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ORIGINAL ARTICLE

Transperitoneal versus retroperitoneal robot-assisted partial nephrectomy: a systematic review and meta-analysis

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Abstract

Introduction Robot-assisted partial nephrectomy (RAPN) can be performed either by a transperitoneal (TP) or a retroperitoneal (RP) approach. However, the superiority of one approach over the other is not established. Hence, the primary aim of this review was to compare perioperative outcomes between these two surgical approaches.

Methods Literature was systematically searched to identify studies reporting perioperative outcomes following TP RAPN and RP RAPN. The study protocol was registered with PROSPERO (CRD42023399496). The primary outcome was comparing complication rates between the two approaches.

Results This review included 22 studies, 5675 patients, 2524 in the RP group, and 3151 in the TP group. The overall complications were significantly lower in the RP group [Odds ratio (OR) 0.80 (0.67, 0.95), $p = 0.01$]. However, the rate of major complications was similar between the two groups. The operative time was significantly shorter with the RP group [Mean Difference (MD)—16.7 (−22.3, −11.0), $p = < 0.0001$]. Estimated blood loss (EBL) and need for blood transfusion (BT) were significantly lower in the RP group. There was no difference between the two groups for conversion to radical nephrectomy [OR 0.66 (0.33, 1.33), $p = 0.25$] or open surgery [OR 0.68 (0.24, 1.92, $p = 0.47$] and positive surgical margins [OR 0.93 (0.66, 1.31, $p = 0.69$]. Length of stay (LOS) was shorter in the RP group [MD −0.27 (−0.45, −0.08), $p = < 0.00001$].

Conclusions RP approach, compared to TP, has significantly lower complication rates, EBL, need for BT and LOS. However, due to the lack of randomized studies on the topic, further data is required.

Keywords Retroperitoneal · Transperitoneal · Robotic partial nephrectomy · Systematic review

Abbreviations

RAPN	Robot-assisted partial nephrectomy
TP	Transperitoneal
RP	Retroperitoneal
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analysis
OR	Odds ratio
MD	Mean Difference
RCT	Randomized controlled trial
PICO	Patient/population, intervention, control, outcome
WIT	Warm ischemia time
PSM	Positive surgical margin
EBL	Estimated blood loss
BT	Blood transfusion
LOS	Length of stay
NOS	Newcastle Ottawa scale
ROBINS-I	The Risk of Bias In Non-randomized Studies of Interventions:
IV	Inverse-variance
SD	Standard deviation
IQR	Interquartile range

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Introduction

Minimally invasive partial nephrectomy has become the preferred surgical technique for managing localized renal masses [1]. A robotic approach is usually preferred for improved dexterity and better surgeon comfort [1]. Robot-assisted partial nephrectomy (RAPN) can be performed transperitoneally or retroperitoneally. The transperitoneal (TP) approach has familiar anatomical landmarks, offers wider surgical space and has a less steep learning curve as compared to the retroperitoneal (RP) approach, where developing the RP space and working in it can be challenging and may lead to an increased risk of renal vascular injuries [2]. At the same time, the risk of bowel injury and an increased rate of postoperative ileus with the TP approach cannot be ignored [3]. Meanwhile, the RP approach offers direct access to the kidney without needing bowel mobilization. The intact peritoneum prevents urine spillage into the peritoneal cavity if urinoma formation occurs postoperatively [4, 5]. TP RAPN offers better access to anteriorly located tumors and the renal hilum. RP approach is preferred for posterior renal masses [6].

Several studies have compared these two techniques; however, none was a randomized controlled trial (RCT). Thus, like every other observational study, they have been plagued by selection bias. Hence, no surgical approach could be considered superior to the other. A few systematic reviews and meta-analyses have previously compared TP and RP RAPN. They have been limited by a lack of comparability for baseline factors that can influence perioperative outcomes following surgery [7, 8]. Thus, with the present study, we aimed to systematically review the published literature for studies comparing RP versus TP RAPN for patients with renal masses. To ensure comparability for baseline factors that can influence the outcomes, we aimed to include only RCTs or observational studies comparable to baseline variables in this review.

Methods

Study design

The existing literature comparing TP and RP RAPN was systematically reviewed. The study protocol was specified and registered with the online depository PROSPERO (CRD42023399496). The study was based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) guidelines [9] and the Cochrane Handbook version 5.1.0 [10].

Search strategy

A literature search was performed by two study authors independently using the available online databases of PubMed/Medline, Embase, Scopus, and Web of Science. Literature was searched from the beginning of these databases till 29th April 2023. Articles in languages other than English were excluded.

We followed PICO (Patient/population, intervention, control, outcome) methodology to design our search strategy.

Patient/population: renal mass OR kidney mass OR Renal Cancer OR Kidney cancer Intervention: Retroperitoneal robot-assisted partial nephrectomy.

Control: Transperitoneal robot-assisted partial nephrectomy.

Outcome: complication rates, operative time, hospital stay, conversion to radical nephrectomy, conversion to open, warm ischemia time (WIT), positive surgical margin (PSM), estimated blood loss (EBL) and need for blood transfusion (BT).

Both keywords and meshed terms were used to develop a search strategy.

The keywords used for this study are as follows:

(((rapn) or (robot assisted partial nephrectomy)) and ((rp) or (retroperitoneal))) and ((transperitoneal) or (tp)).

The initial screening of titles and abstracts was done independently by two authors (NS and PB) and duplicates were removed. Studies selected after initial screening were selected for full-text review. In case of discrepancy, the help of senior authors was sought (GS and GRC). Search strategy used for PubMed has been tabulated in Supplementary Table 1.

Inclusion criteria

The studies (prospective cohort/retrospective cohort/RCT) comparing RP RAPN with the TP RAPN in adults with renal masses were included. We only included the studies that were comparable for baseline characteristics between the two groups. If propensity matching was performed in a study, only propensity-matched data was extracted. In the case of multiple studies from the same institution or database, the latest and largest study was included to minimize data repetition.

Exclusion criteria

We excluded studies describing either of the techniques alone or in combination with other techniques. Reviews, case reports, non-comparative studies, conference abstracts, letters to the editor, book chapters and studies in languages other than English were excluded.

Outcomes

Primary outcome

The primary outcome of the present study was the complication rates as per the Clavien-Dindo classification between the RP and TP RAPN.

Secondary outcomes

Other perioperative outcomes between the two groups include major complications (Clavien- Dindo ≥ 3), operative time, length of stay (LOS), EBL, PSM, need for BT, and conversion to open/ radical nephrectomy.

The outcomes of the included studies have been summarised in Supplementary Tables 2 and 3.

Data extraction

Data extraction was performed independently by the two review authors (NS & PB) using a unique predefined data template. Data was checked for consistency and in case of a discrepancy, data were rechecked. Data on the following variables were extracted: First author, study year, country, type of study, number of participants, type of robotic system used, complication rates, operative time, hospital stay, conversion to radical nephrectomy, conversion to open, WIT, PSM, EBL and need for BT. In studies where propensity matching was performed, post-matching data was extracted and considered for analysis. The authenticity of data was re-checked and discrepancies were resolved with arbitration with the third author (GS).

Risk of bias

For RCTs, the Cochrane risk of the bias assessment tool and for cohort studies, the Newcastle Ottawa scale (NOS) [11] and "The Risk of Bias In Non-randomized Studies of Interventions" (ROBINS-I) scores were used to assess the quality of studies, respectively. As per PRISMA recommendations, two review authors (NS & PB) performed the study quality assessment and discrepancies were sorted by consulting senior author (GS).

The risk of bias assessment with ROBINS-I score is summarised in Supplementary Table 4.

Statistical analysis

Statistical heterogeneity was examined using Chi^2 and I^2 tests. A p-value of < 0.10 was considered to signify the presence of significant statistical heterogeneity. In the presence of heterogeneity, a random-effects model was used. Otherwise, the fixed-effect model was used. For categorical variables, the Mantel–Haenszel method with odds ratio (OR) as an effect measure was used for pooling data in the meta-analysis. The inverse-variance (IV) method with a mean difference (MD) as an effect measure was used for continuous variables. Mean and standard deviation (SD) were required for pooling the data for continuous variables. Mean and SD were estimated from median with range or interquartile range (IQR) [12]. Visual examination of the funnel plot for the primary outcome was used to determine publication bias. A symmetrical curve would denote an absence of publication bias and an asymmetrical curve would denote the presence of publication bias. Analysis was done using the Cochrane Collaboration review manager software RevMan 5 (Review Manager [RevMan], [Computer program], Version 5.4, The Cochrane Collaboration, 2020).

Results

Search strategy and selection

A literature search using the methodology described above was performed, and 341 articles were identified (PubMed: 62, Embase: 141, Scopus: 72, and Web of Science: 66). References were imported on a citation manager and duplicates were removed (92). After initial title and abstract screening, 47 articles were selected for full-text review. Of these 47 articles, 22 studies were included in the meta-analysis [3–6, 13–30]. The remaining 25 studies were excluded for various reasons (Fig. 1). We noted two studies from the same group (using the Vattikuti Collective Quality Initiative database) [25, 31] and included the latest and largest by Sharma et al [25].

Study characteristics

In this study, 22 cohort studies were included with a total of 5675 patients. Of these, 2524 were in the RP group and 3151 in the TP group. Of these,13 were single-centre [4, 13, 15, 16, 18, 20, 21, 23, 24, 27, 30], two were bicentric [5, 26] and seven were multicentric [3, 6, 14, 17, 19, 22, 25]. There were ten studies with propensity-matched groups [3–6, 16, 17, 22, 23, 25, 27]. All the studies were observational (prospective or retrospective) and were comparable for baseline characteristics. Of the 22 studies, 3 included posteriorly located renal tumors [6, 20, 22], 1 considered posterior or lateral tumors [14], 1 study was on lateral tumors only [27], 1 on lower pole tumors [30] and 1 for endophytic tumors [24] (Table 1). Quality assessment of included studies by NOS revealed a NOS score ranging from 6 to 8 (Table 1)

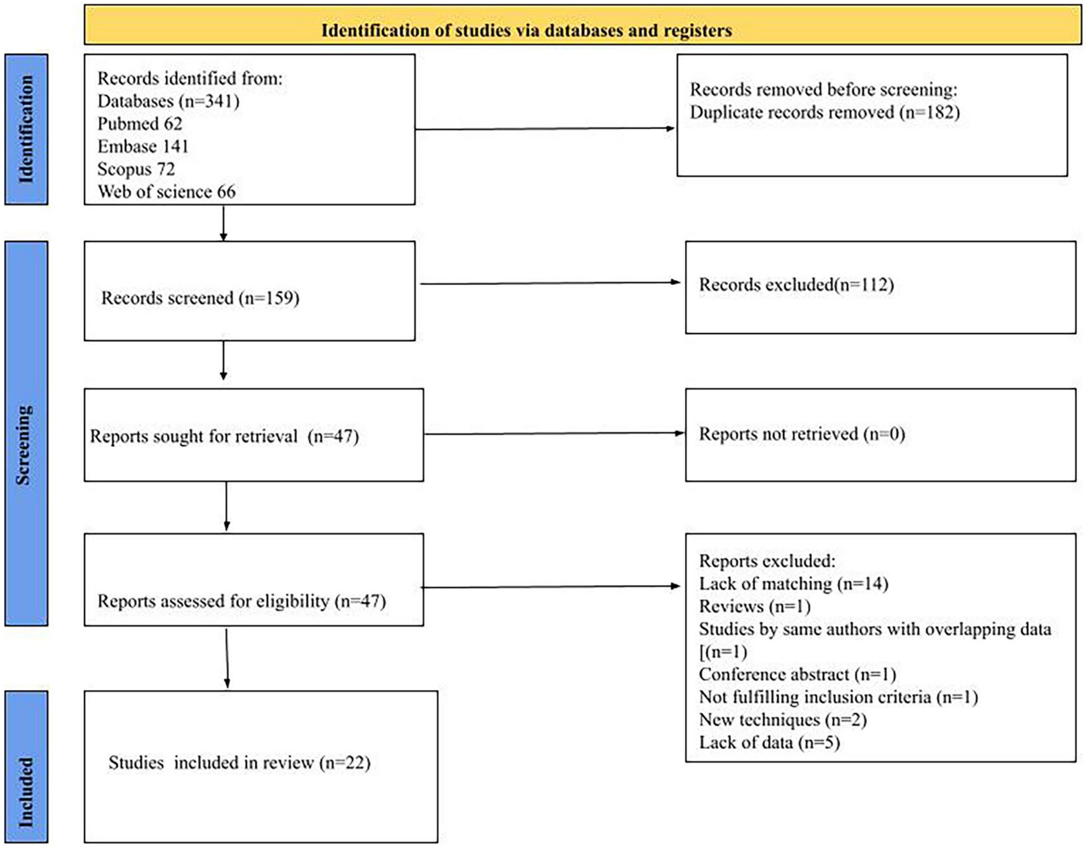

Fig. 1 PRISMA flow-chart depicting the selection of studies for this review

and a moderate risk of bias as per the ROBINS-I tool (Supplementary Table 4).

Primary outcome

Data for primary outcome i.e., complications was available from 21 studies with 5152 patients. Fixed-effect IV analysis was used to analyze overall complications due to the absence of statistical heterogeneity ($I^2 = 3\%$ and $Chi^2 = 20.65$). The overall complications were significantly lower in the RP RAPN group [OR 0.80 (0.67,0.95), $p = 0.01$] compared to TP RAPN (Fig. 2A). Meanwhile, data for major complications was extracted from 18 studies with 4,668 patients. There was no statistically significant difference between the two groups for major complications [OR 0.86 (0.62,1.21), $p = 0.39$] (Fig. 2B).

Secondary outcomes

Operative time was analyzed in 4805 patients from 20 studies, and it was significantly shorter in the RP RAPN group [MD − 16.70 (− 22.37, − 11.04), $p = < 0.001$] (Fig. 3A). The data studied for this parameter was statistically heterogeneous [$I^2 = 79\%$]; thus, random-effect analysis was used. The need for BT was significantly higher in the TP RAPN group [OR 0.35 (0.18, 0.67), $p = 0.002$] (Fig. 3B). The data for EBL was available from 4,036 patients & 17 studies. EBL was significantly lower in the RP RAPN group [MD − 20.44 (− 33.65, − 7.23), $p = < 0.001$] (Fig. 3C). The WIT was lower in the RP RAPN; however, the difference was not statistically significant [MD − 0.93 (− 1.93, 0.07), $p = 0.07$] (Fig. 3D). There was no significant difference between the two groups for conversion to radical nephrectomy [OR 0.66 (0.33, 1.33), $p = 0.25$] (Fig. 4A), need for conversion to open surgery [OR 0.68 (0.24, 1.92, $p = 0.47$] (Fig. 4B) and PSM [OR 0.93 (0.66, 1.31, $p = 0.69$] (Fig. 4C). LOS was shorter in the RP RAPN group [MD − 0.27 (− 0.45,—0.08), $p = < 0.00001$] compared to the TP RAPN group (Fig. 4D). Symmetric funnel plot for the primary outcome suggested the absence of publication bias (Supplementary Fig. 1).

Table 1 Characteristics of the studies included for analysis

Reference	Year	Country	Study setting	Sample size (RP/TP)	Tumor location	Robotic system used	NOS	Study design
Abaza et al. [13]	2019	USA	Single centre	30/107	Any	Da Vinci Xi	6	Retrospective
Carbonara et al. [14]	2021	USA	Multicentric	231/216	Posterior, lateral	NA	7	Retrospective
Choi et al. [15]	2019	Korea	Single centre	213/310	Any	NA	7	Retrospective
Choo et al. [16]	2014	Korea	Single centre	50/57	Any	NA	8	Retrospective
Dell'Oglio et al. [17]	2021	Italy	Multicentric	384/384	Any	NA	7	Retrospective
Eraky et al. [4]	2021	Germany	Single centre	51/51	Any	Da Vinci Si	7	Retrospective
Gu et al. [18]	2022	China	Single centre	60/48	Any	NA	7	Retrospective
Harke et al. [3]	2020	Germany	Multicentric	203/551	Any	Da Vinci S, Si and Xi	7	Retrospective
Hughes-hallet et al. [19]	2013	UK	Multicentric	44/59	Any	NA	7	Retrospective
Kim et al. [20]	2015	USA	Single centre	116/97	Posterior	NA	7	Retrospective
Kobari et al. [21]	2021	Japan	Single centre	65/56	Any	NA	7	Retrospective
Laviana et al. [5]	2017	USA	Bicentric	87/523	Any	NA	7	Retrospective
Maurice et al. [22]	2016	USA	Multicentric	87/523	Posterior	NA	8	Retrospective
Mittakanti et al. [23]	2019	USA	Single centre	281/263	Any	Da Vinci Si and Xi	7	Retrospective
Okhawere et al. [24]	2023	USA	Single centre	44/112	Endophytic	NA	7	Retrospective
Paulucci et al. [6]	2018	USA	Multicentric	162/367	Posterior	NA	7	Retrospective
Sharma et al. [25]	2022	India	Multicentric	309/309	Any	NA	7	Retrospective
Stroup et al. [26]	2017	USA	Bicentric	141/263	Any	NA	7	Retrospective
Takagi et al. [27]	2020	Japan	Single centre	48/290	Lateral	NA	7	Retrospective
Tanaka et al. [28]	2013	Japan	Single centre	10/16	Any	Da Vinci S	7	Retrospective
Tang et al. [29]	2022	China	Single centre	49/43	Any	NA	7	Retrospective
Zhao et al. [30]	2022	China	Single centre	35/116	Lower pole	NA	7	Retrospective

NOS Newcastle Ottawa Score, *TP* transperitoneal, *RP* retroperitoneal

Discussion

Minimally invasive partial nephrectomy is the treatment of choice for T1a and selective T1b renal masses. Both laparoscopic and robotic partial nephrectomy can be performed transperitoneally or retroperitoneally. With the advent of robot-assisted laparoscopy and the associated advantages of having seven degrees of freedom, better ergonomics and easier intracorporeal suturing, it has quickly become the technique of choice for partial nephrectomy, especially in complex tumours. The initial conventional approach for RAPN was TP due to its familiarity and widespread description in literature. In the past decade, RP RAPN has gained popularity owing to its advantages, like better access to posterior renal masses and avoidance of peritoneal breach and bowel mobilization. After that, there have been a number of studies comparing the outcomes of these two surgical modalities. Considering the heterogeneity of the results of the previous studies, there is an unmet need for a comprehensive evaluation of both approaches. Few meta-analyses have previously examined this topic and have reported variable findings. Most of these analyses have been plagued by low-quality of included studies and lack of comparability for baseline variables. The two most recent meta-analyses by Zhou et al. [32] and Carbonara et al. [7] failed to take baseline matched data for analysis, thus making interpretation of results difficult. Carbonara et al. did perform subgroup analysis of studies with propensity-matching; however, overall data of these studies was considered in analysis instead of matched patient data [7]. To improve our understanding and outline the current stance of RP versus TP RAPN, we conducted a thorough up-to-date meta-analysis which included the largest number of studies to date and ensured the inclusion of studies with baseline comparability only.

The primary outcome of the study was the difference in complication rates between the two surgical approaches, which turned out to be significantly lower in the RP approach [OR 0.80 (0.67,0.95)] ($p = 0.01$). On subgroup analysis of complications, major complications were found to be similar between the two groups. Complication rates have varied in different studies previously conducted on the topic. In a previous meta-analysis by Carbonara et al., authors reported similar findings with the TP group noted to have a significantly higher complications rate [7]. However, in their subgroup analysis of matched studies, authors noted no difference between the two groups. Subgroup analysis

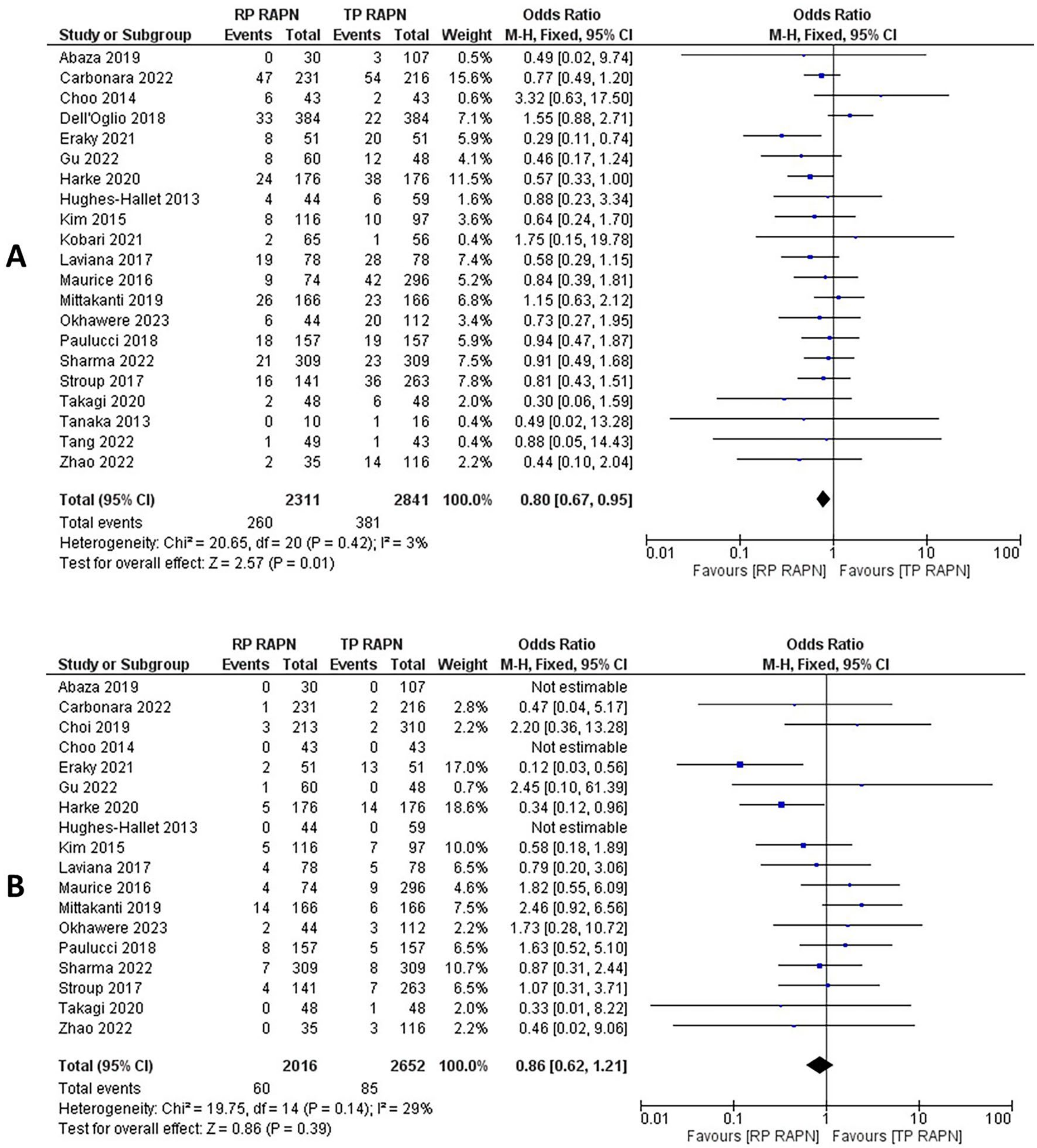

Fig. 2 Forest plots depicting, overall complications (**A**) and major complications (**B**). *RAPN* Robot-assisted partial nephrectomy, *RP* Retroperitoneal, *TP* Transperitoneal

from Carbonara et al. are difficult to interpret due to the reasons mentioned above. Pavan et al., in their meta-analysis, found no statistically significant difference between the groups for overall and major complications [8]. Zhu et al. in their analysis found that only the rate of minor complications (Clavien Dindo grade I and II) was higher in the TP group, with no difference in the rate of major complications [33]. From the results of the present study, it is difficult to interpret causes for higher rates of overall complications with TP RAPN as data for individual complications is missing from most of the included studies. It would have been much more clinically relevant to analyze certain complications such as bowel-related complications, the need for angioembolization and Double J stenting individually. Unfortunately, separate data for these complications is lacking from the majority of studies.

Amongst intraoperative parameters, we noted a shorter WIT in the RP group [MD − 0.93 (− 1.93, 0.07), $p = 0.07$] however, the difference was neither statistically nor clinically significant. This is in line with previous metanalyses where no difference was found in WIT between the two groups [7, 8]. On the contrary, two recently reported

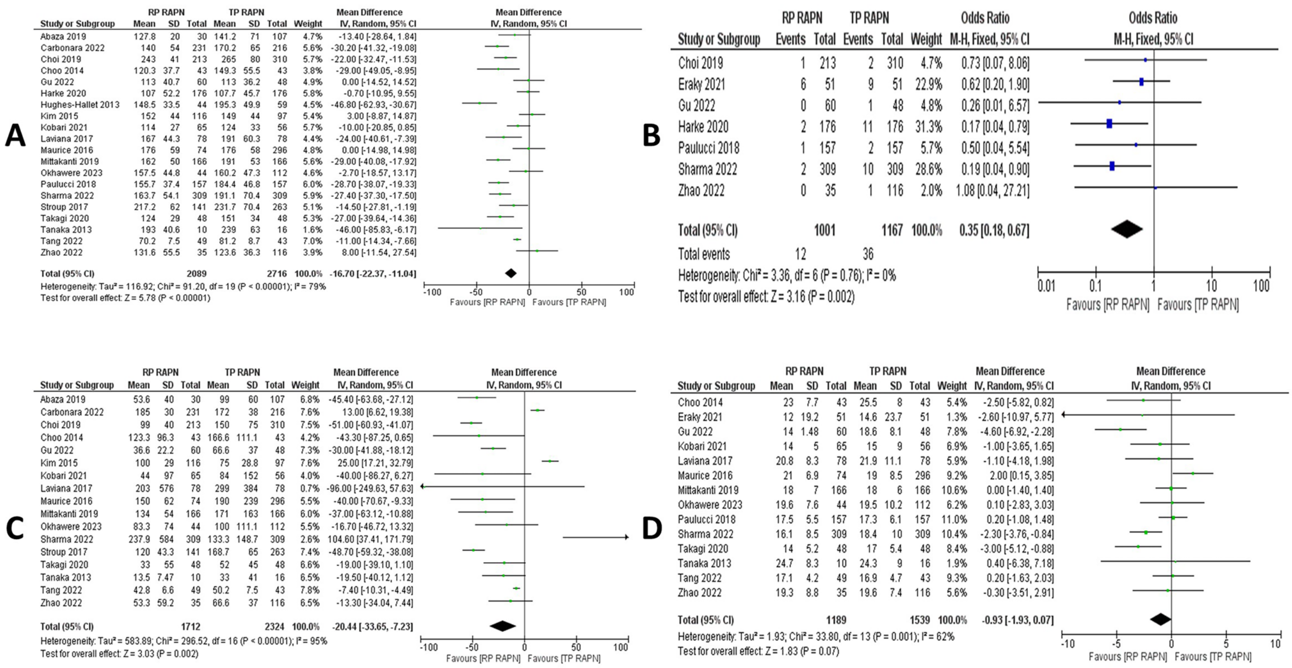

Fig. 3 Forest plots depicting, operative time (**A**), need for blood transfusion (**B**), estimated blood loss (**C**), and warm ischemia time (**D**). *RAPN* Robot-assisted partial nephrectomy, *RP* Retroperitoneal, *TP* Transperitoneal

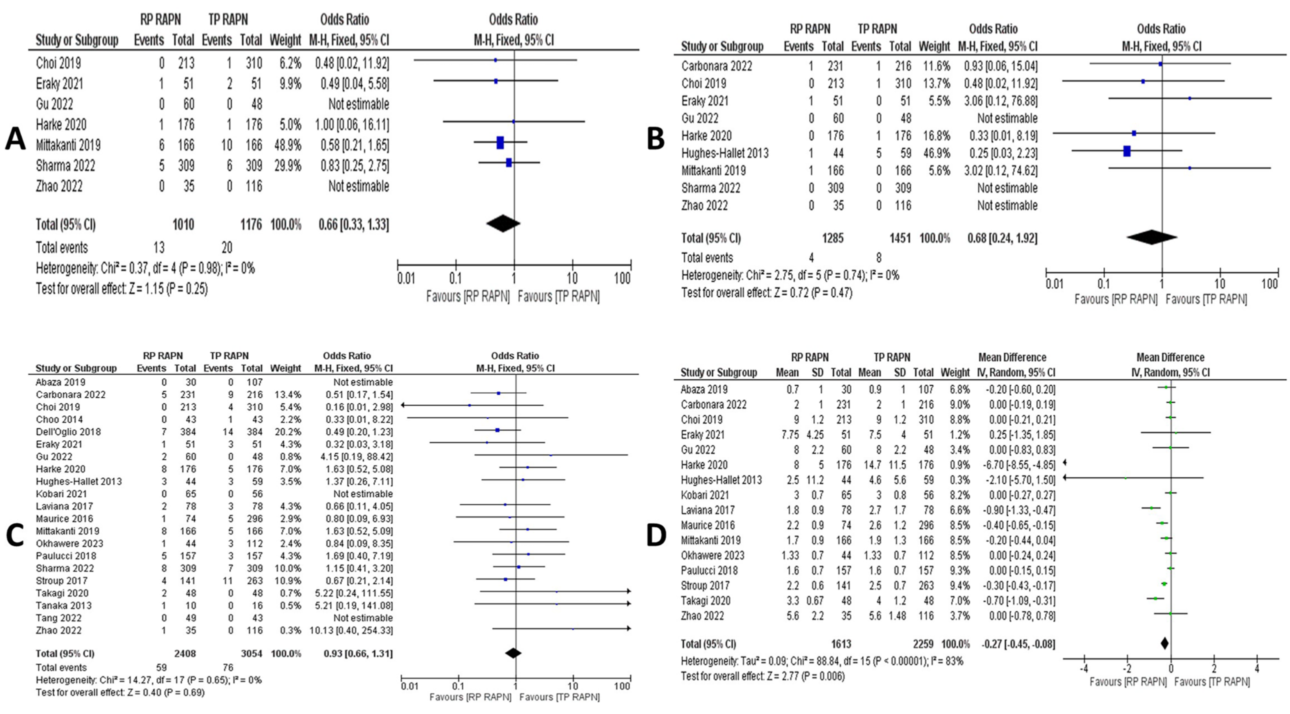

Fig. 4 Forest plots depicting conversion to radical nephrectomy (**A**), need for conversion to open surgery (**B**), positive surgical margins (**C**), and Length of hospital stay (**D**). *RAPN* Robot-assisted partial nephrectomy, *RP* Retroperitoneal, *TP* Transperitoneal

large multicentric studies by Sharma et al. [25] and Harke et al. [3] have reported significantly shorter WIT with the TP approach. The shorter WIT in these studies could be explained by increasing familiarity and expertise amongst surgeons in performing RP RAPN, especially at some centres where it is the preferred approach. Another argument that could be raised to explain such results is the selection bias. The operative time was significantly lower in the RP group [MD − 20.44 (− 33.65, − 7.23), $p = < 0.00001$]. The mean difference of 20 min between the two techniques may be of doubtful clinical significance. A 20-min longer surgery translates to an additional time distributed amongst general anaesthesia time, docking time and time taken in kidney mobilization, and, therefore, the warm ischemia time, which actually has effect on the outcome following partial nephrectomy, would potentially differ by only a few minutes. This can, but is unlikely to cause post-op problems and won't make a significant difference in terms of margin positivity rates and completeness of resection as long as strict operative principles are adhered to. Similar findings have been reported by most of the previous studies and meta-analyses on the topic. Zhou et al. in their study concluded that operative time is more in TP RAPN because of its preference for more complex tumors [32]. However, another more reasonable explanation for this finding is the faster access to renal vasculature and parenchyma in the RP approach as it doesn't require bowel mobilization and flipping the kidney [14].

We noted EBL to be statistically favouring the RP group [MD −20.44 (−33.65, −7.23), $p = < 0.00001$]. However, an MD of 20 ml although statistically significant may not be clinically relevant. The more clinically relevant parameter is the need for blood transfusion. We noted RP RAPN to be associated with a significantly reduced need for blood transfusion as compared to the TP approach [OR 0.35 (0.18, 0.67), $p = 0.002$]. Previous studies have also reported lower EBL with the RP approach [7, 33] as well as lower transfusion rates in the RP group [3, 25]. Lesser surgical dissection and selection bias seem to be the most probable causes explaining the results of EBL and BT favouring RP RAPN [19]. There was no statistically significant difference between the two groups for PSM [$p = 0.69$], conversion to radical nephrectomy [$p = 0.25$], and conversion to open surgery [$p = 0.47$], similar to recently reported studies [24], which are not much different from the previous studies on the topic.

The present study is the largest and latest comparison of TP and RP RAPN surgical approaches and has made genuine attempts to circumvent the limitations of the previous meta-analyses on the topic. However, some limitations of the present study are worth acknowledging. Firstly, to date, there is no RCT comparing these two approaches, so only studies with retrospective or prospectively maintained retrospective data were included. Thus, the possibility of selection bias cannot be completely excluded. However, we did only include studies with baseline matching and considered only matched data for studies with propensity matching. Secondly, the data on the surgeon's expertise and learning curve is lacking. Thirdly, there was sparse data on the history of previous abdominal surgeries, which would cause selection bias and could lead to the increased complexity of the procedure when performed transperitoneally. In addition, there was limited data on the type of robotic systems used. Finally, data were lacking for individual complications in the studies considered for analysis.

Conclusion

Retroperitoneal robot-assisted partial nephrectomy has a lower rate of complications, operative time, estimated blood loss, need for blood transfusion and length of stay. However, positive surgical margin, major complication, conversion to radical or open rates were similar in both approaches. Multicentric randomized controlled trials with large sample sizes are required to give a robust recommendation on the selection of surgical techniques stratified as per patient and tumour characteristics.

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Author contributions All the authors were involved in data acquisition and manuscript editing. N.S., P.B., G.R.C. & G.S were involved in conception, design, analysis, manuscript writing and editing. G.S was involved in the supervision of the project.

Data availability Corresponding author had full access to data and the same can be provided on request to genuine authors.

Declarations

Conflict of interests None to declare.

Research involving human participants and/or animals This is a systematic review and does not involve any Human Participants or Animals.

Informed consent Not applicable.

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