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INVITED REVIEW

Thulium laser VapoResection of the prostate versus traditional transurethral resection of the prostate or transurethral plasmakinetic resection of prostate for benign prostatic obstruction: a systematic review and meta-analysis

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Abstract

Purpose To compare the efficacy and safety of thulium laser VapoResection of the prostate (ThuVaRP) versus standard traditional transurethral resection of the prostate (TURP) or plasmakinetic resection of prostate (PKRP) for benign prostatic obstruction.

Methods Systematic searches were performed in the Medline, EMBASE, the Cochrane Library, Web of Science, and CNKI in December 2017. The outcomes of demographic and clinical characteristics, perioperative variables, complications, and postoperative efficacy including International Prostate Symptom Score (IPSS), quality of life (QoL), maximum flow rate (Qmax), and postvoid residual (PVR) were assessed.

Results 16 studies were selected in the meta-analysis including nine randomized controlled trials (RCTs) and seven non-RCTs. Among of them, nine studies compared ThuVaRP with PKRP, while seven studies compared ThuVaRP with TURP. It seemed that ThuVaRP needed longer operation time than TURP (WMD = 6.41, 95% CI 1.38–11.44, $p = 0.01$) and PKRP (WMD = 10.15, 95% CI 5.20–15.10, $p < 0.0001$). ThuVaRP was associated with less serum hemoglobin decreased, catheterization time, and the length of hospital stay compared with TURP (WMD = − 0.58, 95% CI − 0.77 to 0.38, $p < 0.00001$; WMD = − 1.89, 95% CI − 2.67 to 1.11, $p < 0.00001$; WMD = − 2.25, 95% CI − 2.91 to 1.60, $p < 0.00001$) and PKRP (WMD = − 0.28, 95% CI − 0.46 to 0.10, $p = 0.002$; WMD = − 1.88, 95% CI − 2.87 to 0.89, $p = 0.0002$; WMD = − 2.08, 95% CI − 2.63 to 1.54, $p < 0.00001$). According to our assessment, there was no significantly difference in postoperative efficacy.

Conclusions The pooled data indicated that ThuVaRP had a nearly efficacy to TURP and PKRP based on IPSS, QoL, Qmax, and PVR. Although ThuVaRP was associated with longer operation time, it got distinct superiority on serum hemoglobin decreased, catheterization time, and hospital stay.

Keywords Thulium laser VapoResection of the prostate, · Transurethral resection of the prostate, · Plasmakinetic resection of prostate, · Benign prostatic obstruction, · 2-micron · Thulium laser, · Safety and efficacy

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Introduction

As one of the most common disease of middle-aged to elderly males, the presence of benign prostatic hyperplasia (BPH) is an important factor of lower urinary tract symptoms (LUTS) [1, 2]. Although LUTS is not vital, it can cause serious bother and impair Quality of Life (QoL) significantly [3].

TURP is widely considered as the gold standard on treating bothersome moderate-to-severe lower urinary tract symptoms (LUTS) secondary to benign prostate obstruction (BPO) surgically [4]. However, the traditional transurethral resection of the prostate (TURP) causes complications such as TUR syndrome, blood loss, urinary tract infection (UTI), incontinence, urethral stricture, and erectile dysfunction, and all these led to the development of technological alternatives such as laser treatment and plasmakinetic resection of prostate (PKRP) which may further decrease the incidence of these complications [5]. As a modification of the traditional TURP, PKRP is a technique using radiofrequency energy provided by bipolar plasmakinetic technology to resect the prostatic tissue [6]. PKRP has a more favourable safety profile because of improved hemostasis and using normal saline as the irrigation solution which provides longer operative time [7].

Thulium laser is an emerging surgical laser, which is superior to the other lasers in some respects such as precise incision, operation in pulsed or the continuous wave mode, owing to its 2013 nm wavelength which is close to the 1.92-mm water absorption peak [8, 9]. Therefore, applying thulium laser in the surgical treatment of BPO is preferred by many urologists because of its superior characteristic [10]. Several operation forms have been described, including vaporization (ThuVAP), VapoResection (ThuVaRP), vapoenucleation (ThuVEP), and enucleation (ThuLEP) [10]. In 2005, Xia et al. [11] introduced the Thulium:YAG (Tm:YAG) 2 μm continuous wave (cw) laser prostatectomy and named it as thulium laser resection of the prostate–tangerine technique (TmLRP-TT). They make a transverse incision from the level of the verumontanum to the bladder neck, so that made the resection deep enough to the surgical capsule, and resected the prostatic tissue into pieces, which were small enough to through the resectoscope sheath after being vaporized at the same time. This technique perfectly combined vaporization and resection [12]. In 2008, Xia et al. [13] published a report which compared TmLRP-TT with TURP in 100 patients. The TmLRP-TT was proved to be almost a bloodless procedure with high efficacy and little perioperative morbidity. The TmLRP-TT is superior to TURP in safety and is as efficacious as TURP.

The ThuVaRP is a different technique from enucleation according to the proposition of Herrmann. The procedure of enucleation is associated with a blunt enucleation [10], while the ThuVaRP is relying on the vaporization and resection of the prostatic tissue. Although there were some systematic reviews with meta-analysis comparing ThuLRP with TURP or PKRP [14, 15], no reviewers have picked the ThuVaRP out. Several trails showed the unique superiority of the ThuVaRP compared with TURP or PKRP [13, 16–31]. Therefore, we performed a systematic review and meta-analysis comparing ThuVaRP (no ThuLEP and ThuVEP) individually with TURP or PKRP.

Methods

Literature search strategy

Systematic searches were performed in the Medline, EMBASE, the Cochrane Library, Web of Science and CNKI by two reviewers independently in December 2017 using the terms "thulium," "2-micron," "plasmakinetic resection of prostate," "PKRP," "bipolar transurethral resection of prostate", "transurethral resection of prostate", and "TURP". Our literature researches were not restricted by publication year or language.

Inclusion criteria and exclusion criteria

Criteria were identified before the literature searched. We selected the including studies according to criteria as follows: (1) compared ThuVaRP (no ThuLEP and ThuVEP) with TURP (monopolar TURP) or PKRP (bipolar TURP); (2) patients with BPH who suffered from LUTS; and (3) full papers reporting on at least one of the two primary outcomes of efficacy and safety. On contrast, we excluded studies meeting following criteria: (1) the inclusion criteria were not met or (2) patients with neurogenic bladder, those who were suspected or diagnosed prostate cancer, or (3) not described the operation approach clearly (Fig. 1).

The procedure was performed by two reviewers (Deng and Sun), and the disagreements were solved by consensus.

Data extraction and outcomes of interest

Two reviewers (Deng and Sun) extracted the following data from each eligible study independently: first author, publication year, number of patients, age, prostate volume, International Prostate Symptom Score (IPSS), Quality-of-Life (QoL) score, maximum flow rate (Qmax), postvoid residual (PVR), Prostate-Specific Antigen (PSA), follow-up time, research design type, operative time, serum hemoglobin and sodium decreased, catheterization time, hospital stay, and the complications including blood transfusion, recatheterization, temporary incontinence, UTI, retrograde ejaculation,

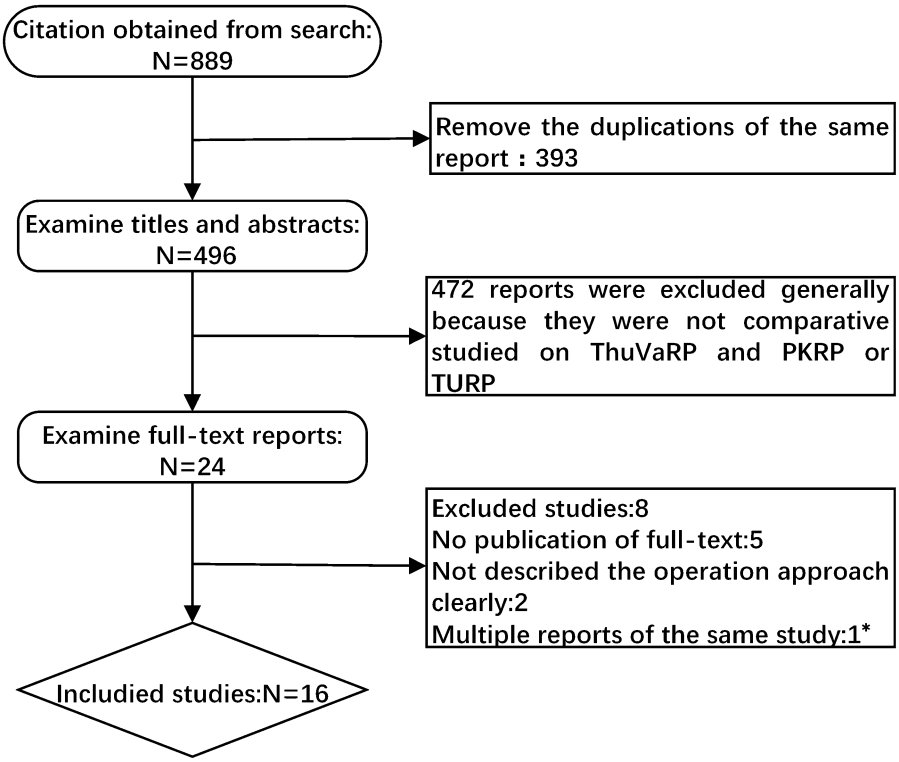

Fig. 1 Flowchart showing the selection of studies for meta-analysis *[23] and [31] is two articles reported the same research

urethral stricture, irritative symptom, and bladder-neck contracture.

Assessment of study quality

The methodological quality of the eligible randomized controlled trial (RCT) studies was assessed using the tool of "risk of bias", according to the recommendation of the Cochrane Handbook Version 5.1.0. The following factors were assessed: (1) random sequence generation; (2) allocation concealment; (3) blinding; (4) incomplete data; and (5) selective reporting. According to the method of each trial, each of factor was graded as "low risk of bias," "unclear risk of bias", and "high risk of bias" which were noted as "Yes", "Unclear", and "No".

The quality of the nRCTs was assessed through the Newcastle–Ottawa Scale which contains three factors: the selection of the study groups, the comparability of the groups, and the ascertainment of the outcome. The range of the scale was from 0 to 9, and only 9-star study was considered quality enough to include in our systematic review.

Statistical analysis

This meta-analysis was performed using the Review Manager Software (RevMan 5.3, Cochrane Collaboration, Oxford, UK) according to the recommendations of the Cochrane Collaboration and the Quality of Reporting of Meta-analysis guidelines. Weighted mean difference (WMD) was used for the continuous variables, and odds ratio (OR) was used for dichotomous data, both with 95% confidence interval (CI). Pooled effects were determined by z test, and a p value of <0.05 was considered statistically significant in all both cases. The Chi-squared test and inconsistency (I^2) were used to assess the heterogeneity of studies. When p was >0.10, we thought that there was no heterogeneity among studies, and selected the fixed-effects model or the random-effects model.

Result

After a comprehensive search of electronic databases, 16 studies were selected in the meta-analysis including nine RCTs and seven nRCTs. Nine studies compared ThuVaRP with PKRP, while seven compared ThuVaRP with TURP. Totally, 855 cases of ThuVaRP, 583 cases of PKRP, and 325 cases of TURP were selected in our meta-analysis. The characteristics of these included studies are summarized in Table 1. Patients in ThuVaRP group are older than TURP group. In addition, patients undergoing ThuVaRP have higher QOL score and more PVR comparing with TURP group. The analysis of baseline parameters between ThuVaRP with PKRP or TURP is shown in Table 2.

Table 3 shows the results of risk of bias assessments of RCTs. Because the intervention is surgical treatment, it is

Table 1 Baseline characteristics of included studies

First author, year	Intervention (I/C)	No. of patients (I/C)	Age (years)	Prostate volume (cc)	Qmax (ml/s)	PSA (ng/ml)	PVR (ml)	QoL	IPSS	Follow-up (months)	Design
Kim 2014 [22]	ThuVaRP	43	71.0 ± 7.1	NA	7.8 ± 4.3	5.2 ± 4.0	106.7 ± 114.5	NA	26.4 ± 5.7	1	nRCT
	PKRP	43	70.5 ± 8.2	NA	8.4 ± 4.4	4.6 ± 5.7	92.4 ± 82.7	NA	25.0 ± 4.0		
Wei 2014 [24]	ThuVaRP	45	69.8 ± 8.1	112.8 ± 28.3	8.1 ± 3.2	NA	90.0 ± 50.4	4.4 ± 0.8	21.6 ± 6.7	1, 6, 12, 18	RCT
	PKRP	45	69.0 ± 7.0	115.0 ± 39.4	7.9 ± 2.9	NA	96.8 ± 42.9	4.5 ± 0.9	21.1 ± 7.0		
Yang 2013 [23]	ThuVaRP	79	62.4 ± 7.2	72.4 ± 21.2	8.7 ± 2.8	2.4 ± 1.2	79.5 ± 29.3	3.9 ± 1.2	22.7 ± 4.3	1, 3, 6, 12, 18	RCT
	PKRP	79	61.4 ± 6.9	69.2 ± 23.1	9.1 ± 3.2	2.3 ± 1.2	72.4 ± 28.1	4.9 ± 1.3	23.4 ± 3.7		
Liu 2011 [18]	ThuVaRP	43	74.8 ± 7.6	72.0 ± 18.8	4.5 ± 1.8	3.7 ± 1.3	132.0 ± 42.0	5.1 ± 0.8	23.3 ± 4.7	6	nRCT
	PKRP	86	73.2 ± 6.9	68.0 ± 16.9	3.6 ± 2.1	3.4 ± 1.6	148.0 ± 49.0	5.8 ± 0.9	27.2 ± 4.8		
Yang 2015 [20]	ThuVaRP	27	71.6 ± 12.4	NA	7.8 ± 2.0	NA	144.3 ± 22.3	4.5 ± 1.4	24.9 ± 2.9	3	RCT
	PKRP	35	71.1 ± 12.3	NA	7.9 ± 1.9	NA	150.3 ± 24.1	4.6 ± 1.3	25.1 ± 3.1		
Zhang 2009 [21]	ThuVaRP	38	72.3	48.6 ± 12.4	2.7 ± 2.2	NA	NA	4.9 ± 0.6	21.5 ± 4.2	1	RCT
	PKRP	56	74.2	51.7 ± 14.3	3.1 ± 2.3	NA	NA	4.7 ± 0.9	23.4 ± 4.1		
Sun 2011 [19]	ThuVaRP	90	72.6 ± 4.7	NA	6.2 ± 2.0	NA	118.4 ± 60.0	4.9 ± 0.6	27.9 ± 4.6	3	RCT
	PKRP	86	71.9 ± 3.7	NA	6.1 ± 2.1	NA	111.3 ± 59.9	5.0 ± 0.7	28.4 ± 3.6		
Hou 2016 [17]	ThuVaRP	45	79.6 ± 8.4	65.8 ± 7.4	6.1 ± 3.5	2.5 ± 1.1	NA	5.6 ± 1.4	24.4 ± 6.2	1, 3	nRCT
	PKRP	43	76.3 ± 6.9	64.7 ± 8.9	6.3 ± 1.7	2.6 ± 0.8	NA	5.5 ± 1.6	23.5 ± 5.6		
Luo 2013 [16]	ThuVaRP	31	76.6(70–91)	NA	6.2 ± 2.1	NA	106.7 ± 42.7	5.2	27.1 ± 4.5	3	RCT
	PKRP	31	73.8(71–86)	NA	7.2 ± 2.6	NA	96.2 ± 47.7	5.3	26.9 ± 4.2		
Zhuo 2007 [30]	ThuVaRP	58	74.3 ± 7.2	58.4 ± 12.5	7.8 ± 4.1	3.2 ± 3.0	93.1 ± 32.1	4.5 ± 1.1	19.1 ± 8.5	3	nRCT
	TURP	66	73.7 ± 8.0	56.6 ± 14.1	8.1 ± 4.4	3.5 ± 3.4	85.0 ± 36.7	4.4 ± 1.3	18.2 ± 9.2		
Yan 2013 [29]	ThuVaRP	40	72.5 ± 7.9	52.9 ± 12.3	7.5 ± 2.6	2.6 ± 2.15	73.8 ± 35.0	NA	21.7 ± 4.2	3	RCT
	TURP	40	74.5 ± 6.5	54.3 ± 11.1	7.8 ± 2.8	2.8 ± 2.18	74.9 ± 35.6	NA	22.6 ± 5.6		
Xia 2008 [13]	ThuVaRP	52	68.9 ± 7.7	59.2 ± 17.7	8.0 ± 2.8	2.1 ± 1.1	93.1 ± 32.1	4.7 ± 0.9	21.9 ± 6.7	1, 6, 12	RCT
	TURP	48	69.3 ± 7.3	55.1 ± 16.3	8.3 ± 3.0	2.3 ± 1.4	85.0 ± 36.7	4.5 ± 1.1	20.8 ± 5.8		
Tai 2015 [28]	ThuVaRP	50	72.51 ± 7.92	52.9 ± 12.3	7.51 ± 2.61	2.60 ± 2.15	NA	NA	21.71 ± 4.22	3	nRCT
	TURP	50	74.52 ± 6.51	55.92 ± 6.54	7.81 ± 2.82	2.65 ± 1.98	NA	NA	22.61 ± 5.62		
Jia 2009 [27]	ThuVaRP	30	74.0 ± 5.5	58.0 ± 7.5	8.0 ± 4.0	NA	NA	4.3 ± 0.8	19.0 ± 8.3	1	nRCT
	TURP	30	72.7 ± 7.7	54.0 ± 6.5	7.5 ± 3.9	NA	NA	4.2 ± 0.7	20.1 ± 7.3		
Fu 2010 [26]	ThuVaRP	58	68.2 ± 8.9	49.8 ± 10.4	6.5 ± 1.8	2.2 ± 1.4	197.4 ± 23.6	4.8 ± 0.6	22.6 ± 4.5	1, 3, 6, 12	nRCT
	TURP	42	65.8 ± 8.4	48.2 ± 7.6	7.3 ± 2.4	2.4 ± 1.5	186.8 ± 37.2	4.4 ± 0.7	21.2 ± 3.7		
Cui 2013 [25]	ThuVaRP	47	67.8 ± 10.1	48.0 ± 18.3	8.62 ± 3.93	3.47 ± 2.67	91.9 ± 119.3	4.43 ± 1.12	21.1 ± 6.21	12, 24, 36, 48	RCT
	TURP	49	70.4 ± 7.02	54.8 ± 27.4	8.40 ± 3.47	3.70 ± 2.77	59.8 ± 106.4	4.49 ± 1.01	20.2 ± 6.78		

Table 2 Comparisons of baseline parameters between ThuVaRP and PKRP or TURP

Parameters	ThuVaRP versus PKRP, ThuVaRP versus TURP							
	No. of studies	No. of patients	*p* value	WMD (95%CI)	Heterogeneity			
					Chi^2	*df*	*p*	I^2 (%)
Age	7, 7	441/504, 335/325	*0.02*, 0.49	1.02 [0.15, 1.90], −0.42 [−1.58, 0.75]	2.52, 7.81	6, 6	0.87, 0.25	0, 23
PV(cc)	5, 7	250/309, 335/325	0.52, 0.63	0.81 [−1.64, 3.25], 0.61 [−1.86, 3.09]	3.53, 11.47	4, 6	0.47, 0.07	0,48
Qmax	9, 7	441/504, 335/325	0.92, 0.13	0.02 [−0.29, 0.32], −0.35 [−0.80, 0.10]	11.35, 2.34	8, 6	0.18, 0.89	30, 0
PSA	4, 6	210/251, 315/305	0.52, 0.25	0.08 [−0.16, 0.32], −0.17 [−0.46, 0.12]	1.73, 0.26	3, 5	0.63, 1	0, 0
PVR	7, 5	358/405, 255/245	0.85, *0.02*	0.52 [−5.06, 6.10], 7.61 [1.02, 14.19]	9.49, 2.57	6, 4	0.15, 0.63	37, 0
QOL	7, 5	367/430, 245/235	0.12, *0.01*	−0.26 [−0.58, 0.07], 0.21 [0.05, 0.37]	35.24,4.14	6, 4	<0.00001, 0.39	83, 3
IPSS	9, 7	441/504, 335/325	0.23, 0.45	−0.60 [−1.58, 0.38], 0.34 [-0.53, 1.20]	22.39, 5.66	8, 6	0.004, 0.46	64, 0

Table 3 Assessment of risk of bias for RCTs

Author, year	Adequate sequence generation	Allocation concealment	Blinding	Incomplete outcome data addressed	Free of selective reporting	Other bias
Wei 2014 [24]	Yes	Yes	Unclear	Yes	Yes	Yes
Yang 2013 [23]	Yes	Unclear	Unclear	Yes	Yes	Yes
Yang 2015 [20]	Yes	Yes	Unclear	Yes	Yes	Yes
Zhang 2009 [21]	Yes	Unclear	Unclear	Yes	Yes	Yes
Sun 2011 [19]	Yes	Unclear	Unclear	Yes	Yes	Yes
Luo 2013 [16]	Yes	Unclear	Unclear	Yes	Yes	Yes
Yan 2013 [29]	Unclear	Unclear	Unclear	Yes	Yes	Yes
Xia 2008 [13]	Yes	Unclear	Yes	Yes	Yes	Yes
Cui 2013 [25]	Yes	Unclear	Yes	Yes	Yes	Yes

impossible to make the surgeons blinding. Therefore, if the study met blinding of patients or outcome assessors, it would be thought to be blind. For non-RCTs, all selected studies met the 9-star standard.

At 1 months after the operation, there was a significant difference between ThuVaRP with TURP in QoL (WMD = 0.27, 95% CI 0.14–0.41, $p < 0.001$) or PKRP (WMD = − 0.30, 95% CI − 0.59 to 0.01, $p = 0.04$) in IPSS. The pooled data showed no significant differences between ThuVaRP with TURP or PKRP during 3-month postoperative follow-up. At 6 months after the surgery, the pooled Qmax was significantly different in both two groups (WMD = 1.56, 95% CI 0.65–2.47, $p = 0.0007$; WMD = − 1.09, 95% CI − 1.91 to 0.28, $p = 0.0009$), and the QoL was different between ThuVaRP and TURP (WMD = 0.20, 95% CI 0.07–0.33, $p = 0.003$). In addition, during the postoperative 12-month follow-up, there were significantly different in Qmax between ThuVaRP and TURP (WMD = − 1.19, 95% CI − 1.89 to 0.49, $p = 0.0009$) and in IPSS both two groups (WMD = 0.57, 95% CI 0.05–1.09, $p = 0.03$; WMD = − 0.64, 95% CI − 1.14 to 0.13, $p = 0.01$). (Table 4.)

We extracted data on the serum hemoglobin decreased, catheterization time, and hospital stay from relevant studies, and the pooled data demonstrated markedly that differences suggest the advantages of ThuVaRP over either the TURP group (WMD = − 0.58, 95% CI − 0.77 to 0.38, $p < 0.00001$; WMD = − 1.89, 95% CI − 2.67 to 1.11, $p < 0.00001$; WMD = − 2.25, 95% CI − 2.91 to 1.60, $p < 0.00001$) or the PKRP group (WMD = − 0.28, 95% CI − 0.46 to 0.10, $p = 0.002$; WMD = − 1.88, 95% CI − 2.87 to 0.89, $p = 0.0002$; WMD = − 2.08, 95% CI − 2.63 to 1.54, $p < 0.00001$). There also was a significate difference in serum sodium decreased between ThuVaRP and TURP (WMD = − 3.64, 95% CI − 4.16 to − 3.11, $p < 0.00001$). Though the data of operative time indicated that ThuVaRP group had longer operative time than TURP (WMD = 6.41, 95% CI 1.38–11.44, $p = 0.01$) and PKRP group (WMD = 10.15, 95% CI 5.20–15.10, $p < 0.0001$), it can be explained by the proficiency of the surgeons. The results are shown in Figs. 2 and 3.

There were significant differences in blood transfusion (OR: 0.14, 95% OR 0.03–0.66, $p = 0.01$) and retrograde ejaculation (OR: 0.65, 95% OR 0.43–0.99, $p = 0.04$) between

Table 4 Comparison of postoperative efficacy between ThuVaRP and PKRP or TURP

Outcomes	ThuVaRP versus PKRP, ThuVaRP versus TURP							
	No. of studies	No. of patients	*p* value	WMD (95% CI)	Heterogeneity			
					Chi^2	d*f*	*p*	I^2 (%)
Qmax (mL/s)								
1 month	5, 3	250/266, 140/120	0.29, 0.06	0.44 [−0.37, 1.25], 0.85 [−0.05, 1.75]	5.84, 0.1	4, 2	0.21, 0.95	31, 0
3 months	5, 4	272/274, 206/198	0.61, 0.06	0.11 [-0.31, 0.53], 0.76 [−0.04, 1.56]	5,00, 0.82	4, 3	0.29, 0.85	20, 0
6 months	3, 2	167/210, 110/90	*0.0007*, *0.009*	1.56 [0.65, 2.47], −1.09 [−1.91, -0.28]	3.26, 1.40	2, 1	0.2, 0.24	39, 29
12 months	2, 3	124/124, 157/139	0.72, *0.0009*	−0.34 [−2.22, 1.54], −1.19 [−1.89,− 0.49]	0.04, 1.92	1, 2	0.84, 0.38	0, 0
PVR (ml)								
1 month	3, 2	167/167, 110/90	0.66, 0.43	−0.73 [−4.03, 2.56], 3.19 [−4.74, 11.12]	0.84, 6.56	2, 1	0.66, 0.01	0, 85
3 months	4, 2	243/282, 116/108	0.48, 0.77	−0.91 [−3.45, 1.64], 0.29 [−1.65, 2.23]	8.55, 0.03	3, 1	0.04, 0.86	65, 0
6 months	3, 2	167/210, 110/90	0.05, 0.21	1.30 [−0.01, 2.62], −1.10 [−2.82, 0.63]	0.15, 2.52	2, 1	0.93, 0.11	0, 60
12 months	2, 3	124/124, 157/139	0.55, 0.75	−1.01 [−4.31, 2.30], 0.52 [−2.70, 3.74]	0.01, 11.87	1, 2	0.93, 0.003	0, 83
QoL								
1 month	4, 3	207/223, 140/120	0.73, *0.0001*	−0.04 [−0.28, 0.20], 0.27 [0.14, 0.41]	14.04, 1.02	3, 2	0.003, 0.6	79, 0
3 months	5, 2	272/274, 116/108	0.18, 0.67	−0.14 [−0.34, 0.06], −0.05 [-0.27, 0.17]	12.04, 1.74	4, 1	0.02, 0.19	67, 42
6 months	3, 2	167/210, 110/90	0.23, *0.003*	−0.13 [−0.35, 0.09], 0.20 [0.07, 0.33]	5.96, 0	2, 1	0.05, 1	66, 0
12 months	3, 3	124/124, 157/139	0.65, 0.59	0.05 [−0.17, 0.26], −0.16 [−0.72, 0.41]	0.59, 13.8	1, 2	0.44, 0.001	0, 86
IPSS								
1 month	5, 3	250/266, 140/120	*0.04*, 0.58	−0.30 [−0.59, −0.01], −0.21 [−0.96, 0.54]	3.7, 0.6	4, 2	0.45, 0.6	0, 0
3 months	5, 4	272/274, 206/198	0.85, 0.05	0.04 [−0.41, 0.49], −0.43 [−0.86, -0.00]	11.1, 1.53	4, 3	0.03, 0.19	64, 0
6 months	2, 2	167/210, 110/90	0.88, 0.6	−0.08 [−1.10, 0.94], 0.12 [−0.33, 0.56]	8.38, 0.03	2, 1	0.02, 1	76, 0
12 months	2, 3	124/124, 157/139	*0.03*, *0.01*	0.57 [0.05, 1.09], −0.64 [−1.14, −0.13]	0.06, 0.22	1, 2	0.8, 0.001	0, 0

ThuVaRP and TURP groups. In addition, there was no visible difference associated with other complications when comparing ThuVaRP with PKRP or TURP.

Discussion

BPH is not deemed as a life-threatening disease, but it does have crucial impact on patients' quality of life [3]. TURP is still the gold standard surgical treatment for patients with BPO, in spite of its inadequacies, such as TURS and transfusion [32]. A modification of monopolar TURP, PKRP, has similar efficacy with TURP and fewer adverse events [5, 33]. ThuVaRP was designed for the surgical treatment of BPO, and the pooled data of patients with BPO accepted ThuVaRP showed promising results in our previous multi-center study [34]. In addition, the thulium laser has been used widely in urology field and overcome some shortcomings of TURP and PKRP [35].

Our meta-analysis showed that ThuVaRP group exhibited a more satisfactory IPSS when versus PKRP and TURP, respectively, in the 1- and 12-month follow-up, and a higher Qmax at the 6-month follow-up between ThuVaRP group and PKRP group. The Qmax of ThuVaRP group was lower than TURP group during the 6- and 12-month follow-ups, the QoL of ThuVaRP group also was lower than TURP group during the 1- and 6-month follow-up and a higher IPSS than PKRP group at 12-month follow-up, although there was no definite clinical significance. In conclusion, our study indicated that ThuVaRP got ideal effect as compared to the PKRP and TURP groups in the postoperative period.

The pooled estimates of our study demonstrated that ThuVaRP had a longer operation time than both TURP and PKRP. However, in related research reports, the thulium

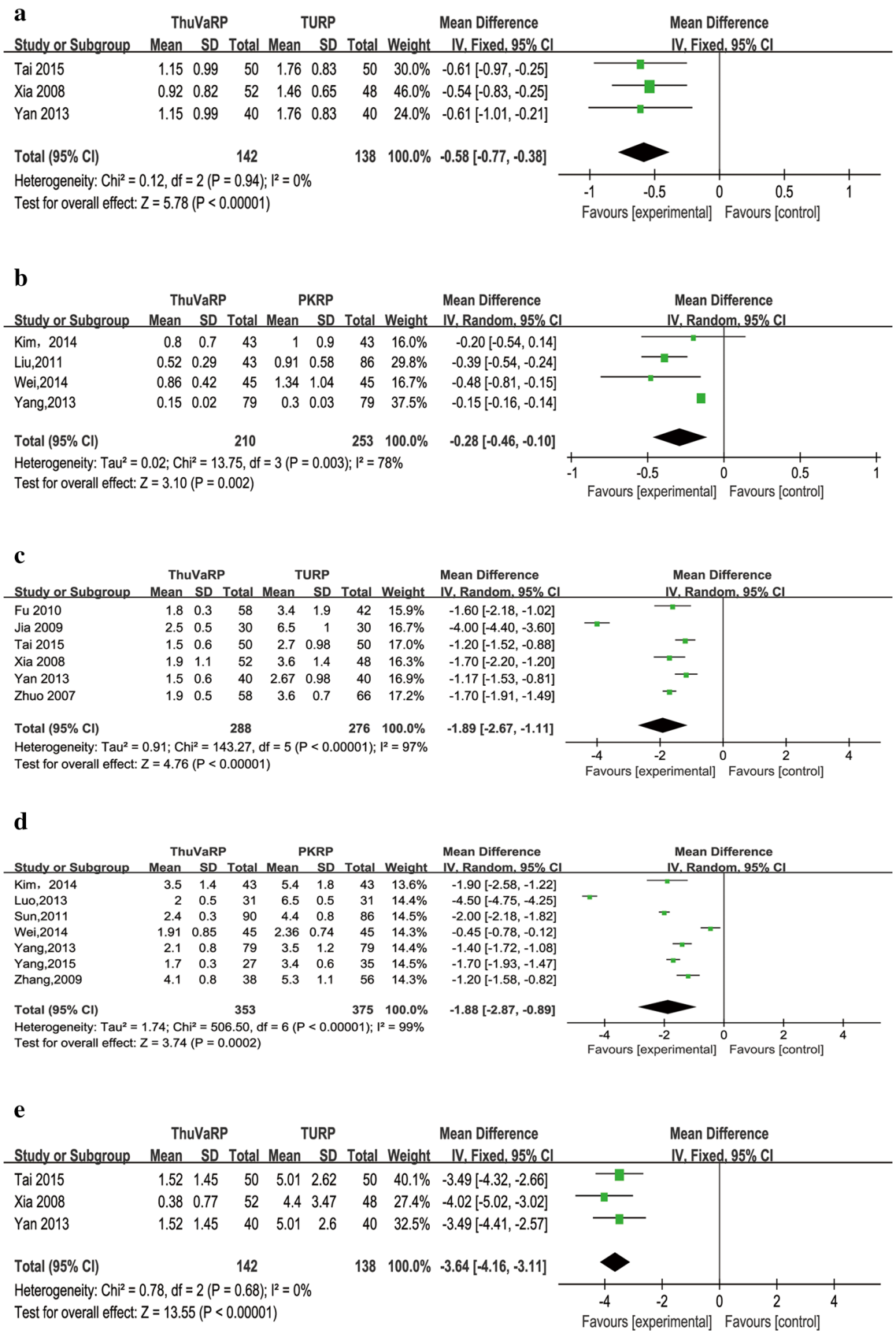

Fig. 2 **a**, **b** Serum hemoglobin decreased between ThuVaRP versus TURP and ThuVaRP versus PKRP. **c**, **d** Catheterization

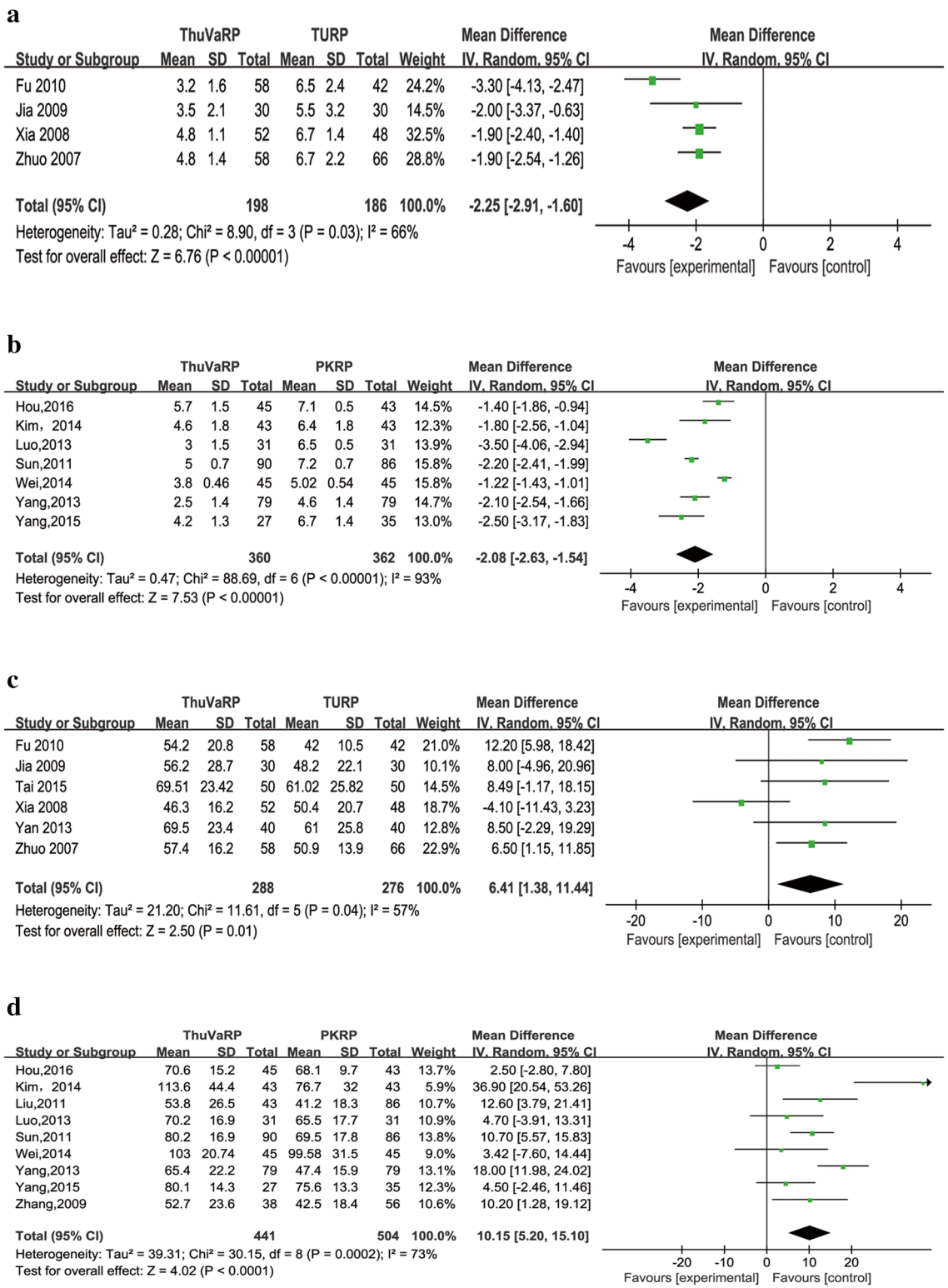

Fig. 3 **a**, **b** Hospital stay between ThuVaRP versus TURP and ThuVaRP versus PKRP. **c**, **d** Operative time between ThuVaRP

laser takes less operative time than standard techniques [12]. Xia et al. showed that ThuVaRP needed less operative time than TURP [13]. There were a few probable explanations about longer operation time: the proficiency of the surgeons and difference of prostate size between groups. The technique of thulium laser resection of the

prostate–tangerine technique (TmLRP-TT), an innovative approach of ThuVaRP, designed by Xia [11], combined the vaporization and resection features of Thulium laser and acquired more precise resection, less bleeding, clearer endo-anatomic vision, lower perioperative morbidity, higher efficacy as well as shorter operation time [12, 13]. TmLRP-TT has a fundamental superiority for large prostates because of efficient resection and vaporization, providing an alternative treatment for large prostates [24]. However, ThuVaRP was associated with less serum hemoglobin decreased, catheterization time, and the length of hospital stay compared with TURP and PKRP from our study. Our meta-analysis also demonstrated that ThuVaRP offered a lower blood transfusion than TURP group. Both of them offered a conclusion that ThuVaRP got a sufficient hemostasis. The center wavelength of thulium laser is ranging from 1.75 to 2.22 um, closing to the water absorption peak (1.92 μm) [8, 36], it cause that the thermal coagulation layer is ranging from 0.5 to 2 mm for thulium laser which is the reason of the sufficient hemostasis and minimal thermal injury to surrounding tissue of ThuVaRP. We found that there are not significant differences between ThuVaRP and other two groups about complications.

There were several techniques that have been described for the utilization of thulium laser in prostatectomy—vaporization (ThuVaP), VapoResection (ThuVaRP), vapoenucleation (ThuVEP), and enucleation (ThuLEP). In addition, the basic principles for each of them have been explained in detail [10]. First, ThuVaRP has apparently differences with ThuVEP and ThuLEP. ThuVaRP combines efficient resection and vaporization, so it greatly improves tissue ablation rate and hemostasis. Second, glandular tissue of prostate could be resected into small tissue chips, so that we do not need to use tissue morcellation; thus, it reduces the risk of potential damage of the bladder or the urethra [37]. Third, the enucleation technique requires a harder learning curve for surgeons [38].

There are a few limitations in our research certainty. First, the majority of the studies included were from Asia. Second, we have brought seven non-RCTs to our researches because of the absence of RCTs. Third, the accuracy and stability of some variables were associated with more or less heterogeneities. The implementation of concrete methods for trails and basic situation of operations were different. These could bring some heterogeneities to our research. Nevertheless, we have done the sensitivity analysis to test those potential deficiencies and made sure that there was not substantial change for our initial conclusions. Fourth, using finasteride or anticoagulant drug can affect the surgical bleeding, but no studies had ever mentioned the pretreatment of patients before operation. Nonetheless, more strictly designed and high-quality multi-center long-term RCTs are still required to validate our findings.

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Author's contribution Deng and Sun: project development, data collection, data analysis, and manuscript writing. These two first authors contributed equally to this meta-analysis. Zhu, Zhuo, and Zhao: data analysis. Xia, Han, and Hermann: project development

Compliance with ethical standards

Ethical approval All included studies have reported institutional ethical approval.

Research involving human participants and/or animals All included studies involving human participants.

Conflict of interest No competing financial interests exist.

Informed consent Formal consent is not required for meta-analysis.

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