debate continues today. In 2004, a large Veteran's Affair study compared open and laparoscopic techniques and declared an open repair with mesh to be the optimal operation for a unilateral primary hernia. This outcome linked LIHR to an increased

✉ M. Goede
mgoede@unmc.edu

1 General Surgery/Bariatric Surgery, Hardin Memorial Hospital, 913 N. Dixie Ave, Elizabethtown, KY 42701, USA

2 Department of Surgery, University of Nebraska Medical Center, 985126 Nebraska Medical Center, Omaha, NE 68198-6246, USA

3 Southcoast Center for Weight Loss, Southcoast Physicians Group, 100 Rosebrook Way, Suite 300, Wareham, MA 02571, USA

4 College of Medicine, University of Nebraska Medical Center, 984350 Nebraska Medical Center, Omaha, NE 68198-5520, USA

5 Department of Biostatistics, College of Public Health, University of Nebraska Medical Center, 984350 Nebraska Medical Center, Omaha, NE 68198-4350, USA

complication and recurrence rate, in addition to its need for general anesthesia [8]. This study has deterred surgeons from repairing inguinal hernias laparoscopically, despite the open technique being shown to have higher rates of chronic pain and recurrence rates being lower in the laparoscopic group. Over the last 9 years, multiple studies have compared these two operations and have concluded that the recurrence rates were similar, but they have disagreed on the perioperative outcomes and costs [9–13].

The aim of this study was to compare outcomes and cost for both open and laparoscopic approaches to inguinal hernia repair in the USA between 2008 and 2011, in dollars (US). This project marries the benefits of the National Surgical Improvement Program (NSQIP) [14] and the University Health system Consortium (UHC) databases to provide a significantly larger sample size than most other studies, while also incorporating the investigatory possibilities unique to each dataset. Similar patient populations were created in both NSQIP and UHC using extensive matching criteria. Creation of these datasets allowed this study to examine outcomes in NSQIP and costs provided by UHC in comparable datasets. By utilizing the data in this manner, we sought to identify where cost savings could be found to make the laparoscopic approach cost-effective enough to warrant its use based on our observed outcomes.

Materials and methods

Data sources

National surgical improvement program (NSQIP)

The NSQIP provides researchers an encompassing dataset based on patient medical records rather than claims data, allowing investigation into surgical details not typically captured in other datasets. Furthermore, patients are tracked over the course of 30 days in addition to the preoperative and intraoperative periods [14]. Data collection for NSQIP is performed by Surgical Clinical Reviewers (SCRs). These individuals collect data on a randomized set of patients from each participating hospital location. All SCRs are trained by the American College of Surgeons and utilize a variety of methods to ensure the reliability of data collected, verifying mortality using both government records and direct contact of patients [14]. Procedures are coded using Current Procedural Terminology (CPT) codes, unique numeric designations for specific procedures [15].

University HealthSystem Consortium (UHC)

The UHC brings together 117 academic medical centers and 338 of their affiliated hospitals to form usable databases covering a wide range of information obtained from discharge records of individual patients. While financial records are utilized specifically by this research study, UHC also contains 30-day surgical outcomes and patients' demographics in addition to administrative information.

Data collection and analysis

Cases were identified using the International Classification of Disease—9th revision (ICD-9) codes for open and laparoscopic inguinal hernia repair within the UHC database. Current Procedure Terminology (CPT) codes, 49650 for LIHR and 49505 for open IHR (OIHR), were used for record identification within NSQIP. Due to the difference in coding between CPT and ICD-9, multiple codes were utilized for the query of UHC records for LIHR (17.11, 17.12, 17.13, 17.21, 17.22, and 17.25) and OIHR (53.0, 53.00, 53.01, 53.02, 53.03, 53.04, 53.05, 53.1, 53.10, 53.11, 53.12, 53.13, 53.14, 53.15, 53.16, and 53.17). The UHC data contain limited surgical outcome measures due to its focus on cost; for this reason NSQIP, which contains extensive surgical data, was matched to allow for accurate comparison of procedure cost while also expanding the surgical conclusions to be made about IHR. Prior to matching, UHC cases flagged as having outlier costs, 99th percentile or greater, were excluded from analysis along with emergency cases from both sets. At the time of analysis NSQIP data were available up to 2011, while UHC data started at 2008, consequently the record date ranges were truncated to 2008–2011.

Matching was accomplished on age, gender, race, year of procedure, and surgical approach using the case–control dialogue within the statistical analysis software, International Business Machines SPSS Statistics (IBM SPSS). Age was matched with a tolerance of 5 years, and year of procedure was given 1 year flexibility. The remaining variables of gender, race, and surgical approach were not allowed any deviation between matched records. Due to the presence of fewer records in the UHC data for the procedures of interest, UHC records were designated as the demander dataset while NSQIP was the supplier for match creation. This matching process generated a third dataset consisting of records from NSQIP with similar demographics to the records already present in the UHC. The new NSQIP dataset and original UHC records were then independently examined. Statistical analysis was conducted within each; costs and overall complication prevalence were compared between OIHR and LIHR within the UHC patient data, while detailed surgical data were compared between OIHR and LIHR with NSQIP patient data. No process, outside of matching, was used to compare records between the UHC and NSQIP datasets.

Laparoscopic and inguinal cases within the NSQIP selection were compared using *t* tests to elucidate differences in detailed surgical and hospital stay durations. Cost, gender, race, and complication frequency were compared using the matched UHC cases; the median and Pearson's χ^2 tests were used. Significance levels for all tests were set to an alpha of 0.05 and were conducted using IBM SPSS version 22.0. The authors compared this study against the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) [16].

Results

A total of 10,936 records were obtained for use in analysis consisting of 5468 pairs between UHC and NSQIP. By matching the populations so that they were similar on the aforementioned factors, we were better able to analyze both cost and outcomes for the procedures of interest from different datasets. Laparoscopy was conducted in 775 of the pairs while 4693 were of the open approach. Body mass index and gender proportions were not found to significantly differ between approaches. Patients undergoing the open technique were older and contained a higher proportion of non-white patients than those receiving laparoscopy (Table 1).

Normality of the cost distribution was analyzed using the Kolmogorov–Smirnov test which revealed that both procedure approaches were shown to have a skew toward more expensive cases which necessitated the use of a median test. The median cost for laparoscopy was shown to be significantly more expensive than that of the open approach, with similarly wide interquartile ranges between procedures. Patients undergoing the open procedure also had 1.76 times the odds of complication compared to the laparoscopic group. Operating time, duration of anesthesia, and time the patient spent in the room were all significantly shorter for patients having an open operation. Conversely, numbers of days from admission to operation were significantly shorter for laparoscopic procedures. Similarly, both overall length of stay, and length of surgical stay were shorter in the laparoscopic group but were not significantly so (Table 2). Within our institution, the total cost of individual products ($1348.06, Table 3) used during LIHR was

Table 1 Summary of demographics of patients undergoing laparoscopic or open inguinal hernia repair and results

	Open	Laparoscopic	*P*
UHC, *N*	4693	775	–
NSQIP, *N*	4693	775	–
Male gender, *N* (%)	4108 (87.5 %)	672 (86.7 %)	0.560
Race, *N* (%)			
White	3156 (67.2 %)	573 (73.9 %)	<0.001
Non-white	1537 (32.8 %)	202 (26.1 %)	–
Age (mean ± SD)	61.4 ± 16.9	60.0 ± 16.1	0.024
BMI (mean ± SD)	25.9 ± 4.3	25.9 ± 4.1	0.946

BMI body mass index

Table 3 Cost of surgical products at our institution

Product	Company	Cost
AbsorbaTack™ fixation device	Covidien	$484.29
ProTack™ fixation device	Covidien	$259.19
ProGrip™ self-fixating mesh	Covidien	$312.38
Parietex composite mesh (10 × 15 cm)	Covidien	$71.89
Tisseal™ (4 ml)	Baxter	$220.31

Table 2 Analysis of direct costs and outcomes between open and laparoscopic inguinal hernia surgeries

Measures	Open	Laparoscopic	*P*
Direct cost			
Median	$4360	$5105	<0.001
Interquartile range	$3148–$6416	$3778–$7140	
UHC complication flag, *N* (%)	147 (3.1 %)	14 (1.8 %)	0.043
Odds ratio, 95 % CI	1.76 (1.01–3.06)		
	Mean ± std. dev		
Length of stay (days)	0.32 ± 3.01	0.22 ± 0.86	0.332
Length of total surgical stay (days)	0.32 ± 3.23	0.21 ± 0.80	0.357
Admission to operation (days)	0.06 ± 0.83	0.02 ± 0.22	0.002
Operating time (min)	59.8 ± 29.1	70.6 ± 38.1	<0.001
Duration of anesthesia (min)	96.3 ± 35.4	112.2 ± 44.1	<0.001
Duration patient is in room (min)	88.4 ± 34.5	104.2 ± 42.5	<0.001

Table 4 Cost breakdown of laparoscopic vs. open surgical supplies, operating room services, and other surgical services

	Median (IQR)		*P*
	Open	Laparoscopic	
Surgical supplies	$717 ($483–$1097)	$1361 ($767–$2025)	<0.001
OR services	$1334 ($1063–$1698)	$1389 ($1206–$1728)	0.250
Other surgical services	$237 ($158–$334)	$304 ($175–$437)	<0.001

IQR interquartile range (range of the middle 50 % of cases), *OR* operating room

similar to the median value total for surgical supplies ($1361, Table 4). Additionally, the cost breakdown between procedure approaches provided by UHC shows that median cost of surgical supplies and "other surgical services" are significantly higher in LIHR ($p < 0.001$). It should be noted that the magnitude of median cost difference for "other surgical services" is only $67 between open and laparoscopic, but median surgical supply cost is $644 more expensive for the laparoscopic group, representing a difference of nearly 90 % from open (Table 4).

Discussion

In the area of surgical outcomes, our results indicate that patients benefit from the laparoscopic approach due to the significantly lower odds of complication when compared to the open approach. Additionally, the current body of research supports our observation, as a meta-analysis of literature on the topic has demonstrated a similar magnitude of protective effect by the laparoscopic approach compared to open [17]. In this study, it was observed that the odds of complication for OIHR were 1.76 times greater than LIHR. With more than 3 % of OIHR patients having a complication compared to 1.8 % of those having LIHR, the outcomes clearly favor the laparoscopic technique. It is important for the physician and patient to understand the benefits of each surgery in light of surgery cost differences.

Studies have shown the overall cost of laparoscopic inguinal hernia repair is higher than open repair [12, 13]. We report similar results, but we have broken down the cost analysis to show that the primary difference in cost is related to laparoscopic supplies and OR time. The OR time was significantly longer in the laparoscopic group, while the length of stay was shorter, though not statistically significant. Interestingly, despite the shorter OR time of OIHR, these patients also waited longer to have surgery after being admitted compared to those having the laparoscopic procedure. This difference may have an impact on cost for OIHR as well as patient satisfaction and warrants further research. To decrease LIHR OR time, the surgeon must become an expert at laparoscopic repairs. With a learning curve of 250 cases, laparoscopic inguinal hernia repairs could arguably be classified as a complex laparoscopic operation, for which additional training is needed [18]. A study conducted by our institution has demonstrated an under-utilization of laparoscopic inguinal hernia repairs, which raises the question, "how can we become more proficient at an operation we do not perform?" [5]. If surgeons continue to improve their laparoscopic skills and decrease their OR time for this operation, it would also decrease its overall cost. By simultaneously decreasing the use of expensive disposable equipment, the cost for a laparoscopic inguinal hernia repair will parallel that of an open repair.

There are currently many tools to aid in laparoscopic inguinal hernia repair, and these tools can be expensive. These added costs could discourage surgeons from using the devices and may be a contributing factor to discourage LIHR in general. Cost-effective product use could increase rates of LIHR by eliminating this concern. Similarly, various fixation devices are currently being used to secure the mesh in place. Available devices include non-absorbable and absorbable tackers, fibrin glue, and self-gripping mesh. The costs for these products at our institution are listed in Table 3. Multiple studies have failed to show a difference in recurrence rate when comparing tacking, glue, self-gripping mesh, or no fixation [19–26]. Eliminating the use of fixation devices will significantly decrease the cost of laparoscopic supplies as well as the overall cost. As fewer disposable instruments are used, the cost of a laparoscopic operation will continue to approach that of an open repair.

An additional benefit to a laparoscopic inguinal hernia repair would be the discovery and repair of an occult contralateral hernia. Studies have shown a rate of up to 25 % asymptomatic contralateral inguinal hernia in those patients undergoing a unilateral repair [27–29]. Concurrent repair could allow a patient to have one operation and anesthesia, rather than waiting until the contralateral side becomes symptomatic. Minimal additional dissection time is required during bilateral LIHR, as opposed to an additional inguinal exposure during bilateral OIHR, therefore the difference in OR time will likely be less significant in these 25 % of hernia patients.

One weakness of this study is the fact that while patients were matched on as many factors as possible, the process resulted in moderately smaller samples. Generally, length of stay is considered to be shorter in minimally invasive surgeries, and our results indicate this potential for IHR. Our results were not statistically significant. Equality of Levene's test for variance indicated that our sample's length of stay was near significance for accepting the equal variances assumption ($p = 0.073$), which would have returned a statistically significant result on a shorter length of stay in laparoscopic patients. A larger sample would likely provide stronger results in this measure. Additionally, it is particularly difficult to obtain accurate cost information between procedures. A variety of factors contribute to cost differences, as stated previously, physician preference in surgical supplies may have a major impact on the cost of inguinal hernia repair procedures. Furthermore, the cost figures themselves are based on complex cost-charge ratios utilized by the UHC to provide a close approximation for the actual cost of the procedure. The true cost of these procedures would be impossible to obtain simply from charges provided by hospitals. As such, this is the best cost information available in such a large database, although thoroughly itemized details are somewhat lacking.

While the operative costs are greater for laparoscopic cases, overall care costs may favor the laparoscopic approach. This study and others have shown an increase in infections in open cases [8, 30]. With the list of "never" events increasing to include such complications as wound infections following bariatric surgery, it is not hard to conceive that the list may be expanded to include inguinal hernia surgery as well. While several studies have shown the costs to be equal 3–5 years following open and laparoscopic IHR, this was frequently due to a higher recurrence rate in laparoscopic repairs. As LIHR techniques improve and surgeon experience increases, one would expect similar recurrence rates between laparoscopic and open procedures.

If experienced, well-trained advanced laparoscopic surgeons perform IHR with appropriate equipment, the cost of the operation may become comparable to an open repair; LOS might then become a major factor in the patients' overall cost, which may result in a cost savings for laparoscopy over the open approach to inguinal hernia repair.

Compliance with ethical standards

Conflict of interest CT, DL, AS, RJ, MH, MD, SC, VS, EB, VK, and MG declare no conflict of interest. DO declares Grant support from LifeCell, Gore, and Virtual Incision and no other conflict of interest that directly relate to this study.

References

1. Bochicchio GV, Jain A, McGonigal K, Turner D, Ilahi O, Reese S, Bochicchio K (2014) Biologic vs. synthetic inguinal hernia repair: 1-year results of a randomized double-blinded trial. J Am Coll Surg 218:751–757
2. Society of American Gastrointestinal and Endoscopic Surgeons. In: www.sages.org. Accessed Sept 2014
3. Fitzgibbons RJ, Richards AT, Quinn TH (2002) Open Hernia Repair. In: Souba WS, Mitchell P, Fink MP, Jurkovich GJ, Kaiser LR, Pearce WH, Pemberton JH, Soper NJ (eds) ACS surgery: principles and practice, 6th edn. Decker Publishing Inc, Philadelphia
4. Kulacoglu H (2011) Current options in inguinal hernia repair in adult patients. Hippokratia 15:223–231
5. Simorov A, Ranade A, Parcells J (2013) Underutilization of laparoscopy and increase in conversion rates in inguinal hernia repairs. Oral presentation at the American Hernia Society Meeting, Orlando
6. Ger R, Monroe K, Duvivier R, Mishrick A (1990) Management of indirect inguinal hernias by laparoscopic closure of the neck of the sac. Am J Surg 159:370–373
7. Tran H, Turingan I, Tran K, Zajkowska M, Lam V, Hawthorne W (2014) Potential benefits of single-port compared to multiport laparoscopic inguinal herniorraphy: a prospective randomized controlled study. Hernia 18:731–744
8. Neumayer L, Giobbie-Hurder A, Jonasson O, Fitzgibbons R Jr, Dunlop D, Gibbs J, Reda D, Henderson W (2004) Open mesh versus laparoscopic mesh repair of inguinal hernia. N Engl J Med 350:1819–1827
9. Zhu X, Cao H, Ma Y, Yuan A, Wu X, Miao Y, Guo S (2014) Totally extraperitoneal laparoscopic hernioplasty versus open extraperitoneal approach for inguinal hernia repair: a meta-analysis of outcomes of our current knowledge. Surgeon 12:94–105
10. Lau H, Patil N, Yuen W (2006) Day-case endoscopic totally extraperitoneal inguinal hernioplasty versus open Lichtenstein hernioplasty for unilateral primary inguinal hernia in males. Surg Endosc Other Interv Tech 20:76–81
11. Lal P, Kajla R, Chander J, Saha R, Ramteke V (2003) Randomized controlled study of laparoscopic total extraperitoneal versus open Lichtenstein inguinal hernia repair. Surg Endosc 17:850–856
12. Papachristou E, Mitselou M, Finokaliotis N (2002) Surgical outcome and hospital cost analyses of laparoscopic and open tension-free hernia repair. Hernia 6:68–72
13. Anadol ZA, Ersoy E, Taneri F, Tekin E (2004) Outcome and cost comparison of laparoscopic transabdominal preperitoneal hernia repair versus open Lichtenstein technique. J Laparoendosc Adv Surg Tech 14:159–163
14. American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP). In: https://www.facs.org/quality-programs/acs-nsqip? 2014
15. American Medical Association CPT–current procedural terminology. In: http://www.ama-assn.org/ama/pub/physician-resources/solutions-managing-your-practice/coding-billing-insurance/cpt.page. Accessed Oct 2014
16. Husereau D, Drummond M, Petrou S, Carswell C, Moher D, Greenberg D, Augustovski F, Briggs AH, Mauskopf J, Loder E, CHEERS Task Force (2013) Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement. BMC Med 11:80-7015-11-80
17. Memon M, Cooper N, Memon B, Memon M, Abrams K (2003) Meta-analysis of randomized clinical trials comparing open and laparoscopic inguinal hernia repair. Br J Surg 90:1479–1492

18. Neumayer LA, Gawande AA, Wang J, Giobbie-Hurder A, Itani KM, Fitzgibbons RJ Jr, Reda D, Jonasson O, CSP #456 Investigators (2005) Proficiency of surgeons in inguinal hernia repair: effect of experience and age. Ann Surg 242:344–348 **discussion 348–52**
19. Moreno-Egea A (2014) Is it possible to eliminate sutures in open (lichtenstein technique) and laparoscopic (totally extraperitoneal endoscopic) inguinal hernia repair? A randomized controlled trial with tissue adhesive (n-hexyl-alpha-cyanoacrylate). Surg Innov 21:590–599
20. Kaul A, Hutfless S, Le H, Hamed SA, Tymitz K, Nguyen H, Marohn MR (2012) Staple versus fibrin glue fixation in laparoscopic total extraperitoneal repair of inguinal hernia: a systematic review and meta-analysis. Surg Endosc 26:1269–1278
21. Topart P, Vandenbroucke F, Lozac'h P (2005) Tisseel versus tack staples as mesh fixation in totally extraperitoneal laparoscopic repair of groin hernias. Surg Endosc Other Interv Tech 19:724–727
22. Ceccarelli G, Casciola L, Pisanelli MC, Bartoli A, Spaziani A, Biancafarina A, Stefanoni M, Patriti A (2008) Comparing fibrin sealant with staples for mesh fixation in laparoscopic transabdominal hernia repair: a case control-study. Surg Endosc 22:668–673
23. Ismail M, Garg P (2009) Laparoscopic inguinal total extraperitoneal hernia repair under spinal anesthesia without mesh fixation in 1220 hernia repairs. Hernia 13:115–119
24. Garg P, Nair S, Shereef M, Thakur JD, Nain N, Menon GR, Ismail M (2011) Mesh fixation compared to non-fixation in total extraperitoneal inguinal hernia repair: a randomized controlled trial in a rural center in India. Surg Endosc 25:3300–3306
25. Teng YJ, Pan SM, Liu YL, Yang KH, Zhang YC, Tian JH, Han JX (2011) A meta-analysis of randomized controlled trials of fixation versus non-fixation of mesh in laparoscopic total extraperitoneal inguinal hernia repair. Surg Endosc 25:2849–2858
26. Birk D, Hess S, Garcia-Pardo C (2013) Low recurrence rate and low chronic pain associated with inguinal hernia repair by laparoscopic placement of Parietex ProGrip^{TM} mesh: clinical outcomes of 220 hernias with mean follow-up at 23 months. Hernia 17:313–320
27. Lal P, Philips P, Chander J, Ramteke VK (2010) Is unilateral laparoscopic TEP inguinal hernia repair a job half done? The case for bilateral repair. Surg Endosc 24:1737–1745
28. Bochkarev V, Ringley C, Vitamvas M, Oleynikov D (2007) Bilateral laparoscopic inguinal hernia repair in patients with occult contralateral inguinal defects. Surg Endosc 21:734–736
29. Sayad P, Abdo Z, Cacchione R, Ferzli G (2000) Incidence of incipient contralateral hernia during laparoscopic hernia repair. Surg Endosc 14:543–545
30. Matthews RD, Anthony T, Kim LT, Wang J, Fitzgibbons RJ, Giobbie-Hurder A, Reda DJ, Itani KM, Neumayer LA, Veterans Affairs Cooperative 456 Studies Program Investigators (2007) Factors associated with postoperative complications and hernia recurrence for patients undergoing inguinal hernia repair: a report from the VA Cooperative Hernia Study Group. Am J Surg 194:611–617