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Costs of laparoscopic and open liver and pancreatic resection: A systematic review

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Abstract

AIM: To study costs of laparoscopic and open liver and pancreatic resections, all the compiled data from available observational studies were systematically reviewed.

METHODS: A systematic review of the literature was performed using the Medline, Embase, PubMed, and Cochrane databases to identify all studies published up to 2013 that compared laparoscopic and open liver [laparoscopic hepatic resection (LLR) *vs* open liver resection (OLR)] and pancreatic [laparoscopic pancreatic resection (LPR) *vs* open pancreatic resection] resection. The last search was conducted on October 30, 2013.

RESULTS: Four studies reported that LLR was associated with lower ward stay cost than OLR (2972 USD *vs* 5291 USD). The costs related to equipment (3345 USD *vs* 2207 USD) and theatre (14538 *vs* 11406) were reported higher for LLR. The total cost was lower in patients managed by LLR (19269 USD) compared to OLR (23419 USD). Four studies reported that LPR was associated with lower ward stay cost than OLR (6755 *vs* 9826 USD). The costs related to equipment (2496 USD *vs* 1630 USD) and theatre (5563 *vs* 4444) were reported higher for LPR. The total cost was lower in the LPR (8825 USD) compared to OLR (13380 USD).

CONCLUSION: This systematic review support the economic advantage of laparoscopic over open approach to liver and pancreatic resection.

Key words: Hepatobiliary resection; Laparoscopic hepatic resection; Open liver resection; Laparoscopic pancreatic resection; Open pancreatic resection

Core tip: Laparoscopic hepatobiliary and pancreatic surgery has progressed over the last years but has been slow to gain widespread acceptance even in some referral centers worldwide. Cost implications of a mini-invasive approach to hepatobiliary and pancreatic surgery are still unknown. A systematic review of the literature was performed. The total cost was lower in patients managed by laparoscopic liver resection. The total cost was lower in the laparoscopic pancreatic resection than in open pancreatic resection. This systematic review support the economic advantage of laparoscopic over open approach to liver and pancreatic resection.

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INTRODUCTION

Laparoscopic hepatobiliary and pancreatic (HPB) surgery has undergone a consistent evolution and a progressive diffusion over the last decade, though it may be complex, technically demanding and requires specific high surgical skills[1]. Despite technical challenges, laparoscopic liver surgery has been widely reported with minor and major resections performed for benign and malignant lesions even in cirrhotic patients[2-9]. Although prospective randomized trials are lacking, the laparoscopic approach to liver resection seems to warrant reduced overall morbidity rate and comparable oncological outcomes than the open approach[10-12]. On the other hand, the progression of laparoscopic pancreatic surgery has been relatively slow among traditional surgeons, with only few emerging specialty centers reporting excellent outcomes for advanced and complex operations, such as laparoscopic pancreaticoduodenectomy (LPD)[13-15]. Whereas LPD should still be considered in its learning curve, due to longer operation time and complicated reconstruction steps, laparoscopic distal pancreatectomy (LDP) has been largely compared with the open approach in literature so far. A recent review, suggested that the mini-invasive approach is associated with lower risk of overall postoperative complications and wound infection, no substantial increase in the operative time, and with a comparable rate of positive resection margin[16]. Despite the above mentioned advantages, the laparoscopic approach to HPB surgery has been slow to gain widespread acceptance even in some referral centers worldwide. Multifactorial reasons to explain this exist, but one that may play an important role is related to the unknown cost implications of a mini-invasive approach to HPB surgical interventions. The systematic reviews and/or meta-analyses published so far have analyzed either short- and long-term results of open versus laparoscopic HPB surgery without focusing on cost-effectiveness[17,18]. The present systematic review of the literature compared costs of laparoscopic and open surgical treatment for liver and pancreatic resection, addressing direct and indirect costs.

MATERIALS AND METHODS

Study selection

A systematic review of the literature was performed using the Medline, Embase, PubMed, and Cochrane databases to identify all studies published form 1987 up to 2013 that compared laparoscopic and open liver and pancreatic resection. This study was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines[19]. The following medical subject heading (MeSH) terms and key words were used: "laparoscopy," "minimally invasive surgery," "laparotomy," "hepatectomy," "liver resection," "open liver resection (OLR)," "hepatic resection," "laparoscopic liver resection," "segmentectomy," "sectionectomy," "treatment outcome," and "wedge resections", "pancreatectomy," pancreatoduodenectomy, distal pancreatectomy, "open pancreatic resection," "laparoscopic pancreatic resection," and "comparative study". Furthermore, the combinations of these terms were used. The term "*vs*" was used to find comparative studies. All the searched abstracts, studies, and citations were analyzed. All the potential articles were cross-referenced. The related article's function was used to broaden the search, and all abstracts, studies, and citations obtained were reviewed. References of the articles acquired were also searched by hand. The last search was conducted on October 30, 2013.

Data extraction

Each study was independently evaluated by 2 reviewers (P.L. and C.V.) for inclusion or exclusion from the review and the following data was extracted: first author, year of publication, characteristics of study population, study design, indications for surgery, matching criteria, number of subjects operated with each technique and direct and indirect costs.

Inclusion criteria

To enter our analysis, studies had to fulfill the following: (1) comparison of costs of laparoscopic (with or without hand-assisted technique) to open approaches in patients undergoing liver and pancreatic resection; (2) objective evaluation of at least one of the outcome measures mentioned below; and (3) when 2 studies were reported by the same institution (and/or authors), either the study with the larger sample size or the one of higher quality was included. However, this was not applicable if the outcome measures were mutually exclusive or measured at different time intervals.

Exclusion criteria

Studies that failed to fulfill the inclusion criteria were excluded. In addition, the following criteria were used to exclude studies: (1) studies in which the outcome of interest mentioned below were not reported or if it was impossible to calculate these from the published reports; (2) studies that focused on other laparoscopic hepatobiliary and pancreatic operations rather than elective resection benign and malignant lesions; (3) studies involving exclusively robotic procedures. However, we included the conventional laparoscopic and open data, if presented by the same group and/or reported in the same study; and (4) studies written in languages other than English.

Assessment of methodological quality

The methodological quality of the studies was assessed independently by two authors. All studies were graded ac-

Table 1 Study characteristics

Ref.	Year	Country	Study design	Sample size	Study interval (yr)	Study population
Polignano *et al*[24]	2008	United Kingdom	Non-randomised prospective cohort	50	2	Liver resection
Tsinberg *et al*[25]	2009	United States	Non-randomised prospective cohort	34	10	Liver resection
Rowe *et al*[26]	2009	United States	Non-randomised prospective cohort	30	3	Liver resection
Vanounou *et al*[27]	2010	United States	Retrospective cohort	73	6	Liver resection
Nguyen *et al*[28]	2011	United States	Retrospective cohort	76	9	Liver resection
Bhojani *et al*[29]	2011	Canada	Retrospective cohort	144	4	Liver resection
Stoot *et al*[30]	2012	Netherlands	Retrospective cohort	28	7	Liver resection
Abu Hilal *et al*[31]	2013	United Kingdom	Retrospective cohort	149	7	Liver resection
Cannon *et al*[32]	2013	United States	Retrospective cohort	98	4	Liver resection
Kim *et al*[33]	2008	South Corea	Retrospective cohort	128	-	Pancreatic resection
Eom *et al*[34]	2008	South Corea	Retrospective cohort	93	11	Pancreatic resection
Waters *et al*[35]	2010	United States	Retrospective cohort	60	1	Pancreatic resection
Fox *et al*[36]	2008	Canada	Retrospective cohort	118	6	Pancreatic resection
Abu Hilal *et al*[37]	2012	United Kingdom	Retrospective cohort	51	6	Pancreatic resection
Limongelli *et al*[38]	2012	Italy	Retrospective cohort	45	10	Pancreatic resection

cording to the Oxford Centre for Evidence-Based Medicine (CEBM) levels of evidence[20]. The risk of bias was assessed using a standardized list of ten potential risks of bias, based on the Oxford CEBM Critical Appraisal Skills Programme appraisal sheets for economic evaluation studies[21].

Outcomes of interest and definitions

Laparoscopic and open approaches to HPB surgery were compared on the basis of cost effectiveness analysis. Liver resections were defined according to the Brisbane 2000 classification[22]: minor (two or fewer segments) or major (at least three segments) according to Couinaud's classification. Cost analysis included theatre costs, equips and equipment costs, nursing, blood transfusion requirement, laboratory testing, postoperative imaging, any re-intervention (radiological and/or surgical) and overall hospital stay. In addition, the cost for readmission from discharge including any associated re-intervention (radiological and/or surgical) and new hospital stay were reviewed. The direct cost of the operation, the direct cost of the postoperative hospital period and the total cost with and without readmission and intervention was analyzed both separately and together. Since most of the data were expressed in US dollars (USD), the remaining were converted to this currency using up to date exchange rates.

Statistical analysis

Mean ± SD or median (range) values were extracted from articles or obtained from the study authors if necessary. Weighted mean ± SD values were calculated using the mean ± SD values reported in the individual studies, or those derived from median (range) values using the methods described by Hozo *et al*[23]. Cost analysis included operative time and supplies, anesthesia, nursing, laboratory, and overall hospital stay costs. The direct cost of operation, as well as the direct cost of the entire associated hospital stay was calculated.

RESULTS

There were total of 15 studies that compared operative costs between laparoscopic and open hepatic and pancreatic resection for benign and/or malignant lesions. Nine studies compared costs between laparoscopic (344/682) and open (338/682) hepatic resection (LLR *vs* OLR)[24-32].

Whereas six studies[33-38] focused on costs differences between laparoscopic (249/495) and open (246/495) pancreatic resection (LPR *vs* OPR). Studies were carried out from different countries all over the word with eight of them reporting figures expressed in USD. The other currencies used to express data in the other studies (pound in 3; Euros in 2; Canadian dollars in 1; South Korean WOW in 1), were converted to USD. Twelve out of fifteen studies were retrospective, with only three reported as prospective cohort studies. All were conducted in a year interval ranging from a minimum of 3 to a maximum of 11 years and on a total number of patients ranging from 30 to 144 patients (Table 1).

Methodological quality

Details of the methodological quality of the included studies are shown in Table 2. All the studies provided evidence that the effects of the intervention were measured and valued appropriately.

In none of the studies an analysis of costs and consequences adjusted for different times at which they occurred (discounting) was applicable. A sensitivity analysis was conducted only in one study[35]. Despite the peculiarity of each patient population and setting where the studies were carried out, the costs appeared to be partly translatable to other settings.

Liver resection

Four studies[24,29-31] reported that LLR was associated with lower ward stay cost than OLR (2972 USD *vs* 5291 USD). This trend concerning hospital costs was confirmed also for High Dependency Unit and Postoperative Anestesia

Table 2 Assessment of methodological quality

Ref.	Level of evidence	Measurements accuracy	Discounting	Sensitivity analysis	Translatability to other setting
Polignano *et al*[24]	3	●	-	□	○
Tsinberg *et al*[25]	3	●	-	□	○
Rowe *et al*[26]	3	●	-	□	○
Vanounou *et al*[27]	4	●	-	□	○
Nguyen *et al*[28]	4	●	-	□	○
Bhojani *et al*[29]	3	●	-	□	○
Stoot *et al*[30]	3	●	-	□	○
Abu Hilal *et al*[31]	3	●	-	□	○
Cannon *et al*[32]	4	●	-	□	○
Kim *et al*[33]	4	●	-	□	○
Eom *et al*[34]	4	●	-	□	○
Waters *et al*[35]	4	●	-	□	○
Fox *et al*[36]	4	●	-	□	○
Abu Hilal *et al*[37]	4	●	-	□	○
Limongelli *et al*[38]	4	●	-	□	○

●: Consistent with criteria, low risk of bias; ○: Partly consistent with criteria, unknown risk of bias; □: Not consistent with criteria, high risk of bias; -: Not applicable.

Table 3 Hospital and operative costs of laparoscopic hepatic resection *vs* open liver resection

Ref. (*n*)	Ward stay	HDU/PACU	Equipment	Theatre	Total costs
Polignano *et al*[24] (50)					
LLR (25)	5535 ± 2576	1558 ± 1940	2302 ± 769	11539 ± 3789	20739 ± 5814
OLR (25)	8306 ± 5567	4178± 1878	1041 ± 668	11755 ± 2353	25285 ± 6750
Tsinberg *et al*[25] (34)					
LLR (18)	-	-	-	28900 ± 2118	36784 ± 3505
OLR (16)	-		-	28023 ± 2247	47358 ± 3717
Rowe *et al*[26] (30)					
LLR (18)	-	-	1071 ± 345	-	-
OLR (12)	-	-	851 ± 424	-	-
Vanounou *et al*[27] (73)[1]					
LLR (44)	-	-	-	-	17290
OLR (29)	-	-	-	-	13962
Nguyen *et al*[28] (76)[2]					
LLR (34)	-	-	-	1.30	1.87
OLR (42)	-	-	-	1.00	1.92
Bhojani *et al*[29] (144)[1]					
OLR (94)	3647	652	-	3598	11376
LLR (50)	5215	641	-	3964	12523
Stoot *et al*[30] (28)					
OLR (14)	2014 ± 510	-	2113 ± 487	3038 ± 743	7167 ± 1335
LLR (14)	1957 ± 599	-	2360 ± 337	3583 ± 794	7901 ± 1107
Abu Hilal *et al*[31] (149)[1]					
LLR (LRH)(38)	2385	4249	5579	10846	7139
OLR (ORH)(46)	5232	9022	2981	7210	18222
OLR (OLLS)(19)	1734	3452	3947	4852	20579
LLR (LLLS)(46)	4300	1918	2613	6557	14252
Cannon *et al*[32] (98)[1]					
OLR (41)	-	-	-	34019	49993
LLR (57)	-	-	-	31400	54703
Overall studies	606[2]				
LLR (310)[2]	2972	1829	3545	14538	19269
OLR (296)[2]	5291	5857	2207	11406	23419

[1]Values are median (range); [2]Nguyen study was excluded from the analysis because raw data were not obtained from the authors. Values are mean ± SD unless indicated otherwise. LRH: Laparoscopic right hepatectomy; ORH: Open right hepatectomy; LLLS: Laparoscopic left lateral sectionectomy; OLLS: Open left lateral sectionectomy; HDU: High dependency unit; PACU: Post anesthesia care unit; LLR: Laparoscopic hepatic resection; OLR: Open liver resection.

Care Unit (HDU/PACU) that resulted more expensive in patients undergoing OLR (5857 USD *vs* 1829 USD) (Table 3)[24,29,31]. On the contrary, costs related to operation were higher in the group of patients undergoing LLR. Specifically both equipment (3345 USD *vs* 2207 USD) and theatre (14538 *vs* 11406) costs were reported higher for LLR respectively by four[24,26,30,31] and six studies[24,25,31,32]. The total cost was lower in patients managed

Table 4 Hospital and operative costs of laparoscopic pancreatic resection *vs* open pancreatic resection

Ref. (*n*)	Ward stay	HDU/PACU	Equipment	Theatre	Total costs
Kim *et al*[33] (128)					
LPR (93)	-	-	-	-	4745 ± 1481
OPR (35)	-	-	-	-	4953 ± 3437
Eom *et al*[34] (31)					
LPR (18)	-	-	-	-	4884 ± 1845
OPR (13)	-		-	-	3401 ± 1247
Waters *et al*[35] (60) [1]					
LPR (32)	9828	-	-	3072	12900
OPR (28)	12011	-	-	3510	15521
Fox *et al*[36] (118) [1]					
LPR (42)	3404	-	-	4655	10842
OPR (76)	5462	-	-	4510	13656
Abu Hilal *et al*[37] (51) [1]					
LPR (35)	7446	-	-	9889	17337
OPR (16)	25441	-	-	9498	34937
Limongelli *et al*[38] (45)					
LPR (16)	7894 ± 1771	-	2496 ± 127	3469 ± 126	11531 ± 1918
OPR (29)	10540 ± 3230	-	1630 ± 329	2388 ± 361	13141 ± 3631
Overall (495)					
LPR (249)	6755	-	2496	5563	8825
OPR (246)	9826	-	1630	4444	13380

[1]Values are median (range). Values are mean ± SD unless indicated otherwise. HDU: High dependency unit; PACU: Post anesthesia care unit; LPR: Laparoscopic pancreatic resection; OPR: Open pancreatic resection.

by LLR (19269 USD) compared to OLR (23419 USD). By analyzing a subset of six[24,25,27,29-31] studies exclusively focused on outcome of minor laparoscopic resection, the total cost of LLR was lower (12720 USD) compared to OLR (17429 USD).

Pancreatic resection

Four studies[35-38] reported that LPR was associated with lower ward stay cost than OLR (6755 USD *vs* 9826 USD). No studies specifically reported on HDU/PACU costs after either LPR or OPR (Table 4). On the contrary, costs related to operation were higher in the group of patients undergoing LPR. Specifically both equipment (2496 USD *vs* 1630 USD) and theatre (5563 *vs* 4444) costs were reported higher for LPR respectively by one[38] and four studies[35-38]. The total cost was lower in the LPR (8825 USD) compared to OLR (13380 USD).

DISCUSSION

This systematic review has compared the costs of laparoscopic and open approach to HPB resection and analyzed methodological quality of the studies. Laparoscopic liver resection was associated with higher costs related to equipment and theatre. On the other hand, LLR carried less expensive hospital costs, such as ward costs and perioperative care. Specifically the costs of HDU and PACU resulted higher in OLR. Finally, when analyzing the total cost of the procedure, the economic advantage for LLR was greater than that for OLR. Laparoscopic pancreatic resection was associated with higher costs related to equipment and theatre. On the other hand, OPR was associated with higher hospital stay cost, such as ward costs, but no studies specifically reported data on costs related to HDU or PACU utilization after LPR or OPR. At last, the total cost of the procedure resulted higher for the group of patients undergoing OPR compared to those treated by LPR. This study is the one of the systematic review to be conducted that specifically compared costs of laparoscopic and open HPB resections. To our knowledge, there has been no randomized controlled trial or systemic review evaluating this topic before. This study included 9 observational studies comparing costs between laparoscopic and open hepatic resection**.** All studies with an overall participants' size of 601 patients were retrospectively conducted, with only 2 of them reported as prospective comparisons[25,26]. The inclusion and exclusion criteria of majority of the studies were clearly stated, with most studies having laparoscopic and open resection matched for demographics and characteristics of the patients. None of the studies but one assess the financial implications of laparoscopy for major and minor liver resections[31]. Authors supported the cost advantage of left lateral sectionectomy (LLS), one of the most performed minor LLR. On the other hand they showed cost neutrality of laparoscopic compared to open right liver resection, suggesting that protocols of enhanced recovery after surgery would be likely to reduce costs of both OLR and LLR. In the present study, by analyzing a subset of six studies reporting only data on minor liver resection we found economic advantages in terms of total cost in the group of patients undergoing LLR than OLR.

Concerning pancreatic resections, we found no specific studies comparing laparoscopic versus open pancreaticoduodenectomy that still represents an uncommon indication to laparoscopic approach, and is still performed in few surgical centers worldwide. On the contrary, LDP seems to carry advantages related to minimal-access sur-

gery, such as reduced postoperative pain, faster recovery, wound complications, lower intraoperative blood loss and fewer postoperative complications[39]. So far, six studies have compared costs between laparoscopic and open distal pancreatic resections (LPR *vs* OPR) and all were retrospective cohorts with a total of 433 patients. Each study had laparoscopic and open resections unmatched for demographics and characteristics of the patients except one who designed a case control comparison with a 2:1 matching[34]. One of the studies also compared the direct cost of operation and of the entire associated hospital stay between OPR, LPR and robotic distal pancreatectomy. Authors showed operative and postoperative costs were similar among all groups, indicating robotic distal pancreatectomy to be safe and cost effective in selected cases. There are some limitations that must be taken into account when interpreting the results of the current analysis. First, by grading down the level of the studies on the basis of study quality, it is clear this systematic review could include only studies of poor-moderate quality. Moreover, we choose not to perform a sensitivity analysis to evaluate the impact of methodological quality on the operative and hospital costs of laparoscopic and open liver and pancreatic resection. This was because of lack of data from studies of the highest quality, defined by a level of evidence of 1 and 2. Confounding by indication was a common risk of bias in most cohort studies because related to the choice of approach merely based on surgeon's clinical judgment. Specifically, due to the severe heterogeneity of liver resection data collected in this analysis, it is safe to assume that centers would have chosen LLR for minor and uncomplicated cases and OLR for major and complicated cases. Despite the peculiarity of each patient population and setting where the studies were carried out, the methodological evaluation costs appeared to be in part translatable to other settings. However, the economic parameters used in the assessment are likely to differ from country to country, based on the type of healthcare and reimbursement system. In a recent study, a higher proportion of patients treated with LDP were readmitted to undergo interventional procedures after an initial shorter hospitalization[40]. Authors suggested that adding days spent in readmission to the initial length of hospital stay eliminates the perceived effect of the laparoscopic approach to pancreatic distal resection. The majority of studies included in this analysis did not assess and compare costs of laparoscopic and open liver and pancreatic resections before and after readmission to hospital. With respect to pancreatic resection, Fox *et al*[36] reported a major impact of pancreatic fistula on total hospital cost in the ODP cohort, but comparable in-hospital complications between LDP and ODP cohorts in terms of total hospital cost. In line with this figures, a recent study included in the present review showed the total cost of OLR and LPR were not significantly different after including patients readmission[37]. Among studies addressing comparative costs between OLR and LLR, two of them employed deviation-based cost modeling and weighted average mean cost. One study showed the overall cost savings per patient undergoing laparoscopic LLS was around three thousand dollars less that a patient undergoing a similar open operation[27]. This results were confirmed by Cannon and coworkers who showed an high average cost savings for patients undergoing LLR compared to those treated by OLR[32]. Authors did not find any advantages of laparoscopy in the subset of patients undergoing right hepatectomy, suggesting the benefit of laparoscopy is related to the difficulty of surgery, resulting into a compensation between higher operative costs and the financial benefits of a shorter and less complicated hospital stay. Whether this finding is due to the complexity of a laparoscopic approach associated with dramatic longer operative time or is the result of both higher morbidity and readmission rate after major LLR is still to be demonstrated.

In conclusion, this study summarized the available evidence on financial comparison between laparoscopic and open approach to liver and pancreatic resections including assessment of methodological quality, without an attempt at meta-analysis, as this would have been inappropriate given the heterogeneity in study designs and protocols.

COMMENTS

Background

Laparoscopic hepatobiliary and pancreatic (HPB) surgery has undergone a consistent evolution and a progressive diffusion over the last decade, though it may be complex, technically demanding and requires specific high surgical skills.

Research frontiers

The present systematic review of the literature compared costs of laparoscopic and open surgical treatment for liver and pancreatic resection, addressing direct and indirect costs.

Innovations and breakthroughs

A systematic review of the literature was performed using the Medline, Embase, PubMed, and Cochrane databases to identify all studies published up to 2013 that compared laparoscopic and open liver and pancreatic resection.

Applications

This systematic review support the economic advantage of laparoscopic over open approach to liver and pancreatic resection.

Peer review

This study focused on the economical aspect of laparoscopic HPB for the first time in English review articles. This article is novel and well-described.

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