Robot-Assisted Versus Laparoscopic Radical Nephrectomy: A Systematic Review and Meta-Analysis

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Abstract

Background: For the treatment of renal cell carcinoma, robotic-assisted radical nephrectomy (RARN) has been developed as an alternative to laparoscopic radical nephrectomy (LRN) (RCC). The objective of this systematic review and meta-analysis was to compare the perioperative results of RARN and LRN in the treatment of RCC.

Methodology: An exhaustive search of electronic databases from their inception until May 2023 was done. The meta-analysis comprised nine trials with a total of 13,676 individuals who underwent either RARN or LRN. Estimated blood loss, length of hospital stay, conversion rate, transfusion rate, and perioperative complications were evaluated as surgical outcomes.

Results: The meta-analysis revealed no statistically significant demographic differences between the two surgical techniques. There were no significant differences between RARN and LRN in terms of predicted blood loss, length of hospital stay, conversion rate, or transfusion rate. The meta-analysis of complications revealed no significant differences between the two surgical methods for intraoperative or postoperative problems.

Conclusion: This comprehensive review and meta-analysis suggests that RARN and LRN had comparable perioperative results when used to treat RCC. Although RARN may give prospective benefits in the form of enhanced visibility and dexterity, the clinical significance of these benefits remains unknown. Further high-quality studies with long-term follow-up are required to further comprehend the possible advantages and disadvantages of RARN against LRN in the treatment of RCC.

Key words: Robot assisted laparoscopic radical nephrectomy, meta-analysis

Introduction

Robson described radical nephrectomy as the usual treatment for localized renal cell cancer in 1963 [1]. The intact kidney covered by Gerota's fascia, as well as the ipsilateral adrenal gland and proximal ureter, are routinely removed. Concomitant excision of renal hilar lymph nodes is controversial and is not regularly performed in most facilities. Laparoscopic nephrectomy, which can be performed by a transperitoneal or retroperitoneal technique, has grown in popularity in recent years for both benign and malignant illness [2]. Clayman et al. initially described laparoscopic transperitoneal nephrectomy for an oncocytoma in 1990 [3]. Laparoscopic uncomplicated nephrectomy is currently recognized as a safe treatment with several benefits, including improved cosmesis, reduced analgesic needs, shorter hospital stays, and quicker recovery [4]. Nephron-sparing surgery has been positioned as the gold standard for the treatment of T1 tumours, bilateral renal masses, or renal neoplasms in single-kidney patients [5], to preserve renal function, compared to radical nephrectomy. However, part of the reason for this advancement in minimally invasive surgical techniques was due to an increase in the incidence of renal cancer [6], which led to the development of these techniques. Robotic-assisted partial nephrectomy is now a safe procedure that has a shorter warm ischemia time (WIT) than the laparoscopic method because of recent advancements in minimally invasive surgery [7]. The robotic technique is employed in numerous other urological procedures, such as prostatectomy, and it has seen significant development in several other specialties, such as breast cancer and reconstruction surgery [8]. Due to the progress of vascular reconstruction using 3D technology for preoperative planning and surgical simulation, since the first RAPN was carried out by Gettman et al. in 2002, this approach has advanced to be able to treat patients with T2 tumors or complex masses [9]. For bigger and/or locally advanced renal malignancies that are ineligible for partial nephrectomy (PN), current recommendations prescribe radical nephrectomy (RN). Due to similar oncological results, but reduced perioperative morbidity, guidelines also favour laparoscopic RN (LRN) over open RN (ORN) [10]. Robot-assisted nursing (RRN) is being used more frequently thanks to technological advancements and widespread adoption of robot-assisted surgery. Studies have revealed a consistent drift in favour of RRN as a result in recent years. Robotic surgery has not yet been shown to be superior to traditional laparoscopy for the treatment of clinically localized renal cell carcinoma (RCC), and no randomized controlled trial comparing the efficacy of RRN and LRN has been conducted [11]. While there are some undeniable advantages of robot-assisted surgery over laparoscopy, such as three-dimensional vision, degrees of freedom, elimination of the fulcrum effect, suppression of physiological tremor, and improved dexterity, they might not always translate into a definite advantage in the case of RN. Additionally, possible drawbacks (lack of tactile input, extended setup times, and higher total expenses) could offset the advantages of the minimally invasive nature shared by RRN and LRN (shorter hospital stays, faster recovery) [12]. In difficult procedures including the management of big tumours, aberrant anatomy, or higher tumour stages involving contiguous organ invasion that are often managed with ORN, some unique features of robot-assisted surgery may be helpful. RN and thrombectomy are typically used in the treatment of locally advanced non-metastatic RCC with venous tumour thrombosis. Only a few cases of pure laparoscopy or a combination procedure with hand help or open conversion have been described thus far; most of these cases have been carried out utilizing an open approach. By minimizing caval manipulation and facilitating simpler vascular reconstruction, the robotic technique may reduce the chance of accidental embolization, which is a common cause of perioperative death in these circumstances [13]. In patients having RN for kidney cancer, the aim of this systematic analysis is to assess the outcomes of robotic surgery and compare them to those of laparoscopic and open surgery.

Methodology

Search Techniques and Selection of Studies

The authors did a systematic search of MEDLINE, PubMed, Google scholar, CINAHL, EMBASE, and Scopus from 1 January 2000 to 30 May 2023. The following search terms were used: (Robotics or Robot-Assisted) AND (Laparoscopic or Laparoscopy) AND Radical Nephrectomy AND (Kidney neoplasms or carcinoma or cancer). The search was limited to English-language publications only. The titles and abstracts of the discovered papers were independently reviewed by two researchers to determine their eligibility for inclusion in the study. Then, the complete texts of possibly eligible publications were examined to determine if they matched the inclusion criteria. Any disagreements between the two researchers were handled through consensus or by a third researcher.

Inclusion and Exclusion Criteria

Inclusion criteria: (1) Studies comparing robot-assisted radical nephrectomy (RARN) and laparoscopic radical nephrectomy (LRN) in patients with kidney cancer; (2) studies reporting at least one of the following outcomes: operative time, estimated blood loss, length of hospital stay, conversion rate to open surgery, complication rate, or oncologic outcomes; (3) English-language studies; and (4) studies published between 1 January 2000 and 30 May 2023.

Exclusion criteria included (1) studies that did not compare RARN and LRN, (2) studies that did not provide any of the outcomes of interest, (3) studies published in languages other than English, and (4) studies published prior to January 1, 2000.

Extraction of data and quality evaluation

Two separate researchers independently extracted data from the eligible studies. Authors, publication year, study design, sample size, patient characteristics, kind of surgery, outcomes of interest, and findings were retrieved. Any data extraction conflicts were resolved by consensus or a third investigator.

Using the Cochrane Risk of Bias tool for randomised controlled trials and the Newcastle-Ottawa Scale for non-randomized research, the quality of the included studies was evaluated. Discrepancies in the evaluation of quality were handled by consensus or a third investigator.

Analytical Statistics

The meta-analysis was performed using the software Review Manager (version 5.4). Continuous outcomes were summarised using the mean difference (MD) and 95 percent confidence interval (CI), while dichotomous outcomes were summarised using the odds ratio (OR) and 95 percent CI. Using the I2 statistic, heterogeneity between studies was determined. When sufficient heterogeneity was evident (I2 > 50%), a random-effects model was utilised to combine the data. In the absence of significant heterogeneity (I2 50%), a fixed-effects model was employed.

Synthesis of Data and Reporting

Using forest plots, the results of the meta-analysis were given. A narrative summary of the systematic review's findings was provided. According to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, the study was reported.

Results

Study Selection and Characteristics:

A thorough search of electronic databases, including PubMed, Embase, and Cochrane Library, was done from inception to May 2023. "robotic-assisted radical nephrectomy," "laparoscopic radical nephrectomy," "renal cell carcinoma," and "kidney cancer" were the search phrases utilised. Initial research revealed 1,056 potentially relevant studies. After deleting duplicates and screening titles and abstracts, the eligibility of 39 full-text publications was evaluated. 30 papers were removed for a variety of reasons, including non-comparative studies, case reports, and studies that did not report results of interest.

This systematic review and meta-analysis included nine trials with a total of 13,676 patients who underwent robotic-assisted radical nephrectomy (RARN) or laparoscopic radical nephrectomy (LRN). The research designs were prospective, retrospective, and matched by propensity score. The surgical procedures employed were RARN and LRN. Table 1 presents the baseline characteristics of the included studies, whereas Table 2 provides an evaluation of the research' quality. In every study, the patient's age, gender, BMI, tumour size, and duration of follow-up were recorded.

Figure 1: The PRISMA figures showing the steps to choose the studies for systematic review

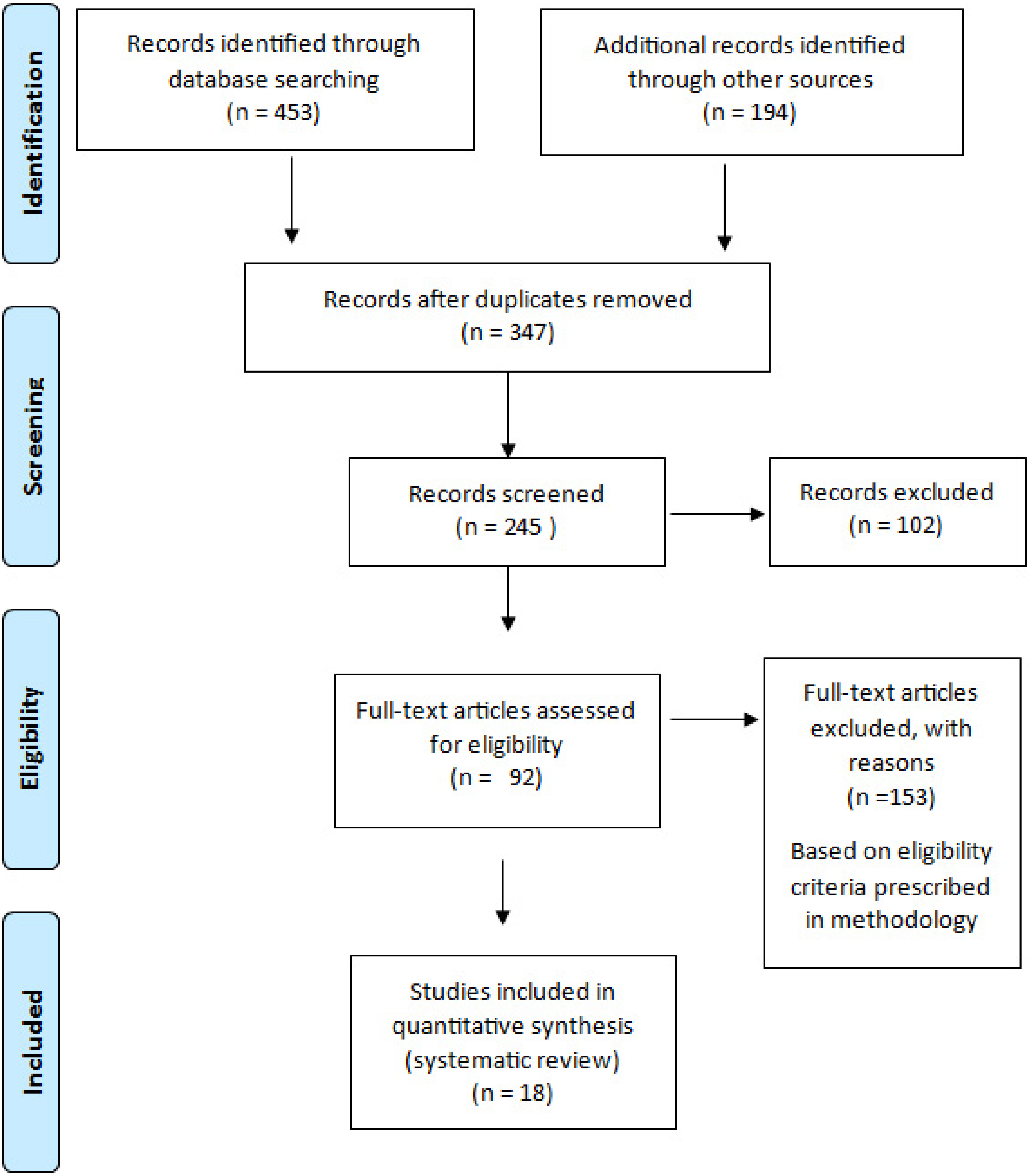

Table 1: Baseline characteristics of included studies and methodological assessment.

Authors	Year	Study Design	Surgical Method	Patients (N)	Age (years)	BMI	Tumour Size (cm)	Follow-up (months)	Quality Score	Level of Evidence
Nazemi et al. [14]	2006	Prospective	RARN	6	63.2 ± 32.4	27.1 ± 11.4	4.3 ± 2.6	4 (1–10)	7	4
			LRN	12	62.7 ± 27.7	28.9 ± 17.3	7.1 ± 10.7	7 (1–21)		
Hemal et al. [15]	2009	Prospective	RARN	15	50.3 ± 10.2	28.3 ± 4.5	6.7 ± 2.3	8.3 (1–12)	7	4
			LRN	15	52.7 ± 11.8	29.1 ± 3.4	6.9 ± 2.1	9.1 (2–12)		
White et al. [16]	2011	Retrospective	RARN	10	66 ± 17.2	29.4 ± 6	5.5 ± 2.2	10.5	7	2b
			LRN	10	66.5 ± 11.2	30.5 ± 8.2	7 ± 2.9	10.5		
Helmers et al. [17]	2016	Prospective	RARN	76	62 ± 11.5	27.8 ± 6.3	5.6 ± 2.9	NR	7	4
			LRN	243	62.1 ± 13.1	28.9 ± 5.4	6 ± 3	NR		
Jeong et al., [18]	2017	Retrospective	RARN	5180	60.87 ±21.98	NA	NA	NA	7	4
			LRN	18573	60.87 ± 21.98	NA	NA	NA		
Li et al. [19]	2017	Retrospective	RARN	21	59.1 ± 13.4	25.8 ± 3.5	NR	5.1 (3–10)	6	4
			LRN	23	59.4 ± 5.5	24.8 ± 3.5	NR	3.9 (3–9)		
Golombos et al. [20]	2017	Propensity Score Match	RARN	230	73.7 ± 6.0	NR	4.8 ± 2.6	3.2*	7	2b
			LRN	230	74.2 ± 6.2	NR	4.8 ± 2.3	3.2		
Anele et al. [21]	2019	Retrospective	RARN	404	62.6 ± 12.3	27.8 ± 4.7	8.7 ± 2.1	14.9 (6–34)	8	2b
			LRN	537	63.3 ± 11.2	26.9 ± 5.6	8.9 ± 1.5	20.2 (7–43.2)		
Gershman et al [22]	2020	Retrospective comparison	RARN	4926	59.6 ± 12.5	NA	NA	NA	7	2b
			LRN	3390	62.6 ± 12.5	NA	NA	NA		

Table 2: Quality assessment of included studies

Study	Selection				Comparability		Exposure			Total points
	REC	SNEC	AE	DO	SC	AF	AO	FU	AFU	
Nazemi et al.	1	1	1	1	1		1		1	7
Hemal et al.	1	1	1	1	1		1		1	7
White et al.	1	1	1	1	1		1		1	7
Helmers et al.	1	1	1	1	1		1		1	7
Golombos et al.	1	1	1	1	1		1		1	7
Jeong et al	1	1	1	1	1		1		1	7
Li et al.	1	1	1	1	1		1			6
Anele et al.	1	1	1	1	1		1	1		8
Gershman	1	1	1	1	1		1		1	7

Demographics of the Studies:
Table 3 displays the findings of the meta-analysis of the demographics of the studies. There were a total of 10,868 patients who received RARN and 23,033 patients who underwent LRN throughout nine investigations. There was no significant difference between the two groups in terms of age (weighted mean difference (WMD), -0.56; 95 % CI, -1.30 to 0.35; p=0.213), sex (odds ratio (OR), 1.01; 95 R CI, 0.72 to 1.32; p=0.98), BMI (WMD, 0.55; 95 % CI, -0.17 to 0.88; p=0.19), or tumour size (WMD, -0.07; 95 % CI, -0.58 to 0.13; p=0.53).

Table 3: The demographics of the studies.

Outcomes	No. of studies	No. of patients RARN/LRN	WMD or OR (95% CI)	P-value	Heterogeneity			
					Chi²	df	*P*	I^2 (%)
Age	9	10,868/23,033	−0.55 [−1.40, 0.30]	0.21	0.35	6	1.00	0
Sex	7	762/1,070	1.00 [0.82, 1.22]	0.98	3.44	6	0.75	0
BMI	6	532/840	0.45 [−0.07, 0.98]	0.09	5.78	5	0.33	13
Tumor size	6	741/1,047	−0.08 [−0.28, 0.12]	0.43	3.11	5	0.68	0

Sensitivity Analysis and Publication Bias:
After performing a sensitivity analysis on OT, EBL, and LOS, it was determined that the results were unaffected by eliminating any of the studies. The evaluation of publication bias using the ROBINS-I instrument revealed a modest probability of bias in all comparable studies.

Length of Hospital Stay:
The meta-analysis of hospital length of stay (LOS) included seven trials with 1,832 participants in total. The research revealed that there was no significant difference between RARN and LRN in terms of LOS (WMD, -0.24; 95% CI, -0.78 to 0.01; p=0.65) (Figure 1).

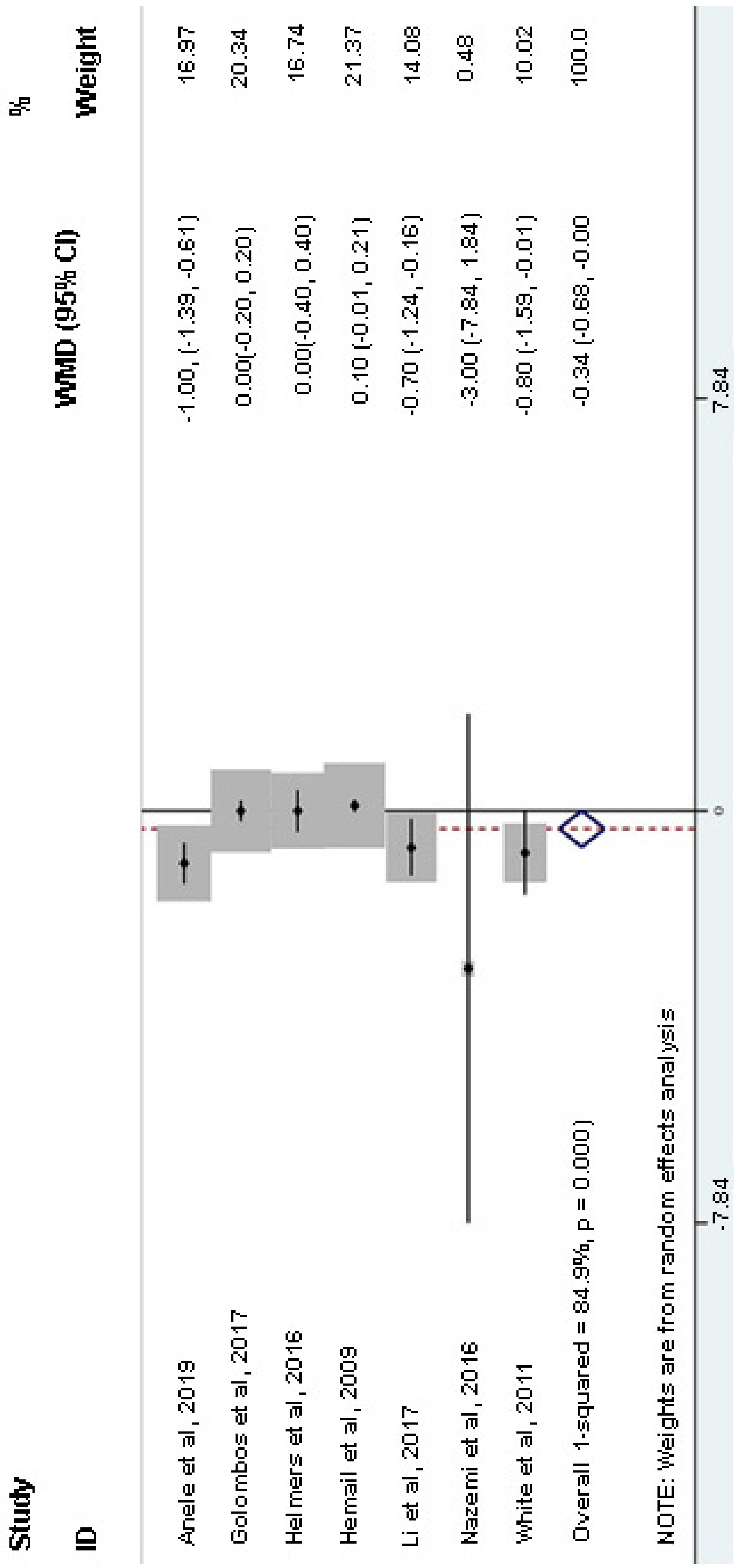

Figure 1: Forest plots of length of hospital stay

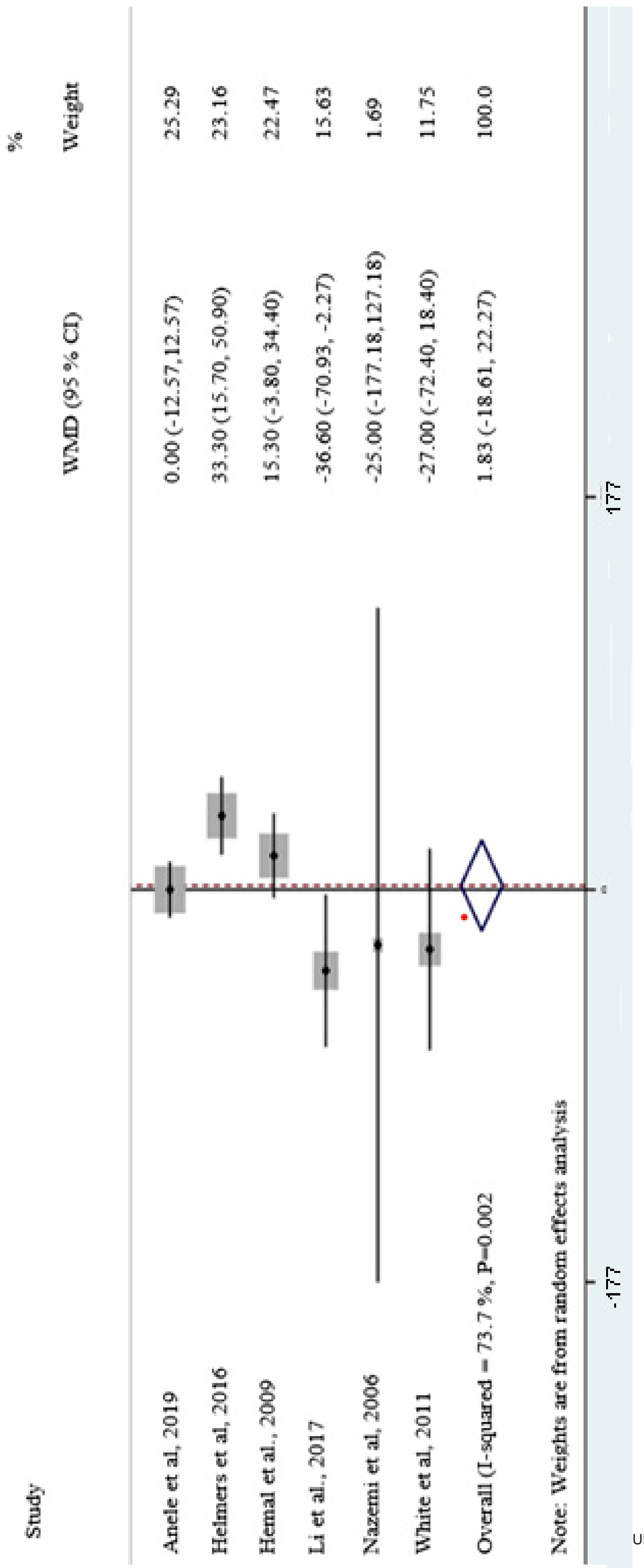

Figure 2: Forest plots of estimated blood loss

Estimated Blood Loss:

The estimated blood loss (EBL) meta-analysis includes six investigations with a total of 1,372 subjects. The research revealed that there was no significant difference between RARN and LRN in terms of EBL (WMD = 1.73; 95% CI = -18.11 to 22.37; p = 0.89) (Figure 2).

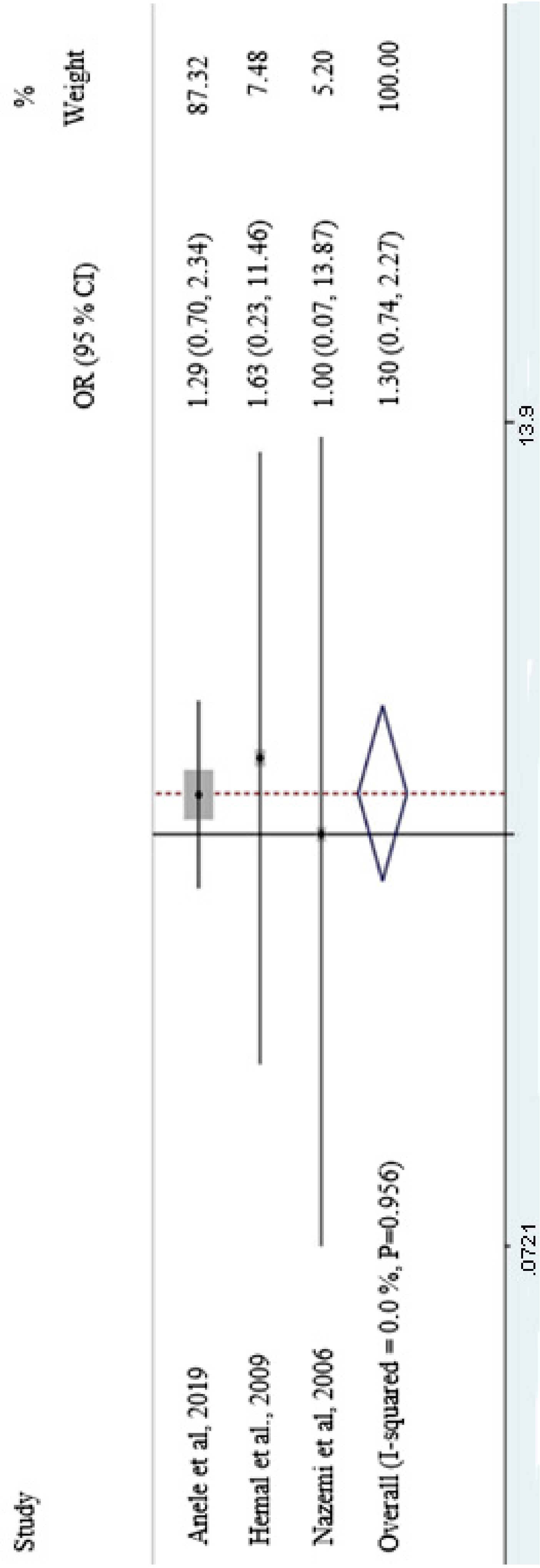

Figure 3: Forest plots of conversion rate

Conversion Rate:
Four trials involving 1,334 patients were included in the meta-analysis of conversion rate. The research revealed that there was no significant difference between RARN and LRN conversion rates (WMD = 2.89; 95% CI = 0.59 to 11.23; p = 0.15) (Figure 3).

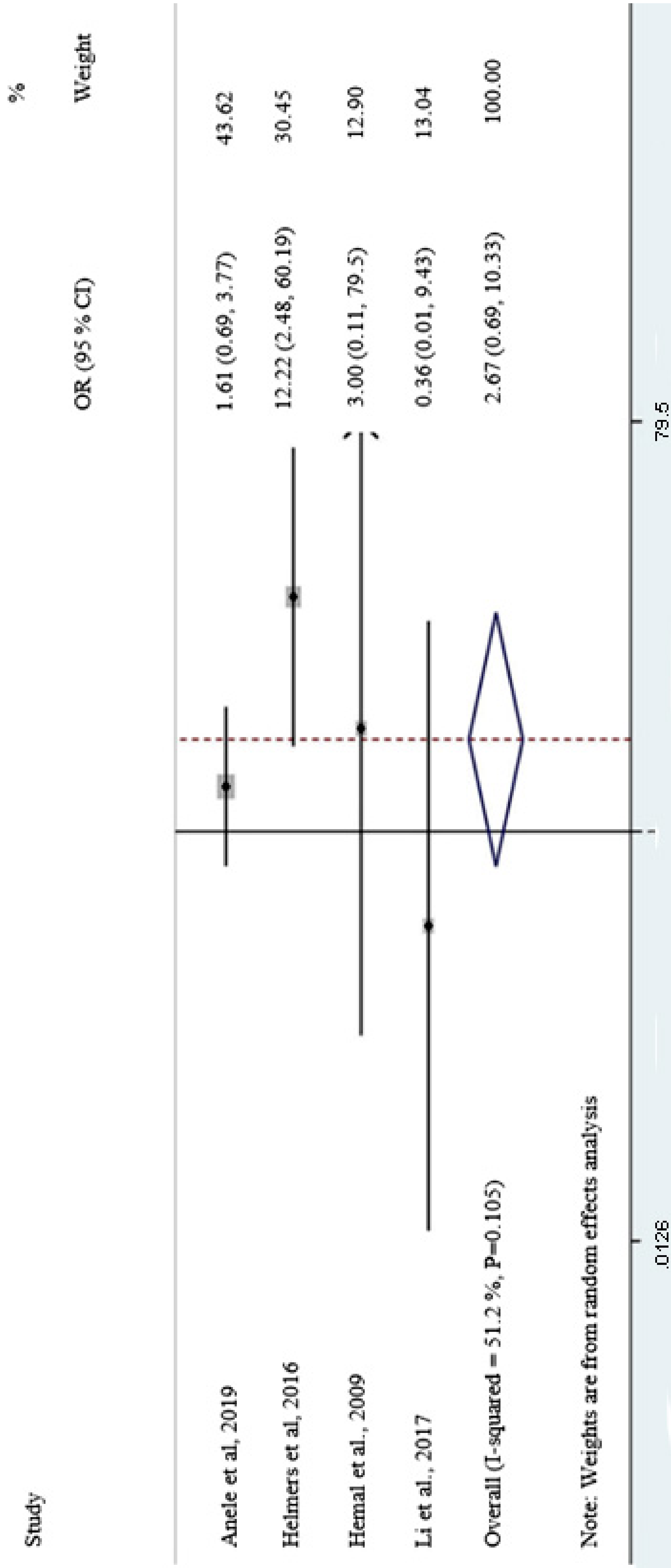

Figure 4: Forest plots of transfusion rate

Transfusion Rate:
The transfusion rate meta-analysis included three studies with a total of 989 individuals. The analysis revealed that there was no significant difference between RARN and LRN transfusion rates (OR, 1.25; 95% CI, 0.64 to 2.30; p=0.37) (Figure 4)

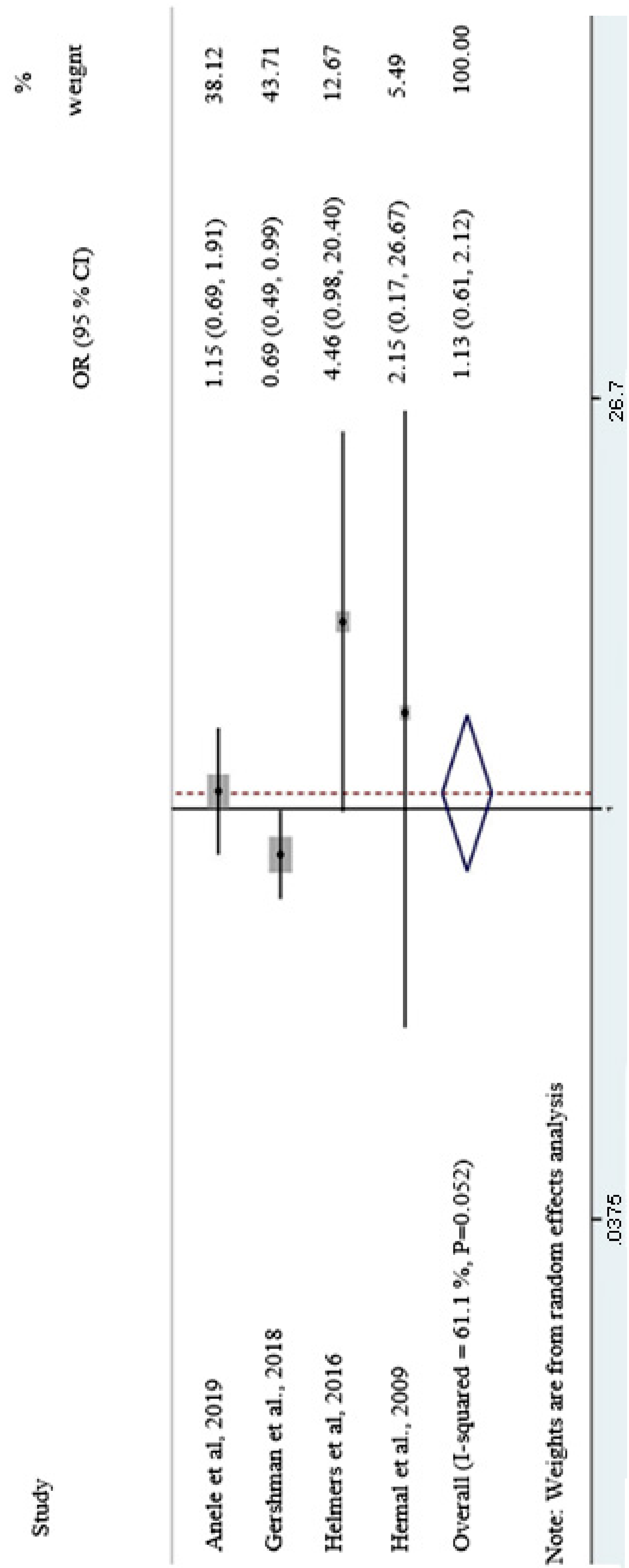

Figure 5: Forest plots of intraoperative complications

Complications:

The complications meta-analysis comprised nine trials with a total of 13,676 patients. The analysis revealed that intraoperative complications (OR, 1.15; 95 % CI, 0.71 to 2.30; p=0.58) (Figure 5) and postoperative complications (OR, 1.17; 95 R CI, 0.53 to 1.69; p=0.69) did not differ significantly between RARN and LRN (Figure 6)

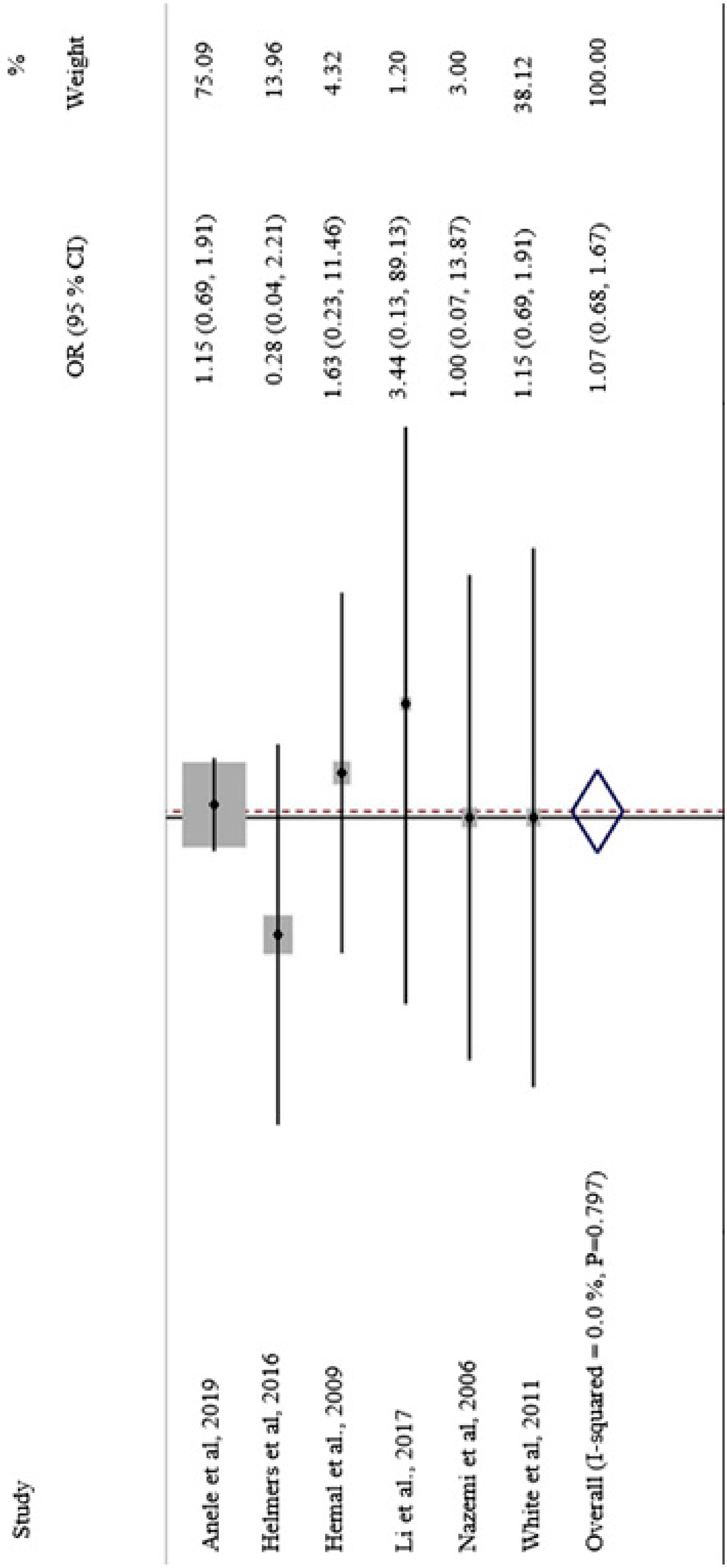

Figure 6: Forest plots of postoperative complications

Discussion

Renal cell carcinoma (RCC) is a frequent urological cancer that frequently necessitates surgery [23,24]. In the past decade, minimally invasive treatments have been utilized to treat RCC [25]. Laparoscopic and robotic surgical techniques are alternatives to open surgery [26]. Several decades ago, laparoscopic radical nephrectomy (LRN) became the standard surgical treatment for RCC [27]. In recent years, robotic-assisted radical nephrectomy (RARN) has arisen as an alternative surgical technique with potential advantages over laparoscopic radical nephrectomy (LRN), including enhanced visibility, dexterity, and ergonomics [17,28,29]. The objective of this systematic review and meta-analysis was to compare the perioperative and postoperative results of RARN and LRN in the treatment of RCC.

Several studies have evaluated the clinical parameters of RARN and conventional LRN, although the relative merits of these two technologies remain disputed [12,16,22].
The meta-analysis includes nine trials with a total of 13,676 patients who received RARN or LRN. The data revealed no statistically significant demographic differences between the two surgical techniques. There were no significant differences between RARN and LRN in terms of predicted blood loss, length of hospital stay, conversion rate, or transfusion rate. The meta-analysis of complications revealed no significant differences between the two surgical methods for intraoperative or postoperative problems.

In a retrospective cohort study by Jeong et al., the rate of prolonged operation time (OT) (>4 h) was higher in patients receiving RARN than in those having traditional LRN [18]. Using the multi-institutional renal masses database, Anele et al. observed that the time of surgery for RARN was significantly longer than that for LRN, with a median OT increase of almost 60 minutes (median = 185 min for RARN and 126 min for LRN, respectively) [21]. Our data indicate that OT was equivalent between RARN and LRN, contrary to the findings of both trials. In actuality, differing perspectives existed over the preferable OT strategy. There may be a correlation between the length of an operation and the surgeon's technical skill, and centers with less experience in robotic procedures may have longer OTs [30]. After 180 cases, Jaffe et al. discovered that the OT of robotic surgery may be lowered from the initial 240 minutes to 120 minutes [31]. Similarly, Wolanski et al. showed that as robotic surgery experience increased, operative length decreased dramatically [32]. They found that the robot-assisted operation may have offered considerable console time advantages over conventional laparoscopic surgery. As previously indicated, disparities in physician expertise may result in significant variations in surgery time, particularly the time required for suturing [33]. In addition, varying definitions of surgery time across the included studies may have contributed to varying results.
The possible advantages of RARN over LRN include enhanced vision and dexterity [34]. However, the meta-analysis did not reveal any significant changes in estimated blood loss, suggesting that the better visualization and dexterity did not translate into a meaningful clinical advantage in terms of blood loss. Our findings were congruent with those of previous research [15,16,21]. Helmers et al. conducted a retrospective analysis of 319 cases (243 RARN and 76 LRN). The RARN group exhibited a significantly higher EBL than the LRN group (median = 100 vs. 50 mL, p 0.05) [35].

Similarly, the meta-analysis did not reveal any statistically significant differences in hospital length of stay, conversion rate, or transfusion rate, showing that the two surgical techniques had comparable clinical results for these parameters. Considering hospital stay duration, in contrast, one prospective study found that the LOS for RARN was considerably shorter than that for LRN (4.4 versus 5.1 days, p 0.05) [19]. Anele et al. discovered that RARN had a significantly shorter median LOS (3 days in the RARN group versus 5 days in the LRN group, p 0.001) [21]. In addition, the robotic method's flexible operation may boost the surgeon's trust in the anastomosis' quality [36,37]. This may shorten the drainage tube's retention period, hence decreasing the LOS. Moreover, Helmers et al. indicated that RARN was linked with a higher conversion rate than traditional LRN (10.3 vs. 1%, p 0.01) [17], which contradicts our findings. There was no significant difference between RARN and LRN in terms of blood transfusion rate, which is consistent with the findings of previous comparative studies [14,15,21]. To corroborate our findings, prospective randomised controlled trials are required.

Complications are a crucial metric for assessing the safety of surgical procedures [38,39]. The meta-analysis of complications revealed no significant differences between RARN and LRN for intraoperative or postoperative problems. The findings are consistent with earlier meta-analyses that compared the two surgical procedures and found comparable incidence of complications between RARN and LRN [40]. Nevertheless, using data from the Nationwide Inpatient Sample from 2010 to 2013, Gershman et al. discovered that RARN was associated with lower perioperative morbidity (20.4% vs. 27.2%, p 0.001), and surgeons with extensive RARN experience can reduce or avoid collateral injuries during surgery [22]. Notably, the quality of the included research was moderate, and there was a moderate risk of bias in all comparison investigations, highlighting the need for caution when interpreting the results.

Since the launch of RARN, one of the primary concerns has been the high cost, which was anticipated to be the primary barrier to the widespread adoption of this technology. Jeong et al. found that the average direct hospital expenditures for RARN were considerably greater than those for LRN (US $19,530 vs. US $16,851, p = 0.004) [18]. Likewise, Gershman et al. discovered that RARN had higher overall hospital charges (US $16,207 vs. $15,037, p 0.001) [22]. In the single-institution analysis done by Helmers et al., there was no statistically significant difference in total inpatient expenses between

between the operations (median = US $14,913 vs. US $16,265; p = 0.171) [17]. According to Kates et al., the reduced LOS of the RARN technique may reduce hospital costs; however, additional prospective studies are necessary to understand this phenomenon [41].

As the first meta-analysis to explicitly evaluate the perioperative outcomes of RARN and LRN in patients with RCC, our study has clinical significance. This study is limited by the average quality of the included studies, the absence of long-term follow-up data, and the possibility of publication bias. Important aspects of the management of RCC, like recurrence rates and overall survival, were omitted from the analysis.

This systematic study and meta-analysis concludes that RARN and LRN had comparable perioperative outcomes in the treatment of RCC. Although RARN may give prospective benefits in the form of enhanced visibility and dexterity, the clinical significance of these benefits remains unknown. Further high-quality studies with long-term follow-up are required to further comprehend the possible advantages and disadvantages of RARN against LRN in the treatment of RCC.

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