Length of hospital stay and procedure time after partial nephrectomy or percutaneous thermal ablation: A systematic review and meta-analysis

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KEY MESSAGES

- The LOS after partial nephrectomy varies by geographic region: shortest stays in North America and longest in Asia.
- Robot-assisted partial nephrectomy and conventional laparoscopic partial nephrectomy are associated with shorter hospital stays compared to open partial nephrectomy.
- Percutaneous thermal ablation generally results in the shortest hospital stays across all regions.
- Procedure times for partial nephrectomy and percutaneous thermal ablation also show regional variations, with significant differences observed between North America, Europe, and Asia.
- Findings emphasize the importance of considering regional healthcare practices and the specific needs of patients when making treatment decisions for small renal masses.

ABSTRACT

Introduction: This systematic review addressed the length of hospital stay (LOS) and procedure time in patients with small renal masses (SRM) undergoing open,

conventional laparoscopic (OPN), and robot-assisted partial nephrectomy (RAPN), as well as percutaneous thermal ablation (PTA) in different geographic areas.
Methods: We conducted a comprehensive search in databases (MEDLINE, EMBASE, CINAHL) until July 2023, and we applied random-effect meta-analysis, with evidence certainty assessed by the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework.
Results: We screened 3456 titles and abstracts, ultimately identifying 60 eligible studies. For the length of LOS (days) following OPN, our pooled estimates revealed means of 5.7 in North America, 7.1 in Europe, and 13.4 in Asia; following laparoscopic partial nephrectomy, means were 3.1, 5.4, and 5.8, respectively; for RAPN, means were 2.7, 3.8, and 7.1; and for PTA, means were 1.2, 1.6, and 1.6. Regarding procedure time (minutes) after OPN, means were 187 in North America, 132 in Europe, and 184 in Asia; after laparoscopic partial nephrectomy, means were 198, 127, and 200; after RAPN, means were 189, 150, and 192; and for PTA, mean was 144 in North America and no studies addressed procedure time in Europe and Asia.
Conclusions: Our study provides the most trustworthy available estimates of LOS and procedure time for patients undergoing invasive procedures for the management of SRM. These findings have emphasized the need for context-specific considerations when informing patients and making treatment decisions.

INTRODUCTION

The increasing utilization of abdominal imaging techniques, such as computed tomography, ultrasound, and magnetic resonance imaging, has led to a rising estimate of the incidence of renal cell carcinoma over the past few decades [1-3]. Renal cell carcinoma is now the 14th most common cancer globally, with over 431,000 new cases diagnosed in 2020 and nearly 180,000 resulting deaths[4]. Its incidence varies geographically and among population subgroups, with higher rates observed in high-income countries, males, and older individuals[5].

Many of the incidentally detected renal lesions are small renal masses (SRMs), typically defined as solid masses with a maximal diameter of ≤4cm[6]. A significant proportion (20-30%) of SRMs are benign renal lesions, such as oncocytomas. Even if malignant, most SRMs have low metastatic potential[7,8]. The most common approaches for managing SRMs are nephron-sparing surgery and percutaneous thermal ablation (PTA), each with their own risks and burdens[9,10]. For nephron-sparing surgery, specifically partial nephrectomy (PN), three surgical approaches are available: open (OPN), conventional laparoscopic (LPN), and robot-assisted (RAPN). Each approach has distinct consequences, with LPN, for instance, resulting in shorter hospital stays (LOS) and less postoperative pain compared to OPN surgery[11]. To minimize treatment costs and serve patients optimally, reduction of LOS has become a priority in many developed countries.

However, variations in healthcare policies across regions and the influence of traditions and beliefs can impact LOS [12].

Patients with a SRM who have opted for PN require estimates of the burdens associated with each approach, in particular LOS. Surgeons who engage with patients in making the decisions regarding management may also consider the procedural time as bearing on the decision. Currently, there is no comprehensive review summarizing the evidence on LOS and procedural time in patients with SRM. Because such a review would help inform relevant shared decision-making regarding choice of procedure, we have summarized the evidence available regarding the LOS and procedural time for OPN, LPN, RAPN, and PTA in patients with SRM.

METHODS

We registered the protocol of this review in the PROSPERO (International Prospective Register of Systematic Review), registration ID is CRD42022308375. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards guided the reporting in our review.

Data sources and searches

We systematically searched MEDLINE (Medical Literature Analysis and Retrieval System Online), EMBASE (Excerpta Medica database), and CINAHL (Cumulative Index of Nursing and Allied Health Literature) from database inception to the end of July 2023. Additional sources included hand searching the reference lists of the included articles and recommendations from our team's two urologist members (PR and PV).

Eligibility criteria

We included studies meeting these criteria: (1) Randomized controlled trials, cohort studies (retrospective or prospective), and case series with over 10 patients; (2) Studies reporting at least one of the following outcomes in SRM patients: LOS and procedure length; (3) Studies providing health outcomes as mean and SD or convertible estimates (median, range, IQR); and (4) Studies written in English. There were no restrictions on publication status, country, or period. Studies were included if 80% of masses had a maximum diameter ≤4 cm, despite varying size thresholds for SRMs.

We excluded studies: (1) on patients with specific health conditions (e.g., diabetes); and (2) without clear treatment specifications.

Procedures included were nephrectomy and thermal ablation. For nephrectomy, we focused on partial nephrectomy (open, laparoscopic, robotic) via transperitoneal or retroperitoneal approaches. For thermal ablation, we included only percutaneous approaches, excluding laparoscopic thermal ablation, and restricted to cryoablation and radiofrequency ablation.

Study selection and data extraction
Reviewers received detailed instructions for each step of title and abstract screening, full text reading, risk of bias assessment, and data abstraction. Pairs of reviewers independently screened titles and abstracts and then reviewed the full text of studies judged potentially eligible. For studies judged eligible, pairs of reviewers abstracted the data and assessed the risk of bias, resolving discrepancies at each step through discussion. When necessary, a third more experience reviewer resolved remaining discrepancies.

We recorded the country in which the study was conducted, participants' age, gender and tumor size distribution, type of tumor, sample size as well as type of intervention.

Risk of bias and certainty of evidence
Our study addresses prognostic outcomes related to LOS and procedure duration for the considered procedures. We chose the QUIPS bias risk assessment tool[13] for prognostic studies, modified for our study designs and outcomes. We assessed bias risk using four QUIPS domains: "study participation," "outcome measurement," "study attrition," and "statistical analysis and reporting." We excluded "prognostic factor measurement" and "study confounding" as they were inapplicable. Studies were categorized as high or low risk of bias, with any high-risk domain marking the study as high risk.

To rate the certainty of the for LOS and procedure time, we used the GRADE approach for prognostic questions[14]. For publication bias, we planned to use Begg's test and funnel plots if sufficient studies were available.

Data analysis
To calculate pooled estimates of LOS and procedure time, we extracted mean and SDs, or converted medians, IQRs, or ranges to means and SDs using Wan et al.'s equations[15].

We hypothesized that LOS might vary by geographic region, expecting longer LOS in Asia compared to other regions[12]. We also anticipated differences in LOS and procedure time between studies with small vs. large sample sizes and low vs. high risk of bias. LOS comparisons across regions (North America, Europe, Asia, and others) were done using Kruskal-Wallis tests. Differences based on sample size and risk of bias were analyzed using independent t-tests and Welch t-tests. Studies were considered small if the sample size was under 100 and were categorized by risk of bias using the QUIPS tool.

A p-value of 0.05 was set for significance in hypothesis tests. Pooled means were calculated using the DerSimonian-Laird random effects method. The credibility of subgroup effect claims was evaluated using a tailored version of the ICEMAN tool [16], assessing the region's influence on prognostic factors.

RESULTS

Literature search and study characteristics

We screened 3,456 titles and abstracts and retrieved 294 possibly eligible full texts. Of these, 60 original studies including 10,416 patients proved eligible (Chart 1 PRISMA diagram). Many participants were males, aged between 50 to 65 years old and the mean tumor size in most studies was between 2-3 cm (table1).

Risk of bias

Of the 60 eligible studies, 31 proved at high risk of bias. Table 2 presents the details of bias risk assessments.

Prognostic factor analysis

We did not see significant results in test for prognostic effect of sample size of included studies and risk of bias. However, we found that chance could not easily explain differences based on region of studies for LOS after OPN, LPN, and RAPN but could for PTA. Table 3 shows the results of test of prognostic factors.

Applying the ICEMAN instrument, we concluded high credibility of prognostic factor modification based on region of studies for LOS after RAPN and a moderate credibility OPN and LPN, and a low credibility for PTA. We concluded high credibility for procedure time of OPN and a moderate credibility for LPN, RAPN, and PTA. For the rest of potential effect modifier, ICEMAN did not suggest a prognostic factor analysis (appendix 1 shows the results of completed ICEMAN tool). Therefore, we analyzed LOS and procedure time in subgroups of area. Table 4 summarizes the results and the GRADE quality of evidence assessments.

Although many of the subgroups did not contain 10 studies, we assessed publication bias in those subgroups that had 10 or more studies (Appendix 2). We did not see any publication bias based on the results of Begg's test and funnel plots in those subgroups (table 3).

Length of hospital stay

Open partial nephrectomy

The pooled mean LOS in the North America subgroup (n=6 studies) was 5.7 days (95% CI of 4.6-6.5); in the Europe subgroup (n=4 studies) 7.1 days (95% CI of 5.7-8.4); and in the Asian subgroup (n=4 studies) 13.4 days (95% CI of 7.6-19.3).

Conventional laparoscopic partial nephrectomy

The pooled mean LOS in North America (n=11 studies) was 3.1 days (95% CI was 2.5-3.6); in the Europe subgroup (n=4 studies), 5.4 days (95% CI 3.4-7.4); and in the Asian subgroup (n=7 studies[17-20]) 5.8 days (95% CI 4.8-6.8).

Robot-assisted partial nephrectomy
The pooled mean LOS in the North America subgroup (n=6 studies) was 2.7 days (95% CI 1.9-3.5); in Europe subgroup (n= 7 studies) 3.8 days (95% CI 2.6-4.9); and lastly, in the Asian subgroup (n=8 studies) 7.1 days (95% CI 5.3-8.9).

Percutaneous thermal ablation
The pooled mean LOS in the North America subgroup (n=6 studies) was 1.2 days (95% CI 0.7-1.6); in Europe was 1.6 days (95% CI 1.0-2.1); and in one study conducted in Brazil (n=60 patients) was 1.6 days (95%CI 1.3-1.9).

Tables 2 and 4 along with Figures 1 to 4, provide detailed information on LOS after OPN, LPN, RAPN, TA.

Procedure time

Open partial nephrectomy
The pooled estimated mean of duration of procedure in the North America subgroup (n=6 studies) was 187 minutes (95% CI 158-215); 132 minutes (95% CI 123-141) in the Europe subgroup (n= 5 studies); and 184 minutes (95% CI 160-208) in the Asian subgroup (n=5 studies).

Conventional laparoscopic partial nephrectomy
The pooled estimated mean of duration of procedure in the North America subgroup (n= 12 studies) was 198 minutes (95% CI 163-221); 127 minutes (95% CI 83-171) in the Europe subgroup (n= 4 studies; and 200 minutes (95% CI 168-231) in Asian subgroup (n=10 studies). One study was conducted in Australia (n=50 patients). The authors reported a mean procedure time of 224 minutes (95%CI 213-234).

Robot-assisted partial nephrectomy
The pooled estimated mean duration of procedure in the North American subgroup (n=10 studies) was 189 minutes (95% CI 172-206); 150 minutes (95%CI 121-178) in the Europe subgroup (n=7 studies); and 192 minutes (95% CI 169-214) in the Asian subgroup (n=11 studies).

Percutaneous thermal ablation
The pooled estimated mean duration of procedure in the North American subgroup (n=5 studies) was 144 minutes (95% CI 115-174); and 98 minutes (95%CI 91-105) in one study (n=60 patients) conducted in Brazil. No studies reported the procedural time in the Europe and Asia subgroups.

Tables 2 and 4, along with Figures 5 to 8 provide detailed information on duration of OPN, LPN, RAPN, TA procedures.

DISCUSSION

The findings of our systematic review and meta-analysis shed light on the LOS in patients with SRMs undergoing different surgical approaches. Specifically, we observed similar durations of hospital stay for both LPN and RAPN procedures, while OPN was associated with longer LOS. Across all approaches, the LOS proved shortest in North America. In contrast, Europe exhibited longer hospital stays, with even longer stays in Asia. The observed regional disparities underscore the potential influence of healthcare practices, healthcare infrastructure, and patient management in shaping hospitalization durations.

Our evaluation revealed that many available studies on PTA were conducted in North America. These patients exhibited shorter hospital stays in comparison to those undergoing partial nephrectomy procedures. This observation may reflect the regional differences in procedural preferences and hospital protocols, potentially indicating variations in postoperative care or recovery trajectories.

Regarding the quality of evidence, our findings indicate a low to high certainty of evidence for studies conducted in North America and Europe and as moderate to high for studies conducted in Asia. This assessment underscores robustness of the findings, particularly observed in Asian studies.

Strengths and limitations

Strengths of this systematic review include, a comprehensive literature search, without any restrictions on the time of publication. The inclusion of at least two trained reviewers in the assessment of all 60 included studies, along with the tailored risk of bias, GRADE assessments, and ICEMAN assessments of subgroup effects, enhance the reliability and validity of the findings. Additionally, the criteria for study inclusion and exclusion resulted in a group of homogeneous studies, contributing to the high directness in GRADE evaluation, particularly for LPN, RAPN, and PTA. The application of the modified ICEMAN tool helped evaluate the credibility of prognostic factor analysis, addressing the lack of a reliable tool for systematic reviews of factors modifying the results of prognostic studies.

One primary methodological limitation of this review was the restriction to English language studies, which may introduce potential language bias. Limitations are inherent in the number and design of the available studies. For instance, only a small number of studies reported procedural time and LOS after PTA, limiting the feasibility of conducting subgroup analysis for this procedure. Furthermore, the inclusion of some studies with patients having tumors >4cm poses potential limitations. However, we restricted studies to those in which over 80% of participants had undergone intervention for tumors ≤4cm. Due to the absence of individual participant data, the impact of outliers on mean LOS and procedural time could not be assessed. Despite the inclusion of 60 studies in this systematic review, many subgroups did not contain enough studies, preventing a robust statistical assessment of publication bias. The other limitation of our study is the inability to account for all factors that may influence the outcomes of interest. Specifically, patient comorbidities, renal tumor complexity, and the presence of multiple tumors were not uniformly collected across the included studies. These variables can significantly impact both hospital-stay duration and procedure time. Future studies should aim to incorporate these factors to provide a more comprehensive analysis.

Relation to prior work

A prior systematic review and meta-analysis reported LOS and procedure time for RAPN and LPN in SRM patients[21]. This review included 6 studies, with 5 overlapping our review[18,19,22-24]. One study on bilateral synchronous kidney tumors was excluded as it did not meet our criteria[25]. The previous review, focusing on studies from North America and Asia, found a LOS of 3.6 days for LPN in North America and 4.8 days in Asia. For RAPN, LOS was 3.5 days in North America and 5.0 days in Asia. This finding is consistent with our results as the LOS for LPN and RAPN in North America was shorter than Asia (3.1 vs 5.8 days for LPN; and 2.8 vs 7.1 for RAPN (North America vs Asia)). The difference in the pooled estimates may be explained by the fact that our study included a larger number of studies as well as those published more recently for both LPN and RAPN. It is plausible that surgeons have reduced the LOS for LPN either given the positive experience observed following robotic-assisted surgery in North America or due to the pressure to reduce costs associated with hospitalisation. As a result of comprehensive nature of our study and since ours included 6 additional studies, our results showed a longer LOS after RAPN in Asia (7.1 days) than in the previously reported meta-analysis. Two of these 6 studies were carried out in Japan, where prolonged hospitalization is influenced by healthcare policies, with mean hospital stays of 12.5[26] and 9[27] days. These studies significantly contributed to an elevated pooled estimation of LOS within the Asian subgroup.

In terms of procedure duration, the previous systematic review reported an average procedure time of 215 minutes for LPN in North America and 150 minutes in Asia. For RAPN, the average procedure time was 215 minutes in North America and 187 minutes in Asia. Our findings indicate slightly shorter procedure times for both LPN and RAPN in North America, with averages of 199 minutes and 189 minutes respectively. Conversely, we observed longer procedure times for both LPN and RAPN in studies conducted in Asia, with averages of 200 minutes and 199 minutes respectively. Again, differences can be explained by our inclusion of more recently published studies which likely reflect greater perioperative and/or intraoperative efficacy due the physicians' experience and the better overall patient care gained over time. On the other hand, our study encompasses three studies conducted in Japan[11,26,28] and one study conducted in Korea[17] that reported prolonged procedure times. As a result, the procedure time within the Asian subgroup of our study is longer compared to that reported in the previous systematic review.

Of importance, the prior review used the Newcastle-Ottawa Scale[29,30] to evaluate risk of bias, while we used the QUIPS instrument developed specifically for prognostic studies. The prior review did not address the certainty of the evidence, nor the credibility of the apparent differences across geographic areas. We applied the GRADE approach to assess the quality of evidence in our meta-analysis and the ICEMAN instrument to address the credibility of the apparent differences across geographic regions. This enhanced methodology allows for a more comprehensive and robust assessment, providing a clearer and more reliable insight into the prognostic outcomes in different geographic regions, making our study an advancement over prior approaches.

Implications of findings for practice and research

This systematic review and meta-analysis offer crucial insights for patients and surgeons in selecting procedures for SRM management, aiding shared decision-making. The findings may guide the creation of point-of-care decision aids, helping patients make informed choices. By detailing LOS variations across regions and surgical approaches, our review enhances the existing evidence base, assisting clinicians and researchers in decision-making and future studies.

Clinicians in Europe and Asia should investigate the factors contributing to longer LOS compared to North America. Adjusting management strategies could reduce LOS, lower costs, and improve patient experiences.

Further research should explore the causes of geographic variations and identify strategies to optimize patient care and outcomes. This review underscores the need for studies with larger, diverse populations to address limitations and bolster evidence on the prognostic outcomes of these interventions.

CONCLUSIONS

In conclusion, our systematic review and meta-analysis present the most accurate estimates of LOS and procedural time for patients undergoing invasive procedures for the management of SRMs. The findings also highlight significant geographic variations in the LOS, emphasizing the need for further research and understanding of the underlying factors contributing to these differences.

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FIGURES AND TABLES

Figure 1. Forest plot of length of hospital stay in patients with small renal masses after open partial nephrectomy.

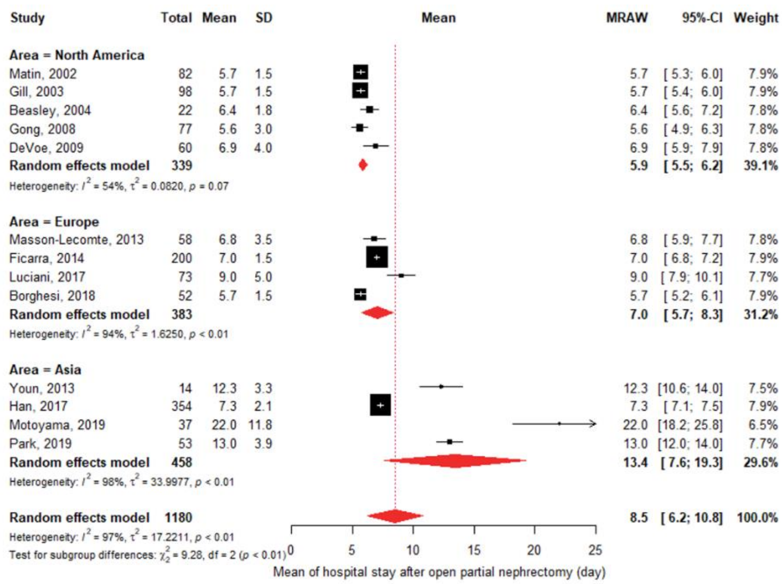

Figure 2. Forest plot of length of hospital stay in patients with small renal masses after conventional laparoscopic partial nephrectomy.

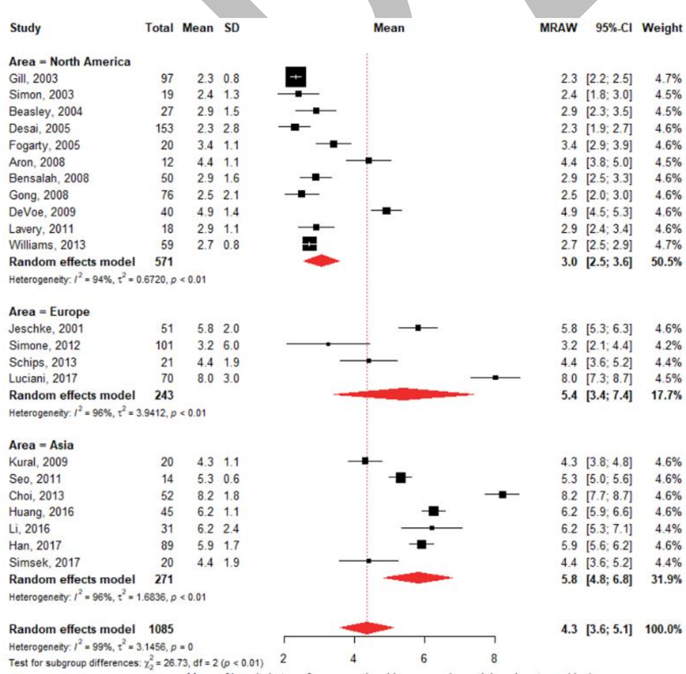

Figure 3. Forest plot of length of hospital stay in patients with SRM after robotic-assisted partial nephrectomy.

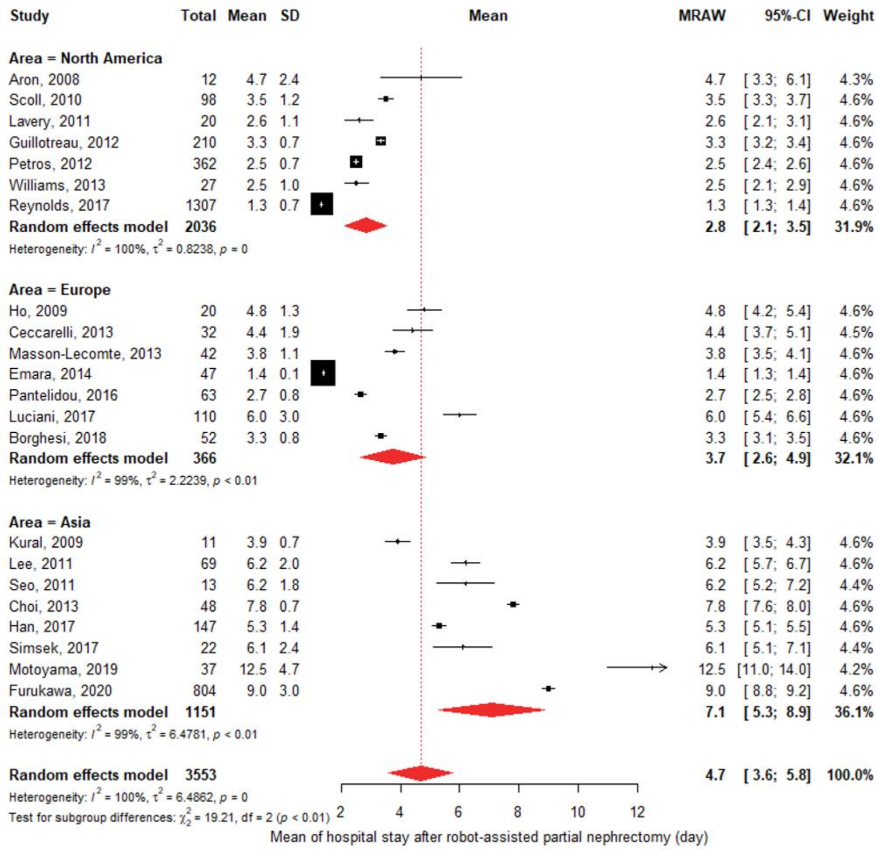

Figure 4. Forest plot of length of hospital stay in patients with small renal masses after percutaneous thermal ablation.

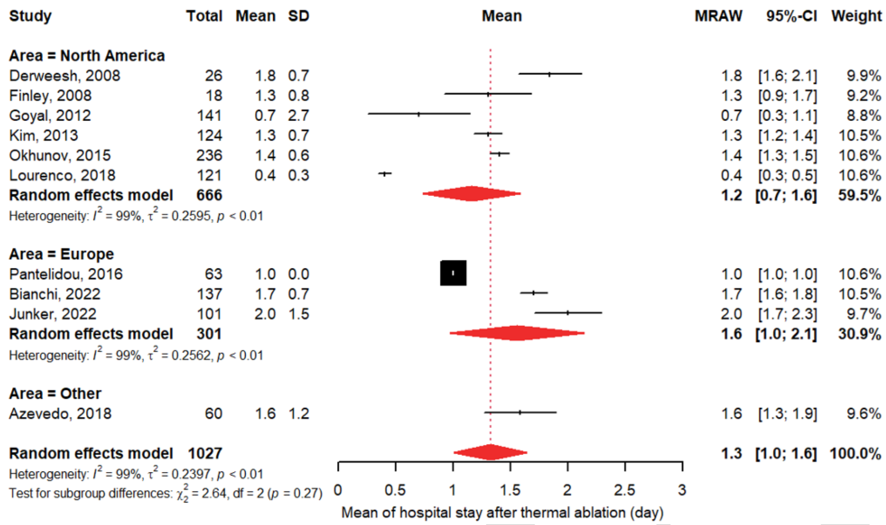

Figure 5. Forest plot of procedure time in patients with small renal masses after open partial nephrectomy.

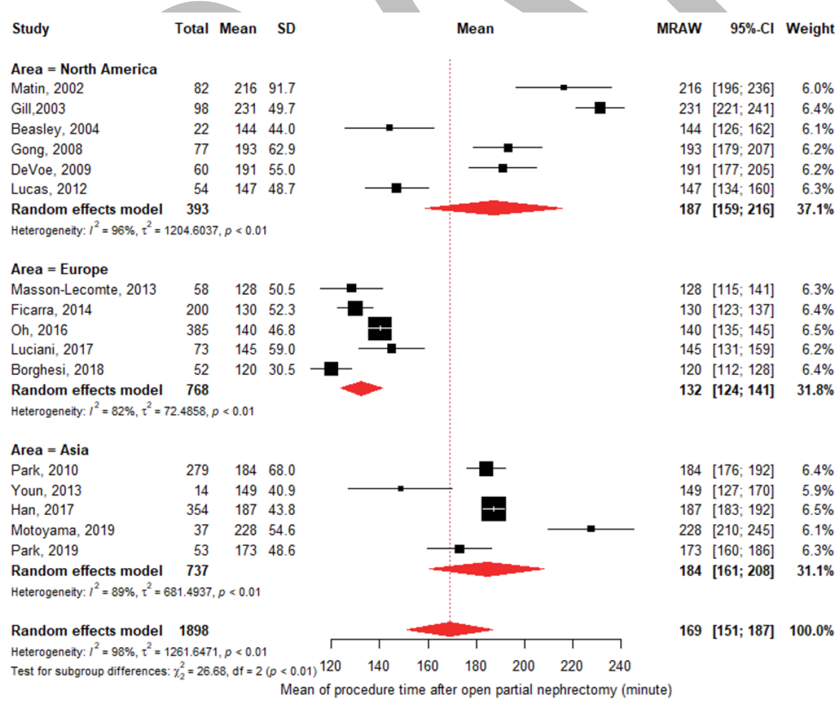

Figure 6. Forest plot of procedure time in patients with small renal masses after conventional laparoscopic partial nephrectomy.

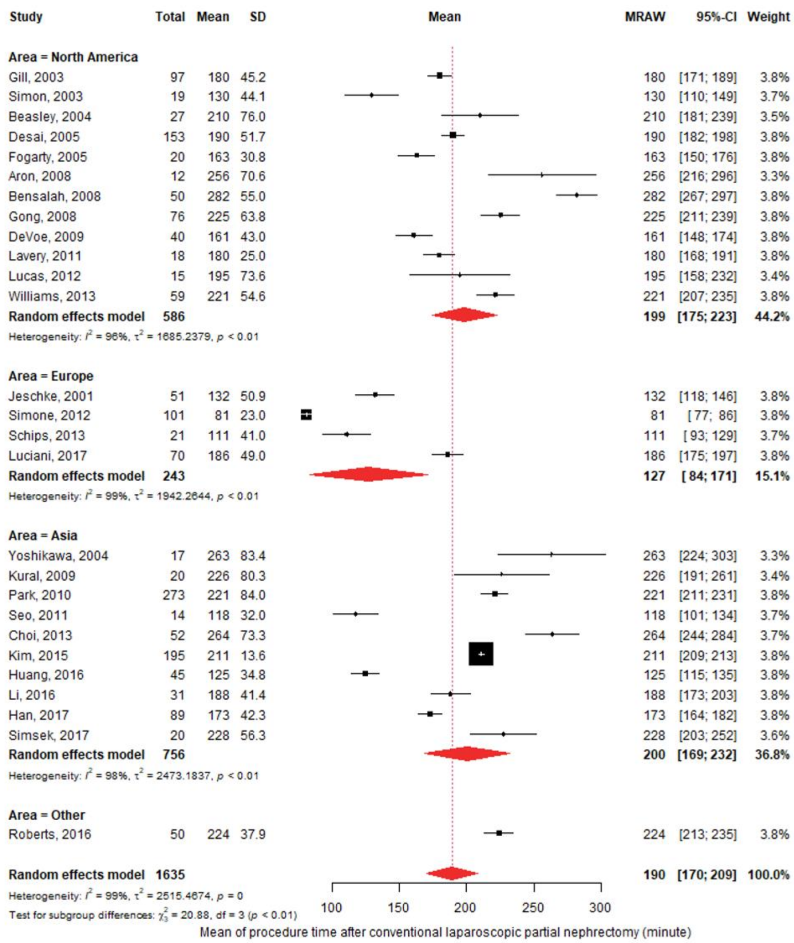

Figure 7. Forest plot of procedure time in patients with small renal masses after robotic-assisted partial nephrectomy.

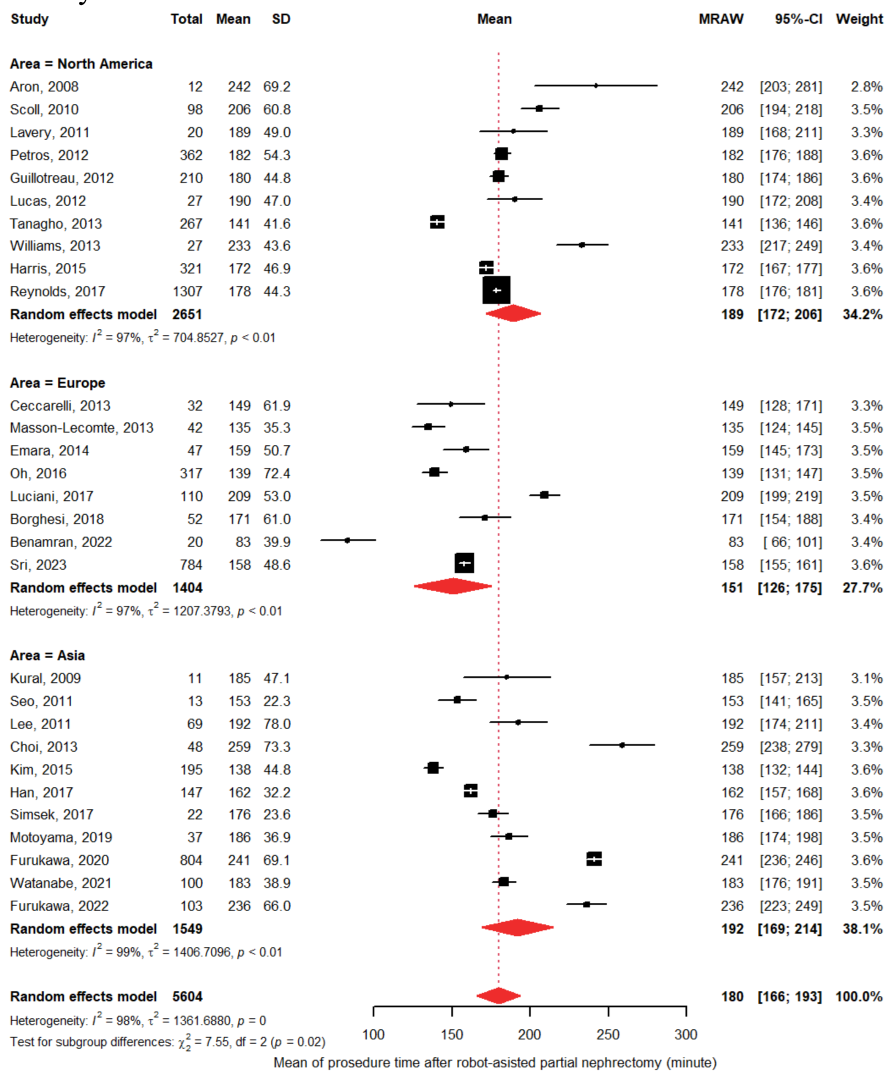

Figure 8. Forest plot of procedure time in patients with small renal masses after percutaneous thermal ablation.

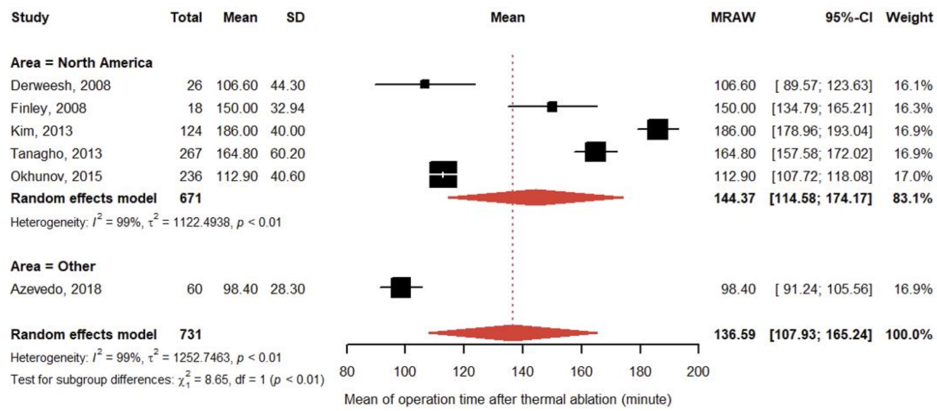

Table 1. Characteristics of original studies included in meta-analysis.

References	Country	Treatment type	Population characteristics			Mean tumor size, cm (SD)	Mean outcome (SD)	
			Sample size	% Male	Mean age (SD)		Hospitalization	Procedure time
Jeschke, 2001[31]	Austria	Laparoscopic partial nephrectomy	51	27.5	59.8 (11.1)	2.0 (0.9)	5.8 (2.0)	132.0 (50.9)
Matin, 2002[32]	U.S.	Open partial nephrectomy	82	61.0	56.2 (11.5)	2.6 (NR)	5.7 (1.5)	216.2 (91.7)
Gill, 2003[33]	U.S.	Open partial nephrectomy	98	67.0	58.8 (11.6)	3.4 (0.8)	5.7 (1.6)	231.2 (49.7)
		Laparoscopic partial nephrectomy	97	58.2	65.1 (11.4)	2.9 (1.5)	2.3 (0.8)	180.1 (45.2)
Simon, 2003[34]	U.S.	Laparoscopic partial nephrectomy	19	78.9	65.5 (11.7)	2.2 (1.3)	2.4 (1.3)	129.5 (44.1)
Beasley, 2004[35]	Canada	Open partial nephrectomy	22	63.6	51.1 (16.4)	2.9 (1.1)	6.4 (1.8)	144.0 (44.0)
		Laparoscopic partial nephrectomy	27	59.3	53.5 (17.7)	2.4 (1.2)	2.9 (1.5)	210.0 (76.0)
Yoshikawa, 2004[11]	Japan	Laparoscopic partial nephrectomy	17	76.5	55.2 (16.7)	2.5 (1.1)	NR	263.3 (83.4)
Desai, 2005[36]	U.S.	Laparoscopic partial nephrectomy	153	58.2	60.6 (13.2)	2.3 (0.7)	2.3 (2.8)	190.1 (51.7)
Fogarty, 2005[37]	U.S.	Laparoscopic partial nephrectomy	20	75.0	65.8 (11.3)	2.6 (0.9)	3.4 (1.1)	163.0 (30.8)
Aron, 2008[22]	U.S.	Laparoscopic partial nephrectomy	12	66.7	61.0 (13.8)	2.9 (0.7)	4.4 (1.1)	256.0 (70.6)
		Robot-assisted partial nephrectomy	12	66.7	64.0 (13.8)	2.4 (0.7)	4.7 (2.4)	242.0 (69.2)
Bensalah, 2008[38]	U.S.	Laparoscopic partial nephrectomy	50	62.0	56.5 (11.7)	2.6 (0.9)	2.9 (1.6)	282.0 (55.0)

Derweesh, 2008[39]	Canada-U.S.	Percutaneous thermal ablation	26	73.0	69.7 (12.3)	3.1 (1.3)	1.8 (0.7)	106.6 (44.3)
Finley, 2008[40]	U.S.	Percutaneous thermal ablation	18	NR	NR	2.7 (0.8)	1.3 (0.8)	150.0 (32.9)
Gong, 2008[41]	U.S.	Open partial nephrectomy	77	54.5	59.7 (13.6)	2.4 (0.9)	5.6 (3.0)	193.0 (62.9)
		Laparoscopic partial nephrectomy	76	46.1	60.1 (12.5)	2.9 (0.8)	2.5 (2.1)	225.1 (63.8)
DeVoe, 2009[42]	U.S.	Open partial nephrectomy	60	56.5	60.0 (9.8)	2.6 (1.1)	6.9 (4.0)	191.0 (55.0)
		Laparoscopic partial nephrectomy	40	67.3	59.2 (12.4)	2.6 (1.2)	4.9 (1.4)	161.0 (43.0)
Ho, 2009[43]	Austria	Robot-assisted partial nephrectomy	20	65.0	58.2 (7.9)	3.5 (0.5)	4.8 (1.3)	NR
Kural, 2009[18]	Turkey	Laparoscopic partial nephrectomy	20	70.0	58.9 (15.4)	3.1 (1.5)	4.3 (1.1)	226.0 (80.3)
		Robot-assisted partial nephrectomy	11	72.7	50.8 (13.2)	3.2 (0.7)	3.9 (0.7)	185.0 (47.1)
Park, 2010[44]	Korea	Open partial nephrectomy	279	74.2	53.1 (13.2)	2.3 (0.9)	NR	184.0 (68.0)
		Laparoscopic partial nephrectomy	273	70.0	54.6 (13.2)	2.1 (0.8)	NR	221.0 (84.0)
Scoll, 2010[45]	U.S.	Robot-assisted partial nephrectomy	100*	68.0	55.0 (12.0)	3.5 (1.4)	3.2 (1.2)	206 (60.8)
Lavery, 2011[23]	U.S.	Laparoscopic partial nephrectomy	18	77.8	53.6 (11.1)	2.3 (1.2)	2.9 (1.1)	179.7 (25.0)
		Robot-assisted partial nephrectomy	20	55.0	55.4 (11.1)	2.5 (0.9)	2.6 (1.1)	189.2 (49.0)
Lee, 2011[46]	Korea	Robot-assisted partial nephrectomy	69	72.5	53.5 (11.8)	2.4 (1.3)	6.2 (2.0)	192.4 (78.1)

Seo, 2011[19]	Korea	Laparoscopic partial nephrectomy	14	57.1	53.9 (11.6)	2.0 (1.2)	5.3 (0.6)	117.5 (32.0)
		Robot-assisted partial nephrectomy	13	76.9	54.2 (12.4)	2.7 (1.2)	6.2 (1.8)	153.2 (22.3)
Goyal, 2012[47]	U.S.	Percutaneous thermal ablation	141	65.2	69.5 (10.9)	2.4 (0.7)	0.7 (2.7)	NR
Guillotreau, 2012[48]	U.S.	Robot-assisted partial nephrectomy	210	58.6	57.8 (11.8)	2.4 (0.8)	3.3 (0.7)	180.0 (44.8)
Lucas, 2012[49]	U.S.	Open partial nephrectomy	54	70.4	58.0 (13.4)	2.3 (0.8)	NR	147.0 (48.7)
		Laparoscopic partial nephrectomy	15	41.2	49.4 (20.3)	2.2 (1.6)	NR	195.0 (73.6)
		Robot-assisted partial nephrectomy	27	70.4	62.1 (12.0)	2.4 (0.5)	NR	190.0 (47.0)
Petros, 2012[50]	U.S.	Robot-assisted partial nephrectomy	362	67.7	60.0 (11.0)	2.3 (0.6)	2.5 (0.7)	182.0 (54.3)
Simone, 2012[51]	Italy	Laparoscopic partial nephrectomy	101	62.4	59.0 (5.6)	2.6 (0.5)	3.3 (6.0)	81.3 (23.0)
Ceccarelli, 2013[52]	Italy	Robot-assisted partial nephrectomy	32	68.7	60.8 (14.3)	3.6 (1.2)	4.4 (1.9)	149.2 (61.9)
Choi, 2013[17]	Korea	Laparoscopic partial nephrectomy	52	63.5	51.1 (11.3)	2.2 (1.1)	8.2 (1.8)	263.8 (73.3)
		Robot-assisted partial nephrectomy	48	70.8	50.9 (11.4)	2.5 (1.0)	7.8 (0.7)	258.6 (73.3)
Kim, 2013[53]	U.S.	Percutaneous thermal ablation	124	NR	72.6 (10.2)	2.7 (1.1)	1.3 (0.7)	186.0 (40.0)
Masson-Lecomte, 2013[54]	France	Open partial nephrectomy	58	69.0	60.8 (11.2)	3.1 (1.2)	3.5 (1.0)	128.4 (50.5)
		Robot-assisted partial nephrectomy	42	52.4	61.7 (10.9)	2.8 (1.4)	1.1 (3.0)	134.8 (35.3)

Schips, 2013[55]	Italy	Laparoscopic partial nephrectomy	21	66.7	58.4 (9.0)	2.0 (0.3)	4.4 (1.9)	111.0 (41.0)
Tanagho, 2013[56]	U.S.	Robot-assisted partial nephrectomy	267	54.5	57.4 (11.9)	2.9 (1.5)	NR	140.6 (41.6)
		Percutaneous thermal ablation	267	61.0	69.3 (11.0)	2.5 (1.0)	NR	164.8 (60.2)
Williams, 2011[24]	U.S.	Laparoscopic partial nephrectomy	59	69.5	54.6 (11.7)	3.1 (2.2)	2.7 (0.8)	221.4 (54.6)
		Robot-assisted partial nephrectomy	27	63.0	55.7 (11.2)	2.5 (1.2)	2.5 (1.1)	233.0 (43.6)
Youn, 2013[57]	Korea	Open partial nephrectomy	14	57.1	53.9 (16.1)	2.4 (0.8)	12.2 (3.3)	148.6 (40.9)
Emara, 2014[58]	U.K.	Robot-assisted partial nephrectomy	47	46.3	60.5 (9.5)	2.6 (1.0)	1.4 (0.1)	159.0 (50.7)
Ficarra, 2014[59]	Italy	Open partial nephrectomy	200	65.5	62.4 (11.8)	2.8 (1.1)	7.0 (1.5)	130.0 (52.3)
Harris, 2015[60]	U.S.	Robot-assisted partial nephrectomy	321	NR	59.3 (11.7)	2.7 (1.3)	NR	171.7 (46.9)
Kim, 2015[61]	Korea	Laparoscopic partial nephrectomy	195	66.7	54.7 (12.7)	2.3 (1.1)	NR	211.0 (13.6)
		Robot-assisted partial nephrectomy	195	63.6	54.4 (13.0)	2.4 ± 1.2	NR	138.0 (44.8)
Okhunov, 2015[62]	U.S.	Percutaneous thermal ablation	236	67.4	68.2 (10.6)	2.4 (1.0)	1.4 (0.6)	112.9 (40.6)
Huang, 2016[20]	China	Laparoscopic partial nephrectomy	45	62.2	50.0 (10.4)	2.9 (0.6)	6.3 (1.1)	124.8 (34.8)
Li, 2016[63]	Taiwan	Laparoscopic partial nephrectomy	31	61.3	53.0 (7.5)	2.9 (1.1)	6.2 (2.4)	188.0 (41.4)
Oh, 2016[64]	Germany	Open partial nephrectomy	385	69.6	54.9 (13.1)	2.3 (0.8)	NR	140.2 (46.8)

		Robot-assisted partial nephrectomy	317	72.6	52.1 (12.2)	2.2 (0.8)	NR	138.8 (72.4)
Pantelidou, 2016[65]	U.K.	Robot-assisted partial nephrectomy	63	NR	54.0 (7.0)	2.9 (0.1)	2.7 (0.8)	NR
		Percutaneous thermal ablation	63	NR	61.0 (21.0)	2.1 (0.2)	1.0 (0.0)	NR
Robert, 2016[66]	Australia	Laparoscopic partial nephrectomy	50	54.0	56.9 (10.5)	2.5 (1.3)	NR	224.0 (37.9)
Han, 2017[67]	Korea	Open partial nephrectomy	354	76.3	55.3 (12.4)	2.8 (1.4)	7.3 (2.1)	187.2 (43.8)
		Laparoscopic partial nephrectomy	89	69.7	53.6 (9.7)	2.6 (1.1)	5.9 (1.7)	172.9 (42.3)
		Robot-assisted partial nephrectomy	147	73.5	52.5 (11.9)	2.4 (0.9)	5.3 (1.4)	162.3 (32.2)
Luciani, 2017[68]	Italy	Open partial nephrectomy	73	69.9	63.0 (13.0)	3.6 (2.3)	5.0 (1.0)	145.0 (59.0)
		Laparoscopic partial nephrectomy	70	60.0	62.0 (11.0)	3.5 (1.4)	3.0 (2.0)	186.0 (49.0)
		Robot-assisted partial nephrectomy	110	60.9	61.0 (12.0)	3.6 (1.5)	3.0 (3.0)	209.0 (53.0)
Reynolds, 2017[69]	U.S.	Robot-assisted partial nephrectomy	1307	56.2	58.1 (11.8)	2.5 (0.7)	1.3 (0.7)	178.4 (44.3)
Simsek, 2017[70]	Turkey	Laparoscopic partial nephrectomy	20	75.0	50.2 (11.3)	NR	4.4 (1.9)	227.5 (56.3)
		Robot-assisted partial nephrectomy	22	54.5	54.8 (9.6)	NR	6.1 (2.4)	176.0 (23.6)
Azevedo, 2018[71]	Brazil	Percutaneous thermal ablation	60	80.0	63.9 (12.54)	1.6 (0.82)	1.6 (1.2)	98.4 (28.3)
Borghesi, 2018[72]	Italy	Open partial nephrectomy	52	57.7	62.7 (16.0)	3.0 (1.5)	5.7 (1.5)	120.0 (30.5)

		Robot-assisted partial nephrectomy	52	51.1	61.3 (16.0)	3.0 (1.5)	3.3 (0.8)	171.0 (61.0)
Lourenco, 2018[73]	Canada	Percutaneous thermal ablation	121	64.5	71.0 (10.8)	2.6 (0.9)	0.4 (0.3)	NR
Motoyama, 2019[27]	Japan	Open partial nephrectomy	37	62.2	59.8 (10.6)	3.3 (1.5)	22.0 (11.8)	227.5 (54.6)
		Robot-assisted partial nephrectomy	37	59.5	62.0 (12.7)	2.5 (0.8)	12.5 (4.7)	186.3 (36.9)
Park, 2019[74]	Korea	Open partial nephrectomy	53	75.5	53.0 (13.2)	2.5 (0.6)	13.0 (3.9)	173.0 (48.6)
Furukawa, 2020[26]	Japan	Robot-assisted partial nephrectomy	804	72.6	63.0 (11.1)	2.6 (1.0)	9.0 (3.0)	241.0 (69.1)
Watanabe, 2021[75]	Japan	Robot-assisted partial nephrectomy	100	64.0	62.6 (13.6)	2.5 (1.1)	NR	183.2 (38.9)
Benamran, 2022[76]	France	Robot-assisted partial nephrectomy	20	55.0	61.3 (5.6)	2.5 (0.7)	NR	63.3 (23.9)
Bianchi, 2022[77]	Italy	Percutaneous thermal ablation	137	65.7	72.0 (10.5)	2.3 (0.8)	1.7 (0.7)	NR
Furukawa, 2022[28]	Japan	Robot-assisted partial nephrectomy	103	74.8	61.0 (11.6)	2.7 (1.0)	NR	234.0 (66.0)
Junker, 2022[78]	Denmark	Percutaneous thermal ablation	101	71.3	69.2 (10.5)	3.1 (0.9)	2.0 (1.5)	NR
Sri, 2023[79]	U.K.	Robot-assisted partial nephrectomy	784	68.0	54.8 (10.0)	3.1 (1.5)	NR	158.0 (48.6)

*Duration of hospitalization is reported for 98 patients. NR: not reported; SD: standard deviation.

Table 2. Risk of bias in included studies.

Study	**Domain**				**Total ROB assessment**	**Comment**
	Study participation	**Outcome measurement**	**Study Attrition**	**Statistical Analysis and Reporting**		
Jeschke, 2001[31]	High	Low	Low	Low	High	Inadequate description of the sampling frame, recruitment, inclusion and exclusion criteria
Matin, 2002[32]	Low	High	Low	Low	High	A clear definition of the outcomes of interest is not provided
Gill, 2003[33]	Low	Low	Low	Low	Low	NA
Simon, 2003[34]	High	High	Low	Low	Very high	Inadequate description of the sampling frame, recruitment, inclusion and exclusion criteria; a clear definition of the outcome (s) of interest is not provided

Beasley, 2004[35]	Low	Low	Low	Low	Low	NA
Yoshikawa, 2004[11]	High	High	Low	Low	Very high	Inadequate description of the sampling frame, recruitment, inclusion and exclusion criteria; a clear definition of the outcome (s) of interest is not provided
Desai, 2005[36]	Low	Low	Low	Low	Low	NA
Fogarty, 2005[37]	High	Low	Low	Low	High	Inadequate description of the sampling frame
Aron, 2008[22]	Low	Low	Low	Low	Low	NA
Bensalah, 2008[38]	High	Low	Low	Low	High	Inadequate description of inclusion and exclusion criteria
Derweesh, 2008[39]	Low	Low	Low	Low	Low	NA
Finley, 2008[40]	Low	Low	Low	Low	Low	NA
Gong, 2008[41]	Low	Low	Low	Low	Low	NA
Ho, 2009[43]	Low	Low	Low	Low	Not serious	NA
DeVoe, 2009[42]	High	High	Low	Low	Very high	Inadequate description of

						inclusion and exclusion criteria; a clear definition of the outcomes of interest is not provided
Kural, 2009[18]	High	Low	Low	Low	High	Inadequate description of inclusion and exclusion criteria
Park, 2010[44]	Low	Low	Low	Low	Low	NA
Park, 2010[44]	Low	Low	Low	Low	Low	NA
Lavery, 2011[23]	Low	Low	Low	Low	Low	NA
Lee, 2011[46]	Low	Low	Low	Low	Low	NA
Seo, 2011[19]	High	Low	Low	Low	High	Inadequate description of inclusion and exclusion criteria
Goyal, 2012[47]	High	Low	Low	Low	High	Inadequate description of the sampling frame, recruitment, inclusion and exclusion criteria
Guillotreau, 2012[48]	High	Low	Low	Low	High	Inadequate description of the sampling frame,

						recruitment, inclusion and exclusion criteria
Lucas, 2012[49]	Low	Low	Low	Low	Low	NA
Petros, 2012[50]	Low	Low	Low	Low	Low	NA
Simone, 2012[51]	Low	Low	Low	Low	Low	NA
Ceccarelli, 2013[52]	Low	Low	Low	Low	Low	NA
Choi, 2013[17]	Low	Low	Low	Low	Low	NA
Kim, 2013[53]	High	Low	Low	Low	High	Inadequate description of exclusion criteria
Masson-Lecomte, 2013[54]	High	Low	Low	Low	High	Inadequate description of the sampling frame, recruitment, inclusion and exclusion criteria
Schips, 2013[55]	High	High	Low	Low	Very high	Inadequate description of the sampling frame and exclusion criteria; inadequate method of outcome measurement -

						may not be validated or reliable
Tanagho, 2013[56]	High	Low	Low	Low	High	Inadequate description of the inclusion and exclusion criteria
Williams, 2011[24]	High	Low	Low	Low	High	Inadequate description of the sampling frame, recruitment, inclusion and exclusion criteria
Youn, 2013[57]	High	Low	Low	Low	High	Inadequate description of the sampling frame, Recruitment, inclusion and exclusion criteria, and place of recruitment
Emara, 2014[58]	Low	Low	Low	Low	Low	NA
Ficarra, 2014[59]	High	High	Low	Low	Very high	Sampling frames were two different databases resulting in heterogeneity in surgical

						techniques; outcomes of interest were not measured in a similar way for all participants
Harris, 2015[60]	Low	High	Low	Low	High	A clear definition of the outcome (s) of interest is not provided
Kim, 2015[61]	High	Low	Low	Low	High	Inadequate description of the sampling frame, recruitment, inclusion and exclusion criteria
Okhunov, 2015[62]	High	Low	Low	Low	High	Inadequate description of the sampling frame, recruitment, inclusion and exclusion criteria
Huang, 2016[20]	High	Low	Low	Low	High	Inadequate participation in the study by eligible persons
Li, 2016[63]	High	Low	Low	Low	High	Inadequate participation in

						the study by eligible persons
Oh, 2016[64]	Low	Low	Low	Low	Low	NA
Pantelidou, 2016[65]	Low	High	Low	Low	High	Outcome of interest was not measured in a similar way for all participants, setting of outcome measurement is not the same for all study participants
Robert, 2016[66]	High	Low	Low	Low	High	Inadequate description of the sampling frame, recruitment, inclusion and exclusion criteria
Han, 2017[67]	Low	Low	Low	Low	Low	NA
Luciani, 2017[68]	Low	Low	Low	Low	Low	NA
Reynolds, 2017[69]	Low	Low	Low	Low	Low	NA
Simsek, 2017[70]	High	Low	Low	Low	High	Inadequate description of the source population

Azevedo, 2018[71]	Low	High	Low	Low	High	A clear definition of the outcome (s) of interest is not provided
Borghesi, 2018[72]	High	Low	Low	Low	High	Inadequate description of the sampling frame, recruitment, inclusion and exclusion criteria
Lourenco, 2018[73]	High	Low	Low	Low	High	Inadequate description of the sampling frame and recruitment
Motoyama, 2019[27]	Low	Low	Low	Low	Low	NA
Park, 2019[74]	Low	Low	Low	Low	Low	NA
Furukawa, 2020[26]	High	Low	Low	Low	High	Inadequate description of the sampling frame, recruitment, inclusion and exclusion criteria
Watanabe, 2021[75]	High	Low	Low	Low	High	Inadequate description of the sampling frame, recruitment,

						inclusion and exclusion criteria
Benamran, 2022[76]	Low	Low	Low	Low	Low	NA
Bianchi, 2022[77]	Low	Low	Low	Low	Low	NA
Furukawa, 2022[28]	Low	Low	Low	Low	Low	NA
Junker, 2022[78]	Low	Low	Low	Low	Low	NA
Sri, 2023[79]	Low	Low	Low	Low	Low	NA

Table 3. Test of prognostic factors, Kruskal Wallis test, independent t-test, and Welch t-test

Prognostic factor	**Outcome**	**Intervention**	**Chi square/t**	**df**	**p**
Region of studies	Hospital stays	OPN	8.25	2	0.012
		LPN	12.18	2	0.002
		RAPN	13.19	2	0.001
		PTA	1.65	2	0.439
	Procedure time	OPN	9.05	2	0.011
		LPN	9.15	3	0.010
		RAPN	7.22	2	0.027
		PTA	3.86	2	0.145
Sample size of study	Hospital stays	OPN	0.94	11	0.365
		LPN	1.32	20	0.201

		RAPN	0.14	20	0.891
		PTA	0.53	8	0.610
	Procedure time	OPN	0.55	14	0.592
		LPN	0.61	25	0.546
		RAPN	0.26	27	0.794
		PTA	-0.03	5	0.975
Risk of bias	Hospital stays	OPN	0.50	11	0.629
		LPN	-0.18	20	0.855
		RAPN	0.25	20	0.808
		PTA	2.50	8	0.037
	Procedure time	OPN	1.61	14	0.131
		LPN	0.56	25	0.580
		RAPN	0.42	27	0.680
		PTA	-1.21	5	0.282

LPN: laparoscopic partial nephrectomy; OPN: open partial nephrectomy; PTA: percutaneous thermal ablation; RAPN: robot-assisted partial nephrectomy.

Table 4. GRADE, quality assessment of included studies and summary of findings.

Out-comes	Intervent-ions	Subgroups	Number of studies	Number of patients	Estimates (mean, 95%CI)	ROB	Inconsistency	Imprecision	Indirectness	Other considerat-ions	Certainty
Hospital stays (day)	OPN	North America	5	339	5.9 (5.5-6.2)	Not serious	Not serious	Not serious	Serious[a]	None	⊕⊕⊕◯ Moderate
		Europe	4	383	7.1 (5.7-8.4)	Serious[b]	Serious[c]	Serious[d]	Not serious	None	⊕⊕◯◯ Low
		Asia	4	458	13.4 (7.6-19.3)	Not serious	Not serious	Not serious	Not serious	None	⊕⊕⊕⊕ High
	LPN	North America	11	571	3.0 (2.5-3.6)	Not serious	Serious[c]	Not serious	Serious[e]	None	⊕⊕◯◯ Low
		Europe	4	243	5.4 (3.4-7.4)	Not serious	Serious[c]	Serious[d]	Not serious	None	⊕⊕◯◯ Low
		Asia	7	271	5.8 (4.8-6.8)	Serious[f]	Not serious	Not serious	Not serious	None	⊕⊕⊕◯ Moderate
	RAPN	North America	7	2,036	2.8 (2.1-3.5)	Not serious	Serious[c]	Serious[d]	Not serious	None	⊕⊕⊕◯ Moderate
		Europe	7	366	3.7 (2.6-4.9)	Not serious	Serious[c]	Serious[d]	Not serious	None	⊕⊕⊕◯ Moderate
		Asia	8	1,151	7.1 (5.3-8.9)	Not serious	Serious[c]	Not serious	Not serious	None	⊕⊕⊕◯ Moderate
	PTA	North America	6	666	1.2 (0.7-1.6)	Serious [g]	Not serious	Not serious	Not serious	None	⊕⊕⊕◯ Moderate

		Europe	3	301	1.6 (1.0-2.1)	Not serious	Not serious	Not serious	Not serious	None	⊕⊕⊕⊕ High
		Brazil	1	60	1.6 (1.3-1.9)	Serious[h]	Not applicable	Not serious	Not serious	None	⊕⊕⊕◯ Moderate
Procedure time (minute)	**OPN**	North America	6	393	187 (159-216)	Not serious	Not serious	Not serious	Serious [a]	None	⊕⊕⊕◯ Moderate
		Europe	5	768	132 (124-141)	Serious[b]	Not serious	Not serious	Not serious	None	⊕⊕⊕◯ Moderate
		Asia	5	737	184 (161-208)	Not serious	Not serious	Not serious	Not serious	None	⊕⊕⊕⊕ High
	LPN	North America	12	586	199 (175-223)	Not serious	Serious[i]	Not serious	Serious[j]	None	⊕⊕⊕◯ Moderate
		Europe	4	243	127 (84-171)	Serious[k]	Serious [l]	Serious[m]	Not serious	None	⊕⊕◯◯ Low
		Asia	10	756	200 (169-232)	Serious[n]	Serious[i]	Not serious	Not serious	None	⊕⊕⊕◯ Moderate
		Australia	1	50	224 (213-234)	Serious[h]	Not applicable	Not serious	Not serious	None	⊕⊕⊕◯ Moderate
	RAPN	North America	10	2,651	189 (172-206)	Not serious	Not serious	Not serious	Not serious	None	⊕⊕⊕⊕ High
		Europe	7	620	150 (121-178)	Not serious	Serious[l]	Not serious	Not serious	None	⊕⊕⊕◯ Moderate
		Asia	11	1,549	192 (169-214)	Serious[o]	Serious[l]	Not serious	Not serious	None	⊕⊕⊕◯ Moderate
	PTA	North America	5	671	144 (115-174)	Serious[p]	Not serious	Not serious	Not serious	None	⊕⊕⊕◯ Moderate

		Brazil	1	60	98 (91-106)	Serious [h]	Not applicable	Not serious	Not serious	None	⊕⊕⊕◯ Moderate

[a]Five out of five studies are published before 2010, methods of diagnosis and treatments have changed during last decade. [b]Two studies have high risk of bias in the study participation domain and one study have a high risk of bias in both study participation and outcome measurement domains. [c]The point estimates show a range of normal to long mean days of hospitalization. [d]The lower boundary of confidence interval does not show a long hospital stay while the upper boundary shows a prolonged hospitalization. [e]Nine out of 11 studies are published before 2010, methods of diagnosis and treatments have changed during last decade. [f]Five studies have high risk of bias in the study participation domain. [g]Four studies have high risk of bias in the study participation domain. [h]This study has high risk of bias in the outcome measurement domain. [i]There is about two and a half hours of difference between points estimates of mean procedure time in this subgroup of studies that is a considerable difference. [j]Nine out of twelve studies are published before 2010, methods of diagnosis and treatments have changed during last decade. [k]One study has high risk of bias in the study participation domain and one study has a serious risk of bias in both study population and outcome measurement domains. [l]There are about two hours of difference between points estimates of mean procedure time in this subgroup of studies that is a considerable difference. [m]The lower boundary of confidence interval does not show a long procedure time while the upper boundary shows a prolonged hospitalization. [n]Six studies have high risk of bias in the study participation domain and one study has a serious risk of bias in both study population and outcome measurement domains. [o]Six studies have high risk of bias in the study participation domain. [p]Three studies have high risk of bias in the study participation domain. LPN: laparoscopic partial nephrectomy; OPN: open partial nephrectomy; PTA: percutaneous thermal ablation; RAPN: robot-assisted partial nephrectomy.