Comparison of effectiveness and postoperative complications of different surgical methods in the treatment of benign prostatic hyperplasia: a systematic review and meta-analysis based on randomized controlled trials

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Background: More and more new surgical procedures for the treatment of benign prostate hyperplasia (BPH) are proposed creatively. However, the existing clinical evidence shows that the effectiveness and safety of various procedures exist inconsistent.

Methods: The randomized controlled trials comparing the international prostate score, length of hospital stay, maximum urinary flow rate, operation time, and complication rates of prostatic artery embolization (PAE), Greenlight-XPS Laser prostate vaporization procedure (GLL PVP), diode laser enucleation of prostate (DILEP) and plasmakinetic resection of the prostate (PKRP), transurethral resection of the prostate (TURP) in patients with BPH were screened out in databases. The primary outcome was pooled using a restricted maximum likelihood-based random-effect model and inverse variance-based fixed-effect model. Cochrane Q statistics and I2 statistics were computed to quantify between-study heterogeneity. The risk of bias of each included study was assessed using the revised Cochrane risk of bias tool.

Results: This meta-analysis ultimately included 14 original research papers, with 1,940 participants enrolled. Eight studies were considered to be at moderate risk of bias, while the others were at mild risk of bias. Although the improvement in functional outcome of the DILEP procedure was equivalent to that of the PKRP procedure, the DILEP procedure group had fewer hospital stays than the PKRP group (P=0.01). In addition, even though the performance of the GLL PVP procedure in the improvement of functional outcome was inferior to the counterpart of TURP (P=0.64), it had a much fewer hospital stays (P=0.01). Moreover, there is still insufficient evidence for the improvement of subjective functional indicators of postoperative patients with PAE compared with TURP [international prostate symptom score (IPSS): P=0.73; IPSS QoL: P=0.91], but achieved less satisfactory objective functional outcomes (Qmax: P=0.06; PVR: P=0.00).

Discussion: New surgical procedures such as GLL PVP, PAE, and DILEP were safer than traditional TURP procedures. However, it is not superior to traditional surgery in the improvement of clinical symptoms. In clinical practice, the pros and cons of the new operation and the traditional operation should be carefully weighed, and the operation that is most suitable for the patient's condition should be selected.

Keywords: Benign prostatic hyperplasia (BPH); surgery treatment; systematic review

Introduction

In men, lower urinary tract symptoms (LUTS) caused by benign prostatic hyperplasia (BPH) are prevalent urinary diseases. It is estimated that the quality of life (QoL) of about 1 in every 3 men over 50 years old is affected by LUTS caused by BPH (1,2). Even BPH with moderate and severe symptoms can even affect the mental state of patients (3,4). Although drug treatment, such as finasteride and dutasteride, can control clinical symptoms to a certain extent, surgical treatment is still the most effective way to treat BPH. Among the surgical options, transurethral prostatectomy (TURP), which involves removing the hyperplastic prostate piece by piece through a unilateral electrode, has been the most widely used in the clinic since 1970. The long-term effectiveness of this procedure in improving a series of clinical indicators of BPH [such as maximum urinary flow rate (Qmax), international prostate symptom score (IPSS), QoL score, and so on] has been explored in many observational studies and randomized controlled trials (RCTs) (5-8). However, complications such as massive hemorrhage or TURP syndrome are also common (9). A study showed that TURP was associated with incidence rate and even mortality of complications (10). Since entering the new century, studies have explored the effectiveness and safety of new surgical methods for the treatment of BPH, such as the use of bilateral electrodes or various laser systems (holmium laser, potassium titanium phosphate laser, thulium laser, diode laser, and so on), prostatic artery embolization (PAE), plasmakinetic resection of the prostate (PKRP), transurethral GreenLight™ laser photovaporization of the prostate (GLL PVP), and so on. These new procedures are safer than traditional TURP procedures, with less risk of surgical bleeding, transprostatectomy syndrome, and decreased hemoglobin levels. Overall, all procedures can be divided into four categories: resection, vaporization, enucleation, and arterial embolization. Resection is the process of cutting out the enlarged prostate tissue piece by piece. Vaporization is the process of using electrodes such as lasers or plasma to vaporize prostate tissue to high temperatures. Enucleation is the process of removing the entire prostate tissue from the internal capsule. Arterial embolization, on the other hand, is a procedure in which the blood supply to the prostate is blocked by direct injection of small particles. Resection usually requires the most prostate tissue to be removed, whereas vaporization usually removes less tissue due to the risk of damaging the sphincter (11).

More and more clinical RCTs are exploring the efficacy and safety of new BPH surgery. However, there are conflicting conclusions about the relative efficacy of different surgical procedures and the corresponding clinical endpoints in the existing evidence. Specifically, Zhang *et al.* (12) and Xu *et al.* (13) compared diode laser enucleation with plasma endoprostate enucleation in a RCT and found that the former can significantly reduce the International Prostate Symptom Score (IPSS) compared with the latter. Wu *et al.* (14) came to the opposite conclusion. Similar contradictory conclusions between the various surgical procedures can also be found in many other RCTs (15-20). This is partly because most RCTs have very limited sample sizes, short follow-up, and are mostly single-center studies. So the results are not necessarily general. Systematic reviews and meta-analysis methods can generate more reliable evidence-based medical evidence by combining the results of as many studies as possible. Therefore, this study systematically quantified the relative efficacy and safety of various surgical procedures by systematically searching relevant literature. We present the following article in accordance with the PRISMA reporting checklist (available at https://tau.amegroups.com/article/view/10.21037/tau-22-377/rc).

Methods

Literature search

This study mainly searched the databases of PubMed, Ovid, Embase, ScienceDirect China National Knowledge Infrastructure Project and Wanfang database for clinical RCTs comparing the international prostate score, length of hospital stay, maximum urinary flow rate, operation time, and complication rates (outcome) of PAE, GLL PVP, diode laser enucleation of prostate (DILEP) (Intervention) and PKRP, TURP (Comparison) in patients with BPH (Population). The search terms "prostate hyperplasia",

844

Fu et al. Different surgical methods for BPH

"prostate hypertrophy", "prostate tumor", "TURP", "enucleation vaporization diode laser", "greenlight laser", "prostate artery embolization", and "plasma kinetics" were systematically searched in the databases in a reasonable combination. Endnote X9 (Clarivate, London, UK) was used for document management, and the documents that met the inclusion criteria were screened one by one.

Inclusion and exclusion criteria

The inclusion criteria were as follows: (I) the type of literature design was a clinical RCT; (II) the interventions studied were PAE, GLL PVP, DILEP. PKRP, TURP in patients with BPH were the control group; (III) the primary endpoints studied included functional indicators such as IPSS, IPSS QoL, Qmax, prostate size, operation time, hospital stay, complication rate, and other indicators; and (IV) the standard deviation of the studied indicators was either provided in the literature or it could be calculated.

The exclusion criteria were as follows: (I) observational studies, reviews, academic conferences, reviews, and case reports; (II) the study population was a special subgroup of BPH rather than the general population (e.g., only patients with a prostate larger than a specific diameter or patients with other diseases); (III) Gray literature or withdrawn articles; and (IV) original data were not provided in the appendix materials. A total of 14 clinical RCTs were included in this study for meta-analysis.

Document sorting and evaluation

In this study, two independent researchers screened the literature and extracted the following data from the included literature: the author and the time of the study, the operation method of the intervention and control group, the sample size of the experimental group and the control group, the main indicators, the IPSS, the QoL indicator IPSS QoL, the Qmax, the post-void residual volume (PVR), the size of the prostate, the level of serum prostate-specific antigen (PSA), and the incidence of postoperative complications, operation duration, hospital stay, and so on. This study used the Cochrane Risk of Bias tool for systematic reviews and meta-analyses of RCTs. Two investigators independently assessed risk of bias for each included study based on seven aspects (21): (I) method of random number generation (selection bias); (II) group concealment (selection bias); (III) blinding of investigators and subjects (implementation bias); (IV) blinding (detection

bias) to the primary endpoint measure; (V) integrity of research results and data; (VI) selective reporting; (VII) other biases. The evaluation criteria are as follows: (I) if the evaluation criteria are met, the risk of bias is low; (II) a risk of bias was considered possible if one or more of the criteria were only partially met or were less accurate; (III) a high risk of bias was considered to exist if one or more of the criteria were not met or not reported.

Statistical methods

All data analysis in this study were statistically analyzed by Stata SE 17.0 software (Stata Corp., College Station, TX, USA). Since the main clinical indicators observed in this study were continuous variables, they were expressed in the form of mean ± standard deviation. The incidence of complications was the measurement data, the statistics were expressed in percentage, and the effective value was expressed in a 95% confidence interval (CI). The Cochrane Q test evaluated the heterogeneity between studies, and I^2 statistic was calculated to quantify the heterogeneity between studies. When the statistic I^2 corrected by degrees of freedom was ≥50%, the random-effects model of the limited maximum likelihood probability method was used to merge the mean difference. Otherwise, the fixed-effects model of the reverse variance method was used to merge the effect values, and the chi-square test evaluated the intergroup difference in complication rate. Heterogeneity between studies was assessed using the Cochrane Q test and the I^2 statistic. Meta-analyses with 5 or more included studies were evaluated for publication bias by funnel plot description and using Egger's and Begg's tests (22,23). All statistical results of this study were statistically significant, with P≤0.05, and the hypothesis tests were two-sided.

Results

Search results

Using the combination of medical subject words (MeSH) to systematically search in PubMed, Ovid, Embase, ScienceDirect, and other medical databases, 434 relevant literatures were retrieved. With reference to the established literature inclusion criteria, a total of 14 articles were finally included in the meta-analysis. The detailed literature retrieval and screening process are shown in the PRISMA flow chart, as shown in *Figure 1*. The included articles were 14 clinical RCTs. A total of 1,940 patients were divided into
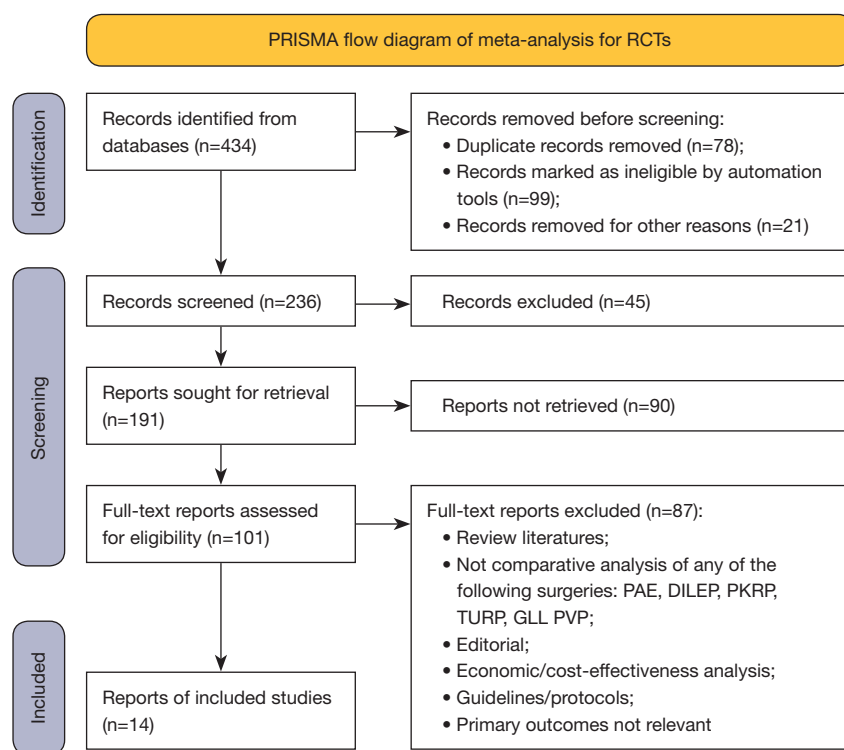
Figure 1 Literature screening process and results. RCT, randomized controlled trial; PAE, prostatic artery embolization; GLL PVP, GreenLightTM laser photovaporization of the prostate; PKRP, plasmakinetic resection of the prostate; TURP, transurethral prostatectomy; DILEP, diode laser enucleation of prostate.

three groups to compare the effectiveness and safety of the different surgical procedures. Namely, the comparison of GLL PVP and TURP, the comparison of PAE and TURP, and the comparison of DILEP and PKRP, with 7, 4, and 3 articles included in each group, respectively. The basic information of the included articles is shown in *Table 1*. The Cochrane system evaluation system assessed the bias risk of the included literature. As shown in *Table 2*, there was a possible selection bias in the random number generation method in the 5 literatures. There may be a hidden selection bias in the 6 literatures. There was obvious selection bias with hidden grouping in 3 literatures. There was obvious bias in the blinding of investigators and subjects in 4 studies. Five studies had possible biases in blinding investigators and subjects. Seven studies had possible outcome measurement bias. One article had significant outcome measurement bias. There are possible biases in the research results and data integrity of the three literatures. Four studies were subject to selective reporting bias. There were possible other biases in 8 studies.

Comparison between the experimental group of DILEP and the control group of PKRP

IPSS comparison

A total of 317 patients in three studies were included in this analysis. The heterogeneity test results were $H^2=1.00$, $I^2=0.00\%$, and P=0.49, indicating that there was no heterogeneity in the three studies. The fixed-effects model based on reverse variance was used to combine mean difference. The results of the meta-analysis showed that the mean difference (95% CI) of IPSS score between the DILEP group and PKRP group was –0.45 (–0.92 to 0.03), and the difference was not statistically significant, indicating that there was no statistically significant difference between the two methods in improving IPSS score, Q=1.44, P=0.06 (*Figure 2*).

Comparison of postoperative prostate volume (PV)

A total of 317 patients in three studies were included in this analysis. The heterogeneity test results were $H^2=1.00$,

Table 1 Basic characteristics of the included literature

Author	Intervention/control	Sample size in each group	Age (years), mean ± SD	IPSS, mean ± SD	IPSS QoL, mean ± SD	IIEF-S, mean ± SD	Qmax, mean ± SD	Post-void residual, mean ± SD	Prostate volume, mean ± SD	PSA, mean ± SD	Complication events	Operative time (minutes), mean ± SD	Hospital stays (days), mean ± SD	Quality score of NOS
Zhang et al. [2019] (12)	DILEP	79	73.7±8.4	24.5±3.2	4.7±0.7	N/a	N/a	204.6±191.1	56.2±11.9	N/a	30.3% (2376)	61.3±19.0	7.9±1.1	7
	PKRP	78	71.5±8.9	25.3±3.0	4.9±0.7			199.5±186.8	55.5±13.1		21.1% (1676)	94.5±31.5	9.5±1.1	
Xu et al. [2013] (13)	DILEP	40	N/A	4.88±1.24	1.18±0.45	N/a	23.45±3.33	1.25±3.10	27.4±5.54	1.14±0.28	25.0%	33.73±6.96	4.95±0.95	6
	PKRP	40		5.28±1.32	1.23±0.48		23.32±3.67	2.15±5.02	26.1±5.12	1.05±0.26	47.5%	50.28±6.24	5.30±0.93	
Wu et al. [2016] (14)	DILEP	40	75.4±8.4	22.4±5.3	N/a	17.1±2.7	6.8±2.8	163.8±41.7	98.6±21.6	5.6±3.2	50.0%	113.5±25.4	3.6±1.5	7
	PKRP	40	73.6±6.2	21.8±4.5		17.5±2.6	7.6±3.1	147.5±47.2	93.3±18.5	6.2±3.8	82.5%	98.7±31.5	4.8±1.8	
Al-Ansari et al. [2010] (24)	GLL PVP	60	66.3±9.4	27.2±2.3	N/a	N/a	6.9±2.2	53.2±25	61.8±22	N/a	0%	89±18	2.3±1.2	8
	TURP	60	67.1±8	27.9±2.7			6.4±2	57±21	60.3±20		16.7%	80±13	1.4±0.6	
Bachmann et al. [2014] (25)	GLL PVP	136	65.9±6.8	21.2±5.9	4.6±1.1	N/a	9.5±3.0	110.1±88.5	48.6±19.2	N/a	12.7%	N/a	2.6±1.3	8
	TURP	133	65.4±6.6	21.7±6.4	4.5±0.9		9.9±3.5	109.8±103.9	46.2±19.1		16.8%		4.1±2.1	
Capitán et al. [2011] (16)	GLL PVP	50	69.8±8.44	23.74±5.242	4.52±0.27	N/a	8.03±3.14	N/a	51.29±14.72	2.13±1.21	14%	N/a	1.6±1.2	7
	TURP	50	67.7±6.7	3.52±4.38	4.14±1.06		3.88±2.71		53.10±13.75	1.79±1.15	32%		3.6±2.1	
Elshal et al. [2020] (15)	GLL PVP	60	64.5±6	4.9±1.3	1.23±0.99	21.1±2.3	25.5±3.12	35.5±4.1	N/a	N/a	26.5%	92±32	N/a	8
	TURP	62	66.1±7	6.1±2.1	1.36±1.1	20.4±2.4	22.1±3.66	16.3±5.4	55±4.1		27.5%	83±28		
Lukacs et al. [2012] (26)	GLL PVP	69	66.9±7.8	22±2.1	N/a	N/a	7.79±2.75	89.5±2.3	50.54±16.53	N/a	26.5%	N/a	N/a	6
	TURP	70	67.6±7.6	20±3.2			7.76±2.64	75±3.1	50.11±14.73		39.7%			
Telli et al. [2015] (17)	GLL PVP	39	67 [51–87]	20±3.1	N/a	N/a	10.6±3.1	60±5.3	60±3.4	N/a	39.4%	N/a	2±1.1	8
	TURP	62	69 [56–87]	19±4.2			12.5±2.2	65±6.2	55±4.1		32.1%		5±2.5	
Thomas et al. [2016] (18)	GLL PVP	139	63.1±7.3	6.9±6.0	1.3±1.2	12.9±7.5	21.6±10.7	45.6±65.5	23.9±13.0	1.4±1.7	16.4%	N/a	N/a	7
	TURP	142	66.2±8.1	5.9±6.1	1.2±1.3	13.9±8.2	22.9±9.3	34.9±47.1	22.4±13.3	1.1±0.9	21.1%			
Carnevale et al. [2016] (27)	PAE	15	63.5±8.7	12.8±8.0	2.2±1.2	12.6±7.7	10.1±6.5	62.3±71.0	50.9±19.0	2.2±1.1	N/a	N/a	N/a	6
	TURP	15	66.4±5.6	6.1±8.6	0.9±1.4	16.1±5.7	27.1±8.7	8.3±11.9	32.0±11.4	1.6±0.9				
Abt et al. [2018] (20)	PAE	48	65.7±9.3	10.15±4.1	1.67±2.11	14.64±5.31	13.00±2.32	70.3±7.86	40.67±8.23	2.3±1.7	N/a	N/a	2.2±0.6	7
	TURP	51	66.1±9.8	6.82±5.5	1.55±3.21	11.67±4.13	22.52±6.55	33.7±8.23	27.16±6.44	1.33±1.12			4.2±1.7	
Insausti et al. [2020] (8)	PAE	23	75.53±4.74	5.6±3.5	0.7±0.7	15.7±7.2	13.8±4.2	13.1±5.6	39.5±7.5	N/a	N/a	90±35	N/a	6
	TURP	22	73.35±4.75	8.8±4.5	1.64±0.6	13.8±6.8	16.7±3.7	15.0±7.7	18.2±4.6			112±21		
Pisco et al. [2020] (28)	PAE	40	66±7.4	25.5±3.1	4±2.3	52.5±5.6	7.9±7.5	119.6±44.3	68.5±43.1	N/a	18.6%	N/a	0.2±1.2	7
	TURP	40	70±7.5	27.5±4.5	4.5±2.1	46±6.6	7.3±5.4	106±33.2	65.5±32.3		63.9%		1.2±2.2	

PAE, prostatic artery embolization; GLL PVP, GreenLight™ laser photovaporization of the prostate; PKRP, plasmakinetic resection of the prostate; TURP, transurethral prostatectomy; DILEP, diode laser enucleation of prostate; PSA, prostate specific antigen; IPSS, international prostate symptom score; QoL, quality of life; IIEF-S, international erectile function index; Qmax, maximum urinary flow rate; SD, standard deviation; N/a, not available.

Table 2 Risk of bias assessment of included studies

Author	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias
Zhang *et al.* [2019] (12)	Low	Low	Low	Low	Low	Low	Low
Xu *et al.* [2013] (13)	Unclear	Unclear	High	Unclear	Low	Unclear	Unclear
Wu *et al.* [2016] (14)	Unclear	Unclear	Low	Unclear	Low	Low	Unclear
Al-Ansari *et al.* [2010] (24)	Low	High	High	Low	Low	Low	Low
Elshal *et al.* [2020] (15)	Low	Unclear	Unclear	Unclear	Low	Low	Unclear
Capitán *et al.* [2011] (16)	Unclear	Unclear	Low	Unclear	Unclear	Unclear	Unclear
Bachmann *et al.* [2014] (25)	Low	High	Unclear	Unclear	Low	Low	Unclear
Lukacs *et al.* [2012] (26)	Unclear	Unclear	Unclear	Low	Unclear	Low	Low
Telli *et al.* [2015] (17)	Low	Low	Unclear	Low	Low	Unclear	Low
Thomas *et al.* [2016] (18)	Unclear	Low	High	Unclear	Unclear	Low	Unclear
Carnevale *et al.* [2016] (27)	Low	High	Unclear	High	Low	Low	High
Abt *et al.* [2018] (20)	Low	Unclear	High	Unclear	Low	Unclear	Unclear
Insausti *et al.* [2020] (8)	Low	Low	Low	Unclear	Low	Low	Unclear
Pisco *et al.* [2020] (28)	Low	Low	Low	Low	Low	Low	Low
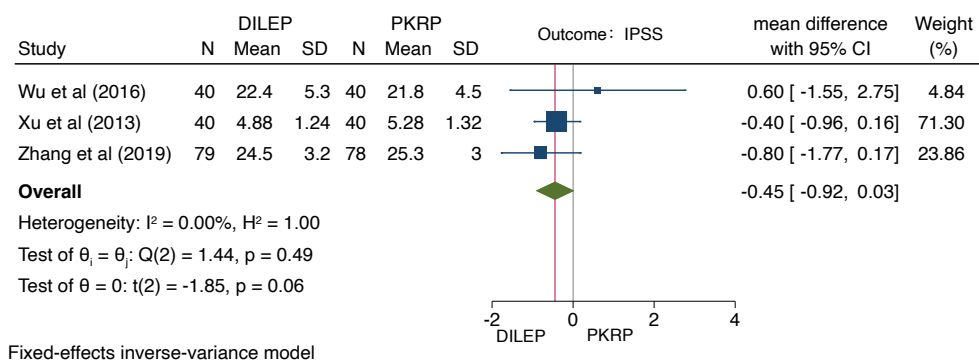
Figure 2 Comparison of IPSS between DILEP experimental group and PKRP. IPSS, international prostate symptom score; DILEP, diode laser enucleation of prostate; PKRP, plasmakinetic resection of the prostate; CI, confidence interval; SD, standard deviation.
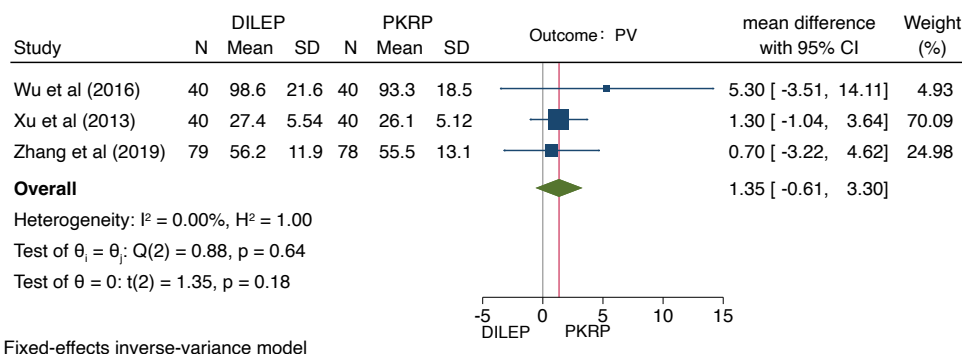
Figure 3 Comparison of PV after DILEP and PKRP. PV, prostate volume; DILEP, diode laser enucleation of prostate; PKRP, plasmakinetic resection of the prostate; CI, confidence interval; SD, standard deviation.
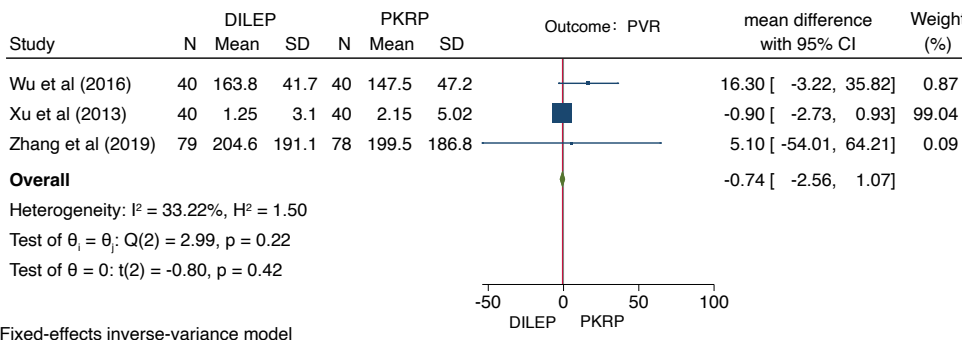

Figure 4 Comparison of PVR between DILEP experimental group and PKRP. PVR, post-void residue; DILEP, diode laser enucleation of prostate; PKRP, plasmakinetic resection of the prostate; CI, confidence interval; SD, standard deviation.

I^2=0.00%, P=0.64, indicating that there was no heterogeneity in the three studies. The fixed-effects model based on reverse variance was used to combine mean difference. The results of the meta-analysis showed that the mean difference (95% CI) in postoperative PV between DILEP group and the PKRP group was 1.35 (–0.61 to 3.30). The difference was not statistically significant, indicating that there was no statistically significant difference between the two methods in the change of postoperative PV, Q=0.88, P=0.18 (*Figure 3*).

Comparison of PVR

A total of 317 patients in three studies were included in this analysis. The heterogeneity test results were H^2=1.50, I^2=33.22%, P=0.22, indicating that there was no heterogeneity in the three studies. The fixed-effects model based on reverse variance was used to combine the mean difference. The results of meta-analysis showed that the mean difference (95% CI) of PVR between the DILEP

group and PKRP group was –0.74 (–2.56 to 1.07), and there was no significant difference, indicating that there was no significant difference in the effectiveness of the two methods in improving the PVR, Q=2.99, P=0.42 (*Figure 4*).

Comparison of hospital stay between DILEP and PKRP

A total of 317 patients in three studies were included in this analysis, and the heterogeneity test result was H^2=8.14, I^2=87.72%, P=0.00, indicating that there was heterogeneity in the three studies. The random-effects model based on the restricted maximum likelihood probability method was used to combine mean difference. The meta-analysis results showed that the mean difference (95% CI) in hospital stay between the DILEP group and PKRP group was –1.05 (–1.81 to –0.28), which was statistically significant. It showed that DILEP could shorten the hospital stay by about 1 day compared with PKRP, and the difference was
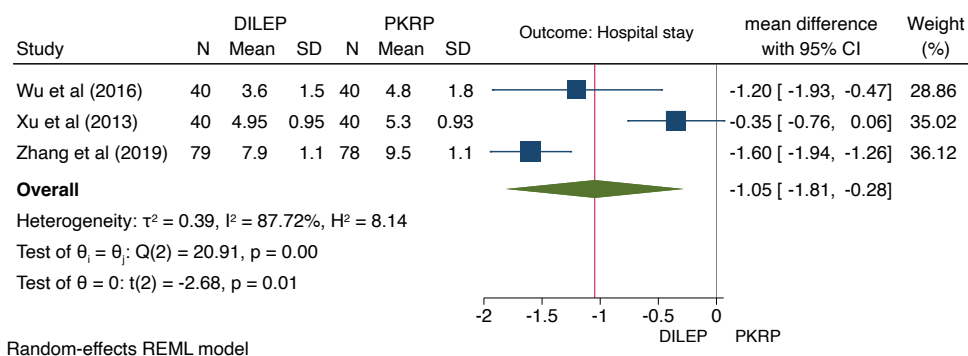
Figure 5 Comparison of hospital stay between DILEP experimental group and PKRP. DILEP, diode laser enucleation of prostate; PKRP, plasmakinetic resection of the prostate; CI, confidence interval; REML, restricted maximum likelihood; SD, standard deviation.
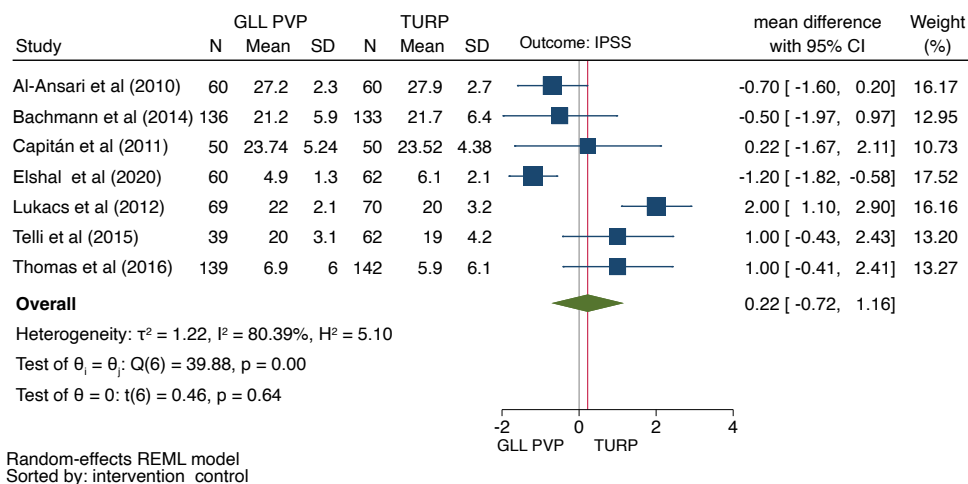

Figure 6 Comparison of IPSS between GLL PVP and TURP. IPSS, international prostate symptom score; GLL PVP, GreenLight[TM] laser photovaporization of the prostate; TURP, transurethral prostatectomy; CI, confidence interval; REML, restricted maximum likelihood; SD, standard deviation.

statistically significant, Q=20.91, P=0.01 (*Figure 5*).

Comparison between GLL PVP and TURP

IPSS comparison

A total of 1,132 patients in 7 studies were included in this analysis. The heterogeneity test results were H[2]=5.10, I[2]=80.39%, P=0.00, indicating that there was heterogeneity in the 7 studies. The random-effects model based on the restricted maximum likelihood probability method was used to combine mean difference. The results of the meta-analysis showed that the mean difference (95% CI) in IPSS score between the GLL PVP group and the TURP group was 0.22 (–0.72 to 1.16), and the difference was

not statistically significant, indicating that there was no statistically significant difference between the two methods in improving IPSS score, *t*=0.46, P=0.64 (*Figures 6,7*).

Comparison of postoperative QoL IPSS QoL

A total of 632 patients in four studies were included in this analysis. The heterogeneity test results were H[2]=1.53, I[2]=34.75%, P=0.20, indicating that there was no heterogeneity in the four studies. The fixed-effects model based on reverse variance was used to combine the mean difference. The results of the meta-analysis showed that the mean difference (95% CI) of IPSS QoL score between the GLL PVP group and the TURP group was 0.13 (–0.02 to 0.27), which was not statistically significant, indicating

that there was no statistically significant difference in the effectiveness of the two methods in improving postoperative QoL, IPSS QoL, t=1.74, P=0.08 (*Figure 8*).

Comparison of postoperative maximum urinary flow rate Qmax

A total of 1,132 patients in 7 studies were included in this analysis. The heterogeneity test results were H^2=18.79, I^2=94.68%, P=0.00, indicating that there was heterogeneity in the 7 studies. The random-effects model based on the restricted maximum likelihood probability method was used to combine mean difference. The results of meta-analysis showed that the mean difference (95% CI) of postoperative Qmax between the GLL PVP group and the TURP group was 0.68 (–1.01 to 2.36), which was not statistically significant, indicating that there was no

statistically significant difference in the effectiveness of the two methods in improving postoperative Qmax, t=0.79, P=0.43 (*Figures 9,10*).

Comparison of PVR

A total of 832 patients from 6 studies were included in this analysis. The heterogeneity test results were H^2=72.38, I^2=98.63%, P=0.00, indicating that there was heterogeneity in the 7 studies. The random-effects model based on the restricted maximum likelihood probability method was used to combine mean difference. The results of the meta-analysis showed that the mean difference (95% CI) of PVR between the GLL PVP group and the TURP group was 6.62 (–2.54 to 15.78). The difference was not statistically significant, indicating that there was no statistically significant difference in the effectiveness of the two methods for improving PVR, t=1.42, P=0.16 (*Figures 11,12*).

Comparison of postoperative PV

A total of 742 patients in five studies were included in this analysis. The heterogeneity test results were H^2=2.08, I^2=51.93%, P=0.07, indicating that there was heterogeneity in the five studies. The random-effects model based on the restricted maximum likelihood probability method was used to combine mean difference. The results of the meta-analysis showed that the mean difference (95% CI) of postoperative PV between the GLL PVP group and the TURP group was 2.28 (–0.52 to 5.08), which was not statistically significant, indicating that there was no statistically significant difference in the effectiveness of the two methods in improving IPSS score, t=1.60, P=0.11 (*Figures 13,14*).
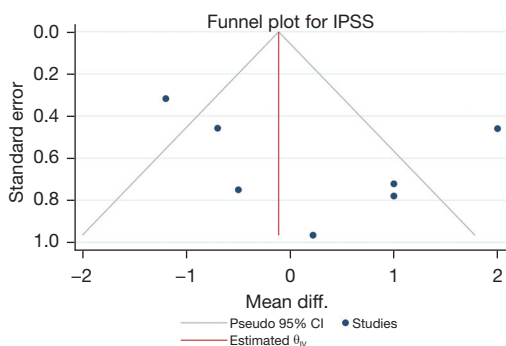

Figure 7 Funnel plot of IPSS meta-analysis of GLL PVP *vs.* TURP. IPSS, international prostate symptom score; GLL PVP, GreenLight™ laser photovaporization of the prostate; TURP, transurethral prostatectomy; CI, confidence interval.
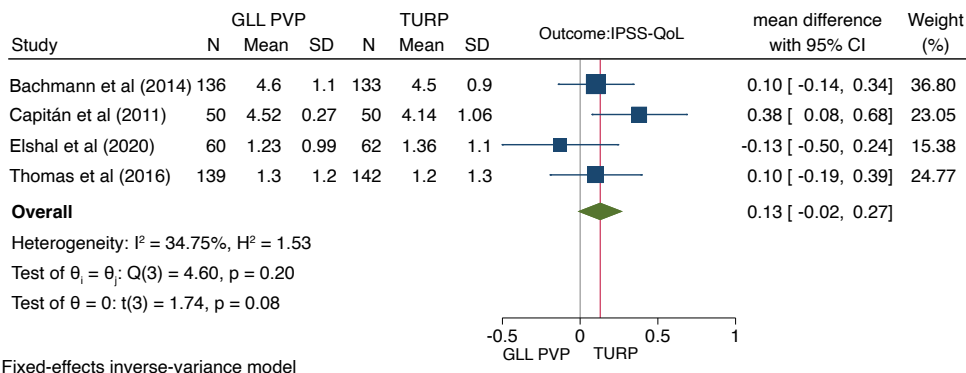

Figure 8 Comparison of IPSS QoL after GLL PVP and TURP. IPSS, international prostate symptom score; QoL, quality of life; GLL PVP, GreenLight™ laser photovaporization of the prostate; TURP, transurethral prostatectomy; CI, confidence interval; SD, standard deviation.
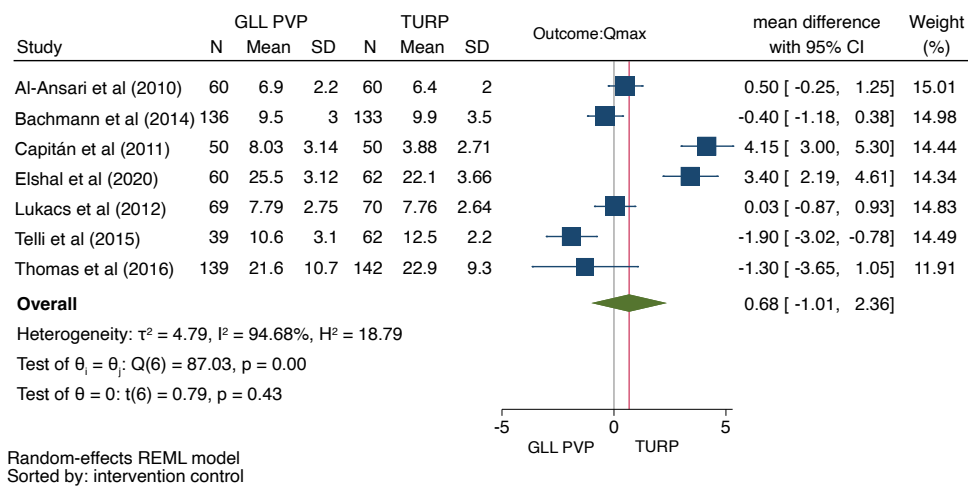

Figure 9 Comparison of Qmax after GLL PVP and TURP. Qmax, maximum urinary flow rate; GLL PVP, GreenLight™ laser photovaporization of the prostate; TURP, transurethral prostatectomy; CI, confidence interval; REML, restricted maximum likelihood; SD, standard deviation.
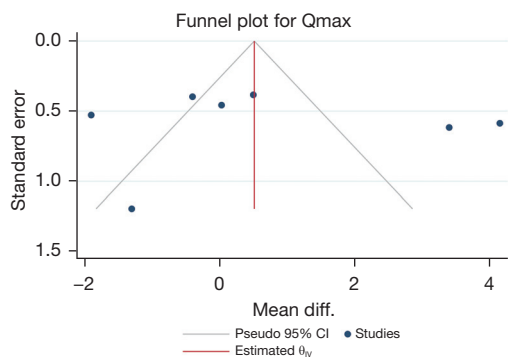

Figure 10 Funnel plot of the Qmax meta-analysis of GLL PVP *vs.* TURP. Qmax, maximum urinary flow rate; GLL PVP, GreenLight™ laser photovaporization of the prostate; TURP, transurethral prostatectomy; CI, confidence interval.

Comparison of hospital stay between GLL PVP and TURP

A total of 632 patients in four studies were included in this analysis. The heterogeneity test results were H^2=43.39, I^2=97.70%, P=0.00, indicating that there was heterogeneity in the four studies. The random-effects model based on the restricted maximum likelihood probability method was used to combine mean difference. The results of the meta-analysis showed that the mean difference (95% CI) in hospitalization time between the GLL PVP group and the TURP group was –1.38 (–3.01 to 0.25), and the difference was not statistically significant, indicating that the difference in hospitalization time between the two methods was not

statistically significant, t=–1.66, P=0.10 (*Figure 15*).

Comparison of PAE and TURP

IPSS comparison

A total of 254 patients in four studies were included in this analysis. The heterogeneity test results were H^2=12.02, I^2=91.68%, P=0.00, indicating that there was heterogeneity in the four studies. The random-effects model based on the restricted maximum likelihood probability method was used to combine mean difference. The results of the meta-analysis showed that the mean difference (95% CI) in IPSS score between the PAE group and the TURP group was 0.73 (–3.44 to 4.90). The difference was not statistically significant, indicating that PAE can improve IPSS score by about 0.73 points compared with TURP, t=0.34, P=0.73 (*Figure 16*).

Comparison of postoperative PV

A total of 174 patients in three studies were included in this analysis. The heterogeneity test results were H^2=4.51, I^2=77.85%, P=0.00, indicating that there was heterogeneity in the four studies. The random-effects model based on the restricted maximum likelihood probability method was used to combine mean difference. The results of the meta-analysis showed that the mean difference (95% CI) in postoperative PV between the PAE group and the TURP group was 17.56 (11.84 to 23.28). The difference was statistically significant, indicating that the diameter of the
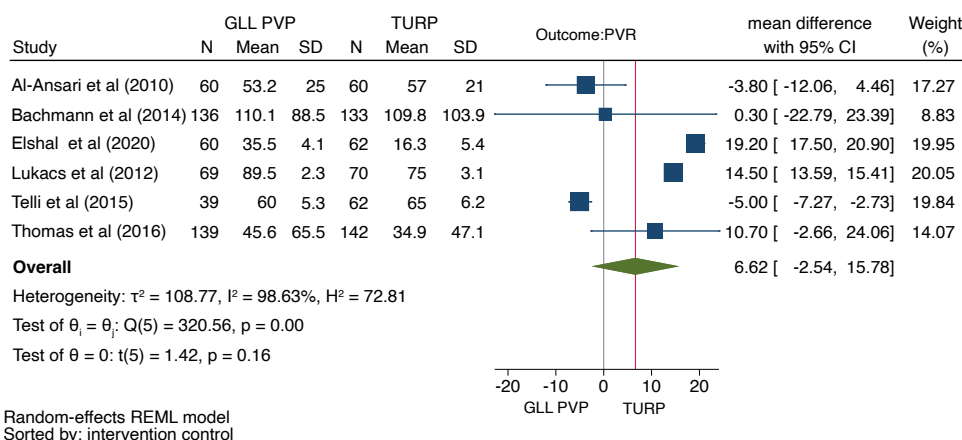
Transl Androl Urol 2022;11(6):842-858 | https://dx.doi.org/10.21037/tau-22-377

Study	GLL PVP N	GLL PVP Mean	GLL PVP SD	TURP N	TURP Mean	TURP SD	Outcome:PVR	mean difference with 95% CI	Weight (%)
Al-Ansari et al (2010)	60	53.2	25	60	57	21		-3.80 [-12.06, 4.46]	17.27
Bachmann et al (2014)	136	110.1	88.5	133	109.8	103.9		0.30 [-22.79, 23.39]	8.83
Elshal et al (2020)	60	35.5	4.1	62	16.3	5.4		19.20 [17.50, 20.90]	19.95
Lukacs et al (2012)	69	89.5	2.3	70	75	3.1		14.50 [13.59, 15.41]	20.05
Telli et al (2015)	39	60	5.3	62	65	6.2		-5.00 [-7.27, -2.73]	19.84
Thomas et al (2016)	139	45.6	65.5	142	34.9	47.1		10.70 [-2.66, 24.06]	14.07
Overall								6.62 [-2.54, 15.78]	

Heterogeneity: τ^2 = 108.77, I^2 = 98.63%, H^2 = 72.81

Test of $\theta_i = \theta_j$: Q(5) = 320.56, p = 0.00

Test of θ = 0: t(5) = 1.42, p = 0.16

Random-effects REML model
Sorted by: intervention control

Figure 11 Comparison of PVR between GLL PVP and TURP. PVR, post-void residue; GLL PVP, GreenLight™ laser photovaporization of the prostate; TURP, transurethral prostatectomy; CI, confidence interval; REML, restricted maximum likelihood; SD, standard deviation.
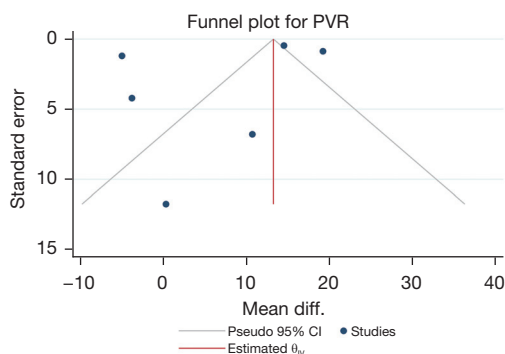
Figure 12 Funnel plot of the PVR meta-analysis of GLL PVP *vs.* TURP. PVR, post-void residue; GLL PVP, GreenLight™ laser photovaporization of the prostate; TURP, transurethral prostatectomy; CI, confidence interval.

prostate after PAE was about 17.56 mm compared with that after TURP. The difference was statistically significant, t=6.02, P=0.00 (*Figure 17*).

Comparison of postoperative Qmax

A total of 254 patients in 4 studies were included in this analysis. The heterogeneity test results were H²=28.63, I²=96.51%, P=0.00, indicating that there was heterogeneity in the 4 studies. The random-effects model based on the restricted maximum likelihood probability method was used to combine mean difference. The results of the meta-analysis showed that the mean difference (95% CI) of postoperative Qmax between the PAE group and the TURP group was –6.97 (–14.32 to 0.38), which was statistically

significant, indicating that there was a statistically significant difference in the effectiveness of the two methods in improving postoperative maximum urinary flow rate Qmax, t=−1.86, P=0.06 (*Figure 18*).

Comparison of postoperative QoL IPSS QoL

A total of 254 patients in four studies were included in this analysis. The heterogeneity test results were H²=6.10, I²=83.62%, P=0.00, indicating that there was heterogeneity in the four studies. The random-effects model based on the restricted maximum likelihood probability method was used to combine mean difference. The results of the meta-analysis showed that the mean difference (95% CI) in IPSS QoL score between the PAE group and the TURP group was –0.06 (–1.04 to 0.93). The difference was statistically significant. Compared with traditional TURP, PAE was shown to improve the QoL score of patients by about 0.06, t=–0.11, P=0.91 (*Figure 19*).

Comparison of PVR

A total of 209 patients in three studies were included in this analysis. The heterogeneity test results were H²=4.36, I²=77.06%, P=0.02, indicating that there was heterogeneity in the three studies. The random-effects model based on the restricted maximum likelihood probability method was used to combine mean difference. The results of the meta-analysis showed that the mean difference (95% CI) of PVR between the PAE group and the TURP group was 31.53 (11.62 to 51.43). The difference was statistically significant, indicating that the improvement of the urinary
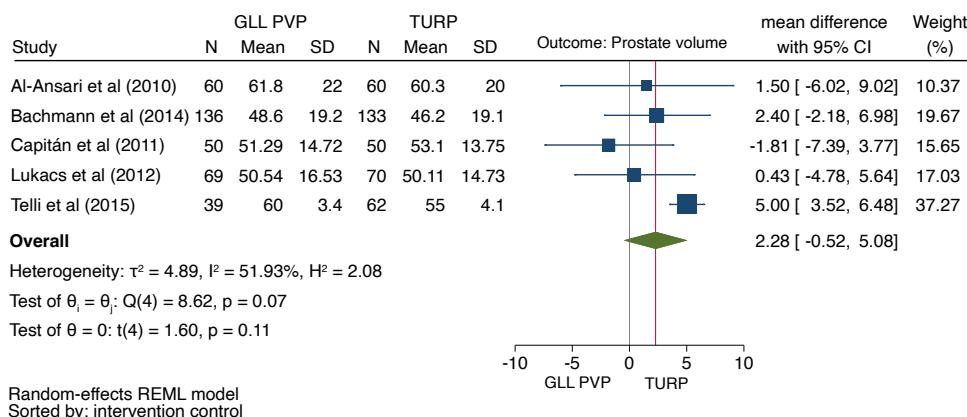
Figure 13 Comparison of PV after GLL PVP and TURP. PV, prostate volume; GLL PVP, GreenLight™ laser photovaporization of the prostate; TURP, transurethral prostatectomy; CI, confidence interval; REML, restricted maximum likelihood; SD, standard deviation.
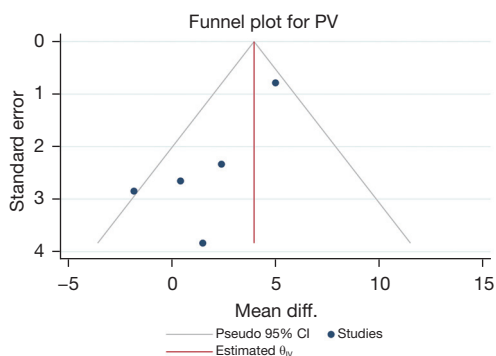

Figure 14 Funnel plot of the PV meta-analysis of GLL PVP *vs.* TURP. PV, prostate volume; GLL PVP, GreenLight™ laser photovaporization of the prostate; TURP, transurethral prostatectomy; CI, confidence interval.

excretion control residue index by PAE was not as effective as traditional TURP, t=3.10, P=0.00 (*Figure 20*).

Comparison of international erectile function index

A total of 209 patients in three studies were included in this study. The heterogeneity test results were H^2=10.46, I^2=90.44%, P=0.00, indicating that there was heterogeneity in the three studies. The random effect model based on the restricted maximum likelihood probability method was used to combine mean difference. The results of the Meta-analysis showed that the mean difference (95% CI) between the PAE group and the TURP on international erectile function index (IIEF-S) was 2.32 (–3.07 to 7.70), and there was no significant difference, indicating that there was no
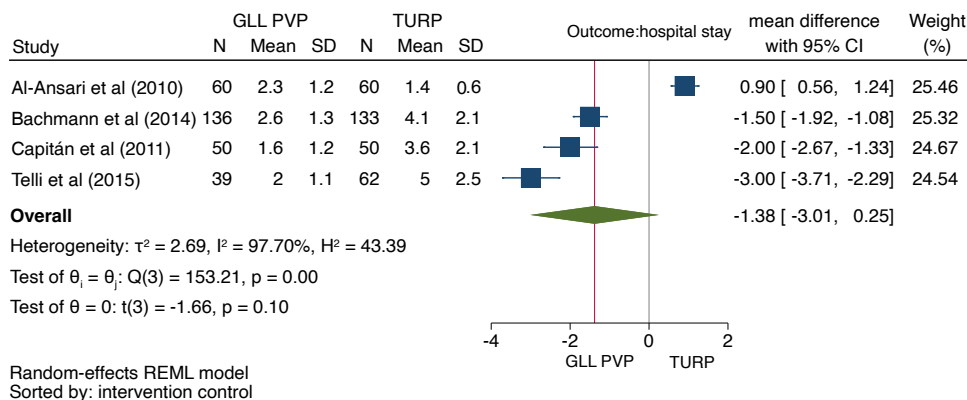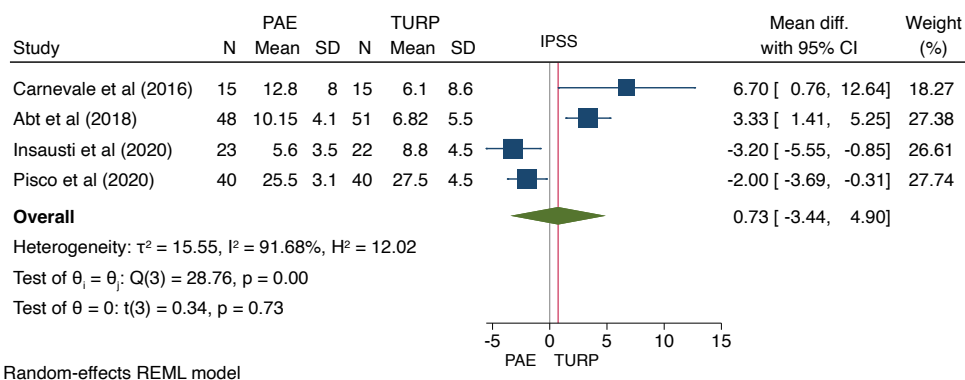

Figure 15 Comparison of hospital stay after GLL PVP and TURP. GLL PVP, GreenLight™ laser photovaporization of the prostate; TURP, transurethral prostatectomy; CI, confidence interval; REML, restricted maximum likelihood; SD, standard deviation.

854

Fu et al. Different surgical methods for BPH

Figure 16 Comparison of IPSS between PAE and TURP. IPSS, international prostate symptom score; PAE, prostate artery embolization; TURP, transurethral prostatectomy; CI, confidence interval; REML, restricted maximum likelihood; SD, standard deviation.
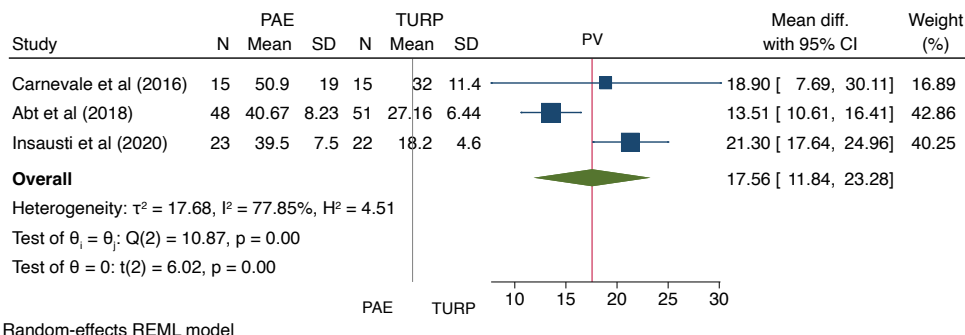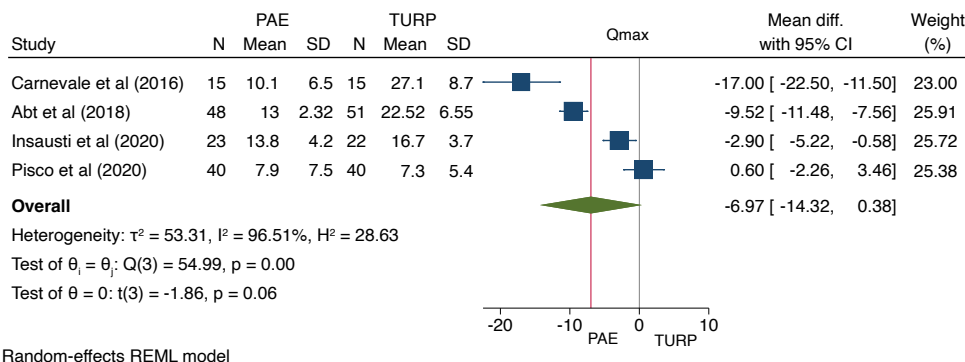

Figure 17 Comparison of PV after PAE and TURP. PV, prostate volume; PAE, prostate artery embolization; TURP, transurethral prostatectomy; CI, confidence interval; REML, restricted maximum likelihood; SD, standard deviation.

Figure 18 Comparison of Qmax after PAE and TURP. Qmax, maximum urinary flow rate; PAE, prostate artery embolization; TURP, transurethral prostatectomy; CI, confidence interval; REML, restricted maximum likelihood; SD, standard deviation.

significant difference in the effectiveness of the two methods for the improvement of international erectile function index IIEF-S, $t=0.84$, $P=0.40$ (*Figure 21*).

Discussion

The procedure of TURP remains the gold standard for treating BPH with a PV of 30–80 mL (15). Although
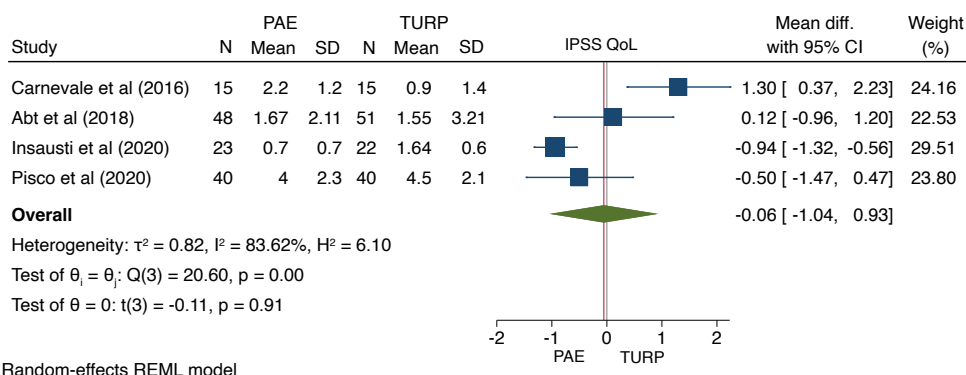
Figure 19 Comparison of IPSS QoL after PAE and TURP. IPSS, international prostate symptom score; QoL, quality of life; PAE, prostate artery embolization; TURP, transurethral prostatectomy; CI, confidence interval; SD, standard deviation; REML, restricted maximum likelihood.
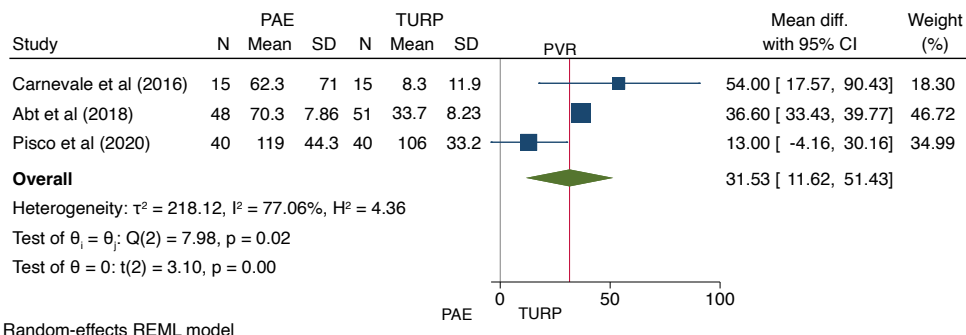

Figure 20 Comparison of PVR between PAE and TURP. PVR, post-void residue; PAE, prostate artery embolization; TURP, transurethral prostatectomy; CI, confidence interval; REML, restricted maximum likelihood; SD, standard deviation; REML, restricted maximum likelihood.
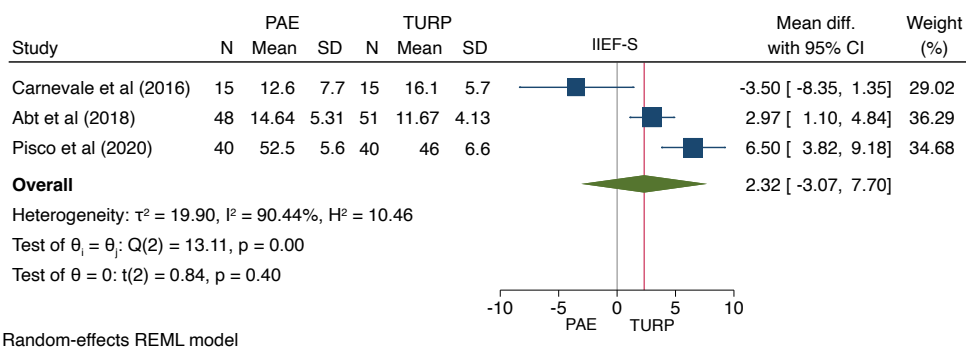

Figure 21 Comparison of international erectile function index IIEF-S between PAE and TURP. IIEF-S, international erectile function index; PAE, prostate artery embolization; TURP, transurethral prostatectomy; CI, confidence interval; REML, restricted maximum likelihood; SD, standard deviation.

856

Fu et al. Different surgical methods for BPH

TURP is more satisfactory than other minimally invasive surgical methods, such as laser vaporization and prostate kernel dissection, and postoperative patient subjective functional indicators such as IPSS, QoL, and IIEF-S, TURP is associated with a significant increase in the incidence of postoperative complications, reoperation rate, and perioperative mortality in patients with a large volume of BPH (>80 mL). Most of them are caused by massive postoperative bleeding (29). More importantly, postoperative complications are higher in patients with long-term use of anticoagulants and PV greater than 80 mL. Therefore, urologists have been trying to find a new minimally invasive endoscopic therapy for BPH. These new methods can be divided into three categories according to their respective treatment principles: resection (piece by piece resection of prostate tissue), vaporization (vaporization of prostate tissue using electrode or laser), and prostate core stripping (stripping large prostate from prostate capsule) including the use of bipolar energy and various laser systems, such as holmium laser, potassium titanium phosphate laser, thulium laser, and diode laser.

The prostate core stripping method uses laser or double electrodes to imitate the traditional prostatectomy. Therefore, some studies have found that the core stripping method usually has better postoperative functional indexes than the resection method and vaporization method, such as Qmax, IPSS, QoL, and so on, because the core stripping method can remove more prostate tissue compared with the other two methods, resulting in a significant reduction in the level of serum PSA (30), Although our results are inconsistent with this, considering that most of the people in the literature comparing vaporization and traditional resection in this study are people with PV greater than 80 mL, which itself has a less favorable postoperative prognosis and the incidence of complications, we speculate that the reason for this result is selection bias. However, this study found that the kernel stripping method can effectively shorten the hospital stay by 1.05 days (–1.81 to –0.28 days), and the difference is statistically significant, which is consistent with other previous studies. In addition, this study found that vaporization has lower postoperative functional improvement than traditional TURP, which is consistent with other previous studies (31).

There were some limitations to this study. We only compared the effectiveness and safety of three different surgical methods for BPH. Due to the research characteristics of systematic review and meta-analysis, we could only follow the grouping method of the experimental group and control group in the original contribution and could not cross-compare the effectiveness and safety of more surgical methods. Secondly, due to the different follow-up times between different studies, the measured postoperative functional indexes were not necessarily homogeneous, which may explain the high heterogeneity of some of our models. In addition, this study did not evaluate more novel surgical methods, such as robot-assisted prostatectomy.

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Footnote

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at https://tau.amegroups.com/article/view/10.21037/tau-22-377/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tau.amegroups.com/article/view/10.21037/tau-22-377/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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