Platinum Priority – Review – Kidney Cancer

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Robotic Versus Laparoscopic Partial Nephrectomy: A Systematic Review and Meta-Analysis

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Abstract

Context: Centres worldwide have been performing partial nephrectomies laparoscopically for greater than a decade. With the increasing use of robotics, many centres have reported their early experiences using it for nephron-sparing surgery.

Objective: To review published literature comparing robotic partial nephrectomy (RPN) with laparoscopic partial nephrectomy (LPN).

Evidence acquisition: An online systematic review of the literature according to Cochrane guidelines was conducted from 2000 to 2012 including studies comparing RPN and LPN. All studies comparing RPN with LPN were included. The outcome measures were the patient demographics, tumour size, operating time, warm ischaemic time, blood loss, transfusion rates, length of hospital stay, conversion rates, and complications. A meta-analysis of the results was conducted. For continuous data, a Mantel-Haenszel chi-square test was used; for dichotomous data, an inverse variance was used. Each was expressed as a risk ratio with a 95% confidence interval p < 0.05 considered significant.

Evidence synthesis: A total of 717 patients were included, 313 patients in the robotic group and 404 patients in the laparoscopic group (seven studies). There was no significant difference between the two groups in any of the demographic parameters except for age (age: p = 0.006; sex: p = 0.54; laterality: p = 0.05; tumour size: p = 0.62, tumour location: p = 0.57; or confirmed malignant final pathology: p = 0.79). There was no difference between the two groups regarding operative times (p = 0.58), estimated blood loss (p = 0.76), or conversion rates (p = 0.84). The RPN group had significantly less warm ischaemic time than the LPN group (p = 0.0008). There was no difference regarding postoperative length of hospital stay (p = 0.37), complications (p = 0.86), or positive margins (p = 0.93).

Conclusions: In early experience, RPN appears to be a feasible and safe alternative to its laparoscopic counterpart with decreased warm ischaemia times noted.

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1. Introduction

Partial nephrectomy (PN) is the gold standard for treatment of small renal masses, with laparoscopy becoming a more commonly used approach [1]. With advancements in laparoscopic techniques, equipment, and operator skills, laparoscopic PN (LPN) has emerged as a viable alternative to open PN with comparable oncologic outcomes, less morbidity, and faster postoperative recovery [1–4]. However, LPN is technically challenging and has a steeper
learning curve because it requires not only precise tumour margin resection but complex and time-dependent renal reconstruction [5–9]. This led the European Association of Urology to propose that these techniques be performed only in experienced centres [1].

Current robotic surgical systems provide not only optically magnified three-dimensional imaging but also a greater range of fully articulated wristed-instrument motion. This provides precision control with scaling of the surgeons’ movements [1,2].

Numerous centers have published their experiences with robotic PN (RPN) [1–3,6,7,9–11]. RPN outcomes have been reported to be similar to laparoscopic or open procedures in terms of oncologic and functional outcomes [6–9]. Enhanced precision robotic handling has reduced the technical challenges posed by LPN, helped reduce the surgical learning curve needed, and shortened operative and ischaemic times with less blood loss compared with LPN [1,2,4]. Several studies have emerged recently comparing experience with outcomes of RPN and LPN [2,8,11,12].

We conducted a systematic review of the literature with a meta-analysis of the results to compare RPN and LPN in terms of operative and ischaemic times, blood loss, hospital stay, conversion rates, positive surgical margin rates, and perioperative complications.

2. Evidence acquisition

2.1. Search strategy and study selection

The systematic review was performed according to the Cochrane review guidelines. The search strategy was conducted to find relevant studies from Medline (2000–2012), Embase (2000–2011), Cochrane Central Register of Controlled Trials—CENTRAL (in the Cochrane Library, Issue 1, 2011), CINAHL (2000–2012), Clinicaltrials.gov, Google Scholar, and individual urologic journals. The search was conducted on February 6, 2012.


Papers in languages other than English were included if data were extractable. References of searched papers were also evaluated for potential inclusion. Authors of the included studies were contacted wherever the data were not available or not clear. If data were not provided or clarified, the study was excluded.

Two reviewers (O.A. and R.S.) identified all studies that appeared to fit the inclusion criteria for full review. Four reviewers (O.A., R.S., R.E., and B.S.) independently selected studies for inclusion in the review. Disagreement between the extracting authors was resolved by consensus by all authors.

2.2. Data extraction and analysis

Studies comparing RPN with LPN were included. The main outcome was to assess the pre-, peri-, and postoperative results between the two procedures. The secondary outcome will be to assess the learning curve required and a cost analysis. The following variables were extracted from each study: patient demographics, tumour size, operating time, warm ischaemic time, blood loss, transfusion rates, length of hospital stay, conversion rates, and complications. The data of each study were grouped into a meta-analysis, in an intention-to-treat basis, to allow a numerical representation of the results. Only similar results that were pooled from the included studies were meta-analysed. A subgroup analysis was conducted to evaluate whether or not the tumour location or the complication classification varied between the two procedures. For continuous data, a Mantel-Haenszel chi-square test was used and expressed as the mean difference with 95% confidence interval (CI). For dichotomous data, an inverse variance was used and expressed as risk ratio with 95% CI. In both cases p < 0.05 was considered significant.

Taking into consideration that the first 25 procedures can be attributed to the learning curve for the procedures, we conducted a subgroup analysis to compare the two procedures regarding operative times, estimated ischaemic times, blood loss, length of hospital stay, and complication rates.

Heterogeneity will be analysed using a chi-square test on n-of-1 degree of freedom, with an α of 0.05 used for statistical significance and with the I² test [13]. I² values of 25%, 50%, and 90% correspond to low, medium, and high levels of heterogeneity. A fixed-effect model was used unless statistically significant high heterogeneity (ie, I² > 90%) existed between studies. A random-effects model was used if heterogeneity existed. Although not included in the meta-analysis, studies of relevance were included in the systematic review for a general overview.

An assessment of the methodological quality of the included studies in the meta-analysis was conducted in line with the Cochrane handbook [13,14]. For quality assessment, the selection bias, performance bias, detection bias, attrition bias, and reporting bias were assessed in each of the included studies. We used Review Manager (RevMan v.5.0.23) to plot the quality assessment.

3. Evidence synthesis

3.1. Literature search

The literature search yielded 521 studies, of which 447 were excluded due to nonrelevance based on the titles and 51 excluded due to nonrelevance based on the abstracts (Fig. 1). Full manuscripts were evaluated in 25 studies, of which 12 were included in the systematic review [4,8,12,15–23]. Of the 12 initially included studies, 7 were included in a pooled meta-analysis [4,12,19–23]. Most of the studies were published within the last 5 yr, reflecting the increased use of this procedure.
After reading the full manuscripts, we excluded 13 studies for various reasons [1–3,7,10,11,24–30]. Laydner and Kaouk was a systematic review of RPN [24]. Lee et al. compared RPN with the open procedure rather than LPN [25]. Yu et al. assessed the use, costs, and outcomes of laparoscopic surgery in urology with no specific comparison of RPN versus LPN [26]. Aron et al. was excluded because the authors provided data of their larger cohort of patients over a longer period of time published more recently [11,12]. The study by Spana et al. only looked at complications of RPN [7]. Gupta et al. reported on RPN for large tumours with no comparison with LPN [27]. Long et al. compared the outcomes of LPN and RPN of just complex renal tumours and therefore was excluded; however, a previously published study comparing LPN and RPN for the same group was included [12,30]. Although the remaining excluded studies were on RPN, no comparison with LPN was made [1–3,6,10,28,29].

All the included studies were cohort observational studies with no randomisation, and all reported on their centres’ experience with RPN compared with LPN. All the studies reported on the patient demographics, tumour size, operating time, warm ischaemic time, blood loss, transfusion rates, length of hospital stay, conversion rates, and complications (plotted into Table 1, Fig. 2, and Fig. 3). Table 2 depicts the data of the five studies that were excluded from the meta-analysis due to lack of data [8,15–18]. All corresponding authors of the studies were contacted for data.

### Table 1: Study results of robotic versus laparoscopic partial nephrectomy

<table>
<thead>
<tr>
<th>Study</th>
<th>Patients, RPN vs LPN, no.</th>
<th>Age, RPN vs LPN, yr</th>
<th>Male:female, RPN vs LPN</th>
<th>Right:left, RPN vs LPN</th>
<th>Pathology, malignant:benign, RPN vs LPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellison et al. [23]</td>
<td>108 vs 108</td>
<td>59.4 ± 12.1 vs 55.9 ± 10.6</td>
<td>66.42 vs 62.42</td>
<td>52.56 vs 57.51</td>
<td>92.16 vs 84.24</td>
</tr>
<tr>
<td>Haber et al. [12]</td>
<td>75 vs 75</td>
<td>62.6 ± 11.3 vs 60 ± 12.05</td>
<td>44.31 vs 40.35</td>
<td>36.39 vs 43.32</td>
<td>59.16 vs 59.16</td>
</tr>
<tr>
<td>Jeong et al. [19]</td>
<td>31 vs 26</td>
<td>53.4 ± 14 vs 58.7 ± 8.4</td>
<td>0.94:1 vs 1:1</td>
<td>NA</td>
<td>22.9 vs 18.8</td>
</tr>
<tr>
<td>Kural et al. [20]</td>
<td>11 vs 20</td>
<td>50.81 ± 13.15 vs 58.9 ± 15.4</td>
<td>8.3 vs 14.6</td>
<td>3.8 vs 8.12</td>
<td>11.0 vs 16.4</td>
</tr>
<tr>
<td>Pierorazio et al. [4]</td>
<td>48 vs 102</td>
<td>60.15 ± 9.13 vs 54.8 ± 11.59</td>
<td>27.21 vs 63.39</td>
<td>22.26 vs 55.47</td>
<td>36.12 vs 84.18</td>
</tr>
<tr>
<td>Seo et al. [21]</td>
<td>13 vs 14</td>
<td>54.2 ± 12.4 (33–72) vs 53.9 ± 11.6 (34–72)</td>
<td>10.3 vs 8.6</td>
<td>4.9 vs 10.4</td>
<td>11.2 vs 9.5</td>
</tr>
<tr>
<td>Williams et al. [22]</td>
<td>27 vs 59</td>
<td>55.74 ± 11.23 vs 54.6 ± 11.69</td>
<td>17.10 vs 41.18</td>
<td>13.14 vs 28.31</td>
<td>22.4 vs 58.2</td>
</tr>
</tbody>
</table>

**Note**: LPN = laparoscopic partial nephrectomy; RPN = robotic partial nephrectomy; NA = not available.
or clarification either by e-mail or by postal address. The corresponding authors of the seven studies in the meta-analysis replied with the missing or unclear data where appropriate [4,12,19–23]. After numerous attempts at contacting the authors of the five remaining studies, no reply was received. Hence they were excluded because their data could not be pooled for analysis [8,15–18]. The authors failed to report the standard deviation of their results that are needed for meta-analysis of the data. The emphasis of this review is on the seven studies included in the meta-analysis.

3.2. Characteristics of the included studies

Although a literature search was conducted between 2000 and 2012, comparison studies were published between 2009 and 2012, four conducted in the United States, two in

![Fig. 2 – Forest plots of outcomes: (a) tumour size in millimetres; (b) tumour location; (c) operative time; (d) warm ischaemic time; (e) estimated blood loss; (f) length of hospital stay; (g) positive margin; (h) conversion. The following studies are cited: Ellison [23], Haber [12], Jeong [19], Kural [20], Pierazzo [4], Seo [21], and Williams [22]. CI = confidence interval; IV = inverse variance; LPN = laparoscopic partial nephrectomy; M-H = Mantel-Haenszel; RPN = robotic partial nephrectomy; SD = standard deviation.

### (d) EURUROPEAN UROLOGY (2012) XXX–XXX

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>RPN</th>
<th>LPN</th>
<th>Mean Difference</th>
<th>Mean Difference IV, Fixed, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellison 2012</td>
<td>24.9</td>
<td>11.9</td>
<td>10.83</td>
<td>10.83 (15.0%  5.60 [5.58, 5.64])</td>
</tr>
<tr>
<td>Haber 2010</td>
<td>18.2</td>
<td>13.2</td>
<td>5.04</td>
<td>5.04 (19.3%  2.10 [5.75, 1.55])</td>
</tr>
<tr>
<td>Jeong 2009</td>
<td>20.9</td>
<td>14.0</td>
<td>6.98</td>
<td>6.98 (24.0%  3.70 [4.27, 11.87])</td>
</tr>
<tr>
<td>Kuril 2009</td>
<td>26.1</td>
<td>14.1</td>
<td>12.08</td>
<td>12.08 (36.4%  4.05 [12.02, 4.42])</td>
</tr>
<tr>
<td>Pierozzo 2011</td>
<td>14.1</td>
<td>6.3</td>
<td>7.82</td>
<td>7.82 (28.4%  3.90 [6.81, 0.80])</td>
</tr>
<tr>
<td>Seo 2011</td>
<td>35.3</td>
<td>8.5</td>
<td>26.8</td>
<td>26.8 (75.5%  1.10 [6.93, 4.73])</td>
</tr>
<tr>
<td>Williams 2011</td>
<td>18.5</td>
<td>7.6</td>
<td>10.9</td>
<td>10.9 (21.5%  9.50 [12.96, 6.94])</td>
</tr>
</tbody>
</table>

Total (95% CI) 313 494 100.0% -2.74 [-4.35, -1.14]

Heterogeneity: \( \chi^2 = 34.65, \text{df} = 8 \) (\( p = 0.00001 \)); \( I^2 = 63 \%
Test for overall effect: \( Z = 3.39 \) (\( p = 0.00001 \))

### (e) EURUROPEAN UROLOGY (2012) XXX–XXX

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Experimental</th>
<th>Control</th>
<th>Mean Difference</th>
<th>Mean Difference IV, Fixed, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellison 2012</td>
<td>2.7</td>
<td>1.0</td>
<td>1.7</td>
<td>1.7 (58.8%  0.50 [0.08, 9.22])</td>
</tr>
<tr>
<td>Haber 2010</td>
<td>4.2</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1 (75.3%  0.10 [0.05, 0.79])</td>
</tr>
<tr>
<td>Jeong 2009</td>
<td>5.2</td>
<td>1.6</td>
<td>3.6</td>
<td>3.6 (87.5%  0.01 [0.06, 0.88])</td>
</tr>
<tr>
<td>Kuril 2009</td>
<td>3.9</td>
<td>0.7</td>
<td>3.2</td>
<td>3.2 (141.4% -0.37 [-1.31, 0.27])</td>
</tr>
<tr>
<td>Pierozzo 2011</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Not estimable</td>
</tr>
<tr>
<td>Seo 2011</td>
<td>6.2</td>
<td>1.8</td>
<td>4.4</td>
<td>4.4 (55.5%  0.90 [0.13, 1.93])</td>
</tr>
<tr>
<td>Williams 2011</td>
<td>2.51</td>
<td>1.05</td>
<td>1.46</td>
<td>1.46 (20.5% -0.20 [-0.95, 0.25])</td>
</tr>
</tbody>
</table>

Total (95% CI) 265 362 100.0% 0.11 [-0.13, 0.35]

Heterogeneity: \( \chi^2 = 8.66, \text{df} = 5 \) (\( p = 0.08 \)); \( I^2 = 48 \%
Test for overall effect: \( Z = 0.89 \) (\( p = 0.37 \))

### (f) EURUROPEAN UROLOGY (2012) XXX–XXX

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>RPN</th>
<th>LPN</th>
<th>Odds Ratio M-H, Fixed, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellison 2012</td>
<td>6</td>
<td>108</td>
<td>1.00 [0.31, 3.20]</td>
</tr>
<tr>
<td>Haber 2010</td>
<td>1</td>
<td>75</td>
<td>0.92 [0.03, 75.83]</td>
</tr>
<tr>
<td>Kural 2009</td>
<td>0</td>
<td>11</td>
<td>0.78 [0.02, 15.06]</td>
</tr>
<tr>
<td>Pierozzo 2011</td>
<td>2</td>
<td>48</td>
<td>0.28 [0.03, 48.66]</td>
</tr>
<tr>
<td>Seo 2011</td>
<td>0</td>
<td>13</td>
<td>Not estimable</td>
</tr>
<tr>
<td>Williams 2011</td>
<td>1</td>
<td>27</td>
<td>0.35 [0.03, 3.35]</td>
</tr>
</tbody>
</table>

Total (95% CI) 282 378 100.0% 0.97 [0.43, 2.17]

Total events 10 15

Heterogeneity: \( \chi^2 = 3.33, \text{df} = 4 \) (\( p = 0.50 \)); \( I^2 = 0 \%
Test for overall effect: \( Z = 0.88 \) (\( p = 0.93 \))

### (g) EURUROPEAN UROLOGY (2012) XXX–XXX

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>RPN</th>
<th>LPN</th>
<th>Odds Ratio M-H, Fixed, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellison 2012</td>
<td>0</td>
<td>108</td>
<td>Not estimable</td>
</tr>
<tr>
<td>Haber 2010</td>
<td>3</td>
<td>75</td>
<td>0.75 [0.31, 3.04]</td>
</tr>
<tr>
<td>Jeong 2009</td>
<td>1</td>
<td>31</td>
<td>0.65 [0.01, 76.73]</td>
</tr>
<tr>
<td>Kural 2009</td>
<td>0</td>
<td>11</td>
<td>0.13 [0.01, 4.61]</td>
</tr>
<tr>
<td>Pierozzo 2011</td>
<td>1</td>
<td>49</td>
<td>0.10 [0.09, 1.20]</td>
</tr>
<tr>
<td>Seo 2011</td>
<td>0</td>
<td>13</td>
<td>Not estimable</td>
</tr>
<tr>
<td>Williams 2011</td>
<td>0</td>
<td>27</td>
<td>0.35 [0.03, 17.87]</td>
</tr>
</tbody>
</table>

Total (95% CI) 313 404 100.0% 1.12 [0.38, 3.32]

Total events 5 7

Heterogeneity: \( \chi^2 = 2.30, \text{df} = 4 \) (\( p = 0.70 \)); \( I^2 = 0 \%
Test for overall effect: \( Z = 0.20 \) (\( p = 0.84 \))

Fig. 2. (Continued)
Korea, and one in Turkey. Among the 717 patients, the ages of 313 patients (the robotic group) ranged from 37 to 73 yr; the ages of 404 patients (the laparoscopic group) ranged from 42 to 73 yr. In the RPN group there were 188 men; 130 procedures were right sided. In the LPN group there were 241 men; 201 procedures were right sided. Jeong et al. did not report on the laterality of their procedure [19].

All seven studies reported on the tumour size, operative times, warm ischaemic times, estimated blood loss, transfusion requirement, length of hospital stay, conversion rates, and malignant and benign rates [4,12,19,23]. Three studies reported on tumour location [12,20,21]. Six studies reported surgical margins and complications [4,12,20–23]; however, only three studies classified their complications using the Clavien scheme [4,22,23]. The data of all the studies were given as means plus or minus the standard deviation, which allowed for a meta-analysis of the pooled data.

### 3.3. Meta-analysis results

Table 1 depicts the demographics of the studies including number of patients, age, sex, laterality, and pathology. There was no significant difference between the two groups for any of the demographic parameters except for age (age: $p = 0.006$, MD: 2.38, 95% CI, 0.69–4.06; sex: $p = 0.54$, odds ratio [OR]: 1.00, 95% CI, 0.81–1.24; laterality: $p = 0.05$, OR: 1.00; 95% CI, 0.80–1.25; malignant pathology: $p = 0.79$, OR: 1.05, 95% CI, 0.72–1.54).

There was no statistical difference found between RPN and LPN regarding tumour size ($p = 0.62$; MD: 0.52; 95% CI, −1.56 to 2.60), tumour location ($p = 1$; OR: 1.0; 95% CI, 0.71–1.4), or positive margins ($p = 0.93$; OR: 0.97; 95% CI, 0.43–2.17) (Fig. 2).

There was no perioperative difference between the two groups regarding operative times ($p = 0.58$; MD: 8.64; 95% CI, −21.72 to 39.00), estimated blood loss ($p = 0.15$; MD: −24.04; 95% CI, −56.86 to 8.77), or conversion rates ($p = 0.84$; OR: 1.12; 95% CI, 0.38–3.32). However, the RPN group had significantly less warm ischaemic time than the LPN group ($p = 0.0008$; MD: −2.74; 95% CI, −4.35 to −1.14) (Fig. 2). There was no difference regarding postoperative length of hospital stay ($p = 0.37$; MD: 0.11; 95% CI, −0.35 to 0.35) (Fig. 2).

There was no statistical difference between the two groups regarding complications ($p = 0.86$; OR: 0.96; 95% CI, 0.65–1.43). There was no difference between the two groups regarding the Clavien classification (CC) of complications...
Table 2—Study results of robotic versus laparoscopic partial nephrectomy of studies excluded

<table>
<thead>
<tr>
<th>Study</th>
<th>Tumour size, mm (mean)</th>
<th>Age, yr</th>
<th>Gender</th>
<th>Male: Female</th>
<th>Right: Left</th>
<th>Male vs LPN</th>
<th>Female vs LPN</th>
<th>Male vs LPN (mean)</th>
<th>Female vs LPN (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowman and al. [17]</td>
<td>28 vs 25</td>
<td>50.2</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Deo et al. [18]</td>
<td>31 (25–40)</td>
<td>53.2</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Cincu et al. [19]</td>
<td>15.5 vs 21.8</td>
<td>54</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Dzolcik et al. [18]</td>
<td>28 vs 28</td>
<td>50.5</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Chit et al. [16]</td>
<td>27 (9–35)</td>
<td>56.5</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>LPN—laparoscopic partial nephrectomy: RPN—robotic partial nephrectomy: 1st—upper; M—middle; L—lower; NA—not available</td>
<td></td>
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<td></td>
<td></td>
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</tbody>
</table>

3.3.1. Subgroup analysis

Removing the studies with <25 procedures, there was no difference found between the two groups regarding operative times (p = 0.55; MD: 11.32; 95% CI, −25.90 to 48.55), estimated blood loss (p = 0.13; MD: −27.53; 95% CI, −63.13 to 80.07), or postoperative length of hospital stay (p = 0.31; MD: 0.14; 95% CI, −0.13 to 0.41). Fig. 4. Furthermore, there was no difference regarding the complication rates (p = 0.81; OR: 0.95; 95% CI, 0.64–1.42). However, similar to the general analysis, the RPN group had significantly less warm ischaemic time than the LPN group (p = 0.001; MD: −2.83; 95% CI, −4.53 to −1.13) (Figs. 2 and 4).

3.4. Methodological quality assessment

All the studies were observational controlled studies. Figure 5 depicts the summary of the quality assessment based on the reviewing author’s judgement of risks of bias for each included study. Only Pierorazio et al. had a high risk of selection bias due to the difference noted between the demographics of the LPN and RPN groups (the RPN group tended to be older) [4]. Otherwise the studies had a low risk of bias in all the categories. None of the studies were randomised or blinded, and the LPN groups were considered the control group.

3.5. Discussion

3.5.1. Summary of the main results

This review found no significant difference between RPN and LPN, except that the RPN group had significantly less warm ischaemic time (Fig. 2). With the exception of Pierorazio et al. and Ellison et al., there was no difference between the two groups regarding age, sex, tumour size, laterality, or location. However, a pooled analysis did show that the RPN group had older patients, implying the procedure can safely accommodate a wider age range than its laparoscopic counterpart.

Regarding the operative parameters, no significant difference was found pertaining to the operative time, blood loss, or conversion rate (Fig. 2). No statistical significance was found regarding the postoperative and oncologic parameters such as hospital stay, surgical margins, or complications (Fig. 2 and 3).

Four studies reported less warm ischaemia time in the RPN group [4,20,22,23]. One study had less blood loss in the LPN group [12]; another had less blood loss in the RPN group [4]. Seo et al. reported that the overall operative time in the LPN group was shorter; however, they further subdivided the operative time into laparoscopic time, defined as the insertion of the ports to their removal, which did not show any difference between the two groups [21]. Ellison et al. also found that the LPN group had shorter operative times, overall ischaemic time, and shorter length of hospital stay [23]. Pierorazio et al. reported that the RPN group had less operative time [4]. Despite the subtle variations between the
groups, the pooled meta-analysis found no statistical difference between the two groups regarding most of the outcome parameters, except for warm ischaemic time favouring the RPN group with less time needed [4,12,19–23]. Although the only significant parameter favouring RPN, it is of vital importance because return of renal function depends on the duration of ischaemic time [31]. In fact, it is recommended that the pedicle clamping necessary during PN should be limited to 20 min of warm ischaemia [31,32]. Although the kidney can tolerate longer cold ischaemic times, up to 2 h, an international collaborative review suggested it should not go beyond 35 min [32]. Nevertheless, controversy exists regarding the importance of warm ischaemia time compared with other modifiable risk factors such as the amount of benign renal parenchyma preserved. Warm ischaemia was used in all studies in this review when hilar clamping was performed (Fig. 2 and Table 2). Because PN is essentially nephron-sparing surgery, every minute is vital for preservation of renal function. Therefore, it can be deduced that RPN is superior
to LPN in preserving nephrons and ultimately renal function.

The meta-analysis for one of the outcome parameters had significant heterogeneity, two other parameters had medium-level heterogeneity, and the remaining comparisons were considered as having low heterogeneity (Fig. 2). No cause for the heterogeneity was found because no difference regarding the risk of bias, timing and length of the studies, inclusion criteria, or country was isolated. Subgroup analysis conducted based on isolating small and large numbered cohort studies had no effect on the heterogeneity; however, no statistical significance between the two groups remained. Heterogeneity also applied to the warm ischaemia time. However, when small and large numbered cohorts were isolated, the heterogeneity did not change, and no change was found regarding the statistical difference, which favoured the RPN with less time. The discrepancy between the patient cohorts in the studies could explain the significant heterogeneity; however, no difference was found with the end result.

Regarding the five studies not included in the meta-analysis due to lack of data, three studies found no significant difference in any of the outcome parameters measured [15–17]. DeLong et al. reported that the LPN had significantly less operative time but significantly longer warm ischaemia time [18]. Benway et al. reported significantly less blood loss, shorter warm ischaemic time, and shorter hospital stay in the RPN group; otherwise no difference was noted regarding the other outcome parameters [8].

3.5.2. Learning curve
Pierorazio et al. conducted a further analysis to determine whether or not a learning curve has an effect on the end result. Comparing their first 25 patients to their most recent patients, they found a significant improvement in the operative time, warm ischaemic time, and estimated blood loss in the LPN group [4]. However, similar differences were not found in the RPN group when comparing the earlier and later patient data. Ellison et al. also found that the ischaemic time, blood loss, and operative times improved after the first 33 cases, suggesting the learning curve does improve with time and more familiarity with the procedure by both the surgeon and the operating team [23]. Mottrie et al. also found that the impact of surgeons’ learning curve improved with time [1]. They showed that with more experience, the operative time, warm ischaemia time, and the need for pelvicaliceal repairs due to injury were reduced; however, no impact was found regarding blood loss or complications. In the largest reported series comparing early and later experiences of RPN, they showed that once the learning curve was past, there was a significantly decreased blood loss, transfusion rate, conversion rate, rate of postoperative complications, mean operative time, and length of hospital stay [33]. With further experience with RPN, lower complication rates and better results, especially with more complex tumours, compared with LPN may be noted. Nevertheless, further study is needed for verification, especially at a multi-institutional level.

3.5.3. Cost analysis
None of the studies conducted a cost analysis comparison between the laparoscopic and robotic groups. Nonetheless, Yu et al. compared the costs of various urologic procedures
carried out, laparoscopically, or using robots [26]. They found that robotic surgery was significantly more expensive than both laparoscopic and open procedures. But it was associated with a significantly shorter hospital stay with fewer complications and transfusion rates compared with laparoscopic and open procedures. Despite this, no social cost analysis was found in the literature that factors in the implications of a quicker recovery and shorter convalescence. It is estimated that RPN costs about $1600 more per person or an additional 6% per case [26].

Despite the increase in costs, numerous reports have suggested that RPN is feasible for tumours >4 cm, complex tumours, in patients with prior abdominal surgery, in children, and even as single-port surgery [27,34–38]. A systematic review that included >700 patients who underwent RPN showed that RPN was feasible and had similar results to laparoscopic and open techniques [24].

### 3.5.4 Strengths and limitations of the review

The main limitation of this review is the inclusion of studies with small patient cohorts in the meta-analysis. Three of the seven studies included had ≥150 patients; the remaining studies had fewer numbers [4,12,23]. This can skew the results because these studies might be reporting on their initial experiences. However, with more experience reported beyond the initial learning curve, results of such comparative analysis may differ. Removing studies with <25 procedures in either group, we found no difference in the end results in any of the parameters.

This review was impartial and conducted systematically and methodically with Cochrane standards. This represents the evidence available in the literature comparing early experiences of RPN with LPN.

It is evident that a large multicentre trial comparing the two procedures in addition to open PN is required once the learning curve for RPN has been overcome. This study needs to include a cost analysis between the procedures, including postdischarge convalescence and return to work analysis, in addition to patient and surgeon perspectives regarding pain and overall satisfaction with the procedure.

### 4. Conclusions

Meta-analysis of the literature reveals that RPN is a feasible and safe alternative to LPN with similar outcomes and low complication rates. RPN was found to have significantly less ischaemic time. Further studies are needed to evaluate the benefits of RPN and its cost effectiveness compared with LPN.

**Author contributions:** Omar M. Aboumarzouk had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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**Analysis and interpretation of data:** Aboumarzouk.

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**References**


