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META-ANALYSIS

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Robot-Assisted Radical Prostatectomy Is More Beneficial for Prostate Cancer Patients: A System Review and Meta-Analysis

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Data Interpretation D
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Background: Robot-assisted radical prostatectomy (RARP) is increasingly used worldwide, but comparisons of perioperative, functional, and oncologic outcomes among RARP, laparoscopic radical prostatectomy (LRP), and open radical prostatectomy (ORP) remain inconsistent.

Material/Methods: Systematic literature searches were conducted using EMBASE, PubMed, the Cochrane Library, CNKI, and Science Direct/Elsevier up to April 2017. A meta-analysis was conducted using Review Manager and Stata software.

Results: We included 33 studies. Meta-analysis revealed that blood loss, transfusion rate, and positive surgical margin (PSM) rate were significantly lower following RARP compared with LRP (SMD (95% confidence interval [CI]) 0.31 [0.01, 0.61]; combined ORs (95% CI) 5.32 [1.29, 21.98]; 1.27 [1.10, 1.46]) and ORP (SMD (95% CI) 0.75 [0.30, 1.21]; and combined ORs (95% CI) 3.44 [1.21, 9.79]); positive surgical margin (PSM) rates were significantly lower following RARP compared with LRP (combined ORs (95% CI) 1.27 [1.10, 1.46]), but not ORP. Operation time was also shorter for RARP than for LRP. The rates of nerve-sparing, recovery of complete urinary continence, and recovery of erectile function were significantly higher following RARP compared with LRP (combined ORs (95% CI) 0.55 [0.31, 0.95]; 0.66 [0.55, 0.78]; 0.46 [0.30, 0.71]) and ORP (combined ORs (95% CI) 0.36 [0.21, 0.63]; 0.33 [0.15, 0.74]; 0.65 [0.37, 1.14]).

Conclusions: This meta-analysis demonstrates that RARP results in better overall outcomes than LRP and ORP in terms of blood loss, transfusion rate, nerve sparing, urinary continence and erectile dysfunction recovery, and suggests that RARP offers better results than LRP and ORP in treatment of prostate cancer. However, studies with larger sample sizes and long-term results are needed.

MeSH Keywords: Erectile Dysfunction • Hand-Assisted Laparoscopy • Prostatic Neoplasms

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Background

The incidence rates of prostate cancer are currently increasing in most countries, especially in some developed countries [1,2]. Open radical prostatectomy (ORP) has been the criterion standard for the treatment of prostate cancer for some time; however, this procedure is associated with considerable blood loss and postoperative pain, and a prolonged hospital stay. Laparoscopic radical prostatectomy (LRP) was first reported in the early 1990s [3], and demonstrated advantages in terms of reduced blood loss and postoperative pain, and shorter hospital stay, as well as lower rates of urinary incontinence and erectile dysfunction, compared with open procedures [4–6]. LRP has thus since become the standard procedure in many institutions. However, there have been numerous refinements in terms of both prostatectomy techniques and equipment. Although ORP and LRP have thus formed the mainstay of treatment for prostate cancer, technical procedures for radical prostatectomy have recently been improved and updated to ensure oncological control and satisfactory postoperative functional outcomes, and the use of Robotic-assisted radical prostatectomy (RARP) has subsequently increased dramatically. Robot-assisted surgery offers several advantages compared with standard laparoscopy, including the use of a high-resolution camera with three-dimensional visualization, while the robotic arms allow surgeons to perform more precise dissection of the anatomic structures, potentially leading to better preservation of functional structures, reduced PSM, and better perioperative outcomes [7–9].

Although several studies have compared the perioperative, functional, and oncologic outcomes among RARP, LRP, and ORP, the results have been inconsistent. Some studies reported significantly lower blood loss, transfusion rate, and positive surgical margin (PSM) rate with RARP compared with LRP and ORP, and higher nerve-sparing, recovery of complete urinary continence, and recovery of erectile function rates, while others have failed to find these relationships [7–39]. We therefore conducted a systematic review of the existing literature and conducted a meta-analysis to assess the perioperative, functional, and oncologic outcomes after RARP, LRP, and ORP, to help provide valuable insights into the appropriate choice of surgical procedures for patients with prostate cancer.

Material and Methods

Literature search

This study was limited to published studies that compared the perioperative, functional, and oncologic outcomes after RARP, LRP, and ORP. The literature was searched in the Cochrane Library, Medline, EMBASE, CNKI, Elsevier, and PubMed by 2 independent reviewers, from their inception to April 2017. The search terms comprised MeSH terms and text words. For example, perioperative, functional, and oncologic outcomes were: 'perioperative outcomes', 'functional outcomes', 'oncologic outcomes', 'operation time', 'blood loss', 'transfusion rate', 'erectile function', 'urinary continence', 'nerve sparing', 'positive surgical margin', and 'PSM', while those for surgical method were: 'open radical prostatectomy', 'laparoscopic radical prostatectomy', 'robot-assisted radical prostatectomy', 'RARP', 'LRP', and 'ORP'. All related articles and abstracts were retrieved.

Eligibility criteria

Studies in which patients were diagnosed with prostate cancer and underwent primary treatment with RARP, LRP, or ORP were included. Included studies also reported on the perioperative, oncological, and functional outcomes after RARP, LRP, and ORP. Perioperative outcomes included operation time, blood loss, and transfusion rate; oncological outcomes included PSM; and functional outcomes included nerve-sparing, urinary continence, and erectile dysfunction. Data on operation time and blood loss are presented as continuous data with means and standard deviations (SDs). Transfusion rate, PSM, nerve-sparing, urinary continence, and erectile dysfunction are presented as dichotomous variables.

We excluded case reports, review articles, meeting reports, and abstracts, as well as studies reporting on duplicate patient populations where some or all of the same patients were included in more than 1 study reporting on the same parameters, as well as studies in which the patients had urinary incontinence or erectile dysfunction before surgery.

Study selection and validity assessment

The titles and abstracts of the relevant literature were screened by 2 independent reviewers, and relevant reports were retrieved. If the title and abstract were ambiguous, the full text was analyzed. The final decision on eligible studies was made after reviewing the selected articles. If 2 independent reviewers disagreed on the same document, then the inclusion of the document required consensus or consultation with a third reviewer.

Data extraction and statistical analysis

Data, including demographic data and outcome data (operation time, blood loss, transfusion rate, PSM, nerve sparing, urinary continence, and erectile dysfunction), were recovered from the selected literature. The differences were settled by consensus. Quantitative meta-analysis was performed using Review Manager (RevMan) software and Stata software by 2 reviewers. Available data, including mean, SD, and available

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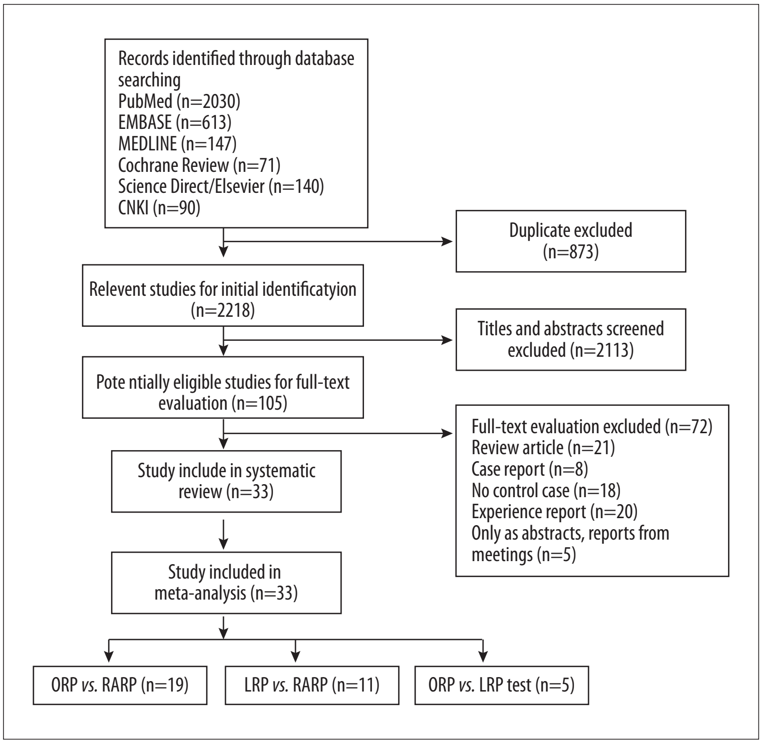

Figure 1. Flow diagram of selection of eligible studies.

number, were analyzed in the meta-analysis to calculate standard mean differences (SMD), combined odds ratios (ORs), and 95% confidence intervals (CIs). Heterogeneity assessment used the *p*-value and the I-squared statistic (I^2) in pooled analyses, representing the percentage of total variation across studies. If $p<0.1$ or $I^2>50\%$, the summary estimate was analyzed in a random-effects model; otherwise, a fixed-effects model was applied. The results are expressed as SMDs for continuous outcomes and as ORs for dichotomous variables. Publication bias was assessed by assessing visual symmetry of funnel plots, in which asymmetry may indicate publication bias, and by Begg's and Egger's tests in the meta-analysis. Publication bias was indicated by $p<0.05$.

Results

Characteristics of included studies

Figure 1 shows the review process in detail. A total of 3091 nonduplicate studies were extracted, 33 of which were ultimately selected according to the eligibility criteria: 19 compared the perioperative, functional, and oncologic outcomes between ORP and RARP; 11 compared the 3 outcomes between LRP and RARP; and 5 compared the 3 outcomes between LRP and ORP. After group discussion, all reviewers agreed to include all 33 papers.

Table 1 summarizes the general data from the 33 studies. The mean age ranges of the patients who underwent ORP, RARP, and LRP were 49.3±2.4–70.03±6.10 years, 32.6±2.9–69.05±4.78 years, and 57.2±7.4–62.5±6.0 years, respectively. All of the included studies reported exclusion/inclusion criteria [7–39]. The 19 studies [8,10,14,16–20,22,23,27,29,30–33,36–38] that compared the outcomes between ORP and RARP groups included 16 830 prostate cancer patients. Eleven of these studies [7,9–13,15,21,34,35] compared the outcomes between LRP and RARP, and 5 studies [10,24–26,39] compared the outcomes between ORP and LRP.

Meta-analysis

This meta-analysis revealed that blood loss, transfusion rate, and positive surgical margin (PSM) rate were significantly lower following RARP compared with LRP (SMD (95% confidence interval [CI]) 0.31 [0.01, 0.61]; combined ORs (95% CI) 5.32 [1.29, 21.98]; 1.27 [1.10, 1.46]) and ORP (SMD (95% CI) 0.75 [0.30, 1.21]; and combined ORs (95% CI) 3.44 [1.21, 9.79]); positive surgical margin (PSM) rate were significantly lower following RARP compared with LRP (combined ORs (95% CI) 1.27 [1.10, 1.46]), but not ORP (combined ORs (95% CI) 1.27[0.93, 1.72]). These results are presented in Figures 2–4. Operation time was also shorter for RARP than for LRP (SMD (95% CI) 0.71 [0.18, 1.25]), but not significantly shorter than in the ORP group (SMD (95% CI) –0.28 [–0.61, 0.06]). These results are presented in Figure 5. The nerve-sparing, recovery of complete urinary continence, and recovery of erectile function

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Table 1. Characteristics of included studies.

Study	Country	Mean age (case/control)	Study design	Case (n)	Outcomes
Papachristos A et al. 2014	Australia	62.5/60.5	LRP *vs.* RARP, retrospective	LRP: 100, RARP: 100	OT, BL, PSM, NS, UC, EF
Koo KC et al. 2014	Korea	65.9/65.6	ORP *vs.* RARP, retrospective	ORP: 580, RARP: 592	PSM
Tozawa K et al. 2014	Japan	67.4/67.0	LRP *vs.* RARP, retrospective	LRP: 551, RARP: 551	PSM
Sugihara T et al. 2014	Japan	68/68/67	ORP, LRP *vs.* RARP, retrospective	ORP: 7202, LRP: 2483, RARP: 2126	OT, TF
Rozet F et al. 2007	France	62.5/62.0	LRP *vs.* RARP, retrospective	LRP: 133, RARP: 133	OT, BL, TR, NS
Hakimi AA et al. 2009	America	59.6/59.8	LRP *vs.* RARP, prospective	LRP: 75, RARP: 75	OT, BL, PSM, NS, UC, EF
Ploussard G et al. 2014	France	62.7/62.7	LRP *vs.* RARP, prospective	LRP: 1377, RARP: 1009	OT, BL, PSM, NS, UC, EF
Froehner M et al. 2012	Germany	65.2/62.8	ORP *vs.* RARP, prospective	LRP: 1925, RARP: 252	TR
Park JW et al. 2011	Korea	65.7/62.7	LRP *vs.* RARP, prospective	LRP: 62, RARP: 44	OT, BL, PSM, NS, UC, EF
Martinschek A et al. 2012	Germany	67.6±5.3/69.1±4.8	ORP *vs.* RALP, prospective	ORP: 19, RARP: 19	PSM
Barry MJ et al. 2012	America	49.3±2.4/32.6±2.9	ORP *vs.* RARP, prospective	ORP: 220, RARP: 406	EF
Choo MS et al. 2013	Korea	67±6.3/66±7.8	ORP *vs.* RARP, prospective	ORP: 176, RARP: 77	BL, PSM, NS, UC, EF
Schroeck FR et al. 2008	America	60.3/59.2	ORP *vs.* RARP, prospective	ORP: 219, RARP: 181	EF
Voss BL et al. 2013	Grenada	61.9±4.1/61.1±5.8	ORP *vs.* RARP, prospective	ORP: 10, RARP: 10	OT, BL
Henry C et al. 2011	America	65.1±5.9/61.9±7.2	LRP *vs.* RARP, prospective	LRP: 97, RARP: 312	OT, PSM, NS
Philippou P et al. 2012	United Kingdom	62.5±6.4/62.4±5.6	ORP *vs.* RARP, prospective	ORP: 50, RARP: 50	OT, BL, TR, PSM, NS
Barocas DA et al. 2010	America	62±7.3/61±7.3	ORP *vs.* RARP, prospective	ORP: 491, RARP: 1413	PSM
Springe C et al. 2013	Germany	56.8±6.7/57.2±7.4	ORP *vs.* LRP, prospective	LRP: 125, RARP: 128	OT, BL, TR, PSM, UC, EF
Rassweiler J et al. 2003	Germany	65/64	ORP *vs.* LRP, prospective	ORP: 219, LRP: 219	OT, BL, TR, NS, UC, EF
Roumeguere T et al. 2003	Belgium	63.9±5.5/62.5±6.0	ORP *vs.* LRP, prospective	ORP: 77, LRP: 85	OT, BL, PSM, NS, UC, EF
Wallerstedt A 2015	Sweden	63/63	ORP *vs.* RARP, prospective	ORP: 778, RARP: 1847	OT, BL
Akand M et al. 2015	Turkey	62.7/60.3	LRP *vs.* RARP, retrospective	LRP: 308, RARP: 79	TR, PSM

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Table 1 continued. Characteristics of included studies.

Study	Country	Mean age (case/control)	Study design	Case (n)	Outcomes
Lee D et al. 2015	Korea	66.0/66.5	ORP *vs.* RARP, retrospective	ORP: 106, RARP: 250	PSM
Di Pierro GB et al. 2011	Switzerland	64.3/62.8	ORP *vs.* RARP, prospective	ORP: 75, RARP: 75	OT, PSM, UC
Ou YC et al. 2009	America	70.0±6.1/67.3±6.2	ORP *vs.* RARP, prospective	ORP: 30, RARP: 30	OT, BL, PSM, NS, UC
Rocco B et al. 2007	Italy	63/63	ORP *vs.* RARP, prospective	ORP: 240, RARP: 120	OT, BL, EF
Krambeck AE et al. 2002	America	61.0/61.0	ORP *vs.* RARP, prospective	ORP: 588, RARP: 294	NS, EF
Trabulsi EJ et al. 2010	America	58.1/59.9	LRP *vs.* RARP, prospective	LRP: 45, RARP: 205	OT, TR, BL, PSM, NS, UC
Kwon EO et al. 2010	America	59.4±67.4/58.8± 6.6	LRP *vs.* RARP, prospective	LRP: 165, RARP: 121	PSM
Chung JS et al. 2011	Korea	65.8±6.6/66.3±7.6	ORP *vs.* RARP, retrospective	LRP: 155, RARP: 105	OT, BL, EF
Ficarra V et al. 2009	Italy	65/61	ORP *vs.* RARP, prospective	ORP: 105, RARP: 103	
Yaxley JW et al. 2016	Australia	59.64/60.38	ORP *vs.* RARP prospective	RARP: 157 ORP: 151	OT, TR, BL, PSM, NS, UC

OT – operate time; BL – blood loss; TR – transfusion; NS – nerve sparing; PSM – positive surgical margin; UC – urinary continence; EF – erectile function.

rates were also significantly higher in the RARP compared with the LRP (combined ORs (95% CI) 0.55 [0.31, 0.95]; 0.66 [0.55, 0.78]; 0.46 [0.30, 0.71]) and ORP groups (combined ORs (95% CI) 0.36 [0.21, 0.63]; 0.33 [0.15, 0.74]; 0.65 [0.37, 1.14]). These results are presented in Figures 6–8.

Operation time was lower in the ORP group compared with the LRP group (SMD (95% CI) –1.18 [–1.68, –0.69] (Figure 5), while blood loss and transfusion rate were significantly higher (SMD (95% CI) 1.65 [0.56, 2.74] combined ORs (95% CI) 9.06 [6.35, 12.94]) (Figures 2, 3). However, there was no significant difference in PSM, nerve-sparing, complete urinary continence rate, or erectile dysfunction between the ORP and LRP groups (Figures 7, 8). Begg's funnel plot showed no substantial asymmetry, except for transfusion rate (Figures 9–15). Begg's and Egger's regression tests indicated no significant publication bias ($p>0.05$) (Tables 2, 3).

Discussion

This meta-analysis reviewed and analyzed 33 published studies to investigate and compare the perioperative, functional, and oncologic outcomes of RARP, LRP, and ORP in patients with prostate cancer. The results revealed that RARP was preferable to the other 2 techniques with regard to blood loss, transfusion, nerve-sparing, recovery of urinary continence, and recovery of erectile function rates.

The outcomes were relatively inconsistent because of differences in surgical experiences, equipment, and patient conditions. Among these, surgical experience has been shown to play an important role in improving perioperative outcomes and complications [40–44]. RARP involves high abdominal pressure during surgery by pneumoperitoneum, which could explain the lower bleeding and transfusion rates in the robot-assisted group. Positioning of the patient in the Trendelenburg position, which reduces venous blood pressure, may also contribute to the positive effect of RARP on perioperative bleeding. The longer operating time compared with the open technique, as reported in this study, may explain the more precise operative procedure in RARP, as confirmed in other reports [45,46].

With regard to oncologic outcomes, some studies found that surgical technique was not an independent predictor of PSM [47,48], while some reported that the risk of PSM was

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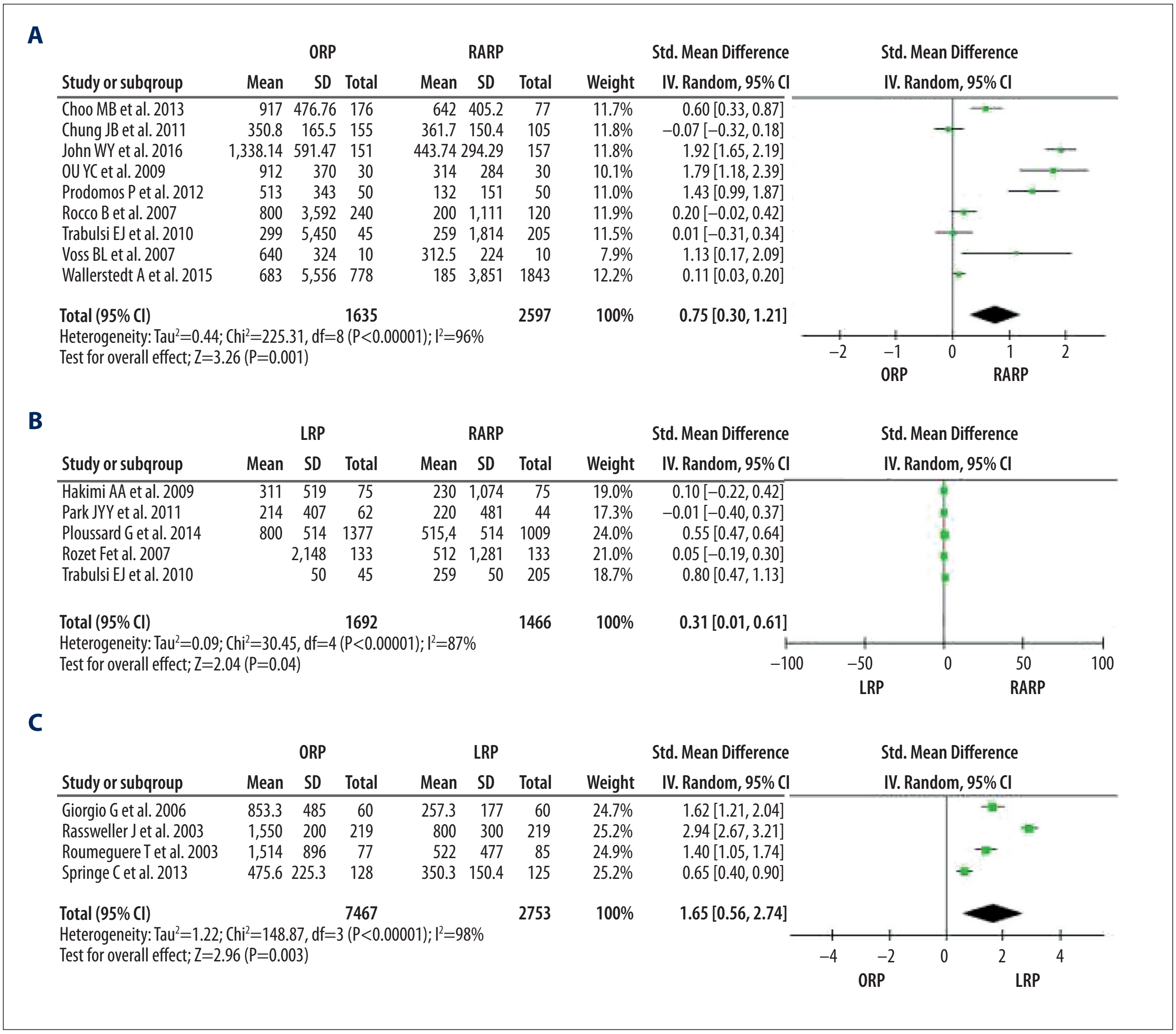

A

Study or subgroup	ORP Mean	ORP SD	ORP Total	RARP Mean	RARP SD	RARP Total	Weight	Std. Mean Difference IV. Random, 95% CI
Choo MB et al. 2013	917	476.76	176	642	405.2	77	11.7%	0.60 [0.33, 0.87]
Chung JB et al. 2011	350.8	165.5	155	361.7	150.4	105	11.8%	−0.07 [−0.32, 0.18]
John WY et al. 2016	1,338.14	591.47	151	443.74	294.29	157	11.8%	1.92 [1.65, 2.19]
OU YC et al. 2009	912	370	30	314	284	30	10.1%	1.79 [1.18, 2.39]
Prodomos P et al. 2012	513	343	50	132	151	50	11.0%	1.43 [0.99, 1.87]
Rocco B et al. 2007	800	3,592	240	200	1,111	120	11.9%	0.20 [−0.02, 0.42]
Trabulsi EJ et al. 2010	299	5,450	45	259	1,814	205	11.5%	0.01 [−0.31, 0.34]
Voss BL et al. 2007	640	324	10	312.5	224	10	7.9%	1.13 [0.17, 2.09]
Wallerstedt A et al. 2015	683	5,556	778	185	3,851	1843	12.2%	0.11 [0.03, 0.20]
Total (95% CI)			**1635**			**2597**	**100%**	**0.75 [0.30, 1.21]**

Heterogeneity: $Tau^2=0.44$; $Chi^2=225.31$, df=8 (P<0.00001); $I^2=96\%$
Test for overall effect: Z=3.26 (P=0.001)

B

Study or subgroup	LRP Mean	LRP SD	LRP Total	RARP Mean	RARP SD	RARP Total	Weight	Std. Mean Difference IV. Random, 95% CI
Hakimi AA et al. 2009	311	519	75	230	1,074	75	19.0%	0.10 [−0.22, 0.42]
Park JYY et al. 2011	214	407	62	220	481	44	17.3%	−0.01 [−0.40, 0.37]
Ploussard G et al. 2014	800	514	1377	515,4	514	1009	24.0%	0.55 [0.47, 0.64]
Rozet Fet al. 2007		2,148	133	512	1,281	133	21.0%	0.05 [−0.19, 0.30]
Trabulsi EJ et al. 2010		50	45	259	50	205	18.7%	0.80 [0.47, 1.13]
Total (95% CI)			**1692**			**1466**	**100%**	**0.31 [0.01, 0.61]**

Heterogeneity: $Tau^2=0.09$; $Chi^2=30.45$, df=4 (P<0.00001); $I^2=87\%$
Test for overall effect: Z=2.04 (P=0.04)

C

Study or subgroup	ORP Mean	ORP SD	ORP Total	LRP Mean	LRP SD	LRP Total	Weight	Std. Mean Difference IV. Random, 95% CI
Giorgio G et al. 2006	853.3	485	60	257.3	177	60	24.7%	1.62 [1.21, 2.04]
Rassweller J et al. 2003	1,550	200	219	800	300	219	25.2%	2.94 [2.67, 3.21]
Roumeguere T et al. 2003	1,514	896	77	522	477	85	24.9%	1.40 [1.05, 1.74]
Springe C et al. 2013	475.6	225.3	128	350.3	150.4	125	25.2%	0.65 [0.40, 0.90]
Total (95% CI)			**7467**			**2753**	**100%**	**1.65 [0.56, 2.74]**

Heterogeneity: $Tau^2=1.22$; $Chi^2=148.87$, df=3 (P<0.00001); $I^2=98\%$
Test for overall effect: Z=2.96 (P=0.003)

Figure 2. Forest plot showing the meta-analysis outcomes of the comparisons of blood loss after ORP, LRP and RARP, (**A**) ORP *vs.* RARP; (**B**) LRP *vs.* RARP; (**C**) ORP *vs.* LRP.

dependent on TNM stage and the patient's preoperative prostate-specific antigen level. Coelho et al. reported that clinical stage was the only preoperative variable independently associated with PSM after RARP [49]. However, the present meta-analysis showed that the PSM rate of RARP was significantly lower than those of LRP. Our results thus differed from the previous studies. The prostatic apex was reported to be the most common location of PSM, and improved visualization of the prostatic apex during RARP may reduce the risk of PSM [8,50–53].

The main objective of radical prostatectomy is cancer control, but maintaining quality of life is an important secondary goal [54]. Many studies have shown that the most common factors influencing quality of life following radical prostatectomy are decreased erectile ability and urinary incontinence [55,56]. Although conventional nerve-sparing radical prostatectomy generally preserves some erectile function, most patients suffer some loss of erectile ability. Some researchers have suggested that bilateral nerve-sparing may aid the recovery of urinary continence and erectile function, but Ludovice et al. reported that bilateral nerve-sparing RARP was associated with faster recovery of continence, but not of erectile function, compared with open prostatectomy [57]. Novara et al. suggested that patient selection was a key factor determining the success of the nerve-sparing technique in the era of robotic surgery [58]. In patients younger than 65 years, the absence of associated co-morbidities and good preoperative erectile function were the most important preoperative factors in selecting patients for bilateral nerve-sparing RARP [58]. In our study, nerve sparing was significantly higher in the RARP group compared with the LRP and ORP groups, but the correlation between nerve sparing and erectile function requires further study.

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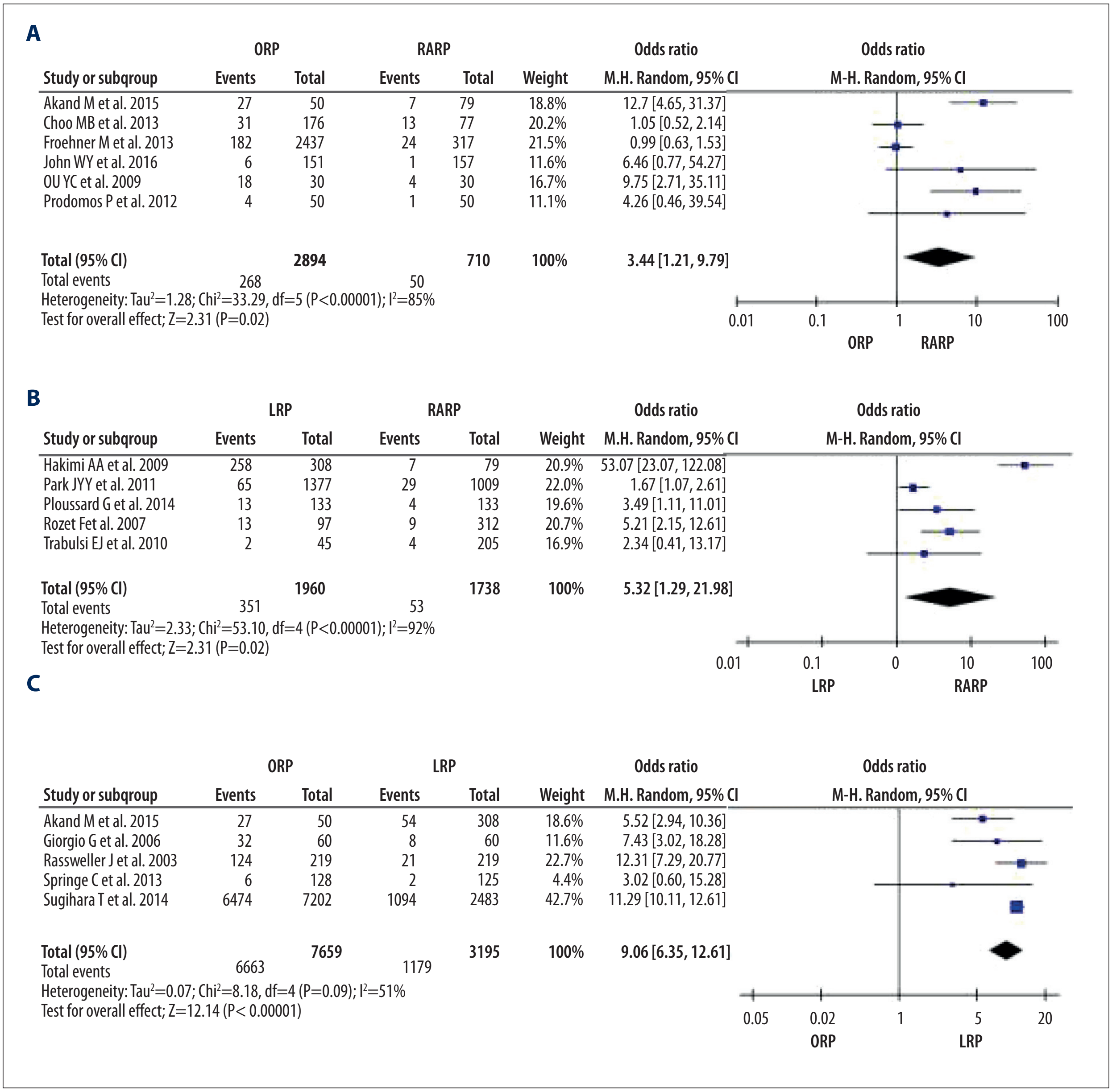

Figure 3. Forest plot showing the meta-analysis outcomes of the comparisons of transfusion rate after ORP, LRP, and RARP, (**A**) ORP *vs.* RARP; (**B**) LRP *vs.* RARP; (**C**) ORP *vs.* LRP.

Urinary continence and erectile function after radical prostatectomy are difficult to compare among studies because their etiology and pathophysiology are poorly understood, and their definitions vary among different investigators. Furthermore, different studies may involve multiple surgeons with different levels of training and laparoscopic surgical experience. These factors thus limit the direct comparison of continence and erectile outcomes between RARP, LRP, and ORP [59].

The advantages of RARP include visualization of locations within the pelvic cavity from various angles, providing excellent views for the surgeon. High-resolution cameras generating three-dimensional images and robotic arms allow surgeons to perform more precise dissection of the anatomic structures, potentially leading to better functional preservation. We suggest that these advantages of RARP would help to overcome the potential impact of prostatic apical shape on the postoperative recovery of urinary continence.

However, the etiologies of incontinence and erectile dysfunction after radical prostatectomy remain unclear. Several studies reported that various factors, including patient characteristics [60–64], surgical techniques, and surgeon experience [65–67], were also associated with postoperative

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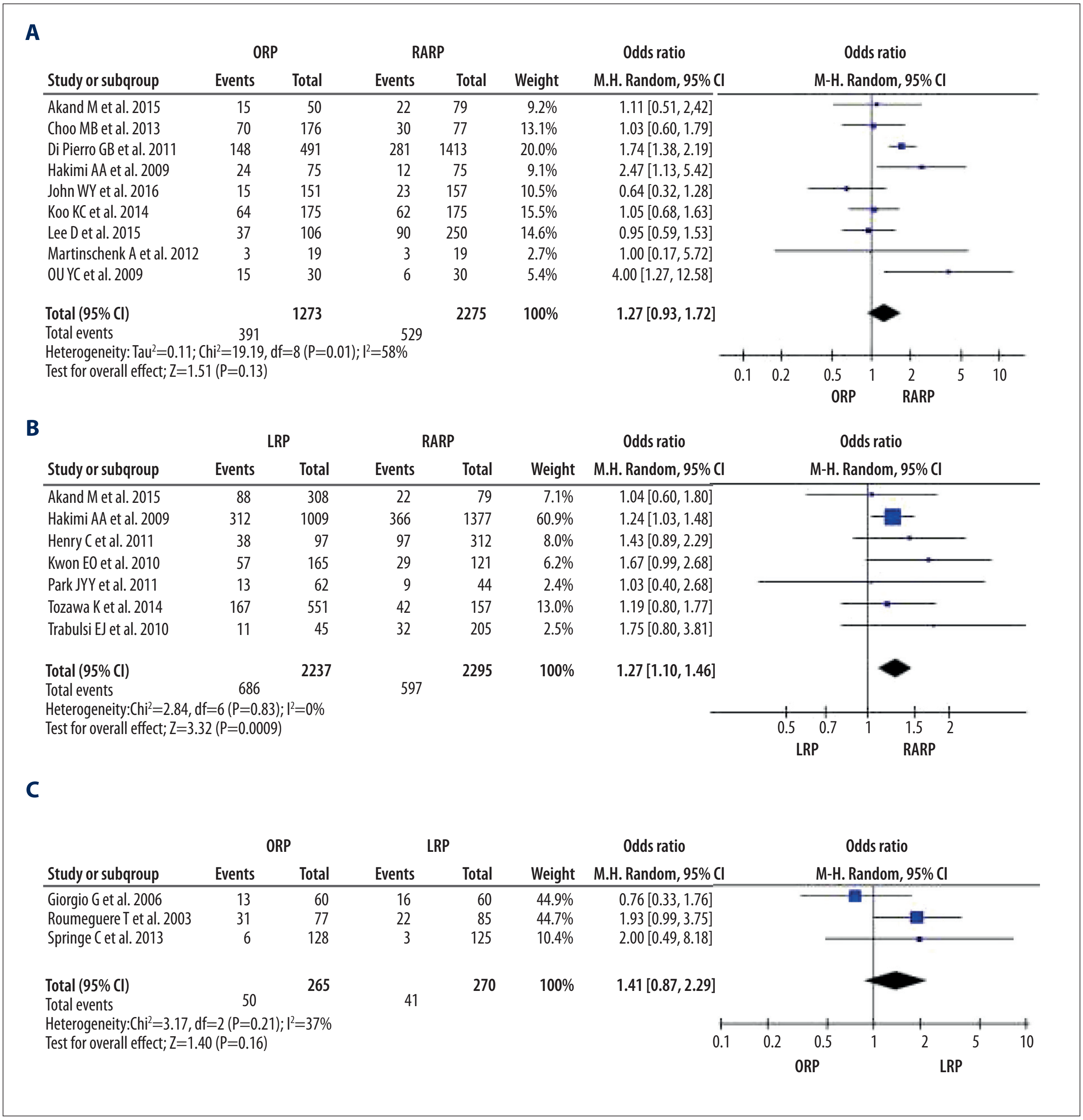

Figure 4. Forest plot showing the meta-analysis outcomes of the comparisons of PSM after ORP, LRP and RARP, (**A**) ORP *vs.* RARP; (**B**) LRP *vs.* RARP; (**C**) ORP *vs.* LRP.

incontinence and erectile dysfunction after radical prostatectomy. A detailed description of pelvic anatomy in relation to radical prostatectomy suggests a positive association between the location of the prostatic apex and membranous urethra in terms of postoperative incontinence [68]. It was suggested that overlap of the urethra by the prostatic apex may be associated with prolonged postoperative incontinence, and overlap may exist anteriorly, posteriorly, or on both sides. Maximal preservation of the sphincter mechanism is widely regarded to be essential for preventing postoperative incontinence. The distal sphincter only extends from the penile bulb to the prostate apex, whereas the proximal sphincter extends to the verumontanum. In our meta-analysis, urinary continence rate and erectile function were significantly better in the RARP group compared with the ORP and LRP groups. However, urinary incontinence and erectile dysfunction are complex multifactorial conditions that require further studies.

There were some limitations to this meta-analysis that need to be considered when interpreting the results. First, the samples

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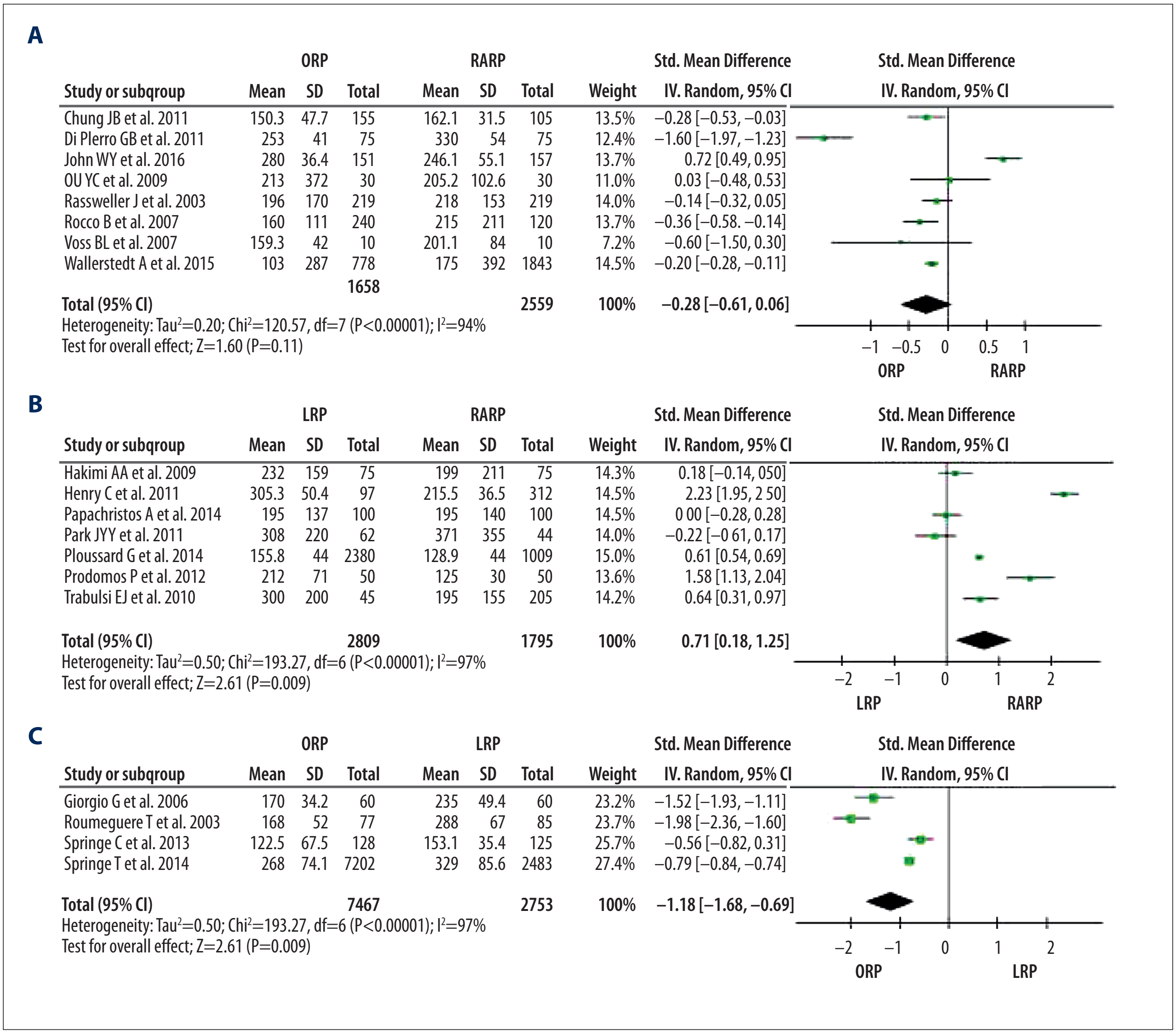

Figure 5. Forest plot showing the meta-analysis outcomes of the comparisons of operate time after ORP, LRP and RARP, (**A**) ORP *vs.* RARP; (**B**) LRP *vs.* RARP; (**C**) ORP *vs.* LRP.

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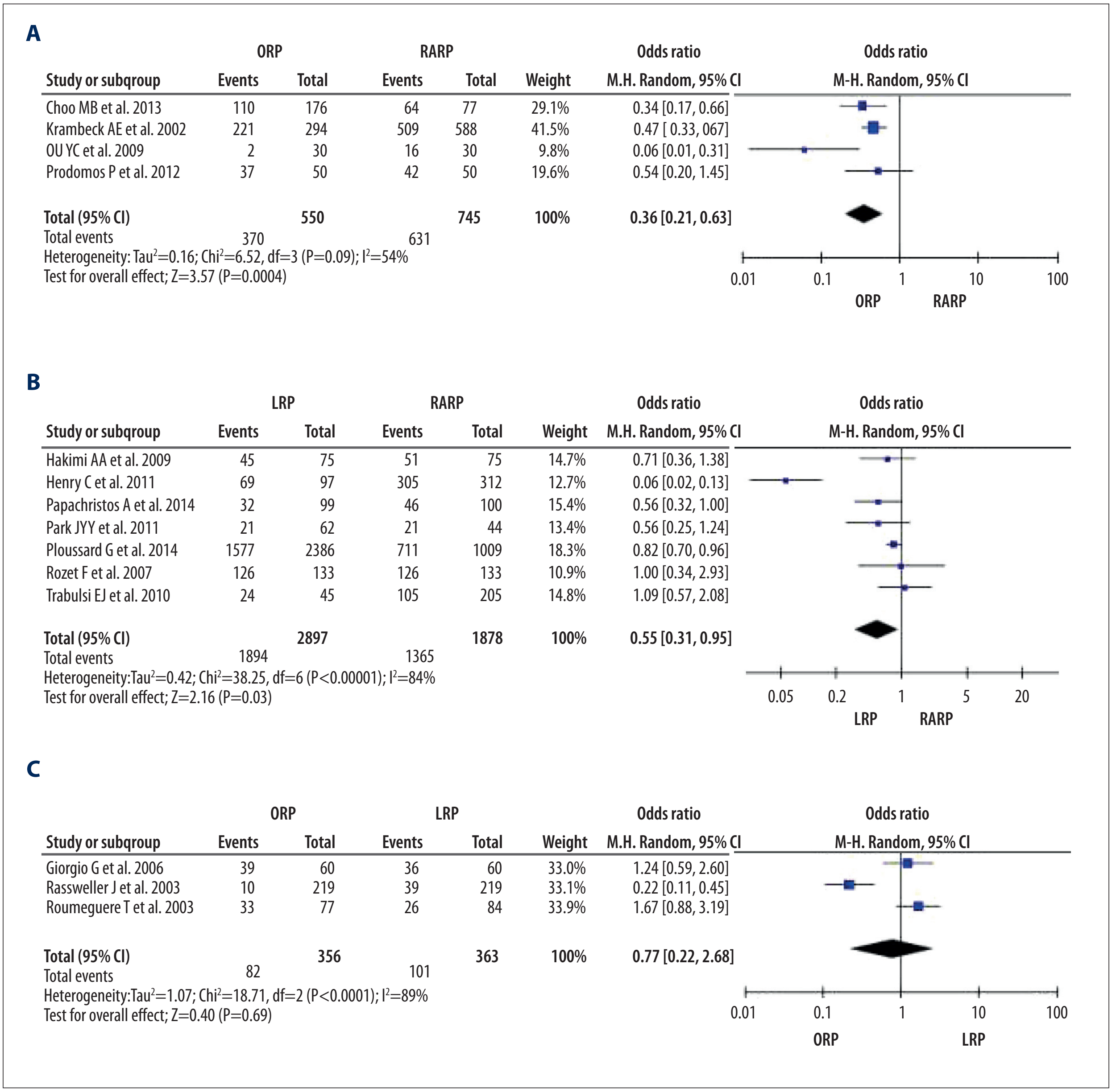

Figure 6. Forest plot showing the meta-analysis outcomes of the comparisons of nerve sparing rate after ORP, LRP and RARP, (**A**) ORP *vs.* RARP; (**B**) LRP *vs.* RARP; (**C**) ORP *vs.* LRP.

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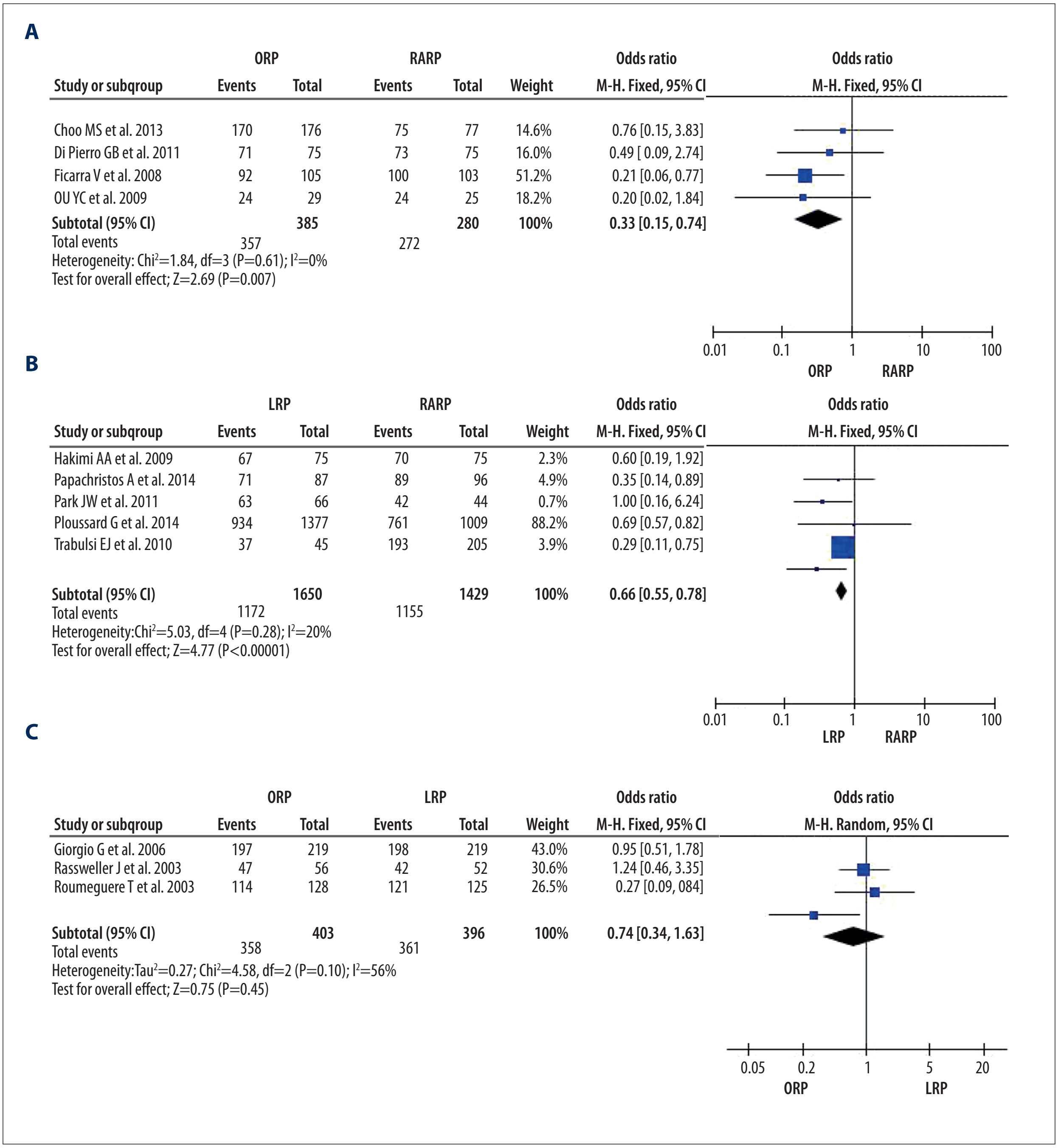

Figure 7. Forest plot showing the meta-analysis outcomes of the comparisons of urinary continence after ORP, LRP and RARP, (**A**) ORP *vs.* RARP; (**B**) LRP *vs.* RARP; (**C**) ORP *vs.* LRP.

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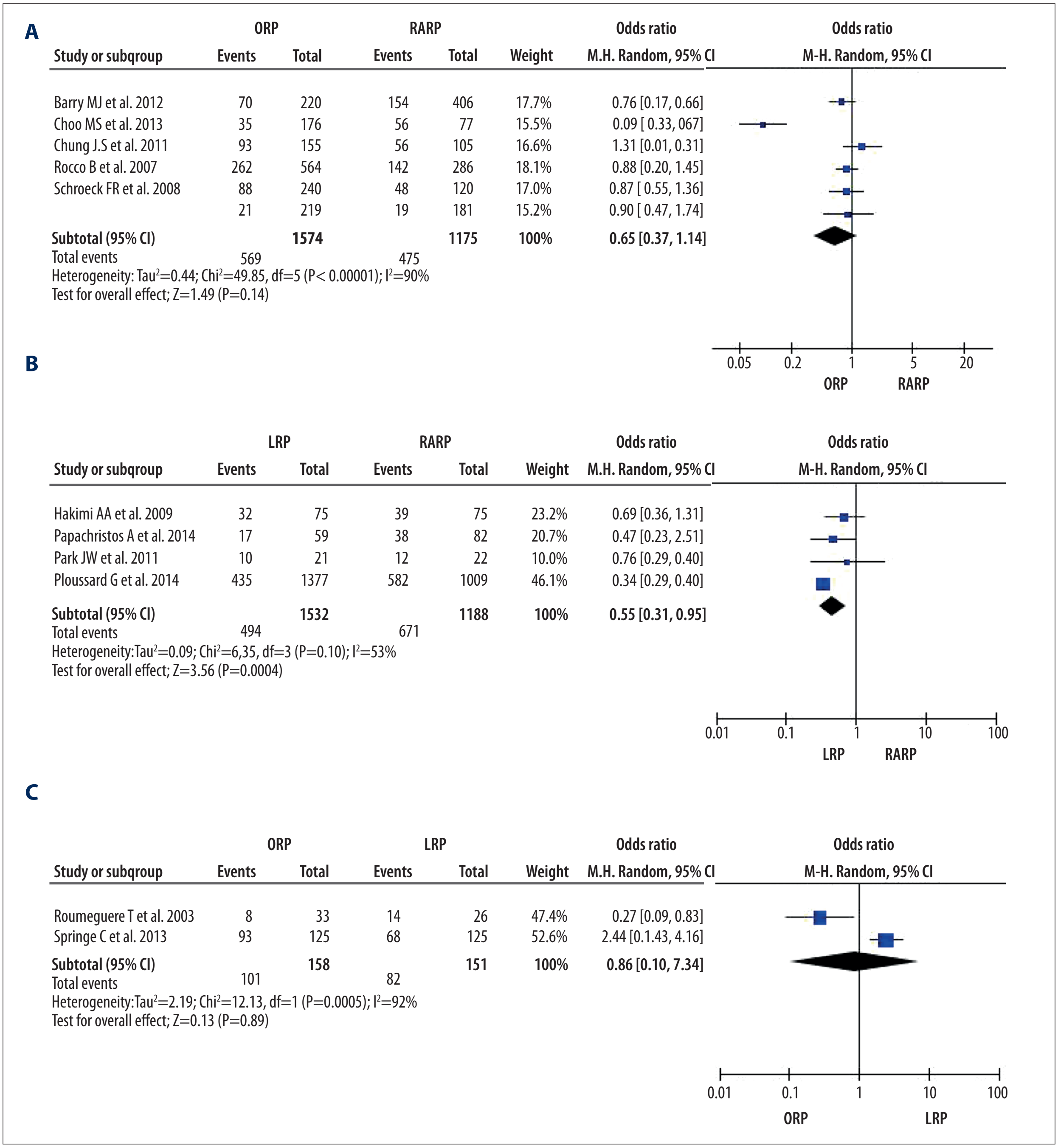

Figure 8. Forest plot showing the meta-analysis outcomes of the comparisons of erectile function after ORP, LRP and RARP, (**A**) ORP *vs.* RARP; (**B**) LRP *vs.* RARP; (**C**) ORP *vs.* LRP.

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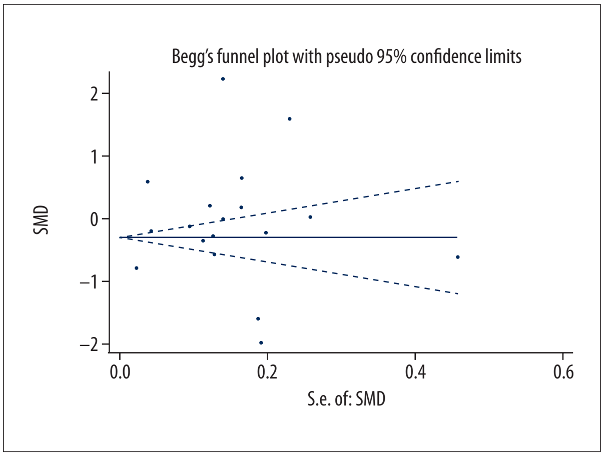

Figure 9. Begg's publication bias plot of operate time.

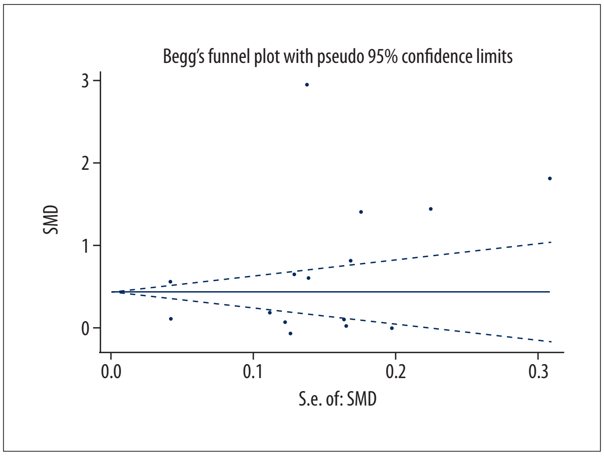

Figure 10. Begg's publication bias plot of blood loss.

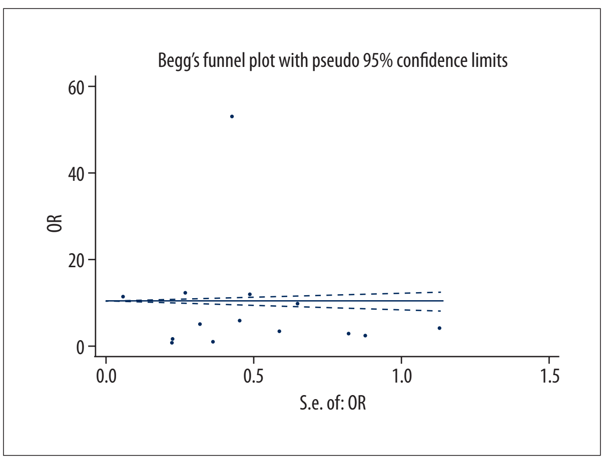

Figure 11. Begg's publication bias plot of transfusion rate.

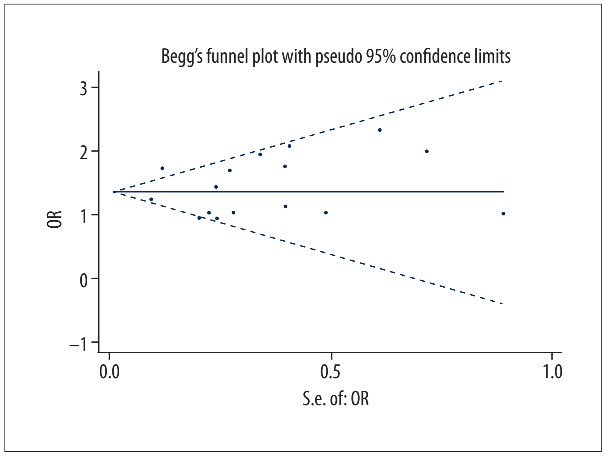

Figure 12. Begg's publication bias plot of PSM.

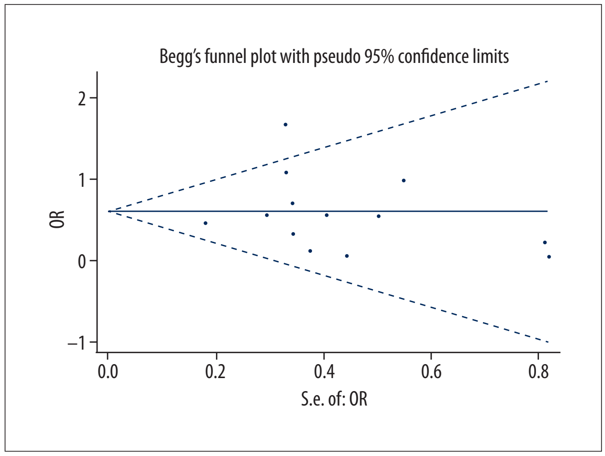

Figure 13. Begg's publication bias plot of nerve sparing.

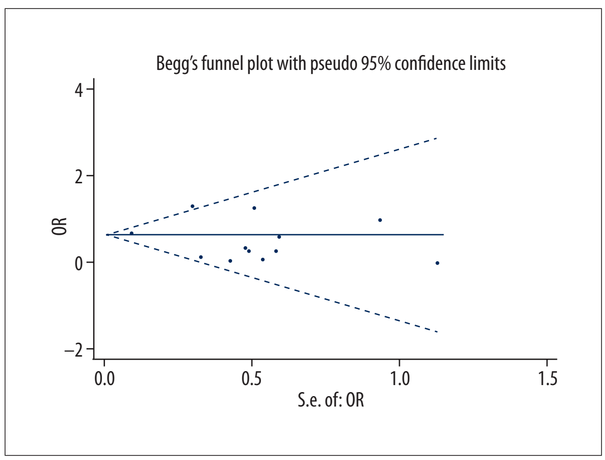

Figure 14. Begg's publication bias plot of urinary continence.

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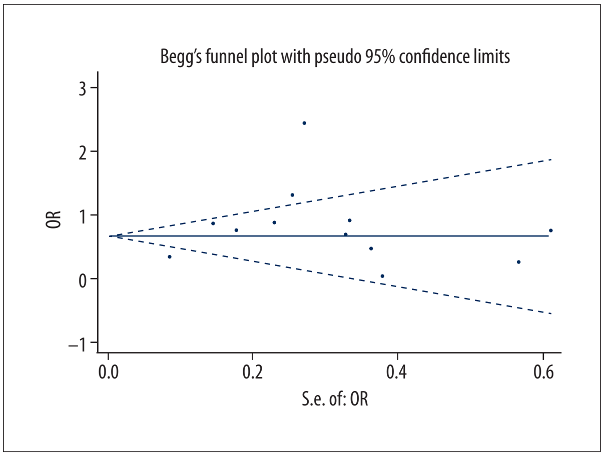

Figure 15. Begg's publication bias plot of erectile function.

were relatively small in all 33 studies. Second, several related studies were excluded because of a lack of control data, or means and SDs. Third, because the studies were conducted in different hospitals, the uneven surgical technique of surgeons may have influenced the results. Fourth, there was strong evidence of heterogeneity among the included studies. Some differences among the studies should be considered: the included studies were based on different populations; PSM was influence by the subjectivity of pathologists and surgeons; and we did not compare the cost of consumables and capital between RARP and LRP or ORP, but a study suggested that RARP con reduce the cost of consumables [69]. These factors limit the ability to form definitive conclusions about the relative clinical value of different prostatectomy procedures. However, this meta-analysis demonstrates that RARP provides more advantages in prostate cancer patients, especially regarding decreased adverse events.

Conclusions

This meta-analysis demonstrates that RARP is superior to LRP and ORP in terms of blood loss, transfusion rate, nerve sparing, urinary continence, and erectile dysfunction recovery, and suggests that RARP offers better results than LRP and ORP in treatment of prostate cancer. However, studies with larger sample sizes and long-term results are needed.

Conflict of interests

None.

Table 2. The Begg's test of publication bias.

	Operate time		Blood loss		Transfusion rate		Nerve sparing		PSM		Urinary continence		Erectile function	
	Z	P	Z	P	Z	P	Z	P	Z	P	Z	P	Z	P
ORP *vs.* RARP	−1.33	0.171	0.96	0.319	0.97	0.321	−1.36	0.174	0.71	0.455	−0.68	0.497	−0.56	0.573
LRP *vs.* RARP	0.25	0.805	0.49	0.624	−0.49	0.624	−0.75	0.453	0.45	0.652	0.00	1.000	0.68	0.497
ORP *vs.* LRP	−1.54	0.113	−1.39	0.177	0.69	0.492	−1.00	0.315	1.00	0.314	−1.57	0.117	−1.00	0.317

Table 3. The Egger's test of publication bias.

	Operate time		Blood loss		Transfusion rate		Nerve sparing		PSM		Urinary continence		Erectile function	
	Bias	P	Bias	P	Bias	P	Bias	P	Bias	P	Bias	P	Bias	P
ORP *vs.* RARP	−2.17	0.312	14.51	0.258	8.47	0.279	−0.36	0.391	−0.72	0.549	−0.17	0.334	−0.91	0.633
LRP *vs.* RARP	0.34	0.924	28.88	0.683	6.53	0.602	−0.78	0.559	0.43	0.647	−0.36	0.372	0.88	0.093
ORP *vs.* LRP	−2.89	0.650	−9.85	0.322	8.55	0.267	33.71	–	0.16	–	−2.46	0.447	−7.38	–

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