Robotic versus conventional laparoscopic pancreaticoduodenectomy: a systematic review and meta-analysis

Sivesh K. Kamarajah a,b,*, James Bundred c, Olivier Saint Marc d, Long R. Jiao e, Derek Manas a,b, Mohammed Abu Hilal f, Steven A. White a,b

a Department of HPB and Transplant Surgery, The Freeman Hospital, Newcastle upon Tyne, Tyne and Wear, UK
b Institute of Cellular Medicine, Newcastle University, Newcastle upon Tyne, Tyne and Wear, UK
c College of Medical and Dental Sciences, University of Birmingham, UK
d Department of Surgery, Centre Hospitalier Régional Orleans, Orleans, France
e Department of Surgery and Cancer, HPB Surgical Unit, Imperial College, Hammersmith Hospital Campus, London, UK
f Department of Surgery, Southampton University Hospital NHS Foundation Trust, Southampton, UK

A B S T R A C T

Background: Robotic pancreaticoduodenectomy (RPD) offers theoretical advantages to conventional laparoscopic surgery including improved instrument dexterity, 3D visualization and better ergonomics. This review aimed to determine if these theoretical advantages translate into improved patient outcomes comparing patients having either robotic pancreaticoduodenectomy or laparoscopic (LPD) equivalent.

Method: A systematic literature search was conducted for studies reporting minimally invasive surgery for pancreaticoduodenectomy either robotic assisted or totally laparoscopic. Meta-analysis of intraoperative (blood loss, operating times, conversion and R0 resections) and postoperative outcomes (overall complications, pancreatic fistula, length of hospital stay) was performed using a random effects model.

Result: This review identified 44 studies, of which six were non-randomised comparative studies including 3462 patients (1025 robotic and 2437 laparoscopic). Intraoperatively, RPD was associated with significantly lower conversion rates (OR 0.45, p < 0.001) and transfusion rates (OR: 0.60, p = 0.002) compared to LPD. However, no significant difference in blood loss (mean: 220 vs 287 mL, p = 0.1), operating time (mean: 405 vs 418 min, p = 0.3) was noted. Postoperatively RPD was associated with a shorter hospital stay (mean: 12 vs 11 days, p < 0.001) but no significant difference was noted in postoperative complications, incidence of pancreatic fistulae and R0 resection rates.

Conclusion: RPD appears to offer some advantages compared to conventional laparoscopic surgery, although both approaches appear to offer equivalent clinical outcomes. Importantly, the quality of evidence is generally limited to cohort studies and a high-quality randomised trial comparing both techniques is needed.

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Introduction

Over the last decade, robotic surgery has emerged as a potential valid alternative to conventional laparoscopic surgery. Advantages of current robotic surgical platforms include 3D visualisation of the surgical field and improved instrument dexterity which may facilitate complex dissection and surgical reconstructions. In addition the use of an ergonomic surgical console may reduce surgeon fatigue for long and complex procedures which is one of the reasons why the laparoscopic approach remains unpopular [1]. RPD may also encourage more surgeons to take up complex minimally invasive techniques which they previously would not have considered doing. Robotic surgery has been shown to be superior to conventional laparoscopic surgery in a variety of different complex surgical procedures. For example, in radical prostatectomy the robotic approach has been associated with an earlier return of sexual function when compared to conventional laparoscopic surgery.

* Corresponding author. Department of Hepatobiliary, Pancreatic and Transplant Surgery, Academic Department of Surgery, Freeman Hospital, Newcastle upon Tyne, Tyne and Wear, UK.
E-mail address: siveshkk93@gmail.com (S.K. Kamarajah).
which is attributed to an increased ability to preserve the cavernous nerve [2,3]. A similar reduction in impotency rates have been reported in robotic rectal surgery, presumably for similar reasons [4].

Minimally invasive PD (MIPD) has been gaining popularity in recent years, with systematic reviews suggesting MIPD (both laparoscopic and robotic) were associated with significantly less blood loss and lower rates of margin-positive resections compared to conventional (open) PD [5–7]. A recent meta-analysis comparing LPD and open PD for the management of periampullary malignancies have concluded that the use of the laparoscopic approach did not impact on short-term survival or the incidence of pancreatic fistula. The laparoscopic approach was however associated with a shorter duration of hospital stay and lower overall complications [8]. Whether the use of a robotic approach may prove to be superior to both the conventional laparoscopic and open techniques for complex pancreatic resections although this still remains to be determined [9].

To date, evidence comparing the benefits of robotic PD (RPD) and LPD is limited [10], and more data is still needed to offer clearer guidance on the future development of minimally invasive pancreatic surgery. The aim of this systematic review was to summarise current evidence for laparoscopic of robotic PD and perform meta-analysis to evaluate the current evidence regarding RPD and to compare its advantages with the conventional laparoscopic approaches.

Methods

Search strategy

A systematic search of PubMed, EMBASE and the Cochrane Library databases was conducted on the 24th April 2019 by two independent investigators (SKK, JB). The search terms used were ‘robotic surgery’, or ‘laparoscopic surgery’, or ‘open surgery’, and ‘pancreatoduodenectomy’, or ‘Whipple’s’ either individually or in combination. The ‘related articles’ function was used to broaden the search, and all citations were considered for relevance. A manual search of reference lists in recent reviews and eligible studies was also undertaken. This paper is reported according to the PRISMA guidelines and flow diagram presented in Fig. 1 [11]. This study was prospectively registered with the PROSPERO database (Registration CRD42018126797)

Inclusion and exclusion criteria

Inclusion criteria were: (1) studies reporting the use of minimally invasive surgery comparing robotic and laparoscopic surgery for PD for benign and malignant indications, (2) single arm studies

Fig. 1. Flowchart of PRISMA diagram.
reporting either LPD or RPD (3) published in the English language. Exclusion criteria were: (1) Conference abstracts, review articles, and case reports (<5 patients) - (2) comparative analysis between minimally invasive surgery, where outcomes not reported for RPD and LPD separately. After excluding duplicates, two researchers (SKK, JB) independently reviewed the titles and abstracts of studies identified by the literature search. Where a study was considered to be potentially relevant to the research question a full copy of the publication was obtained for further review. The reference lists of all included studies were hand-searched in order to identify other potentially relevant studies. Any areas of disagreement between the two primary researchers were resolved through discussion.

Study outcomes

The primary outcome measure was post-operative complications such as overall and major complications (≥Grade III reported according to Clavien-Dindo Classification) [12]. Secondary outcome measures were intraoperative (operative time, blood loss, transfusion rate, conversion rate), oncological (lymph nodes harvested, R0 resection rates), and surgery-specific complications such as overall and clinically-relevant pancreatic fistula, overall and clinically-relevant delayed gastric emptying, bile leak, surgical site infection, pulmonary complications, mortality, length of stay, 90-day readmission and reoperation rates.

Definitions

Surgical technique is any method of surgical extirpation of the pancreatic head such as open, totally laparoscopic (TL), and totally robotic (TR). TR was defined as complete use of the robotic technique for PD, including resection and reconstruction without laparoscopic or hand-assisted techniques, nevertheless this did include the use of laparoscopic ports by a surgical assistant as part of the robotic procedure which is regarded as standard. TL was defined as complete use of a laparoscopic technique for PD, including resection and reconstruction without robotic or hand-assisted techniques.

Overall and major complications were defined according to the Clavien-Dindo classification, whereby major complications were defined as ≥ Grade III Clavien-Dindo complications [12–15]. Overall pancreatic fistula and clinically-relevant fistula were defined according to the International Study Group for Pancreatic Fistula (ISGPF) classification [16,17].

Data extraction

The following data were extracted from the papers: name of first author, year of publication, country of study conducted, study design, number of patients in robotic and laparoscopic group, patients' characteristics (age, gender, ASA score, body mass index (BMI), pathology type, size of lesion), intra-operative variables (operative time, total blood loss, transfusion rate, conversion rate, spleen preservation rate, R0 margin status, lymph node harvested), and post-operative variables (length of stay, 90-days readmission rate, 90-days reoperation rate, complication rate, pancreatic fistula rate, high-grade pancreatic fistula rate).

Quality assessment

Methodological quality and standard of outcome reporting within included studies were assessed by two independent researchers (SKK, JB). Methodological quality was formally assessed using the Newcastle-Ottawa score (NOS) for cohort studies (SKK, JB) and the Cochrane Risk of Bias Tool for randomised controlled trials [18,19].

Statistical analysis

This systematic review and meta-analysis were conducted in accordance with the recommendations of the Cochrane Library and PRISMA guidelines [11,20,21]. For categorical variables, analysis was performed by calculating the odds ratio (OR). The random effects, the DerSimonian-Laird method was used for the meta-analysis of outcomes. Heterogeneity between studies was assessed using the I² value in order to determine the degree of variation not attributable to chance alone. I² values were considered to represent low, moderate, and high degrees of heterogeneity where values were <25%, 25–75%, and >75%, respectively. Funnel plot asymmetry was assessed using the Egger test. Statistical significance was considered when p < 0.05. Statistical analyses were performed using the R Foundation Statistical software (R 3.2.1) and Stata 15 (Version 15.1, StataCorp, College Station, Texas) as previously described [21].

Results

This review identified 44 studies, of which six were comparative studies on LPD vs RPD and 38 were non-comparative single arm studies on either laparoscopic or robotic PD. Study selection as a PRISMA flowchart is summarised in Fig. 1.

Comparative studies

Patients' characteristics and pre-operative variables
Comparative studies on robotic and laparoscopic surgery comprised of six studies involving 3462 patients (1025 robotic and 2437 laparoscopic) undergoing PD. Study-level and patient-level characteristics of RPD and LPD groups are listed in Table 1. Median NOS study quality assessment score was 8, ranging from 6 to 9 across the studies (Supplementary Table 1), reflecting high study qualities. None of the studies had a blinded assessment of the outcomes or performed a prospective calculation of sample size.

Patient-level characteristics were analysed through meta-analysis. There were no significant differences in age, gender, American Society of Anaesthesiologist (ASA) grade, and malignant tumour pathology between both groups (Table 1, Supplementary Figs. 1A–E). Patients undergoing RPD had significantly lower BMI than LPD (mean: 26.7 vs 27.1 kg/m², p < 0.001, I² = 0%, Supplementary Fig. 1D). Tumour size was reported in only one study, with no significant differences between RPD and LPD (2.2 vs 1.9 cm, p = 0.4) [22]. None of the studies reported tumour number (solitary vs multiple) in each RDP and LDP, hence, both tumour number and tumour size were not included in the meta-analysis.

Intra-operative outcomes
A summary of intraoperative outcomes are presented in Table 2. Five studies reported operative times, all of which included docking times. There was no significant difference in operating times between RPD and LPD (mean: 405 vs 418 min, p = 0.3 - I² = 80%) (Supplementary Fig. 2A). Two studies reported blood loss showing no significant difference in blood loss between either RPD and LPD (mean: 220 vs 287 mL, p = 0.1 - I² = 34%) (Supplementary Fig. 2B). Two studies reported transfusion rates where patients undergoing RPD had significantly lower transfusion rates than LPD (10% vs 18%, OR: 0.60, Cl95%: 0.44–0.83, p = 0.002 - I² = 0%) (Supplementary Fig. 2C). All studies reported conversion rates in both groups. Patients undergoing RPD (n = 1025) had significantly lower conversion rates between than LPD (n = 2437) (12% vs 26%, OR: 0.45, Cl95%: 0.36–0.56, p < 0.001 - I² = 0%) (Supplementary Fig. 2D). Lymph nodes harvested and R0 resection rates were reported in two
studies respectively. Patients undergoing RPD had significantly higher lymph nodes harvested than LPD (mean: 13 vs 12, p < 0.001 - $I^2 = 0\%$ - Supplementary Fig. 2E).

**Post-operative outcomes**

A summary of postoperative outcomes is presented in Table 2. Overall and major complications were reported in four and two studies respectively. There were no significant differences in complication rates between RPD and LPD for overall (48% vs 47%, OR: 1.04, CI95%: 0.73–1.48, p = 0.8 - $I^2 = 64\%$ - Supplementary Fig. 3A) and major complications (42% vs 41%, OR: 1.02, CI95%: 0.71–1.48, p = 0.9 - $I^2 = 0\%$ - Supplementary Fig. 3B). Pancreatic fistula and delayed gastric emptying were reported in five studies. There were no significant differences between RPD (n = 860) and LPD (n = 579) for overall pancreatic fistula (all grade) (19% vs 19%, OR: 1.02, CI95%: 0.81–1.29, p = 0.9 - $I^2 = 0\%$ - Supplementary Fig. 3C) and delayed gastric emptying (15% vs 17%, OR: 0.88, CI95%: 0.68–1.15, p = 0.3 - $I^2 = 0\%$ - Supplementary Fig. 3D). Grade B and C pancreatic fistula (5% vs 15%) and biliary leaks (5% vs 10%) were reported in one study with no significant difference between RPD and LPD. None of the studies reported grade B and C delayed gastric emptying [23]. Hence, grade B and C pancreatic fistula, grade B and C delayed gastric emptying and biliary leaks were not included in the meta-analysis.

Surgical site infection (SSI) and pulmonary complications were reported in two studies. There was no significant difference in rates of SSI (25% vs 21%, OR: 1.24, CI95%: 0.96–1.61, p = 0.1 - $I^2 = 0\%$) or pulmonary complications (3% vs 4%, OR: 0.57, CI95%: 0.20–1.65, p = 0.3 - $I^2 = 47\%$) between RPD and LPD. Peri-operative 30-day mortality was reported in six studies. There was no significant difference in mortality rates between RPD (n = 1025) and LPD (n = 2437) (2% vs 3%, OR: 0.92, CI95%: 0.55–1.54, p = 0.8 - $I^2 = 0\%$).

Length of hospital stay was reported in all six studies. Patients undergoing RPD (n = 1025) had significantly shorter hospital stay than LPD (n = 2437) (mean: 12 vs 11 days, p < 0.001 - $I^2 = 77\%$) (Supplementary Fig. 3E). Readmission rates at 90-days were reported in all six studies. Patients undergoing RPD (n = 1025) had significantly higher readmission rates than LPD (n = 2437) (2% vs 3%, OR: 0.92, CI95%: 0.55–1.54, p = 0.8 - $I^2 = 0\%$). (Supplementary Fig. 3F).

**Publication biases**

Funnel plot analysis for the intra-operative and post-operative variables was done to assess the possibility of publication bias.
addition, the median length of stay was similar across both groups (median: 13 vs 13 days). The 90-day readmission (17% vs 8%) and reoperation (10% vs 6%) rates were higher in RPD than LPD.

Discussion

Over the last decade, laparoscopic and robotic approaches have been adapted for various hepato-pancreatico-biliary (HPB) procedures. However, MIPD remains limited to only a few centres with very little available data and no general consensus regarding the translatability of MIPD for improving clinical outcomes. Whilst open PD has traditionally been the mainstay surgical approach for resection of tumours in the pancreatic head, MIPD is slowly being adopted in selected high-volume centres [5–7,24,25]. Several meta-analyses have published outcomes comparing robotic and open PD, which have demonstrated that RPD were associated with significantly lower blood loss, overall complications and a lower positive margin rate [26,27]. Recently, the first randomised clinical trial (LEOPARD-2) comparing LPD and open PD did not demonstrate any significant differences in major complications and Grade B/C pancreatic fistula [9]. However, this trial was stopped early due to an unexpected high mortality rate (10% vs 2%) in the LPD (n = 50) when compared to open (n = 49).

To date, no previous meta-analysis has compared outcomes between RPD and LPD, although several individual centres have published their outcomes comparing these two different techniques [22,23,28–31]. This systematic review and meta-analysis highlights (i) the current evidence supporting both LPD and LDP

### Table 3

<table>
<thead>
<tr>
<th>Study Name</th>
<th>Country</th>
<th>Study Interval</th>
<th>Surgical Approach</th>
<th>Patients, n</th>
<th>Male, %</th>
<th>Age, yrs</th>
<th>ASA Grade, %</th>
<th>BMI, kg/m²</th>
<th>Previous Abdominal Surgery, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lee 2013 [63]</td>
<td>Korea</td>
<td>2009–2012</td>
<td>LPD</td>
<td>42</td>
<td>43%</td>
<td>60 (8)</td>
<td>33%</td>
<td>22 (2)</td>
<td>-</td>
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<td>Liu 2015 [64]</td>
<td>China</td>
<td>2011–2012</td>
<td>LPD</td>
<td>21</td>
<td>38%</td>
<td>66 (12)</td>
<td>-</td>
<td>25 (17-37)</td>
<td>-</td>
</tr>
<tr>
<td>Lu 2016 [65]</td>
<td>China</td>
<td>2012–2015</td>
<td>LPD</td>
<td>120</td>
<td>67%</td>
<td>60 (12)</td>
<td>81%</td>
<td>24 (3)</td>
<td>19%</td>
</tr>
<tr>
<td>Wang 2016 [66]</td>
<td>China</td>
<td>2016</td>
<td>LPD</td>
<td>36</td>
<td>58%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Duan 2017 [67]</td>
<td>China</td>
<td>2014–2015</td>
<td>LPD</td>
<td>52</td>
<td>56%</td>
<td>57.8 (28–73)</td>
<td>100%</td>
<td>22 (3)</td>
<td>-</td>
</tr>
<tr>
<td>Wu 2017 [68]</td>
<td>China</td>
<td>2014–2015</td>
<td>LPD</td>
<td>22</td>
<td>63%</td>
<td>56 (28–73)</td>
<td>100%</td>
<td>22 (3)</td>
<td>-</td>
</tr>
<tr>
<td>Cai 2018 [69]</td>
<td>China</td>
<td>2018</td>
<td>LPD</td>
<td>84</td>
<td>43%</td>
<td>62 (6)</td>
<td>-</td>
<td>21 (2)</td>
<td>50%</td>
</tr>
<tr>
<td>Dokmak 2018 [70]</td>
<td>Germany</td>
<td>2011–2017</td>
<td>LPD</td>
<td>4</td>
<td>25%</td>
<td>73 (69-77)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Guerra 2018 [71]</td>
<td>Italy</td>
<td>2014–2017</td>
<td>RPD</td>
<td>59</td>
<td>58%</td>
<td>69 (38-85)</td>
<td>86%</td>
<td>24 (19-32)</td>
<td>-</td>
</tr>
<tr>
<td>Jung 2018 [72]</td>
<td>Korea</td>
<td>2017</td>
<td>LPD</td>
<td>107</td>
<td>51%</td>
<td>62 (11.8)</td>
<td>100%</td>
<td>26</td>
<td>51%</td>
</tr>
<tr>
<td>Ren 2018 [73]</td>
<td>Korea</td>
<td>2012–2016</td>
<td>RPD</td>
<td>100</td>
<td>53%</td>
<td>55 (14)</td>
<td>37%</td>
<td>24 (4)</td>
<td>-</td>
</tr>
<tr>
<td>Zhang 2018 [74]</td>
<td>Italy</td>
<td>2002–2006</td>
<td>LPD</td>
<td>19</td>
<td>37%</td>
<td>64 (12)</td>
<td>89%</td>
<td>-</td>
<td>-</td>
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<td>Pugliese 2008 [75]</td>
<td>Italy</td>
<td>2007–2009</td>
<td>LPD</td>
<td>62</td>
<td>52%</td>
<td>66 (12)</td>
<td>-</td>
<td>26 (17-40)</td>
<td>-</td>
</tr>
<tr>
<td>Kendrick 2011 [76]</td>
<td>USA</td>
<td>2007–2010</td>
<td>LPD</td>
<td>11</td>
<td>71%</td>
<td>-</td>
<td>-</td>
<td>24</td>
<td>-</td>
</tr>
<tr>
<td>Cho 2013 [77]</td>
<td>Japan</td>
<td>2013</td>
<td>LPD</td>
<td>15</td>
<td>40%</td>
<td>69 (54-77)</td>
<td>-</td>
<td>22 (18-26)</td>
<td>-</td>
</tr>
<tr>
<td>Nakimura 2012 [78]</td>
<td>Japan</td>
<td>2011</td>
<td>LPD</td>
<td>17</td>
<td>41%</td>
<td>64 (19-81)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bogg 2013 [79]</td>
<td>Italy</td>
<td>2008–2011</td>
<td>RPD</td>
<td>34</td>
<td>-</td>
<td>60 (33-80)</td>
<td>91%</td>
<td>24 (18-29)</td>
<td>56%</td>
</tr>
<tr>
<td>Coricione 2013 [80]</td>
<td>Italy</td>
<td>2003–2010</td>
<td>LPD</td>
<td>22</td>
<td>45%</td>
<td>62 (45-73)</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Kim 2013 [81]</td>
<td>Korea</td>
<td>2012</td>
<td>LPD</td>
<td>100</td>
<td>46%</td>
<td>50 (14-51)</td>
<td>-</td>
<td>23 (3)</td>
<td>-</td>
</tr>
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<td>Wang 2015 [82]</td>
<td>China</td>
<td>2010–2013</td>
<td>LPD</td>
<td>31</td>
<td>39%</td>
<td>62 (11)</td>
<td>100%</td>
<td>22 (3)</td>
<td>-</td>
</tr>
<tr>
<td>Senshithnathan 2014 [83]</td>
<td>India</td>
<td>1998–2013</td>
<td>LPD</td>
<td>130</td>
<td>38%</td>
<td>54 (28-76)</td>
<td>-</td>
<td>28 (23-34)</td>
<td>-</td>
</tr>
<tr>
<td>Boone 2015 [84]</td>
<td>USA</td>
<td>2008–2014</td>
<td>RPD</td>
<td>120</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Nguyen 2015 [85]</td>
<td>USA</td>
<td>2008–2013</td>
<td>RPD</td>
<td>112</td>
<td>50%</td>
<td>68 (13)</td>
<td>-</td>
<td>27 (5)</td>
<td>-</td>
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<tr>
<td>Panniccia 2015 [86]</td>
<td>USA</td>
<td>2013–2014</td>
<td>LPD</td>
<td>30</td>
<td>-</td>
<td>63 (54-71)</td>
<td>-</td>
<td>27 (5)</td>
<td>-</td>
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<td>Luo 2016 [87]</td>
<td>Taiwan</td>
<td>2012–2015</td>
<td>LPD</td>
<td>12</td>
<td>67%</td>
<td>60 (13)</td>
<td>-</td>
<td>26 (3)</td>
<td>-</td>
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<tr>
<td>Machado 2016 [88]</td>
<td>Brazil</td>
<td>2012–2015</td>
<td>LPD</td>
<td>50</td>
<td>46%</td>
<td>63 (23-76)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Napoli 2016 [89]</td>
<td>Italy</td>
<td>2009–2014</td>
<td>RPD</td>
<td>112</td>
<td>46%</td>
<td>60 (14)</td>
<td>87%</td>
<td>24 (4)</td>
<td>54%</td>
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<td>150</td>
<td>53%</td>
<td>67 (12)</td>
<td>-</td>
<td>25 (7)</td>
<td>53%</td>
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<tr>
<td>Poves 2016 [91]</td>
<td>Spain</td>
<td>2013–2016</td>
<td>LPD</td>
<td>13</td>
<td>54%</td>
<td>65 (12)</td>
<td>-</td>
<td>26 (5)</td>
<td>-</td>
</tr>
<tr>
<td>Li 2016 [92]</td>
<td>China</td>
<td>2013–2016</td>
<td>LPD</td>
<td>27</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>Khatov 2017 [93]</td>
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<td>LPD</td>
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<td>43%</td>
<td>66 (10)</td>
<td>-</td>
<td>27 (16-38)</td>
<td>-</td>
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<td>LPD</td>
<td>31</td>
<td>58%</td>
<td>60 (10)</td>
<td>100%</td>
<td>25 (3)</td>
<td>-</td>
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<td>Giulianotti 2018 [95]</td>
<td>USA</td>
<td>2007–2016</td>
<td>RA-PD</td>
<td>28</td>
<td>57%</td>
<td>62 (12)</td>
<td>96%</td>
<td>27 (5)</td>
<td>-</td>
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<td>Jiang 2018 [96]</td>
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<td>2010–2016</td>
<td>RA-PD</td>
<td>34</td>
<td>38%</td>
<td>47 (15)</td>
<td>38%</td>
<td>23 (3)</td>
<td>21%</td>
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<td>Japan</td>
<td>2007–2016</td>
<td>LPD</td>
<td>150</td>
<td>53%</td>
<td>69 (26-86)</td>
<td>-</td>
<td>22 (15 - 31)</td>
<td>-</td>
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<td>Zhang 2018 [99]</td>
<td>China</td>
<td>2015–2017</td>
<td>LPD</td>
<td>45</td>
<td>56%</td>
<td>63 (12)</td>
<td>-</td>
<td>24 (3)</td>
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is similar but limited to retrospective cohort studies (ii) Although the robotic approach was associated with a shorter hospital stay, lower transfusion rates and less blood loss, the most important clinically relevant difference confirmed in this study is the lower incidence of conversion. This highlights the importance of the robotic assistance in improving the feasibility, reproducibility and likely in shortening the learning curve when compared to the laparoscopic approach. To gain a wider expansion, a surgical approach should demonstrate to be feasible and reproducible with no great benefit of an approach or a technique bound to be limited to a very highly skilled range of surgeons and not reproducible to the majority. Whilst laparoscopic left pancreatectomy has been gaining wide expansion with an acceptable learning curve [32,33,35] and is now considered the gold standard approach in specialist centres, at least for benign disease [34,35], On the contrary significant advantages offered by robotic platforms include 3D visualisation of the surgical field and improved instrument dexterity which may facilitate complex dissection and surgical reconstructions have been suggested to enhance the feasibility of the minimally invasive approach thus reducing the operative time, conversion rate and learning curve as seen in this study.

Similar trends were seen in comparisons between the robotic and the laparoscopic approach in other surgical procedures such as nephrectomy [36], hysterectomy [37] and anterior resections for rectal cancers [38], where similar morbidity and mortality of the two minimally invasive approaches was reported but with a lower conversion rate after robotic surgery during hysterectomy [37] (OR: 0.29, CI95%: 0.18–0.46) and anterior resections [38] (OR: 0.58, CI95%: 0.35–0.97, p = 0.04), although non-significant during radical nephrectomy [36] (OR: 0.44, CI95%: 0.18–1.09, p = 0.08) were noted. In addition the robotic approach may enhance the surgical feasibility in complex patients by facilitating surgical maneuvers in constrained and awkward spaces [39]. For instance, the ROLARR randomised trial highlighted that conversion rates were significantly higher in obese compared to normal and overweight patients (25% vs 7%), suggesting possible benefits of robotic surgery in this subset of patients [40]. Since converted patients have higher complication rates and worse oncological outcomes [41–43], the low conversion rate for RPD may lead to quicker recovery and allow earlier treatment with adjuvant chemotherapy in patients with malignancy.

Whilst pancreatic fistula remains the most common and serious technical complication after pancreaticoduodenectomy (PD) accounting for 20% of cases [16,17,44], this current study found no significant difference between the RPD and LPD techniques, as well as overall and major complications or delayed gastric emptying. Patients who experience pancreatic fistula incur higher hospital costs, suffer high morbidity, ranging between 30% and 50% [44–47] with a post-operative mortality of around 4% [48–52]. These patients may also suffer poorer long-term survival compared to patients who have an uneventful recovery (median: 13 vs 25 months, p = 0.01) [25,53,54]. Many peri-operative factors are thought to be responsible for pancreatic fistula following PD such as methods of pancreatic anastomosis, patient fitness [55], size and consistency of the duct and pancreatic parenchyma and surgical approach technique [16,44,56,57]. For instance, Ausania et al. highlighted low cardiopulmonary reserve is associated with significantly higher pancreatic fistula than patients with high cardiopulmonary reserve (45% vs 19%, p = 0.001) [55]. Importantly, RPD were associated with significantly shorter length of hospital stay compared to conventional LPD.

Since none of the studies in this review report total costs of RPD, we did not evaluate the cost associated with RPD although it has been well described elsewhere that this procedure does typically incur an increased cost for the institution [58]. Notwithstanding this disadvantage having a robotic program may actually have the opposite effect by increasing the number of referrals (patient choice) thus actually increasing income for the institution but again this is yet to be proven. It is perceived that over coming years the development of new robotic systems will increase competition in the marketplace and lower the overall cost of robotic surgery making it more accessible for institutions and thus making RPD more likely to achieve at least cost neutrality when compared to LPD. Also, lower conversion rates as shown in this review may translate to lower overall hospital costs. Nevertheless, it could also be argued that robotic systems will become technologically more advanced thus actually increasing cost.

Over the coming years, quality assessment and standardising operative techniques of robotic surgery is important to allow wider adoption within HPB surgery. Firstly, whilst operative time has
largely been reported with a learning curve in robotic surgery, this may not be an accurate assessment on the quality of robotic surgery [23,59–61]. A study from Boone et al. [60] highlights that the achieving the learning curve in RPD varies according to the different outcomes assessed. For instance, this study demonstrated that improvement in blood loss and conversion rates seen after 20 RPD cases. However, these differed for pancreatic fistula (40 cases), operative time (60 cases), and lymph node harvest (60 cases). Hence, benchmarking clinically outcomes to that which are relevant to patients is important in assessing quality of robotic surgery. Secondly, improving techniques and the safety of robotic PD through post-hoc video analysis may be useful in achieving the learning curve. Jung et al. highlighted that intraoperative findings are not sensitive in predicting R0/R1 status through video analysis in RPD [62]. Such comprehensive technology may allow robotic surgeons to learn from each case and improve techniques.

Our review has strengths important to note such as high-quality rating of all included studies and detailed data extraction encompassing several intra-operative and postoperative outcomes. This review has limitations which are important to address. Firstly, all studies included in this review were mainly retrospective, lacking any randomised controlled trials. This may reflect that RPD is still in the early phase of the learning curve. Secondly, none of the studies have evaluated the long-term outcomes, which limits our ability to draw useful prognostic conclusions and quality of life. Finally, all studies in this review do not stratify outcomes between benign and malignant indications which are also unimportant to know.

Conclusion

In summary, this systematic review and meta-analysis comparing RPD and LPD suggests that both techniques can be used safely for both benign and malignant cases. RPD appears to offer some advantages compared to LPD although both techniques appear equivalent. However, the advantage on reducing the conversion rates thus reflecting a higher feasibility and reproducibility potential is worth highlighting. Further studies and in particular a RCT is badly needed to enable us to draw useful conclusions regarding patients’ survival, quality of life, cost and long-term oncological outcome.

Conflict of interest

All authors declare no conflict of interest.

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Conflict of interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejso.2019.08.007.

References


