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REVIEW

A comparison of perioperative outcomes of transperitoneal versus retroperitoneal robot-assisted partial nephrectomy: a systematic review

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Abstract

RAPN can be carried out via a transperitoneal or retroperitoneal approach. The choice between the two approaches is open to debate and usually based on surgeon preference. The perioperative outcomes of transperitoneal robot-assisted partial nephrectomy versus retroperitoneal robot-assisted partial nephrectomy were compared. A systematic review of the literature was performed up to May 2020, using PubMed, Cochrane, Scopus and Ovid databases. Articles were selected according to a search strategy based on PRISMA criteria. Only studies comparing TRAPN with RRAPN were eligible for inclusion. Eleven studies were included in the quantitative synthesis. Baseline demographics (age, BMI, ASA, tumour size, and RENAL nephrometry score), intraoperative data (operative time, estimated blood loss, and warm ischaemia time) and postoperative outcomes (major complications according to Clavien–Dindo, length of hospital stay (LOS) and positive surgical margin rate) were recorded. A total of 3139 patients were included (2052 TRAPN vs. 1087 RRAPN). There was no significant difference in demographic variables (age, BMI), tumour size ($p = 0.06$) nor the nephrometry score ($p = 0.20$) between the two groups. Operative time ($p = 0.02$), estimated blood loss ($p < 0.00001$) and LOS ($p < 0.00001$) were significantly lower in the RRAPN group. No differences were found in major postoperative complications (Clavien–Dindo > 3; $p = 0.37$), warm ischaemia time ($p = 0.37$) or positive surgical margins ($p = 0.13$). Future researchers must attempt to achieve adequately powered, expertise based, multi-surgeon and multi-centric studies comparing TRAPN and RRAPN. RRAPN gives similar outcomes to TRAPN. RRAPN is associated with reduced operative time and LOS. Ideally, surgeons should be familiar and competent in both RAPN approaches and adopt a risk-stratified and patient-centred individualised approach, dependent on the tumour and patient characteristics. RAPN is feasible via two approaches. The retroperitoneal approach seems to be associated with a shorter operation time and hospital stay.

Keywords Partial nephrectomy · Transperitoneal · Retroperitoneal · Robotic surgery

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Introduction

The increased use of diagnostic imaging over the last decade has contributed to the diagnosis of a greater number of asymptomatic renal masses [1]. These tumours (most often classified as T1a or T1b) are candidates for nephron-sparing surgery. Nowadays, partial nephrectomy is considered the gold standard for T1a tumours, for most T1b tumours and even for highly selected T2 tumours [2–4].

Laparoscopic partial nephrectomy (retroperitoneal or transperitoneal) has been adopted in some tertiary centres seeking minimal invasive techniques. This procedure offers similar functional and oncological outcomes to open partial nephrectomy, with less blood loss and a shorter hospital stay. Nevertheless, its use is restricted to specialised experienced laparoscopic surgeons due to its steep learning curve [5, 6]. The development of robot-assisted surgery (DaVinci robot; Intuitive Surgical, Sunnyvale, CA) has overcome the disadvantages of the standard laparoscopic approach, improving instrument movement and enabling easy working and suturing, even in confined spaces [7, 8].

In 2010, a relative annual increase of 45.4% was noted for robot-assisted laparoscopic partial nephrectomy, whereas open and laparoscopic partial nephrectomy increased by 7.9% and 6.1%, respectively [9]. Nowadays, robot-assisted partial nephrectomy (RAPN) has become the surgical intervention of choice for renal masses suitable for a nephron-sparing approach [10].

RAPN can be carried out via a transperitoneal or retroperitoneal approach. The transperitoneal approach is preferred in laparoscopic partial nephrectomy due to a larger working space and better recognition of anatomical structures. The choice between the two approaches is open to debate and usually based on surgeon preference.

The retroperitoneal approach has been popularised as it avoids the peritoneal cavity and potential adhesions from previous transabdominal surgeries. This approach grants direct access to the hilar structures without any kidney mobilisation and would hypothetically give easier access to posterior tumours. The confined retroperitoneal space would contain any potential bleeding or urine leaks, thereby decreasing postoperative complications [11]. Nevertheless, the retroperitoneal approach is more challenging due to the confined space and less familiar landmarks.

In order to determine the potential superiority of one approach over the other, we carried out a systematic review of the literature in order to compare the two robotic approaches according to several per- and postoperative criteria.

Materials and methods

Search strategies and study selection

All studies comparing transperitoneal robot-assisted partial nephrectomy (TRAPN) versus retroperitoneal robot-assisted partial nephrectomy (RRAPN) were considered for inclusion.

A systematic review of the literature was performed up to May 2020, in accordance with the Cochrane Guidelines and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The bibliographic databases searched were PubMed, Cochrane, Ovid and Scopus. No language restrictions were applied.

A review protocol was established prior to the study. The PICO model used was as follows: the study population (P) consisted of patients with kidney tumours who underwent RRAPN (I) or TRAPN (C). Outcomes of interest were perioperative outcomes (O), as described below. Identification and selection of the studies were conducted according to PRISMA criteria (www.prisma-statement.org) (Fig. 1). Separate searches were performed using a combination of the search terms 'nephron-sparing', 'retroperitoneal', 'retroperitoneoscopic', 'robotic partial nephrectomy'.

A total of 37 potential publications were identified and 24 articles were eliminated after screening of the abstracts (5 were review articles, 3 were rejected due to low quality and 16 were not relevant). Thirteen full-text articles were assessed for eligibility and 2 were subsequently excluded due to a lack of sufficient data. Eleven studies were finally included in the quantitative synthesis (systematic review).

Selection criteria

Two of the authors (AB and EA) performed the article selection. Only original studies comparing the outcomes of RRAPN and TRAPN for renal tumours were included. The article titles and abstracts were first reviewed to ascertain whether they fulfilled the inclusion criteria. For those passing the first screening, a full-text analysis was performed to confirm inclusion. Studies without primary data (letters to the editor/authors, case reports and commentaries) and conference abstracts were not considered. The references of collected studies were reviewed manually in order to identify additional studies of interest.

Quality assessment of studies

Each study was classified according to the level of evidence (http://www.cebm.net/explanation-2011-ocebm-levels-evidence/). The quality of the studies was determined

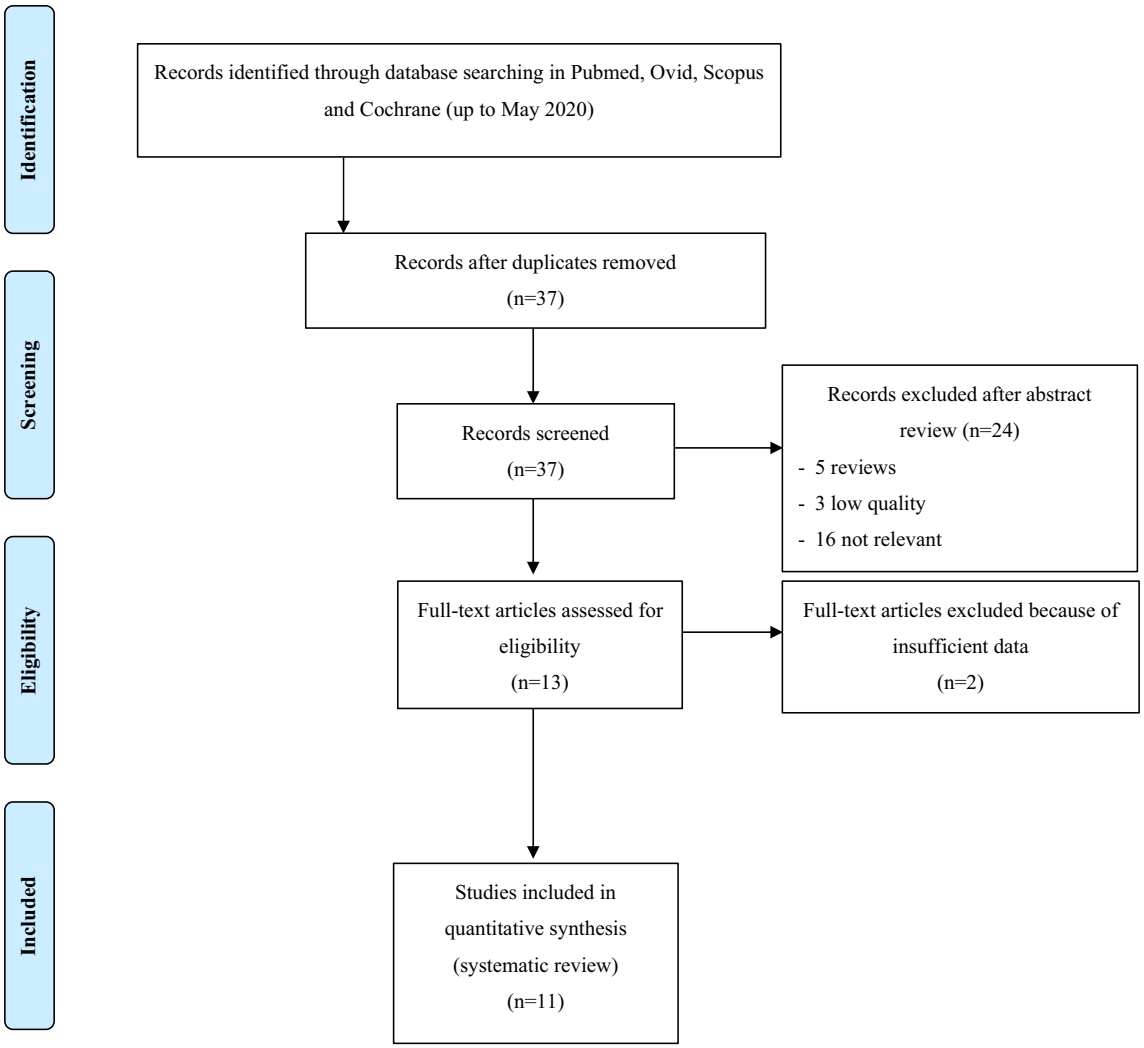


Fig. 1 PRISMA flow diagram

using the Newcastle–Ottawa scale for non-randomised controlled trials (http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp). The maximum score for each study is 9, with studies scoring < 5 identified as containing at high risk of bias.

Risk of bias for observational studies

Non-randomised studies were also assessed for a risk of bias. Due to the inherently higher risk of selection bias in non-randomised studies, the Cochrane risk of bias tool (ROBINS-1 tool) was used to assess bias in included non-randomised studies, with the addition of pre-specified confounders. The confounders considered were: age, RENAL score, tumour size, ASA or CCI score and body mass index (BMI) (Fig. 2).

Data extraction and analysis

All studies that fulfilled the inclusion criteria were identified and reviewed. Disagreement was resolved by consensus.

Data were extracted from each selected study. Baseline demographics (age, BMI, ASA or CCI score, tumour size, RENAL nephrometry score), intraoperative data (operative time, estimated blood loss, warm ischaemia time) and postoperative outcomes (major complications according to Clavien–Dindo, length of hospital stay (LOS) and positive surgical margin rate) were recorded.

For continuous outcomes, the weighted mean difference (WMD) was used as a summary measure, whereas the odds ratio (OR) or risk ratio (RR) with 95% confidence intervals (CI) was calculated for binary variables. RR was preferred in cases of a high number of events to avoid overestimation. As only means and standard deviations

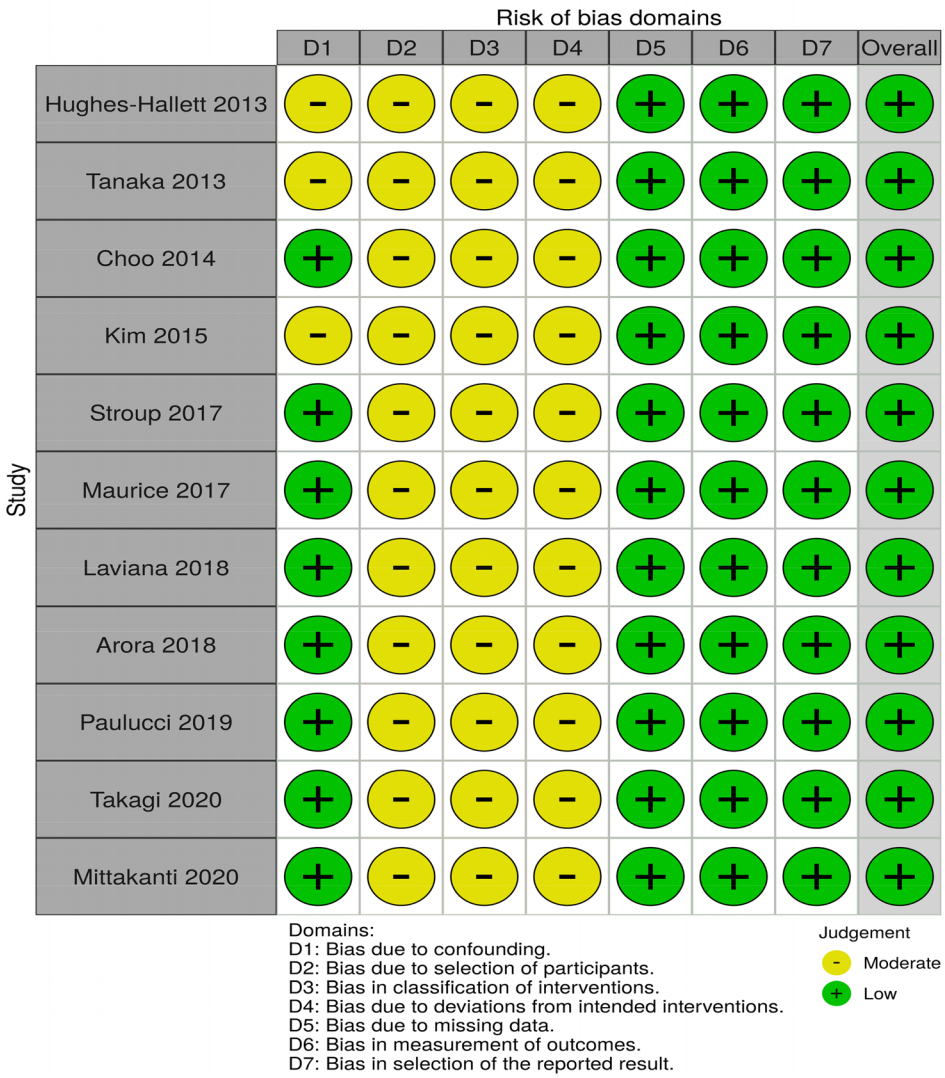


Fig. 2 Risk of bias for observational studies

(SD) are permitted for the computational portion of meta-analyses, a validated mathematical model was used to convert median (range) to mean (SD) for studies reporting medians and ranges. The Mantel–Haenszel Chi^2 test was used for continuous data and expressed as the WMD with 95% CI, and for dichotomous data inverse variance was used and expressed as OR or RR with 95% CI. *p* value was deemed significant if < 0.05. Heterogeneity was analysed using a Chi^2 test on $N - 1$ degrees of freedom, with an alpha risk of 0.05 used for statistical significance, and with the I2 test [12].

Pooled estimates were calculated using the random-effect model to account for study heterogeneity. Evaluation of potential publication bias was done by funnel plot analysis for each outcome. All statistical analyses were performed using Review manager 5 (Cochrane Collaboration, Oxford, UK).

Results

Description of included studies and quality assessment

Eleven studies, published between 2013 and 2020, were identified and included in the analysis (Table 1) [13–23]. There were no randomised clinical trials. Three studies were observational, retrospective, case–control studies, five were retrospective, matched cohort studies and three were prospective, non-randomised studies. Study quality was high for all studies and ranged between 7 and 8. Due to small number of studies, visual assessment was unlikely to be accurate, but no obvious publication bias was observed.

Table 1 Demographics of the study populations in the studies analysed

Study/year	Design	Setting	TRAP N (N)	RRAPN (N)	Age	ASA/CCI	Renal score	Tumour size	BMI	Study quality
[13]/2013	Retrospective	Multicentre UK	59	44	Median (IQR) 60.5 (39–87) vs. 63.3 (38–80) ($p=0.227$)	NA	Median (IQR) 5.5 (3–9) vs. 5.5 (4–10) ($p=0.82$)	Median (IQR) 3.07 (1–7.2) vs. 2.84 (6.2–1.1) ($p=0.39$)	NA	7
[14]/2013	Prospective, non-randomised	Single-centre Japan	16	10	Median (IQR) 70 (35–84) vs. 60.5 (46–82) ($p=0.769$)	NA	Mean (SD) 7.4 ± 1.65 vs. 6.9 ± 1.29 ($p=0.777$)	Mean (SD) 3.36 ± 1.1 vs. 2.21 ± 0.55 ($p=0.05$)	Mean (SD) 22.7 ± 2.94 vs. 23.2 ± 2.23 ($p=0.60$)	8
[15]/2014	Retrospective matched pair	Single-centre South Korea	57	50	Median (IQR) 50.0 (41–57) vs. 54.5 (42.75–61.25) ($p=0.069$)	ASA ≥ 2: 51% vs. 48% ($p=0.552$)	Mean (SD) 6.6 ± 1.5 vs. 6.0 ± 1.6 ($p=0.072$)	Mean (SD) 2.7 ± 1.3 vs. 2.8 ± 1.1 ($p=0.20$)	Mean (SD) 24.5 ± 2.8 vs. 24.7 ± 2.8 ($p=0.64$)	8
[16]/2015	Retrospective	Single-centre USA	97	116	Mean (SD) 58.2 ± 11.8 vs. 57.2 ± 12.2 ($p=0.40$)	CCI ≥ 2 22% vs. 26% ($p=0.77$)	Median 8 vs. 8 RENAL ($p=0.93$)	Mean (SD) 2.54 ± 1.44 vs. 2.48 ± 1.14 ($p=0.94$)	BMI > 30, $n=37/97$ (38%) vs. 57/116 (49%) ($p=0.11$)	7
[17]/2017	Retrospective	Two-centre USA	263	141	Mean (SD) 58 ± 15 vs. 59.3 ± 14 ($p=0.40$)	NA	Mean (SD) 7.4 ± 1.7 vs. 7.2 ± 1.9 ($p=0.503$)	Mean (SD) 3.1 ± 1.8 vs. 2.9 ± 1.7 ($p=0.122$)	Mean (SD) 28.6 ± 6.4 vs. 29.8 ± 6.7 ($p=0.155$)	7
[18]/2017	Retrospective matched pair	Multicentre USA	296	74	Median (IQR) 59 (52–66) vs. 60 (50–65) ($p=0.92$)	Median (IQR) ASA 2 (2–3) vs. 2 (2–3) ($p=0.56$)	Median (IQR) 7 (6–9) vs. 8 (6–9) RENAL ($p=0.32$)	Median (IQR) 2.5 (1.9–3.5) vs. 2.4 (1.9–3.3) ($p=0.59$)	Median (IQR) 29.4 (25.1–33.0) vs. 30.0 (25.1–33.9 ($p=0.42$)	8
[19]/2017	Retrospective matched pair	Two-centre USA	78	78	($p=0.49$)	($p=0.795$)	($p=0.631$)	NA	BMI > 30 ($p=0.273$)	8
[20]/2018	Prospective matched pair	Multicentre USA	394	99	Median (IQR) 61 (51–71) vs. 61 (55–68) ($p=0.7$)	ASA ≥ 2 86.8% vs. 90.2% ($p=0.7$)	Intermediate 36% vs. 36.9%; High 64% vs. 63.1% ($p=0.5$)	Median (IQR) 3.2 (2.3–4.5) vs. 3.0 (2.3–4.2) ($p=0.2$)	Median (IQR) 27.6 (24.8–31.7) vs. 28.7 (25.8–32.5) ($p=0.6$)	8
[21]/2019	Retrospective matched pair	Single-centre USA	157	157	Median (IQR) 61 (50–69) vs. 61 (53–68) ($p=0.651$)	Median (IQR) (CCI) 3 (2–4) vs. 3 (2–4) ($p=0.053$)	Median (IQR) 7 (5–8) vs. 7 (6–8) RENAL ($p=0.308$)	Median (IQR) 3.0 (2.2–4.1) vs. 2.9 (2.1–4.3) ($p=0.741$)	Median (IQR) 29.1 (25.8–33.3) vs. 28.8 (25.6–33.1) ($p=0.996$)	8
[22]/2019	Retrospective matched pair	Single-centre USA	263	281	Mean (SD) 60 ± 12 vs. 60 ± 12 ($p=0.79$)	Mean (SD) (CCI) 3.6 ± 2 vs. 3.7 ± 1.9 ($p=0.5$)	Mean (SD) 5.6 ± 2.7 vs. 5.7 ± 2.6 (p = 0.5)	Mean (SD) 3.3 ± 1.7 vs. 3.1 ± 1.5 ($p=0.3$)	Mean (SD) 30.3 ± 6.9 vs. 29.7 ± 5.8 ($p=0.28$)	8

Table 1 (continued)

Study/year	Design	Setting	TRAP N (N)	RRAPN (N)	Age	ASA/CCI	Renal score	Tumour size	BMI	Study quality
[23]/2020	Prospective matched pair	Single-centre Japan	145	24	Mean (SD) 55 ± 12 vs. 55 ± 14 ($p = 0.34$)	ASA ≥ 2 87% vs. 83% ($p = 0.70$)	NA	Mean (SD) 3.1 ± 1.3 vs. 3.0 ± 1.2 ($p = 0.40$)	Mean (SD) 25 ± 4.0 vs. 24 ± 3.7 ($p = 0.55$)	8

Demographics and clinical characteristics

Among the 3139 patients included, 1087 underwent RRAPN and 2052 underwent TRAPN. There was no significant difference in age or BMI between the two groups (age, $p = 0.36$, WMD: − 0.60 [95% CI − 1.90–0.70]; BMI, $p = 0.98$, WMD: 0.01 [95% CI − 0.91–0.93]) (Fig. 3a, b). There was no significant difference between the two groups in terms of tumour size ($p = 0.06$, WMD: 0.21 [95% CI − 0.01–0.42] and RENAL score (p = 0.20, WMD: 0.14 [95% CI − 0.07–0.36] (Fig. 3c, d). The demographics of the study populations are summarised in Table 1.

Outcomes

Clavien–Dindo ≥ 3 complication rates

A fixed model was used for this analysis as there was a low degree of heterogeneity ($I^2 = 21\%$). There was no significant difference in ≥ 3 Clavien–Dindo complication rates between the two approaches (WMD: 0.79 [95% CI 0.46–1.33]; p = 0.37) (Fig. 4a).

Operative time

All studies had data available on operative time. A random model was used for analysis as there was a high degree of heterogeneity ($I^2 = 91\%$). There was a statistically significant difference in operative time between the two approaches (WMD: 16.29 [95% CI 2.52–30.05]; $p = 0.02$) (Fig. 4b).

Estimated blood loss

All the studies had data available on estimated blood loss. A random model was used for this analysis as there was a moderate degree of heterogeneity ($I^2 = 70\%$). There was a statistically significant difference in estimated blood loss between the two approaches (WMD: 29.73 [95% CI 24.69–34.77]; $p < 0.00001$) (Fig. 4c).

Warm ischaemia time

Ten studies had data available on warm ischaemia time. A random model was used for this analysis as there was a moderate degree of heterogeneity ($I^2 = 56\%$). There was no significant difference in warm ischaemia time between the two approaches (WMD: 0.10 [95% CI − 0.45–0.66]; $p = 0.37$) (Fig. 4d).

Positive margin rates

Ten studies had data available on positive surgical margin rates. A fixed model was used for this analysis as

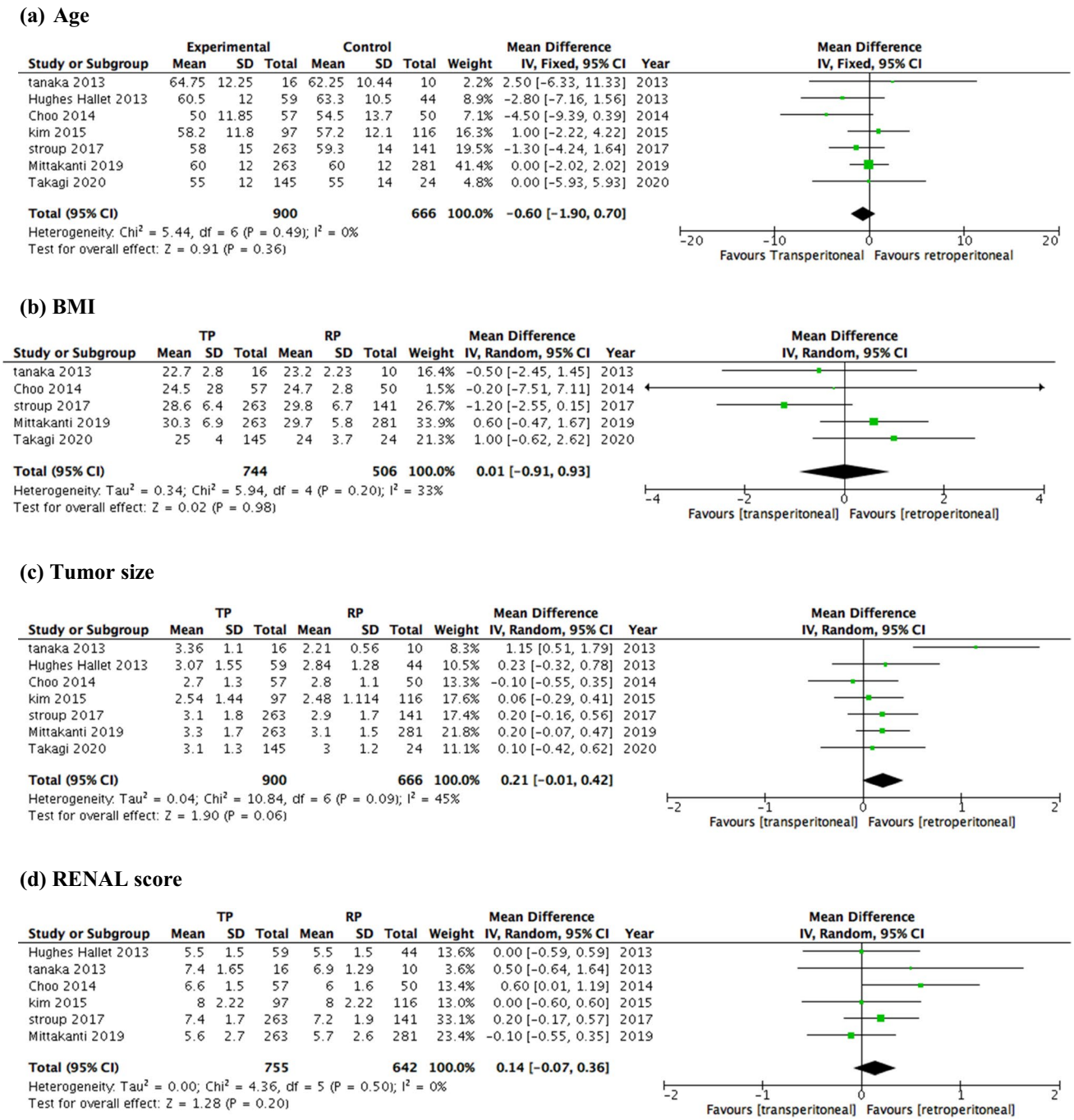


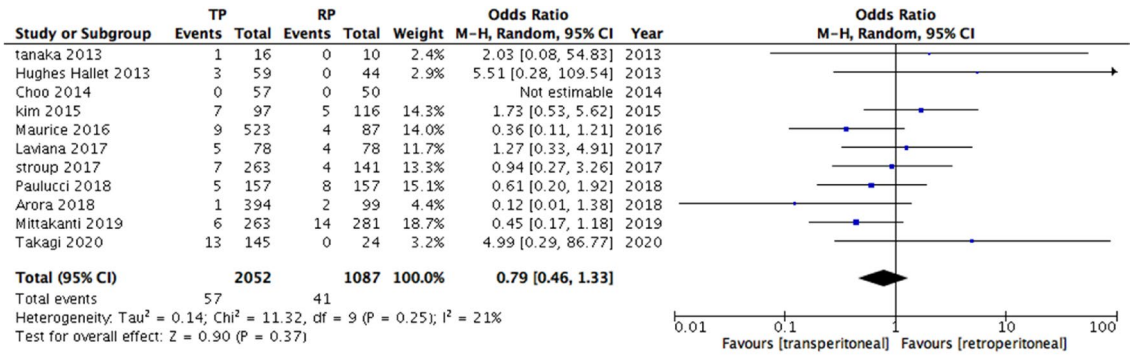
Fig. 3 Comparison of demographics and clinical characteristics between the two groups

there was a low degree of heterogeneity ($I^2 = 0\%$). There was no significant difference in positive surgical margin rates between the two approaches (WMD: 0.68 [95% CI 0.41–1.12]; $p = 0.13$) (Fig. 4e).

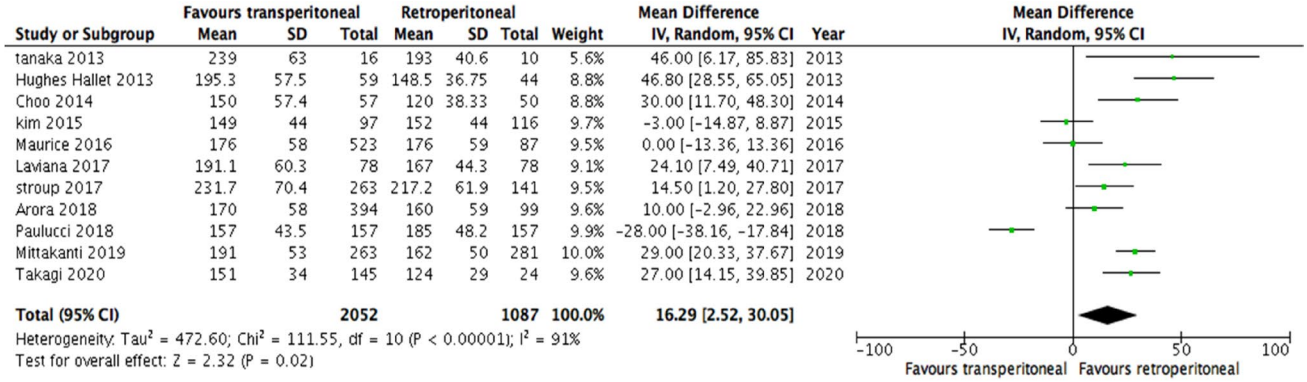
Length of hospital stay

Eight studies had data available on LOS. A random model was used for this analysis as there was a very high degree of

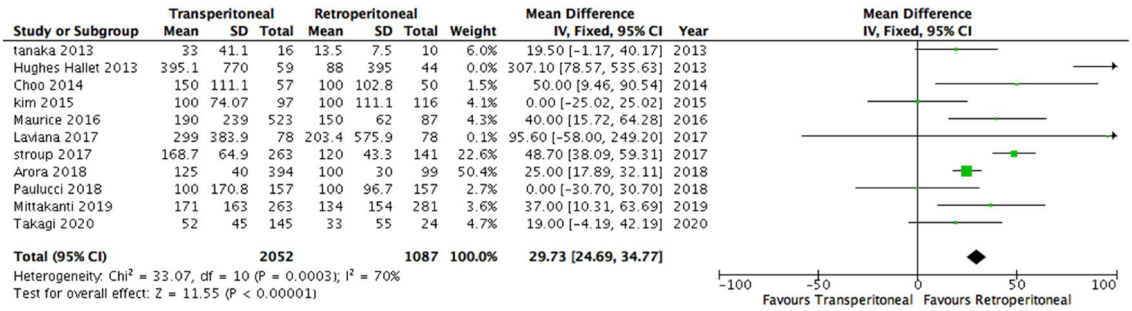
(a) Clavien-Dindo ≥3 complication rates



(b) Operative time



(c) Estimated blood loss



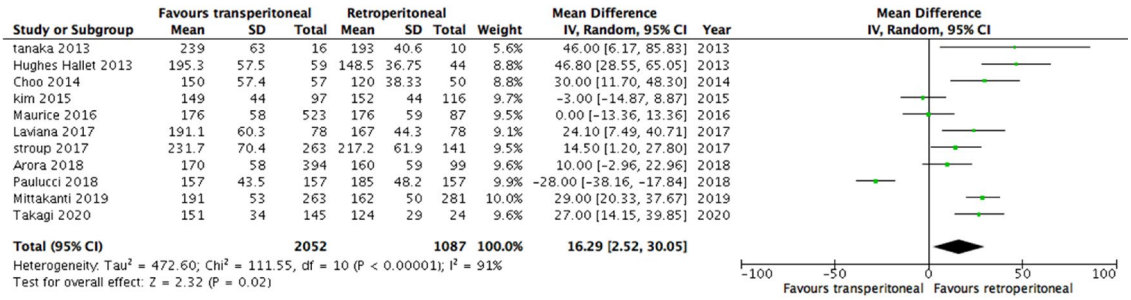
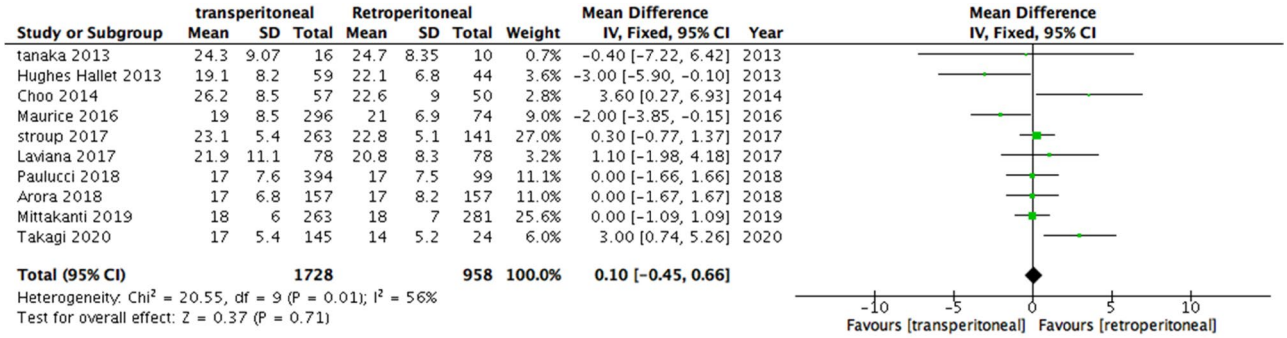
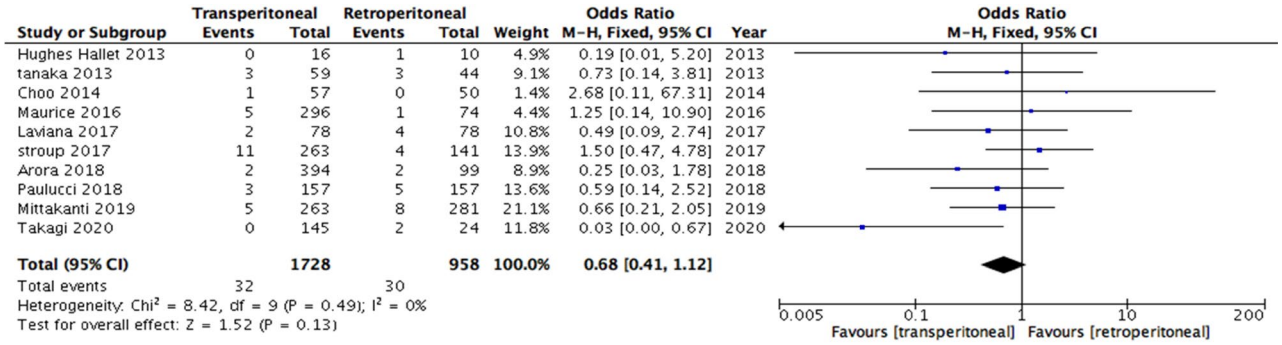


Fig. 4 Comparison of outcomes between the two groups

(d) Warm ischemia time



(e) Positive margin rates



(f) Length of hospital stay

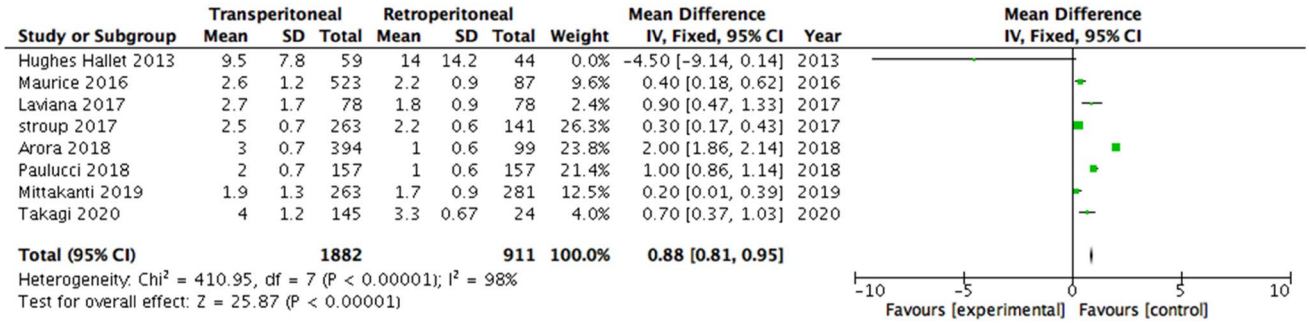


Fig. 4 (continued)

heterogeneity ($I^2 = 98\%$).The analysis favoured the retroperitoneal approach with a lower mean LOS (WMD: 0.88 [95% CI 0.81–0.95]; $p < 0.00001$) (Fig. 4f).

Discussion

Nephron-sparing surgery has become the gold standard for a wide range of renal tumours, mainly classified as T1 (< 7 cm), but also for selected patients with T2 tumours, if technically feasible. Until the recent development of robotic surgery open partial nephrectomy was widely used, but technical difficulties existed with the laparoscopic approach, mainly with suturing of the tumour bed with limited instrument manipulation. With a reduced learning curve, robotic partial nephrectomy, reported for the first time in 2004, has rapidly gained its place in the management of renal masses [24].

Both the retroperitoneal and transperitoneal approach have been reported. The choice between these two techniques is based mainly on the surgeon's preference and his/her training and experience. More robotic surgeons seem to

be attracted to the transperitoneal approach due to the large working space and the ease of instrument movement, especially during suturing. Nevertheless, this technique requires colonic dissection with potential postoperative ileus. The presence of intra-peritoneal adhesions increases the operative time. The retroperitoneal approach has the inconvenience of working in a confined space with an "unfamiliar" anatomy for a large majority of surgeons. It has been hypothesised that this approach would grant easier access to the hilar structures and posteriorly localised tumours without the need for complete renal dissection. It would also confine any possible postoperative bleeding or urine leakage.

Our study presents the most up to date and largest cumulative analysis of studies comparing TRAPN with RRAPN. Overall, our findings suggest equivalent outcomes with the two approaches, in terms of surgical quality or short-term oncological or functional outcomes. There were no significant differences between TRAPN and RRAPN in terms of tumour size (WMD: 0.21 [95% CI − 0.01–0.42]; $p = 0.06$) or RENAL score (WMD: 0.14 [95% CI − 0.07–0.36]; $p = 0.20$). Both operative time (WMD 16.29 min [95% CI 2.52–30.05]; $p = 0.02$) and estimated blood loss (WMD: 29.73 ml [95% CI 24.69–34.77]; $p < 0.00001$) were significantly lower in the retroperitoneal group. LOS was also significantly shorter in the retroperitoneal group (WMD: 0.88 days [95% CI 0.81–0.95]; $p < 0.00001$). No differences were found in major postoperative complications (Clavien–Dindo ≥ 3; $p = 0.37$), warm ischaemia time ($p = 0.37$) and positive surgical margins ($p = 0.13$).

The clinical impact of these differences seems to be negligible however, with respect to functional recovery and oncological efficacy. The impact on quality of life indices remains to be determined.

Not surprisingly, with a more direct approach to the hilum and posterior tumours, the current review reveals a shorter operative time and lower estimated blood loss with RRAPN and thus an advantageous shorter LOS [25].

RRAPN still lags behind TRAPN with regard to its maturity and experience as an approach, suggesting that a learning curve effect may influence contemporary outcomes explaining its non-superiority in terms of oncological and functional outcomes.

Our study has several limitations. Despite representing a robust statistical tool, meta-analyses carry intrinsic biases and randomised controlled trials should ideally be included. The main limitation is the non-randomised nature of the studies analysed. Most of the studies were either retrospective or prospective non-randomised trials, albeit of good quality. Only two of the studies in this review were prospective, matched-paired, highlighting a selection bias. Furthermore, some parameters were not assessed or available to analyse in our study. For example, positive surgical margins were assessed while functional outcome analysis was not possible. It was also not possible to account for existing differences between institutions and surgeons in terms of surgical technique and expertise, as well as protocols of perioperative management and follow-up. It would be interesting to assess how the introduction of the Xi system or the single port system might facilitate or influence clashing issues compared to the Si system.

A recent review carried out by Mclean et al. suggested a slight advantage of RRAPN in terms of LOS compared to TRAPN, especially for posterior tumours. RRAPN did not appear to offer any advantage over TRAPN for other perioperative outcomes such as warm ischaemia time, operative time and estimated blood loss. The surgical margin rates and morbidity of the two approaches appear to be similar [26].

The current review would suggest that the two approaches are equivalent and recruitment into trials is, therefore, feasible. In keeping with the IDEAL guidelines, future researchers must attempt to achieve adequately powered, expertise based, multi-surgeon and multi-centric studies comparing TRAPN and RRAPN [26].

Despite all these limitations, this review provides the most up to date and best available evidence in the field, and therefore, our findings can be used as a reference for further clinical investigations. Comparative prospective, randomised, multicentre or multinational studies are needed for a more robust choice between the two approaches when planning RAPN.

Conclusion

RRAPN offers, in select patients, similar outcomes to those of TRAPN. Furthermore, RRAPN may be particularly advantageous for some patients since it is associated with a reduced operative time and LOS. Ideally, surgeons should be familiar and competent in both approaches when offering RAPN to their patients, adopting a risk-stratified and patient-centred individualised approach, dependent on patient and tumour characteristics. Further randomised, controlled trials and high-quality observational studies with larger sample sizes and long-term follow-up are needed for an informed decision on the best approach.

Author contributions AB: project development, data collection, manuscript writing, EA: data collection, data analysis, SM: manuscript writing, MR: manuscript editing, FB: project development, manuscript editing.

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Declarations

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Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

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