Comparative efficacy and safety of new surgical treatments for benign prostatic hyperplasia: A systematic review and network meta-analysis

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Complete List of Authors:	Tu, Yu-Kang; National Taiwan University, Institute of Epidemiology & Preventive Medicine; National Taiwan University, Institute of Epidemiology and Preventive Medicine Huang, Shi-Wei; National Taiwan University Hospital Yun-lin Branch, Department of Urology Tsai, Chung-You ; Far Eastern Memorial Hospital Tseng, Chi-Shin ; Department of Urology, National Taiwan University Hospital Shih, Ming-Chieh ; Institute of Epidemiology and Preventive Medicine, National Taiwan University Yeh, Yi-Chun; National Taiwan University, Graduate Institute of Epidemiology and Preventive Medicine Chien, Kuo-Liong; Institute of Preventive Medicine, College of Public Health, National Taiwan University PU, Yeong-Shiau ; Department of Urology, National Taiwan University Hospital
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Comparative efficacy and safety of new surgical treatments for benign prostatic hyperplasia: A systematic review and network meta-analysis

Shi-Wei Huang, MD[1], Chung-You Tsai, MD, PhD[2], Chi-Shin Tseng MD[3], Ming-Chieh Shih MD, PHD[4], Yi-Chun Yeh, PHD[5], Kuo-long Chien, MD, PHD[4], Yeong-Shiau Pu, MD, PHD[3], Yu-Kang Tu, DDS, PHD[4,5]

[1] Department of Urology, National Taiwan University Hospital Yun-lin Branch, Taiwan (SW H, MD)

[2]Division of Urology, Department of Surgery, Far Eastern Memorial Hospital, Taiwan (CY T, MD PHD)

[3]Department of Urology, National Taiwan University Hospital, Taiwan (CS T, MD, YS P, MD PHD)

[4] Institute of Epidemiology and Preventive Medicine, National Taiwan University, Taipei, Taiwan (MC S, MD PHD, YK T, DDS PHD, KL C, MD PHD)

[5] Department of Medical Research, National Taiwan University Hospital (YC Y, PHD, YK T, DDS PHD)

Correspondence to: Prof Yu-Kang Tu, Institute of Epidemiology and Preventive

Medicine, National Taiwan University, Taipei Taiwan. 5F, NO. 17, Hsu-Chow Road,

Taipei100, Taiwan

Tel： +886 2 3366-8039; Fax：+886-2-2351-1955; E-mail：yukangtu@ntu.edu.tw

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What is already known

Monopolar transurethral resection has long been the standard treatment of benign prostate hyperplasia.

Many new energy systems (e.g. bipolar electrode, thulium, holmium, diode and KTP laser) emerged after year 2000 and have been used for transurethral treatment of benign prostate hyperplasia.

What this study adds

All endoscopic enucleation methods, whether bipolar electrode, holmium, thulium or diode laser, demonstrated better functional outcomes than vaporization and resection methods.

Eight new methods using bipolar electrode or laser treatments were superior in controlling bleeding (intraoperatively and postoperatively) to monopolar TURP.

ABSTRACT

Objectives

To assess the efficacy and safety of different endoscopic surgical treatments of benign prostate hyperplasia.

Design

Systematic review and network meta-analysis of randomized controlled trials.

Data sources

A comprehensive search of Pubmed, Embase, and Cochrane databases from each database's inception to March 31, 2018 was conducted.

Study selection

We included randomized controlled trials to compare vaporization, resection, and enucleation of the prostate using monopolar, bipolar, or various laser systems (holmium, thulium, potassium titanyl phosphate, or diode) for surgical treatments of BPH. The primary outcomes were maximal flow rate (Qmax), and the International Prostate Symptoms Score (IPSS) at 6, 12, 24, and 36 months after surgery. Secondary outcomes were perioperative parameters and surgical complications.

Data extraction and synthesis

Two independent reviewers extracted the study data and performed quality assessments using the Cochrane Risk of Bias Tool. The effect sizes were summarized using weighted mean differences for continuous outcomes and risk ratios for binary outcomes. Frequentist approach to the network meta-analysis was used and ranking probabilities of each treatment were calculated in terms of comparative effects and safety.

Results

We identified 105 trials that enrolled a total of 13,176 participants. Nine surgical treatments were evaluated. Enucleation achieved better Qmax and IPSS than resection and vaporization at 6 and 12 months after surgery, and the difference maintained up to postoperative 24 and 36 months. For 12-month Qmax, the best 3 methods, compared to monopolar TURP, were diode laser enucleation [mean difference (95% Confidence Interval): 3.15 (0.63 to 5.67) ml/sec], bipolar enucleation [2.80 (1.43 to 4.16)] and holmium laser enucleation [1.13 (0.13 to 2.13)]. The worst was diode laser vaporization [-1.90 (-5.04 to 1.24)]. Eight new methods were all superior in controlling bleeding than monopolar TURP, resulting in shorter catheterization duration, reduced postoperative hemoglobin declination, fewer blood clot tamponade events and lower blood transfusion rate. However, short-term transient urinary incontinence might still be a concern for enucleation methods. No inconsistency between direct and indirect evidence was detected in either primary or secondary outcomes.

Conclusion

Eight new endoscopic surgical methods for BPH were superior in safety compared with monopolar TURP. Enucleation methods showed better Qmax and IPSS than vaporization and resection. The efficacy of vaporization in large prostates seems questionable.

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INTRODUCTION

Lower urinary tract symptoms caused by benign prostatic hyperplasia (BPH) is the most common urological problem among men. Approximately one-third of men over the age of 50 are affected by this problem.[1 2] Surgical intervention is the most effective treatment for BPH, with around 100,000 procedures carried out annually in the United States.[3] Of all the surgical treatments, monopolar transurethral resection of the prostate (TURP), in which the enlarged prostate tissue is resected piece by piece using a monopolar electrode, has been the gold standard since the 1970's. It can substantially improve the maximal flow rate (Qmax), urinary symptoms (International Prostate Symptom Score, IPSS) and health-related life of quality, with long-term durability compared to medications or other minimally invasive treatments.[4 5] However, monopolar TURP is a risky procedure because of the likelihood of severe complications such as massive bleeding or transurethral resection (TUR) syndrome.[6] Therefore, it has been of paramount importance to develop minimally invasive surgical techniques with outcomes similar to those of monopolar TURP, but with fewer side effects.[5]

Since the year 2000, new energy systems for BPH surgical interventions quickly became popular including systems that use bipolar energy and various laser systems, such as the holmium laser, potassium-titanyl-phosphate (KTP) laser, thulium laser, and diode laser.[7 8] The trend in BPH surgical therapy has shifted from monopolar TURP to the laser therapies and bipolar TURP over the past 10 years.[3] Bipolar energy can be used to incise, resect, and vaporize prostate tissue using different electrodes. Holmium and thulium laser beams are mainly absorbed by water, and they act as incisional lasers. The KTP laser is selectively absorbed by hemoglobin, and debunks prostate tissue through vaporization. The diode laser is absorbed by water and hemoglobin and hence, can vaporize and incise prostate tissue. These new methods all use normal saline instead of distilled water to avoid hyponatremia. They can be further divided into three types according to their treatment principles: resection methods (resection of prostate tissue piece by piece), vaporization methods (vaporization of excessive prostate tissue), and enucleation methods (peeling the enlarged prostate from the prostate capsule). The nomenclature and abbreviations of the 8 new surgical methods are listed in Table 1. These new methods are all intended to replace monopolar TURP, which is the standard surgical treatment for BPH.

The aim of this study was to conduct a systematic review and network meta-analysis to investigate the new surgical methods and determine which of them achieves the best functional outcome with fewer complications by evaluating data from published randomized controlled trials.

MATERIALS AND METHOD

Search strategy and selection criteria

This study followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-analyses.[9] The method and analysis was pre-specified in advance and registered on the PROSPERO website (CRD42018099583). To identify published and unpublished trials, we used electronic databases including Pubmed (1966-March 2018), Embase (1974-March 2018), and Cochrane clinical trials registers (inception-March 2018) without language or date restriction, as well as performing manual searches of literature. The detailed study protocol including search terms and searching strategies is provided in the supplement file and supplementary table1**.** We recruited randomized parallel-group design clinical trials comparing any 2 different methods among 9 surgical methods. The 9 methods are listed in Table1. The inclusion criteria were a maximum flow rate <15 mL/s and IPSS >8, and the exclusion criteria were neurogenic bladder, previous urethral, prostate, or bladder surgeries, and suspected prostate cancer.

Outcome measures

The outcome measures for the analysis included: (1) functional outcomes: Qmax and IPSS at 6, 12, 24, and 36 postoperative months; (2) perioperative parameters: catheterization duration and hemoglobin declination (Hb-decline); (3) short-term complications including TUR syndrome, blood clot tamponade, blood transfusion, urinary tract infection, re-catheterization and incontinence; (4) long-term complications including urinary strictures, retrograde ejaculation, and recurrence (BPH recurrence requiring re-operation or repeat apical resection). The long-term complications were only included if the data were from trials with more than 3 months' follow-up.

Data extraction and quality assessment

Two reviewers (HSW, TCS) independently screened the titles and abstracts of the articles for eligibility in this study. They then assessed the full articles to confirm whether they fulfilled the eligibility criteria. We developed a data extraction form, which we pilot-tested in 10 randomly included studies, and then refined it accordingly. Two reviewers (HSW, TCS) extracted the data independently and then cross-checked the data. We used Cochrane Collaboration's Risk of Bias (ROB) tool to appraise the quality of articles.[10] Any unresolved discrepancies in data extraction or appraisal of the results were evaluated by a third reviewer (TCY) who acted as an arbiter.

We attempted to contact some authors about missing data, and several authors responded. When standard deviation (SD) data were missing, or only the pre-therapy SDs were available, we calculated SD with formulae described in Cochrane handbook for systematic reviews of interventions[10] or measured it from the article's figures. If the authors only reported medians, we used medians as means and IQR3-IQR1/1.35 as the SDs.[11]

Statistical methods

We first conducted a pairwise random effect meta-analysis using the Dersimonian and Laird method. The weighted mean differences and risk ratio reductions were reported for continuous and binary variables, respectively. Heterogeneity was assessed by visual inspection of the forest plot and statistically test using I^2 statistics.[10]

Next, we undertook a frequentist network meta-analysis for each outcome separately. For the continuous variables such as functional outcomes and perioperative parameters, we performed a trial-based network meta-analysis in STATA (StataCorp.2011. Stata Statistical Software: Release 14. College Station, TX), using the 'meta' and 'mvmeta' commands for pairwise and multiple treatment comparisons, respectively, and self-programmed the STATA routines.[12]

For dichotomous variables such as complications, rare and zero events were noted. Trials with zero events in all arms of each outcome were deleted during the analysis since they offered no valuable information. We applied a 0.5 zero-cell correction only in the pairwise meta-analysis as a default of the STATA meta command but not in the network-meta-analysis to obtain a more unbiased estimation.

We evaluated the potential inconsistencies between the direct and indirect evidence within the network met-analysis using the loop inconsistency[13] and design-by-treatment interaction model.[14]

We further estimated the probabilities of each of the treatments being at each possible rank for each intervention and each outcome. We obtained a treatment hierarchy using the surface under the cumulative ranking curve (SUCRA) and mean ranks.[15]

Sensitivity analysis

Prostate size could affect the outcomes of the different surgical treatment methods, i.e, large prostates might be better suited to treatment via enucleation methods, and less effectively treated using vaporization methods. We performed a meta-regression analysis according to the mean prostate volume data provided in each trial report. To increase the power of the meta-regression and assuming that the functional outcomes would be similar with similar surgical techniques, we grouped the 9 methods into 4 types: enucleation, vaporization, bipolar TURP, and monopolar TURP. Besides, we further compared short-term transient incontinence (< 1 month postoperatively) and permanent incontinence rate (>6-12 months postoperatively) between enucleation (excluding vapo-enucleation) and resection methods.

This research was done without patient involvement. Patients were not invited to comment on the study design and were not consulted to develop patient relevant outcomes or interpret the results. Patients were not invited to contribute to the writing or editing of this document for readability or accuracy.

RESULTS

The flow chart in supplementary figure 1 shows the literature search process for the eligible trials. We identified 1679, 3297, and 219 articles from Pubmed, Embase, and the Cochrane clinical trials, respectively. After eliminating 1564 duplicate articles, the total number of articles was 3631. Of those, 3419 articles were excluded on the basis of the abstract and title reviews. Of the remaining 212 articles wherein the full texts were reviewed, 131 articles in 105 trials met our inclusion criteria for the systematic review and meta-analysis.

The 105 eligible trials enrolled a total of 13176 participants and evaluated 9 different surgical treatments for BPH with 20 direct comparisons. Among those 105 trials, 4 had 3 arms and 101 had 2 arms, and the majority of the comparisons included bipolar TURP, bipolar VP, Holmium LEP, and KTP LVP with monopolar TURP methods (Figure1). The clinical and methodological characteristics and the studied outcomes in each trial are summarized in supplementary table 2-4. The baseline characteristics including age, preoperative IPSS, Qmax, and QOL were similar in all the trials; however, mean prostate volume was not. The medians±IQRs were 68.0±4.3, 7.2±1.9, 23.2±2.8 and 4.50±0.60 for age, Qmax, IPSS, and QOL, respectively. Among

99 trials that provided preoperative mean prostate volume data, 5, 56, and 38 trials showed mean prostate volumes <=40, 40-60, >60 ml, respectively.

The ROB assessment is shown in supplementary figure 2. High ROB was rare in any domain. However, unclear ROBs were common, since some articles did not describe the randomization methods, nor whether the participants or outcome assessors were blinded. Regarding selective reporting, only 27% of trials were judged as having low ROB in reporting complications because they used modified Clavien-Dindo classifications[16] or provided detailed reports of the complications.

Functional outcomes

A network of eligible comparisons for the primary outcome are presented in Figure1 and supplementary figure3; 48, 51, 18, 14 and 48, 50, 17, and 14 trials reported postoperative 6-, 12-, 24-, 36-month Qmax values and 6-, 12-, 24-, 36-month IPSS values, respectively. These include predominately pairwise comparisons of bipolar TURP, bipolar VP, Holmium LEP, and KTP LVP with monopolar TURP, for 6-12-month postoperative Qmax and IPSS values. However, only seven methods reported outcomes for 24-36-month postoperative follow-up, and these were predominantly pairwise comparisons of bipolar TURP with monopolar TURP.

We summarized our random-effects network meta-analysis and pairwise comparison of functional outcomes in supplementary table 5, 6. We ranked the comparative effects of 8 new methods against the monopolar TURP and the SUCRA probability (Figure 2; see supplementary Figure 5).

The 4 enucleation methods were ranked highly, followed by the resection and vaporization methods with respect to the 6- and 12-month postoperative Qmax values. The mean differences ranged from 2.90 (95% confidence interval, 1.11 to 4.69) ml/sec for the highest ranked treatment (Bipolar EP) to -0.67 (-2.38 to 1.05) ml/sec for the lowest ranked treatment (KTP LVP) at 6 months postop and 3.15 (0.63 to 5.67) ml/sec for the highest ranked treatment (Diode enucleation) to -1.90 (-5.04 to 1.24) ml/sec for the lowest ranked treatment (Diode vaporization) at 12 months postop. Some treatments (Diode LEP, bipolar EP, Holmium LEP, and bipolar TURP) reached statistical significance in 12-month postoperative Qmax compared with monopolar TURP. The significant differences and ranking persisted for postoperative 24 and 36 months.

The enucleation methods also ranked higher than the resection and vaporization methods in the 6- and12-months postoperative IPSS. The mean difference compared with monopolar TURP ranged from -0.70 (-1.92 to 0.52) for the highest ranked treatment (Bipolar EP) to 0.70 (-2.41 to 3.81) for the lowest ranked treatment (Diode LVP) in 6-month postoperative IPSS and -1.25 (-2.95 to 0.45) for the highest ranked treatment (Diode LEP) to 1.30 (-1.17 to 3.77) for the lowest ranked treatment (Diode

LVP) in 12-month postoperative IPSS.

Perioperative parameters

The duration of catheterization was reported in 79 trials. All methods using laser energy (Diode, Thulium, Holmium, KTP) were ranked higher follow by bipolar energy, but all were better than monopolar TURP. Compared with monopolar TURP, catheterization duration decreased from 48.72 (29.99 to 67.46) hours for the highest ranked treatment (Diode LVP) to 11.50 (6.64 to 16.37) hours for bipolar TURP. (Figure 3)

Hb-decline was reported in 67 trials, vaporization and enucleation methods were ranked higher than bipolar TURP, and all were better than monopolar TURP. Compared with monopolar TURP, Hb-decline decreased from 1.25 (0.84 to 1.66) mg/dl for the highest ranked method (KTP LVP) to 0.19 (0.01 to 0.37) mg/dl for the lowest ranked method (Bipolar TURP) (Figure 3).

Complications

Short-term complications, including TUR syndrome, re-catheterization, blood clot tamponade, blood transfusion, incontinence, and long-term related complications including recurrence, urethral stricture, and retrograde ejaculation were analyzed. The results of the network meta-analysis and pairwise comparison are shown in supplementary Table 6 and supplementary Figure 5. Since theses adverse events were sparse and even zero in some trials, some of the interventions were lacking data for comparisons.

Regarding TUR syndrome, no events were reported in the new methods. Blood clot tamponade events and blood transfusion events were reported in 57 and 86 trials, respectively. Vaporization and enucleation methods using either laser or bipolar energy were ranked higher than bipolar TURP, and all were better than monopolar TURP. Compared with monopolar TURP, the odds ratio (OR) ranged from 0.12 (95% confidence interval; 0.02 to 0.76) for the highest ranked method (Bipolar EP) to 0.49 (0.32 to 0.74) for the lowest ranked method (Bipolar TURP) in blood clot tamponade and 0.05 (0.01 to 0.22) for the highest ranked method (Holmium LEP) to 0.42 (0.28 to 0.61) for the lowest ranked method (Bipolar TURP) in blood transfusion.

In the 69 trials that reported re-catheterization events, enucleation methods ranked higher then resection methods and vaporization methods showed the worst outcomes. Compared with monopolar TURP, the OR ranged from 0.24 (0.09 to 0.64) for the highest ranked method (Bipolar EP) to 2.18 (0.34 to 13.9) for the lowest ranked method (Diode LVP). Recurrence was reported in 29 trials. Enucleation methods and bipolar TURP performed better than vaporization methods (Figure 3).

Retrograde ejaculation, urinary tract infection, incontinence, and stricture were reported in 17, 44, 49, and 81 trials, respectively. There was no obvious difference between the different methods and monopolar TURP for these complications. (see supplementary Figure 4 and Table 5).

Sensitivity analysis and inconsistency

For postoperative Qmax, the meta-regression showed that mean prostate volume moderated the treatment effect of different surgical methods. (Table 2) In the large prostate group (mean PV >70 gm), enucleation methods improved the Qmax by 5.47 (2.03 to 8.91) and 4.60 (0.85 o 8.34) ml/sec more than the vaporization method in the 6- and 12- month postoperative Qmax values, respectively. In contrast, if the mean PV<70 gm, enucleation only improved Qmax by 0.54 (-1.01 to 2.08) ml/sec and 0.52 (-0.58 to 1.62) ml/sec more than vaporization at 6 and 12 postoperative months, respectively. Compared with resection methods, enucleation methods had more events of short-term transient urinary incontinence than resection methods. (OR=1.91, 95% CI; 1.35 to 2.71) In contrast, permanent incontinence was rare regardless of enucleation or resection and there was no significant difference between these two methods. (OR for Enucleation vs. resection: 1.23, 95% CI, 0.29 to 5.22) (see supplementary Table 7)

We found no evidence of inconsistency in any primary or secondary outcomes using either loop inconsistency or the design by treatment interaction models. (see supplementary Table 8). Besides, comparison-adjusted funnel plot also showed no small study bias in primary outcomes (see supplementary Figure 4). Heterogeneity was high in many pairwise comparisons of primary outcomes. In contrast, there was low heterogeneity in secondary outcomes (see supplementary Table 6).

DISCUSSION

Principal finding

In our study, enucleation methods, including bipolar EP, holmium, thulium, and diode LEP, yielded greater Qmax values at 6-12-months after surgery than did the resection and vaporization methods, and the difference could still be observed at 24-36 months after treatment. The advantages of the enucleation over vaporization methods were mainly observed in large prostates. Enucleation methods also achieved better IPSS than resection and vaporization methods, although the difference was not statistically significant. The new methods were generally safer than monopolar TURP. They were less likely to require patient transfusion, cause blood clot tamponade, lead to postoperative hemoglobin decline, or cause TUR syndrome. Our findings support changes in the surgical treatment for BPH from monopolar TURP to new surgical methods.

Surgical treatment is usually reserved for patients in whom medications fail to achieve satisfactory outcomes. Consequently, patients are older at the time when surgical interventions are considered, leading to more comorbidities.[17 18] The new methods are therefore more suitable for these patients. Besides, the treatment goals for BPH are not only to relieve lower urinary tract symptoms, but also to prevent BPH-related adverse events, such as acute urinary retention, renal function deterioration, or bladder dysfunction. However, with the widespread use of medications, the prevalence of adverse BPH-related events had increased from 1998 to 2008.[19 20] Besides, Flanigan and colleagues (1998) found that patients who underwent immediate TURP had greater improvements in Qmax and IPSS than men who were followed with an extended period of watchful waiting.[21] This seems to be a consequence of the delay in effective treatment. As new surgical methods showed fewer complications but achieved similar or even better effects compared to monopolar TURP, early surgical treatments may be considered, to avoid BPH-related adverse events.

Enucleation methods using fiberoptic lasers or bipolar loops mimic open prostatectomy.[22] It is not surprising that enucleation methods achieve the best Qmax values compared to resection and vaporization methods since enucleation removes more tissue and results in greater PSA reduction than resection and vaporization.[23] Our analysis showed that vaporization methods seemed to yield a higher BPH recurrence rate than enucleation or resection methods did.

A previous meta-analysis of 6 RCTs with 541 patients found that the holmium LEP achieved better Qmax values at 12 months after surgery than monopolar TURP, although there were no differences in IPSS.[24] Another meta-analysis that compared KTP LVP and monopolar TURP comprised 6 RCTs and 5 case-control studies with in total 889 patients.[25] That report found no difference in Qmax and IPSS when the prostate size was <70 ml, but the Qmax and IPSS in the KTP LVP group were lower when the prostate size was >70. Our results confirmed that the enucleation method was better than resection when either bipolar or laser energy were used, although the vaporization method was not suitable for large prostates.

Complications

Both TUR syndrome and bleeding are the major complications of monopolar TURP. No cases of TUR syndrome associated with the 8 new methods was reported since all the new techniques used normal saline instead of distilled water for intraoperative irrigation.

Regarding bleeding, our study demonstrated that the 8 new methods yielded better outcomes than monopolar TURP, both intraoperatively and postoperatively. Enucleation and vaporization methods were better than resection methods regardless of the energy system used. Vaporization also produced coagulation effects, thereby leading to less bleeding. Only once during an enucleation procedure was a bleeding vessel encountered in the capsule region, compared to several times during resection procedures. This may have contributed to the decrease in blood loss associated with enucleation. With respect to postoperative bleeding, shorter catheterization durations and fewer blood clot tamponade events were associated with less postoperative bleeding and better hemostatic effects. Laser energy, especially diodes and KTP, showed advantages over bipolar and monopolar energy in postoperative bleeding. Shorter catheterization durations and fewer blood clot tamponade events may lead to a shorter hospital stay, reduced hospital cost and re-admission.

Regarding the re-catheterization rate, the enucleation method was also better than resection, and vaporization was the worst. Enucleation methods remove more apical prostate tissue, while vaporization methods remove less of the apical prostate tissue because of the risk of sphincter injury.[26] Hence, some surgeon resect the apex of the prostate after vaporization, to overcome the drawbacks of vaporization.[27]

Our study showed that enucleation methods yielded better results for functional outcomes and equivalent safety compared to vaporization methods. However, the risk of short-term transient incontinence was higher in enucleation than in resection methods. Liu et al compared bipolar EP with bipolar TURP and found that after Foley removal, the incontinence rate was higher in enucleation than in resection at 24 hours (35.6 % vs 18.9%, $p<0.01$) and one week (20% vs 7.8%, $p<0.05$).[28] There was no difference after two weeks postoperatively (3.3% vs 2.2 % at 2 weeks). Hence, some authors used vapoenucleation or modified techniques to reduce the transient incontinence rate.[29]

Monopolar electrode or Nd-YAG laser had been used for vaporization of prostate. However, they was not widely adopted because of inferior long-term results, less efficiency, or greater complications compared to monopolar TURP.[26 30] Bipolar electrode, KTP and diode laser are new energy systems for vaporization. Our results suggest that these new vaporization methods still achieve poorer Qmax or IPSS than enucleation and resection methods. However, these differences were mainly observed in the treatment of large prostates. Besides, the technique is much easier and the bleeding problems are less, especially when using the KTP and diode lasers. Hence, vaporization using new energy system is a promising technique for those with smaller prostates, and among select patients with higher bleeding risks and those more suited for outpatient surgery. Some authors have tried to use a hybrid method (vaporization with resection) to improve the efficacy of vaporization.[31] As the higher energy of the laser is evolving, it obviously improves the efficiency of vaporization. Whether it can improve functional outcomes, especially in patients with large prostates, will required further research.[32]

Regarding bipolar energy, we evaluated bipolar enucleation, resection, and vaporization simultaneously. The efficacy and complication rates were better with bipolar EP and bipolar TURP than with monopolar TURP. Compared with the laser systems, the bipolar energy machine is multi-functional, and the equipment and medical consumable materials are less expensive.[33] Bipolar energy is a promising energy system for BPH surgery and more useful in developing countries. The use of enucleation, resection, or vaporization methods depends on the surgeon's personal preference and the patient's condition, accounting for factors such as prostate volume and comorbidities.

The strength of our research is that we simultaneously compared nine different surgical treatments for BPH surgery using a network meta-analysis. We compared 6-, 12-, 24-, and 36-month postoperative Qmax and IPSS to evaluate the sustainability of different treatments. Besides, we only included randomized controlled trials without language restrictions to avoid bias.

Our network meta-analysis has some limitations. First, the complications were rare, and some trials reported zero events, resulting in a less precise estimation of the pooled ORs. However, the heterogeneity is low and also favored new methods in pairwise comparisons. Second, the functional outcomes were assessed blindly in only 25% of the trials. This may have led to a bias in favor of the new methods. Besides, heterogeneity is high in many comparisons of primary outcomes. Initial prostate volume, the degree of urodynamic obstruction and surgeon experience may account for the high heterogeneity of functional outcomes. Third, we did not analyze early postoperative urinary symptoms such as dysuria, urgency, or post-micturition pain. Few articles reported short-term urinary symptoms, and their measurements were not standardized. Although these symptoms affect short-term patient satisfaction, they usually improved with medications by 2-3 months after surgery. Fourth, we did not differentiate vapo-enucleation from enucleation, since the definition and difference in techniques between vapo-enucleation and enucleation is not standardized. Hence, the differences in the outcomes between vapo-enucleation and enucleation or different enucleation methods necessitates further investigation. Fifth, some new methods for treatment of BPH, such as prostatic urethra lift, prostate artery embolization (PAE), robotics simple prostatectomy and water vaporization were not included in our review. Urethrae lift and PAE are mainly used in patients not suitable for surgery or anesthesia, while robotic simple prostatectomy is indicated for extremely large prostates. Water vaporization was first introduced in 2016 and the randomized controlled trials comparing with TURP from the literature is still lacking. As the target patient population of these new methods is different from that in our review, we therefore excluded these methods in our network meta-analysis.

Conclusion

Eight new endoscopic surgical methods for BPH were superior in safety compared with monopolar TURP. Enucleation methods demonstrated better Qmax and IPSS after surgery than vaporization and resection methods. The efficacy of vaporization in large prostates seems questionable.

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Figure legends

Figure 1: Network treatments comparisons for all studies and maximal flow rate

A: comparisons of all treatment (all studies); B: 6-month postoperative Qmax, C: 12-month postoperative Qmax. The size of the nodes corresponds to the number of trials in which the treatments were studied. The interventions that are compared directly are joined with a line, the thickness of which corresponds to the number of trials that assessed the comparisons, and the number is shown on the line.

Figure 2: Network meta-analysis of the functional outcomes after performance of the new surgical methods compared with monopolar TURP

Common heterogeneity variables for all comparisons in this network meta-analysis included: τ=1.97, 1.11, 1.05,0.72, 1.58, 1.07, 0.98, and 0.75, with reference to 6-month, 12-month, 24-month and 36-month postoperative Qmax values, and 6-month, 12-month, 24-month, 36-month IPSS values, respectively. Treatments are ranked according to the SUCRA values

SUCRA: surface under the cumulative ranking; TURP: transurethral resection of the prostate

Figure 3: Network meta-analysis of perioperative parameters and some complications of the new surgical methods compared with monopolar TURP

Common heterogeneity variables for all comparisons in this network meta-analysis included: τ= 0.39, 12.1 0.57, 0.05, and 0 and 0, with reference to Hb-decline, duration of catherization, blood clot tamponade, blood transfusion, re-catheterization, and recurrence, respectively;

Treatments are ranked according to the SUCRA values

[#]0 events in either new method or monopolar TURP group

TURP: transurethral resection of the prostate; SUCRA: surface under the cumulative ranking

Table 1 Nomenclature of the nine methods of BPH surgery

Surgical technique	Abbreviation	Surgical Method (full terminology)	Energy Source	Alias
Resection	Monopolar TURP	Monopolar transurethral resection of prostate	monopolar	M-TURP
	Bipolar TURP	Bipolar transurethral resection of prostate	bipolar	B-TURP
Enucleation	Thulium LEP	Thulium laser enucleation of prostate	thulium laser	ThuLEP
	Holmium LEP	Holmium laser enucleation of prostate	holmium laser	HoLEP
	Diode LEP	Diode laser enucleation of prostate	diode laser	DioLEP
	Bipolar EP	Bipolar enucleation of prostate	bipolar	Bipolar TUEP
Vaporization	Diode LVP	Diode laser vaporization of prostate	diode laser	DioLVP
	KTP LVP	Potassium-titanyl-phosphate laser vaporization of prostate	KTP laser	PVP, Greenlight
	Bipolar VP	Bipolar vaporization of prostate	bipolar	Bipolar TUVP

BPH: benign prostatic hypertrophy

Table 2. A subgroup analysis of the network estimated mean differences (95% confidence intervals) in postoperative Qmax compared with monopolar TURP according to prostate volume

Six-month postoperative Qmax	Mean PV		>70 gm	<70 gm	*P* for treatment by prostate size interaction	>60 gm	<60 gm	*P* for treatment by prostate size interaction
	Trials (N=) / Methods	43	10	33		17	26	
	bipolar TURP	0.66 (-0.60 to 1.92)	0.36 (-3.02 to 3.73)	0.70 (-0.53 to 1.92)	0.015	0.21 (-2.35 to2.77)	0.86 (-0.51, 2.23)	0.024
	Enucleation	1.52 (0.36 to 2.69) #	2.37 (-0.65 to 5.38)	0.62 (-0.57 to 1.82)		1.85 (-0.41 to 4.1)	0.29 (-1.07, 1.65)	
	vaporization	-0.44 (-1.61 to 0.73)	-3.12 (-7.15 to 0.89)	0.10 (-0.97 to 1.17)		-2.49 (-5.39 to -0.41)	0.20 (-0.88 to 1.29)	
	Enucleation vs vaporization	1.98 (0.55 to 3.41) #	5.47 (2.03 to 8.91)*	0.54 (-1.01 to 2.08)		4.32 (1.69 to 6.95)*	0.09 (-1.65 to 1.83)	

Twelve-month post-operative Qmax	Mean PV		>70 gm	<70 gm	P for treatment by prostate size interaction	>60 gm	<60 gm	P for treatment by prostate size interaction
	Trials (N=) / Methods	45	7	38		17	28	
	bipolar TURP	0.63 (-0.16 to 1.42)	0.05 (-3.36 to 3.45)	0.85 (0.21 to1.49)*	0.002	0.98 (-0.67 to 2.63)	0.73 (0.03 to 1.42)	0.047
	Enucleation	1.49 (0.59 to 2.40)#	2.83 (-0.21 to 5.87)	0.65 (-0.17 to 1.48)		2.51 (0.83 to 4.19)*	0.39 (-0.56 to 1.33)	
	vaporization	-0.21 (-1.19 to 0.76)	-1.77 (-6.43 to 2.88)	0.13 (-0.65 to 0.92)		-0.35 (-2.78 to 2.09)	-0.03 (-0.81 to 0.76)	
	Enucleation vs. vaporization	1.71 (0.53 to 2.88)#	4.60 (0.85 to 8.34)*	0.52 (-0.58 to 1.62)		2.85 (0.50 to 5.20)#	0.41 (-0.81 to 1.62)	

Results are mean differences (95% confidence intervals)

*$P < .01$

#$p < .05$

PV: prostate volume; TURP: transurethral resection of the prostate; Qmax: maximal flow rate

Enucleation: includes bipolar EP, holmium LEP, thulium LEP and diode LEP, vaporization: include bipolar VP, KTP LVP, diode LVP

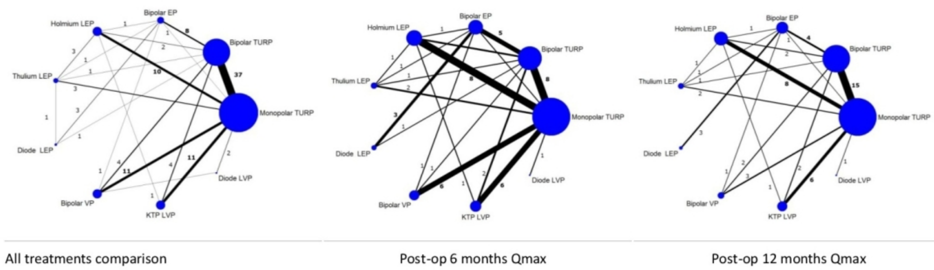

Figure 1

281x85mm (144 x 144 DPI)

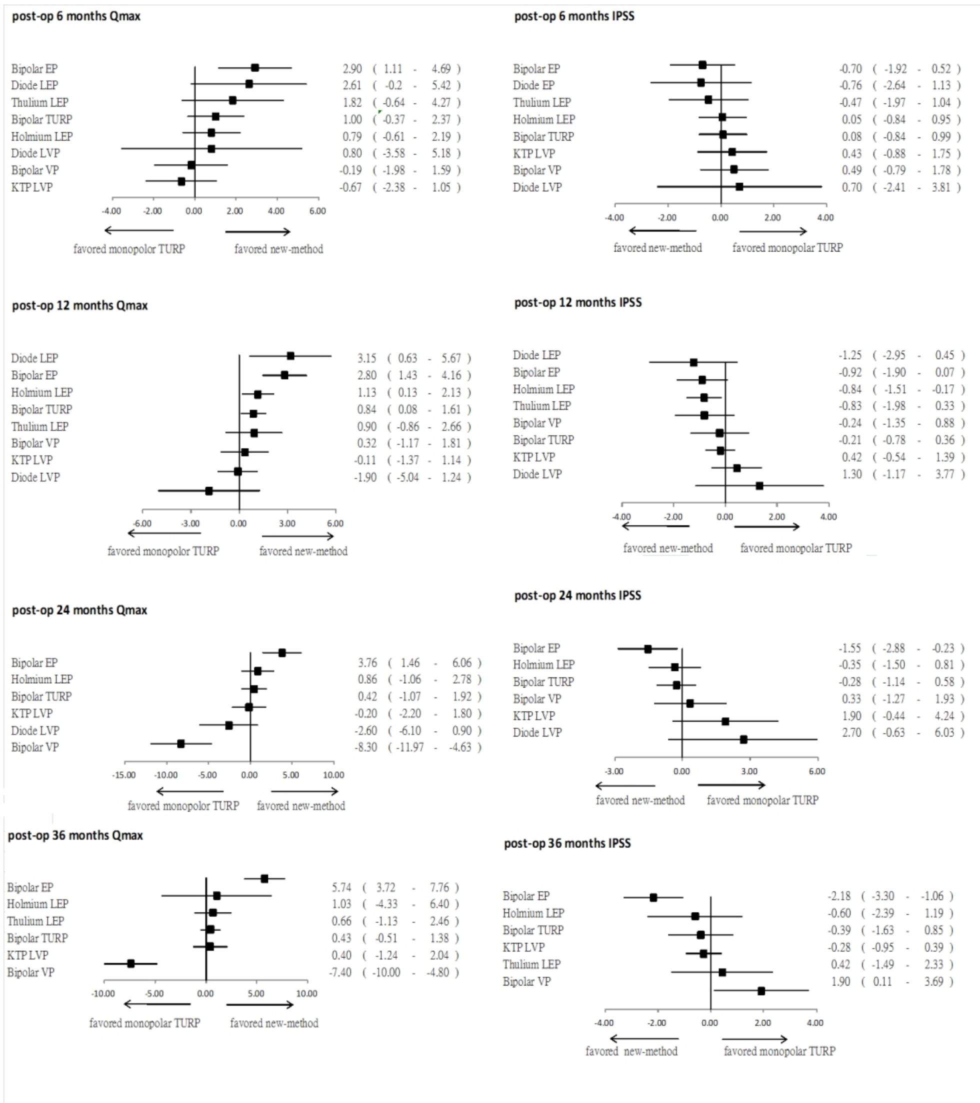
post-op 6 months Qmax
post-op 6 months IPSS
post-op 12 months Qmax
post-op 12 months IPSS
post-op 24 months Qmax
post-op 24 months IPSS
post-op 36 months Qmax
post-op 36 months IPSS
favored monopolor TURP
favored new-method
favored monopolar TURP

Figure 2

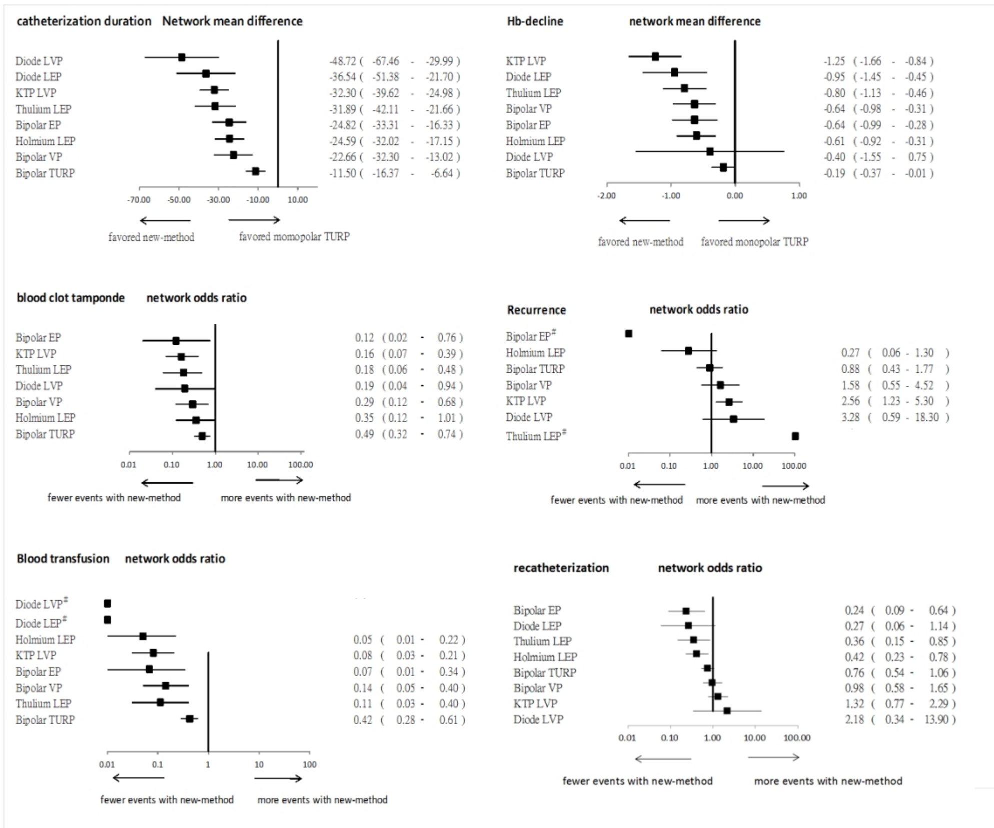
catheterization duration Network mean difference
Diode LVP -48.72 (-67.46 - -29.99)
Diode LEP -36.54 (-51.38 - -21.70)
KTP LVP -32.30 (-39.62 - -24.98)
Thulium LEP -31.89 (-42.11 - -21.66)
Bipolar EP -24.82 (-33.31 - -16.33)
Holmium LEP -24.59 (-32.02 - -17.15)
Bipolar VP -22.66 (-32.30 - -13.02)
Bipolar TURP -11.50 (-16.37 - -6.64)
-70.00 -50.00 -30.00 -10.00 10.00
favored new-method
favored momopolar TURP
Hb-decline network mean difference
KTP LVP -1.25 (-1.66 - -0.84)
Diode LEP -0.95 (-1.45 - -0.45)
Thulium LEP -0.80 (-1.13 - -0.46)
Bipolar VP -0.64 (-0.98 - -0.31)
Bipolar EP -0.64 (-0.99 - -0.28)
Holmium LEP -0.61 (-0.92 - -0.31)
Diode LVP -0.40 (-1.55 - 0.75)
Bipolar TURP -0.19 (-0.37 - -0.01)
-2.00 -1.00 0.00 1.00
favored new-method
favored monopolar TURP
blood clot tamponde network odds ratio
Bipolar EP 0.12 (0.02 - 0.76)
KTP LVP 0.16 (0.07 - 0.39)
Thulium LEP 0.18 (0.06 - 0.48)
Diode LVP 0.19 (0.04 - 0.94)
Bipolar VP 0.29 (0.12 - 0.68)
Holmium LEP 0.35 (0.12 - 1.01)
Bipolar TURP 0.49 (0.32 - 0.74)
0.01 0.10 1.00 10.00 100.00
fewer events with new-method
more events with new-method
Recurrence network odds ratio
Bipolar EP#
Holmium LEP 0.27 (0.06 - 1.30)
Bipolar TURP 0.88 (0.43 - 1.77)
Bipolar VP 1.58 (0.55 - 4.52)
KTP LVP 2.56 (1.23 - 5.30)
Diode LVP 3.28 (0.59 - 18.30)
Thulium LEP#
0.01 0.10 1.00 10.00 100.00
fewer events with new-method
more events with new-method
Blood transfusion network odds ratio
Diode LVP#
Diode LEP#
Holmium LEP 0.05 (0.01 - 0.22)
KTP LVP 0.08 (0.03 - 0.21)
Bipolar EP 0.07 (0.01 - 0.34)
Bipolar VP 0.14 (0.05 - 0.40)
Thulium LEP 0.11 (0.03 - 0.40)
Bipolar TURP 0.42 (0.28 - 0.61)
0.01 0.1 1 10 100
fewer events with new-method
more events with new-method
recatheterization network odds ratio
Bipolar EP 0.24 (0.09 - 0.64)
Diode LEP 0.27 (0.06 - 1.14)
Thulium LEP 0.36 (0.15 - 0.85)
Holmium LEP 0.42 (0.23 - 0.78)
Bipolar TURP 0.76 (0.54 - 1.06)
Bipolar VP 0.98 (0.58 - 1.65)
KTP LVP 1.32 (0.77 - 2.29)
Diode LVP 2.18 (0.34 - 13.90)
0.01 0.10 1.00 10.00 100.00
fewer events with new-method
more events with new-method

Figure3

Study protocol

Here we present the study protocol for a systematic review and network meta-analysis to determine the efficacy and safety of new surgical methods used in the treatment of benign prostate hyperplasia (BPH)

Background

Since the 2000's, new surgical methods using various energy systems, such as bipolar energy and various laser systems (holmium laser, KTP (potassium-titanyl-phosphate) laser, thulium laser and diode laser) to treat BPH rapidly infiltrated urological practices.[1-3] Bipolar systems use a specialized loop or electrode that incorporates both the active and return portions of the circuit on the same electrode. It can incise, resect, or vaporize prostate tissue by creating an ionized plasma corona using an axipolar electrode and normal saline solution to avoid hyponatremia. The holmium laser emits a pulsatile wavelength at 2104 nm, which is mainly absorbed by water and acts as an incisional laser. The thulium laser emits a continuous wavelength at 2013 nm with similar effects to holmium laser. Continuous energy emission has been suggested to create cleaner incisions with stronger hemostatic effects. The KTP laser is a 532-nm wavelength laser that is selectively absorbed by hemoglobin. Debunking of the prostate tissue is achieved by tissue vaporization. The diode laser is a 980-nm laser that is simultaneously absorbed in water and hemoglobin, and can provide significant tissue ablation with good hemostasis. In this analysis, we further differentiated the surgical methods into those that resect, vaporize, and enucleate the prostate.

Presently, there are eight new methods for treating BPH that include bipolar transurethral resection of the prostate, bipolar vaporization of the prostate, holmium laser enucleation of the prostate, thulium laser enucleation of the prostate, KTP laser vaporization of the prostate, diode laser vaporization of the prostate and diode laser enucleation of the prostate, which are the most commonly used methods. Are the outcomes of these new methods all the same or is there a more superior one?

Objective

This network meta-analysis would be conducted to determine which new surgical method could achieve the best functional outcomes with fewer complications, using data from randomized controlled trials.

Material and methods

Data sources and searches

We conducted online English literature searches of Pubmed (1966-March 2018), Embase (1974-March 2018), and Cochrane clinical trial registers(inception-March 2018), not restricted to publication year or language. We also manually searched the reference lists of the identified publications to identify additional potentially eligible studies. The search terms included prostate hyperplasia / prostate hypertrophy / prostate tumor, and bipolar (TURP, enucleation, vaporization) diode laser, thulium laser, KTP laser, greenlight laser, and holmium laser.

Study selection

Inclusion and exclusion criteria were defined prior to the literature search. Studies were chosen if they met the following criteria:

1. Randomized, parallel-group design clinical trials comparing monopolar transurethral resection of the prostate (TURP), bipolar TURP, Bipolar EP (including vapo-enucleation), Holmium LEP, Thulium LEP (including vapo-enucleation), Diode LEP (including vapo-enucleation), Bipolar VP (including vaporization with apical resection), KTP LVP, and Diode LVP for BPH surgeries.
2. Patients with maximal flow rates <15 mL/s and IPSS >8
3. Exclusion criteria: neurogenic bladder, previous urethral, prostate, and bladder surgeries, suspected prostate cancer

Data Extraction

The following information will be extracted and entered independently into the study databases by two investigators.

Study characteristics: Authors, journal and year of publication, country, intervention method, number of patients, age, prostate-specific antigen (PSA), International Prostate Symptoms Score (IPSS), quality of life QOL, post void residual urine (PVR), maximal flow rate (Qmax), prostate volume.

Peri-operative parameters: Hb-decline, operation time, blood loss, duration of catherization, length of hospital stay.

Functional outcomes: IPSS, Qmax, PVR, health-related QOL (HRQOL), postoperative PVR at 6, 12, 24, and 36 months.

Complication:

Early complications: TUR syndrome, blood transfusion, re-catheterization, blood clot tamponade, urinary tract infection.

Late complications: meatal stenosis, urethral stricture, bladder neck contracture, incontinence, BPH recurrence (recurrence requiring surgical intervention or repeat apical resection), retrograde ejaculation, erectile dysfunction.

Studies reported in non-English and non-Chinese language journals will be electronically translated before assessment. Where more than one publication of a study exists, reports will be grouped together. We will plan to contact the author(s) for missing data. In some instances, if standard deviation (SD) data are missing, we calculated SD with formulae described in Cochrane handbook for systematic reviews of interventions or measure it from figure. If the author only offers medians, we would use the median as a mean and the interquartile range (IQR)3-IQR1/1.35 as the standard deviation. [4]

Assessment of Risk of Bias

We plan to use the Cochrane Collaboration's risk of bias tool to appraise the quality of the articles. The following domains will be assessed in all included studies: random sequence generation, allocation concealment, blinding of participants, blinding of outcome assessment (according to functional outcome), incomplete outcome data (only appraised for >3 months' follow-up article), selective reporting (according to the complications reported)[5].

Two reviewers (H-SW, T-CS) will independently appraise the articles and come to an agreement on the final decisions. A third reviewer (TCY), who would act as an arbiter will be consulted for any unresolved discrepancies.

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Outcome measures

The primary outcome will be the functional outcome, and the secondary outcome will be the perioperative parameters and complications.

We will estimate the relative ranking of the competing interventions according to the following outcomes:

1. Functional outcomes: Qmax and IPSS, at 6, 12, 24, and 36 postoperative months.
2. Perioperative parameters: catheterization duration, Hb-decline.
3. Complications: blood clot tamponade (bladder tamponade secondary to blood clot) blood transfusion, urinary tract infection, re-catheterization, urethral stricture, retrograde ejaculation, incontinence, BPH recurrence

Data synthesis and analysis

All data from each eligible study will be extracted and entered into a standardized spreadsheet software program (Microsoft access 2013, Microsoft Corp, Redmond, WA, USA).

Methods for direct treatment comparisons

The weighted mean differences and risk ratio reductions will be reported for continuous and binary variables, respectively. Heterogeneity will be assessed by a visual inspection of the forest plots, and subsequently test using I^2 statistical method. We will choose a random effects model if $I^2 > 50\%$, otherwise the fixed effect model will be used. A traditional pair-wise meta-analysis will be performed using Stata software (StataCorp.2011, Stata Statistical Software: Release 14, College Station, TX).[5]

Methods for direct and indirect comparisons

We will fit a network meta-analysis model separately for each outcome, combining direct evidence for each comparison with indirect evidence for all pair-wise comparisons simultaneously. [6]

For any given comparison, i.e., A vs. B, direct evidence will be provided by trials that compare these two treatments directly, as in a standard comparisons meta-analysis. Indirect evidence for A vs. B can be provided if studies that compare A to C, and B to C are assessed jointly. The assumption of transitivity assumes that the AC trial and the AB trial are similar with respect to the distribution of all possible effect modifiers. Hence, we will assume that the common treatment used to compare the different surgical treatments is similar, and the missing treatment in each trial is missing randomly. The network meta-analysis aims to combine the direct and indirect evidence into a single effect size. [7]

Assessment of statistical inconsistency

We will perform local approaches and global approaches for evaluating inconsistency. [8 9] To evaluate local inconsistencies, we will use the Loop inconsistency method. This method evaluates the consistency assumption in each closed triangular or quadratic loop separately as the difference between the direct and indirect estimate for a specific comparison in the loop and also to test for global loop inconsistencies in the entire network. To evaluate for global inconsistencies in the entire network, we will use the design-by-treatment interaction model. This method accounts for different sources of inconsistency that can occur when studies with different designs give different results or disagreements between direct and indirect evidence. Using this approach, we will infer the presence of inconsistency from any sources in the entire network based on a chi-square test.

We also estimate the probability of each treatment being at each possible rank for each intervention and each outcome. We will obtain a treatment hierarchy using the surface under the cumulative ranking curve (SUCRA) and mean ranks methods.

For continuous variables such as functional outcomes and peri-operative parameters, we will conduct a trial-based meta-analysis using STATA (StataCorp.2011, Stata Statistical Software: Release 14, College Station, TX, USA) using the 'mvmeta' command and self-programmed STATA routines. [10]

For dichotomous variables such as complications, the rare events will be noted. We will perform an arm-based meta-analysis using SAS software without 0-cell correction, version 9.4 (SAS Institute, Cary, NC, USA) using GLIMMIX with Laplace integration methods. Statistical significance will be defined as $p<0.05$ via a two-tailed test.

Sensitivity analysis

Potential effect modifier

Prostate size might affect the outcome of different surgical treatments. Therefore, large prostates might be better treated using enucleation methods and less effectively managed using vaporization methods. We will conduct a meta-regression according to the mean prostate volume provided in each trial. We will use the weighted average preoperative prostate volume reported by the authors in each trial. If prostate volume information is not present, but the resected prostate volume data is reported, we will estimate the preoperative prostate volume as the resected volume/0.5 if the resected volume is <50 and, resected volume/0.8 if the volume is >50.

Since incontinence is always a concern for enucleation methods. We further performed an analysis comparing enucleation methods and resection methods in short-term transient incontinence (incontinence<1 month and used the earliest reported incontinence events if multiple time points) and permanent incontinence (incontinence more than 6 or 12 months). In enucleation methods, we excluded vapo-enucleation study since vapo-enucleation methods are aimed to reduce incontinence events by preserving apex region of prostate.

Post-hoc analysis

During the study, we found that the TURP group in the Bachman et al. trial included both monopolar and bipolar energy methods. The participants were not randomly allocated to monopolar or bipolar treatment groups, and the authors did not reply to our requests for further information. Therefore, we did not include data from this trial in the main analysis. We will perform further analyses by assuming that the TURP group comprises monopolar or bipolar methods to see if the results and ranking changed after adding this trial.

Reference

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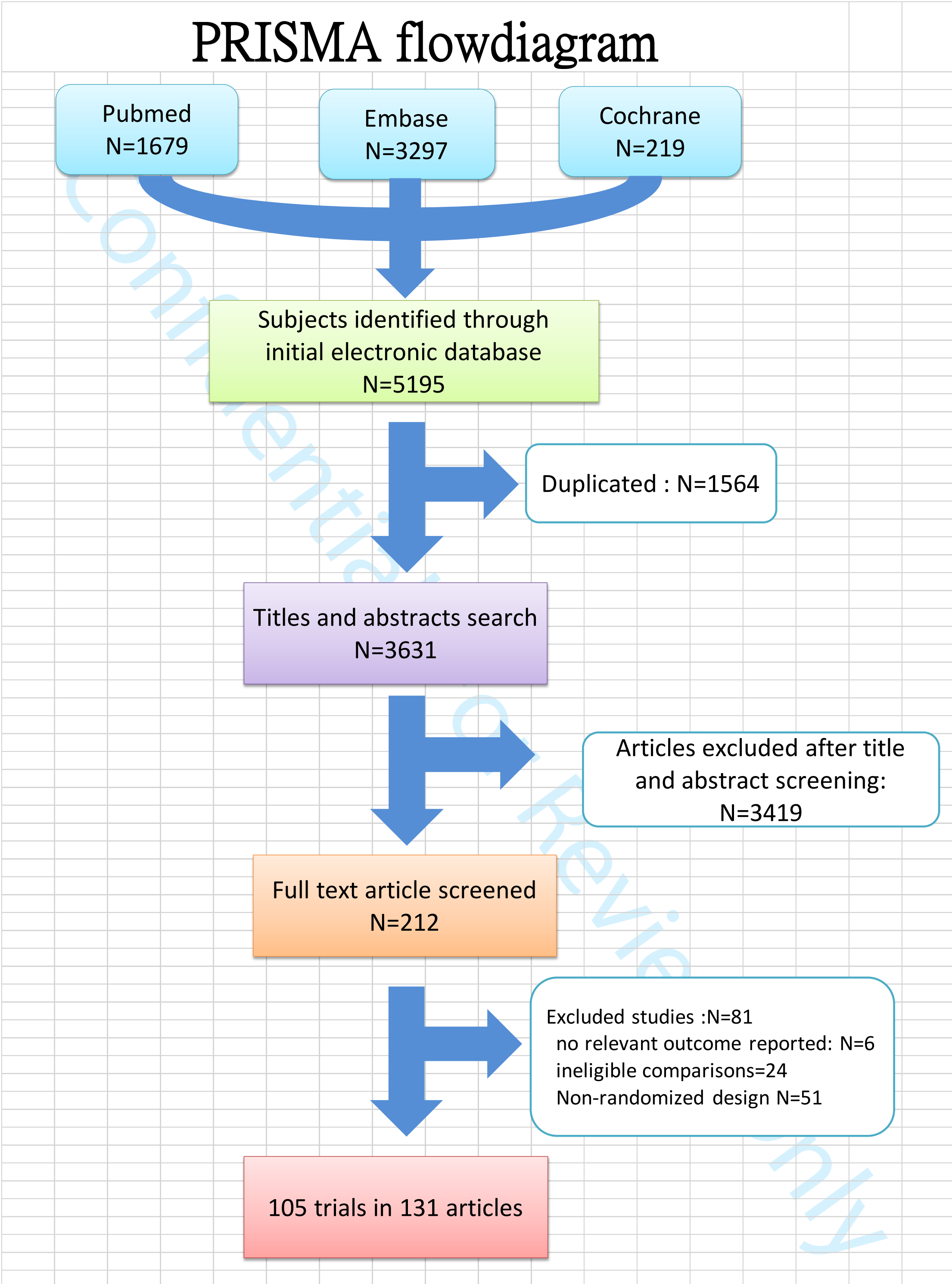
Supplementary materials

Contents

This Supplementary material has been provided by the authors to give readers additional information about their work.

Supplementary figure 1: PRISMA flowdiagram



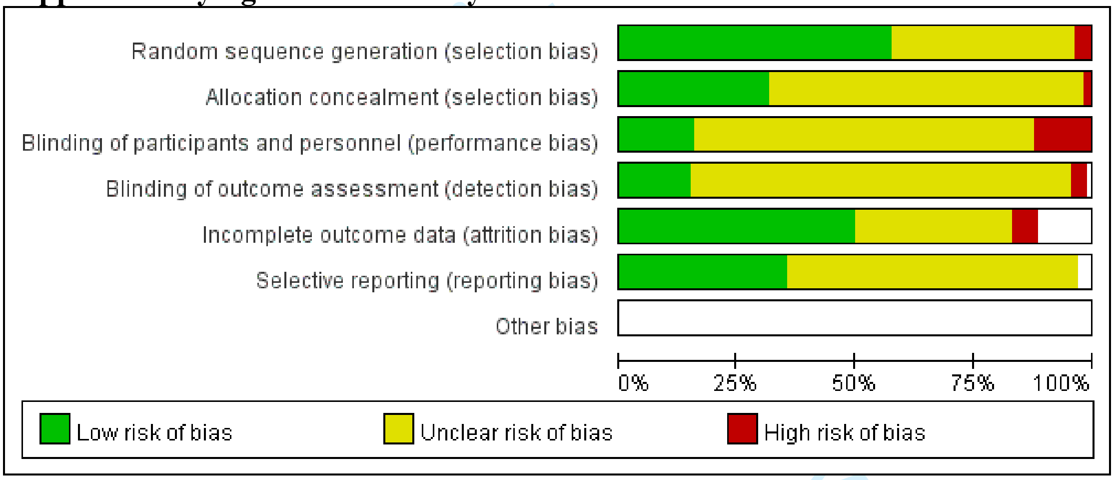
Supplementary figure 2: Risk of bias assessment for the included trials

We used Cochrane Collaboration's risk of bias tool to appraise the quality of article. Each item is adjudicated within each study and the results are represented in a risk of bias table. We considered the study as low risk in blinding of participants if patients were blinded to which surgical methods; blinding of outcome assessment if the outcome assessor for functional outcome (IPSS and Qmax) was blinded; low risk of selective reporting if complication was evaluated with pre-specified form such as modified Clavien-Dindo classification or detailed reported of complication. We only evaluate incomplete outcome data domain if the study was followed-up for more than 3 months.

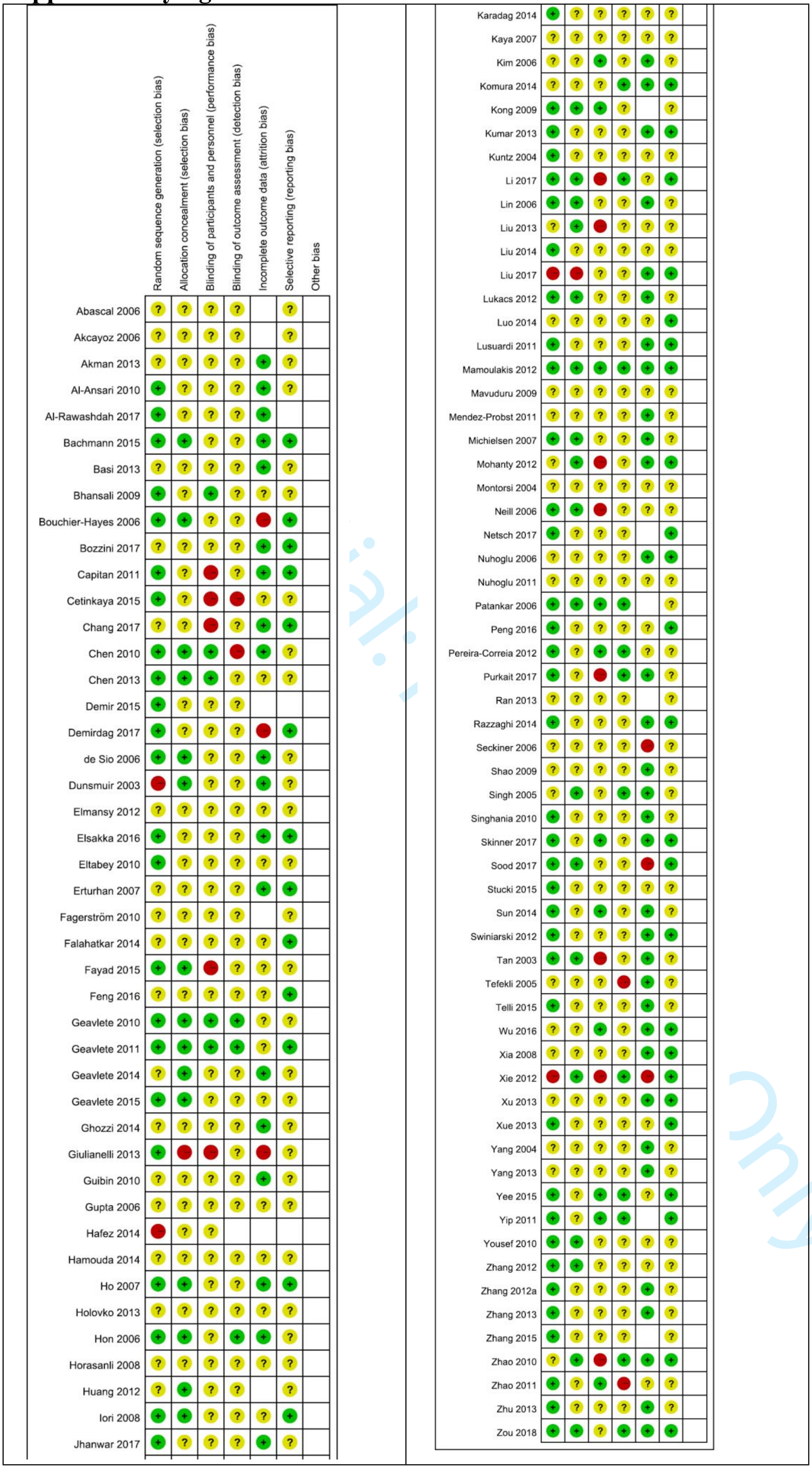
Risk of bias graph of included clinical trials. Each methodological quality item is presented as percentages across all included studies. The figure was generated using Review Manager Version 5.1.

Summary for risk of bias of included clinical trials. The green symbols represent low risk of bias, the yellow symbols represent unclear risk of bias, and the red symbols represent high risk of bias. The figure was generated using Review Manager Version 5.1

Supplementary figure2a: summary across the risk of bias items

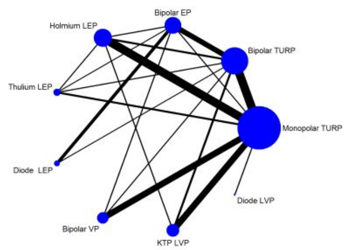


Supplementary figure2b: Detailed risk of Bias assessment of individual studies

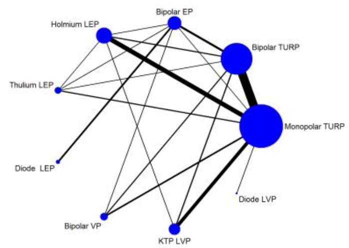


Supplementary figure 3: Network treatment comparisons.

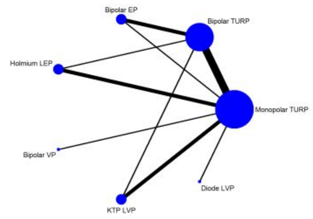
The size of the nodes represented the number of trials that studied the treatments. The directly compared treatments are linked with a line, the thickness of the line represented the number of trials evaluate the comparisons.



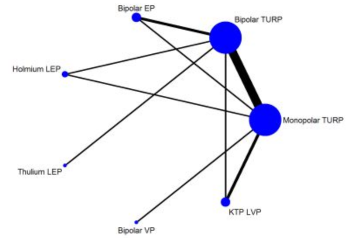
Post-op 6 months Qmax



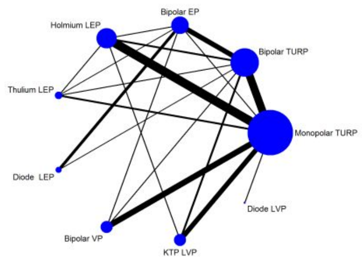
Post-op 12 months Qmax



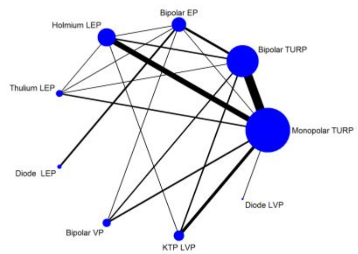
Post-op 24 months Qmax



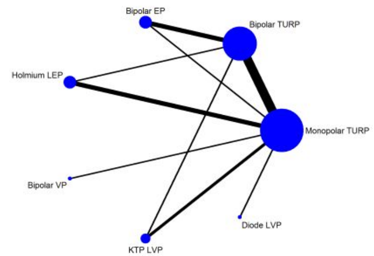
Post-op 36 months Qmax



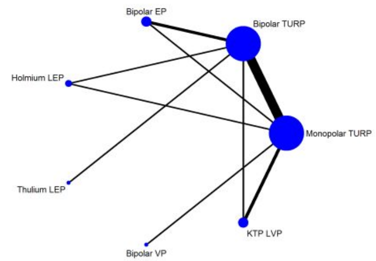
Post-op 6 months IPSS



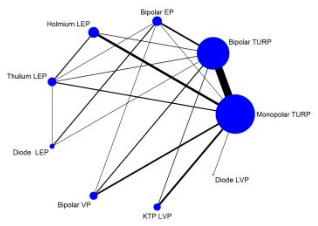
Post-op 12 months IPSS



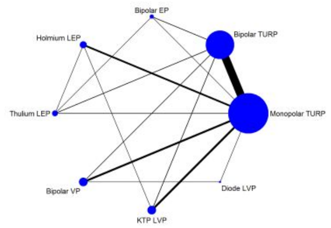
Post-op 24 months IPSS



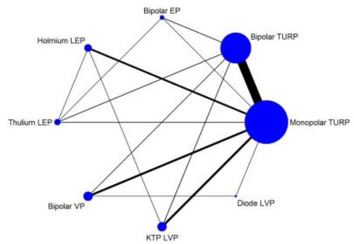
Post-op 36 months IPSS



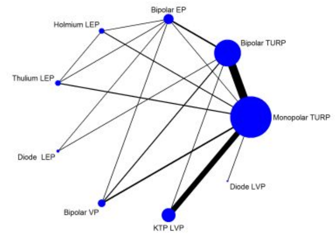
Hb-declination



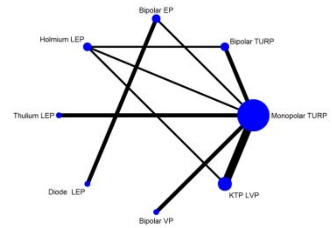
Blood transfusion



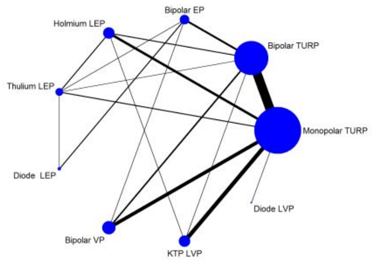
Blood clot tamponade



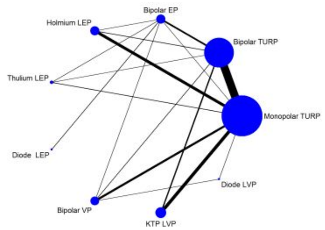
UTI



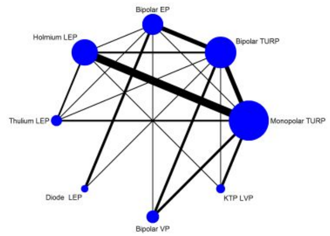
Recatherization



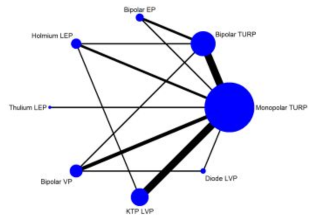
Catherization duration



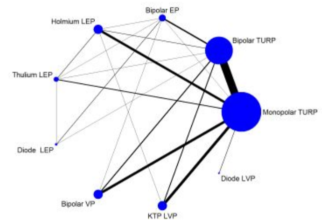
Stricture



Incontinence



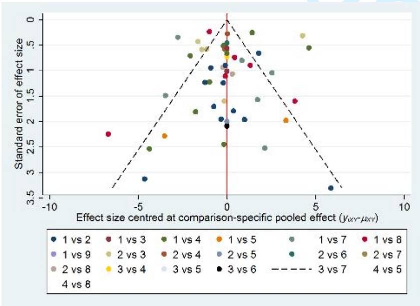
BPH recurrence

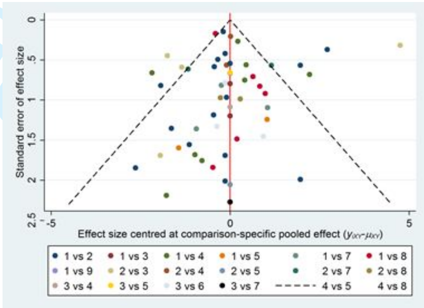


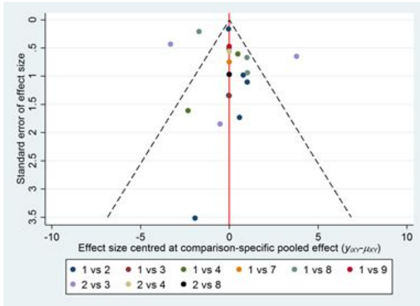
Retrograde ejaculation

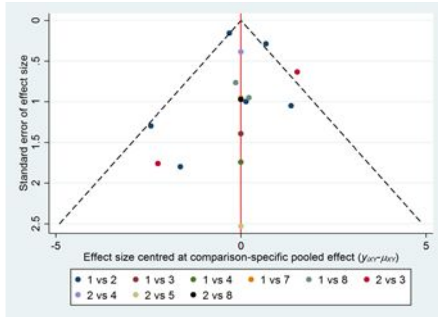
Supplementary figure 4: comparison-adjusted funnel plot for the network of primary outcome

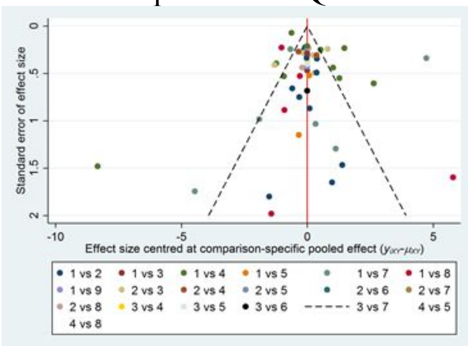
1: Monopolar TURP, 2:Bipolar TURP, 3: Bipolar EP, 4: Holmium LEP, 5: Thulium LEP, 6:Diode LEP, 7: Bipolar VP 8: KTP LVP, 9: Diode LVP

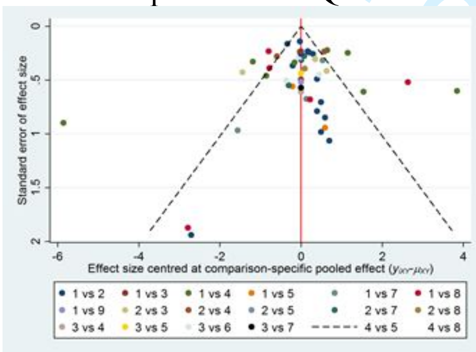

Post-op 6 months Qmax

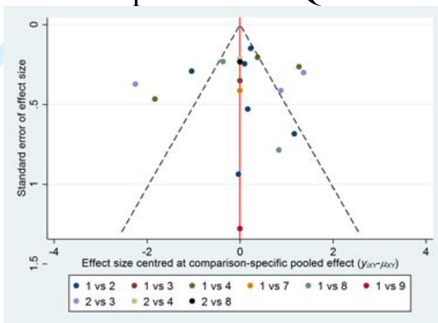

Post-op 12 months Qmax

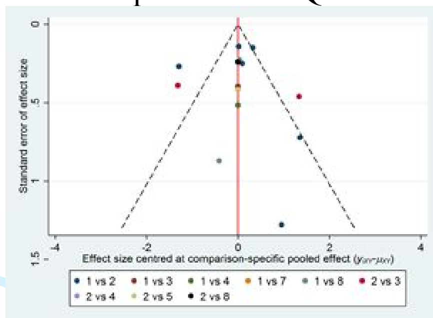

Post-op 24 months Qmax


Post-op 36 months Qmax


Post-op 6 months IPSS


Post-op 12 months IPSS


Post-op 24 months IPSS


Post-op 36 months IPSS

Supplementary figure 5 : Results of network meta-analysis

Common heterogeneity variables for all comparisons in this network meta-analysis were τ= 2.12, 1.46, 1.72,0.92 1.53,1.15,1.12,0.81,0.46 and 13.0 for post-op 6 month Qmax, postop 12 months Qmax, postop 24 months Qmax, postop 36 months Qmax, post-op 6 months IPSS, post-op 12 months IPSS, post-op 24 months IPSS, post-op 36 months IPSS, catheterization duration and Hb-decline, respectively; τ=0.42, 0.13, 0, 0, 0, 0, 0 and 0 for blood clot tamponade, blood transfusion, recatheterization, recurrence, stricture, incontinence, UTI and retrograde ejaculation. respectively.

Treatments are ranked by SUCRA values
SUCRA value:
Post-op 6 months Qmax:
Bipolar EP: 0.89, Diode LEP:0.81, Thulium LEP: 0.69, Bipolar TURP:0.53, Holmium LEP:0.47, Diode LVP:0.47, Bipolar VP: 0.24, KTP LVP: 0.13
Post-op 12 months Qmax:
Diode LEP:0.93, Bipolar EP: 0.92, Holmium LEP:0.63, Bipolar TURP:0.65, Thulium LEP: 0.54, Bipolar VP: 0.38, KTP LVP:0.24, Diode LVP: 0.07
Post-op 24 months Qmax:
Bipolar EP: 1.0, Holmium LEP:0.70, Bipolar TURP:0.60, KTP LVP:0.48, Diode LVP: 0.21, Bipolar VP: 0.00
Post-op 36 months Qmax:
Bipolar EP:0.99, Holmium LEP:0.56, Thulium LEP:0.57, Bipolar TURP:0.51, KTP LVP: 0.51, Bipolar VP: 0.00
Post-op 6 months IPSS
Bipolar EP: 0.80, Diode LEP:0.75,Thulium LEP:0.68,Holmium LEP:0.46, Bipolar TURP:0.44, Diode LVP: 0.33, KTP LVP: 0.30, Bipolar VP: 0.27
Post-op 12 months IPSS
Diode LEP:0.83, Holmium LEP:0.75, Thulium LEP: 0.71, Bipolar EP: 0.77, Bipolar TURP:0.43, Bipolar VP: 0.44, KTP LVP: 0.17, Diode LVP: 0.11
Post-op 24 months IPSS
Bipolar EP:0.98, Bipolar TURP:0.66, Holmium LEP:0.67, KTP LVP: 0.44, Bipolar VP:0.16, Diode LVP: 0.10
Post-op 36 months IPSS
Bipolar EP:0.99, Holmium LEP:0.62, Bipolar TURP:0.57, KTP LVP: 0.57, Thulium LEP: 0.32, Bipolar VP: 0.03
Catheterization duration
Diode LVP: 0.96, Diode LEP:0.80, KTP LVP: 0.71, Thulium LEP: 0.69, Bipolar EP:0.45, Holmium LEP:0.42, Bipolar VP: 0.37, Bipolar TURP:0.13
Hb-decline
KTP LVP: 0.96, Diode LEP:0.79, Bipolar VP: 0.51, Thulium LEP: 0.68, Holmium LEP:0.48, Bipolar EP:0.49, Diode LVP:0.38, Bipolar TURP:0.17
Blood clot tamponade:
KTP LVP: 0.75, Diode LVP: 0.65, Bipolar VP: 0.49, Holmium LEP: 0.40, Thulium LEP: 0.71, Bipolar TURP:0.23, Bipolar EP: 0.77
Blood transfusion:
Holmium LEP: 0.91, KTP LVP: 0.79, Bipolar EP: 0.60, Bipolar VP: 0.57, Thulium LEP: 0.42, Bipolar TURP:0.21
Recatheterization

Bipolar EP: 0.83, Diode LEP:0.69, Holmium LEP: 0.72, Thulium LEP: 0.50, Bipolar TURP:0.47, Bipolar VP: 0.30, KTP LVP: 0.14, Diode LVP:0.13

Recurrence:

Holmium LEP: 0.96, Bipolar TURP:0.70, Bipolar VP: 0.38, Diode LVP: 0.16, KTP LVP: 0.17

Stricture:

Holmium LEP: 0.87, Bipolar EP: 0.75, Diode LEP:0.35, Bipolar VP: 0.54, Thulium LEP: 0.59, Bipolar TURP:0.35, KTP LVP: 0.33

Incontinence:

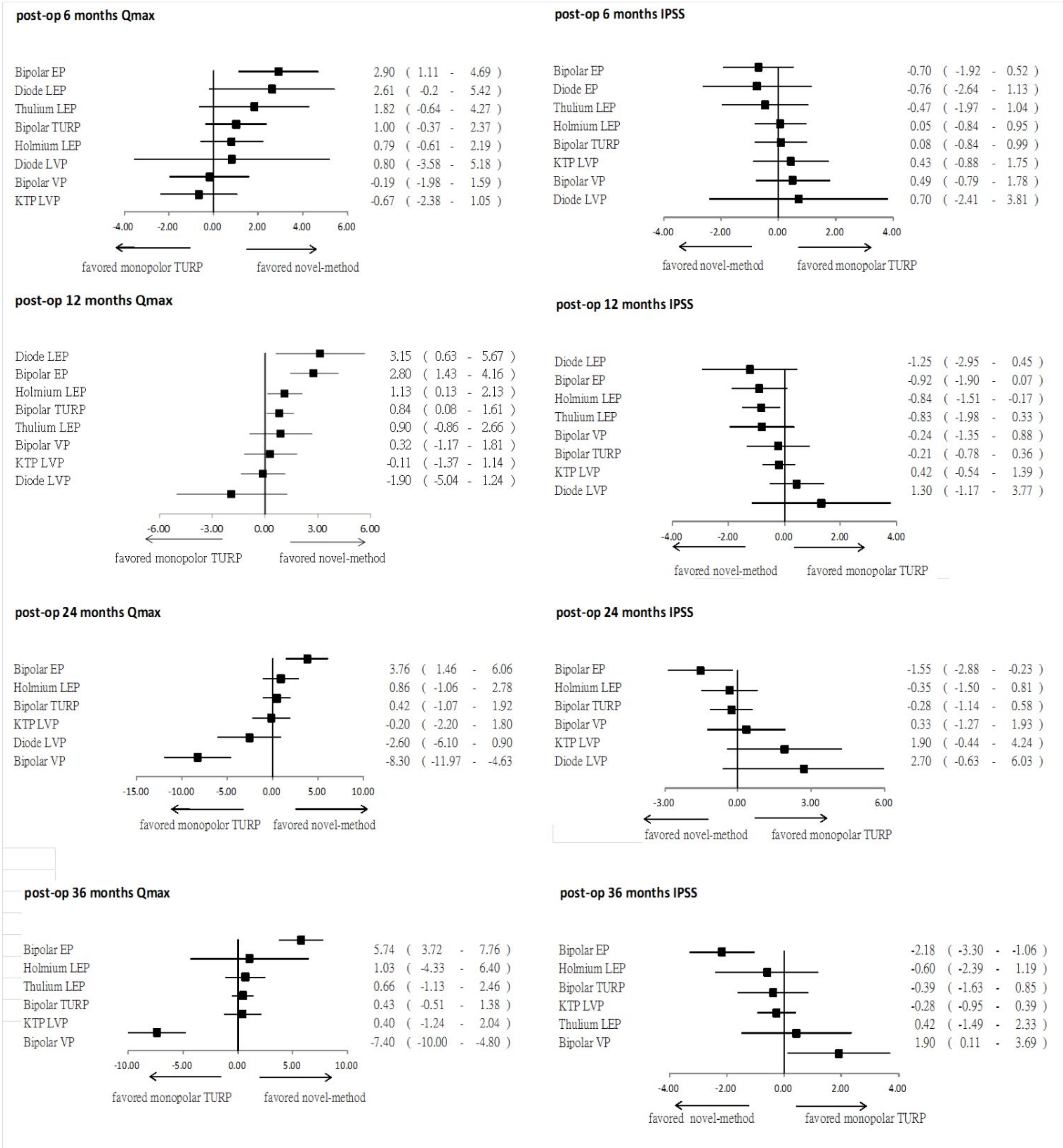
Bipolar VP: 0.84, Thulium LEP:0.79, Bipolar TURP:0.70, Diode LEP:0.57, KTP LVP: 0.26, Bipolar EP: 0.25, Holmium LEP:0.15

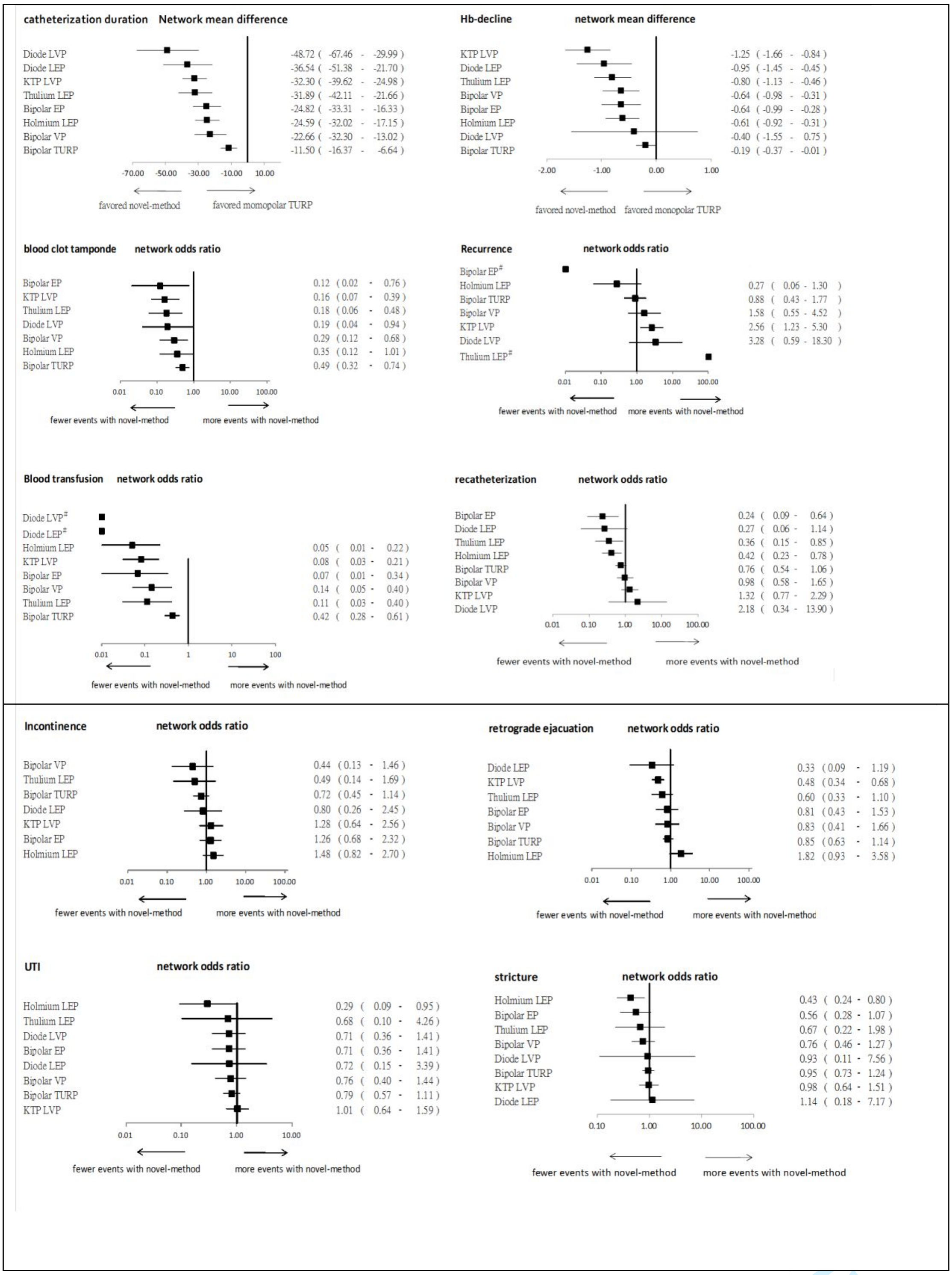
UTI:

Holmium LEP:0.80, Thulium LEP: 0.77, Bipolar EP: 0.51, Diode LVP: 0.50, Bipolar VP: 0.46, Bipolar TURP:0.45, KTP LVP: 0.23

Retrograde ejaculation:

Diode LEP:0.89, KTP LVP: 0.84, Thulium LEP: 0.68, Bipolar EP: 0.45, Bipolar VP: 0.44, Bipolar TURP:0.43, Holmium LEP:0.03


post-op 6 months Qmax
Bipolar EP 2.90 (1.11 - 4.69)
Diode LEP 2.61 (-0.2 - 5.42)
Thulium LEP 1.82 (-0.64 - 4.27)
Bipolar TURP 1.00 (-0.37 - 2.37)
Holmium LEP 0.79 (-0.61 - 2.19)
Diode LVP 0.80 (-3.58 - 5.18)
Bipolar VP -0.19 (-1.98 - 1.59)
KTP LVP -0.67 (-2.38 - 1.05)
-4.00 -2.00 0.00 2.00 4.00 6.00
favored monopolor TURP
favored novel-method
post-op 6 months IPSS
Bipolar EP -0.70 (-1.92 - 0.52)
Diode EP -0.76 (-2.64 - 1.13)
Thulium LEP -0.47 (-1.97 - 1.04)
Holmium LEP 0.05 (-0.84 - 0.95)
Bipolar TURP 0.08 (-0.84 - 0.99)
KTP LVP 0.43 (-0.88 - 1.75)
Bipolar VP 0.49 (-0.79 - 1.78)
Diode LVP 0.70 (-2.41 - 3.81)
-4.00 -2.00 0.00 2.00 4.00
favored novel-method
favored monopolar TURP
post-op 12 months Qmax
Diode LEP 3.15 (0.63 - 5.67)
Bipolar EP 2.80 (1.43 - 4.16)
Holmium LEP 1.13 (0.13 - 2.13)
Bipolar TURP 0.84 (0.08 - 1.61)
Thulium LEP 0.90 (-0.86 - 2.66)
Bipolar VP 0.32 (-1.17 - 1.81)
KTP LVP -0.11 (-1.37 - 1.14)
Diode LVP -1.90 (-5.04 - 1.24)
-6.00 -3.00 0.00 3.00 6.00
favored monopolor TURP
favored novel-method
post-op 12 months IPSS
Diode LEP -1.25 (-2.95 - 0.45)
Bipolar EP -0.92 (-1.90 - 0.07)
Holmium LEP -0.84 (-1.51 - -0.17)
Thulium LEP -0.83 (-1.98 - 0.33)
Bipolar VP -0.24 (-1.35 - 0.88)
Bipolar TURP -0.21 (-0.78 - 0.36)
KTP LVP 0.42 (-0.54 - 1.39)
Diode LVP 1.30 (-1.17 - 3.77)
-4.00 -2.00 0.00 2.00 4.00
favored novel-method
favored monopolar TURP
post-op 24 months Qmax
Bipolar EP 3.76 (1.46 - 6.06
Holmium LEP 0.86 (-1.06 - 2.78
Bipolar TURP 0.42 (-1.07 - 1.92
KTP LVP -0.20 (-2.20 - 1.80
Diode LVP -2.60 (-6.10 - 0.90
Bipolar VP -8.30 (-11.97 - -4.63
-15.00 -10.00 -5.00 0.00 5.00 10.00
favored monopolor TURP
favored novel-method
post-op 24 months IPSS
Bipolar EP -1.55 (-2.88 - -0.23)
Holmium LEP -0.35 (-1.50 - 0.81)
Bipolar TURP -0.28 (-1.14 - 0.58)
Bipolar VP 0.33 (-1.27 - 1.93)
KTP LVP 1.90 (-0.44 - 4.24)
Diode LVP 2.70 (-0.63 - 6.03)
-3.00 0.00 3.00 6.00
favored novel-method
favored monopolar TURP
post-op 36 months Qmax
Bipolar EP 5.74 (3.72 - 7.76)
Holmium LEP 1.03 (-4.33 - 6.40)
Thulium LEP 0.66 (-1.13 - 2.46)
Bipolar TURP 0.43 (-0.51 - 1.38)
KTP LVP 0.40 (-1.24 - 2.04)
Bipolar VP -7.40 (-10.00 - -4.80)
-10.00 -5.00 0.00 5.00 10.00
favored monopolar TURP
favored novel-method
post-op 36 months IPSS
Bipolar EP -2.18 (-3.30 - -1.06)
Holmium LEP -0.60 (-2.39 - 1.19)
Bipolar TURP -0.39 (-1.63 - 0.85)
KTP LVP -0.28 (-0.95 - 0.39)
Thulium LEP 0.42 (-1.49 - 2.33)
Bipolar VP 1.90 (0.11 - 3.69)
-4.00 -2.00 0.00 2.00 4.00
favored novel-method
favored monopolar TURP


catheterization duration Network mean difference
Diode LVP -48.72 (-67.46 - -29.99)
Diode LEP -36.54 (-51.38 - -21.70)
KTP LVP -32.30 (-39.62 - -24.98)
Thulium LEP -31.89 (-42.11 - -21.66)
Bipolar EP -24.82 (-33.31 - -16.33)
Holmium LEP -24.59 (-32.02 - -17.15)
Bipolar VP -22.66 (-32.30 - -13.02)
Bipolar TURP -11.50 (-16.37 - -6.64)
-70.00 -50.00 -30.00 -10.00 10.00
favored novel-method
favored momopolar TURP
Hb-decline network mean difference
KTP LVP -1.25 (-1.66 - -0.84)
Diode LEP -0.95 (-1.45 - -0.45)
Thulium LEP -0.80 (-1.13 - -0.46)
Bipolar VP -0.64 (-0.98 - -0.31)
Bipolar EP -0.64 (-0.99 - -0.28)
Holmium LEP -0.61 (-0.92 - -0.31)
Diode LVP -0.40 (-1.55 - 0.75)
Bipolar TURP -0.19 (-0.37 - -0.01)
-2.00 -1.00 0.00 1.00
favored novel-method
favored monopolar TURP
blood clot tamponde network odds ratio
Bipolar EP 0.12 (0.02 - 0.76)
KTP LVP 0.16 (0.07 - 0.39)
Thulium LEP 0.18 (0.06 - 0.48)
Diode LVP 0.19 (0.04 - 0.94)
Bipolar VP 0.29 (0.12 - 0.68)
Holmium LEP 0.35 (0.12 - 1.01)
Bipolar TURP 0.49 (0.32 - 0.74)
0.01 0.10 1.00 10.00 100.00
fewer events with novel-method
more events with novel-method
Recurrence network odds ratio
Bipolar EP#
Holmium LEP 0.27 (0.06 - 1.30)
Bipolar TURP 0.88 (0.43 - 1.77)
Bipolar VP 1.58 (0.55 - 4.52)
KTP LVP 2.56 (1.23 - 5.30)
Diode LVP 3.28 (0.59 - 18.30)
Thulium LEP#
0.01 0.10 1.00 10.00 100.00
fewer events with novel-method
more events with novel-method
Blood transfusion network odds ratio
Diode LVP#
Diode LEP#
Holmium LEP 0.05 (0.01 - 0.22)
KTP LVP 0.08 (0.03 - 0.21)
Bipolar EP 0.07 (0.01 - 0.34)
Bipolar VP 0.14 (0.05 - 0.40)
Thulium LEP 0.11 (0.03 - 0.40)
Bipolar TURP 0.42 (0.28 - 0.61)
0.01 0.1 1 10 100
fewer events with novel-method
more events with novel-method
recatheterization network odds ratio
Bipolar EP 0.24 (0.09 - 0.64)
Diode LEP 0.27 (0.06 - 1.14)
Thulium LEP 0.36 (0.15 - 0.85)
Holmium LEP 0.42 (0.23 - 0.78)
Bipolar TURP 0.76 (0.54 - 1.06)
Bipolar VP 0.98 (0.58 - 1.65)
KTP LVP 1.32 (0.77 - 2.29)
Diode LVP 2.18 (0.34 - 13.90)
0.01 0.10 1.00 10.00 100.00
fewer events with novel-method
more events with novel-method
Incontinence network odds ratio
Bipolar VP 0.44 (0.13 - 1.46)
Thulium LEP 0.49 (0.14 - 1.69)
Bipolar TURP 0.72 (0.45 - 1.14)
Diode LEP 0.80 (0.26 - 2.45)
KTP LVP 1.28 (0.64 - 2.56)
Bipolar EP 1.26 (0.68 - 2.32)
Holmium LEP 1.48 (0.82 - 2.70)
0.01 0.10 1.00 10.00 100.00
fewer events with novel-method
more events with novel-method
retrograde ejacuation network odds ratio
Diode LEP 0.33 (0.09 - 1.19)
KTP LVP 0.48 (0.34 - 0.68)
Thulium LEP 0.60 (0.33 - 1.10)
Bipolar EP 0.81 (0.43 - 1.53)
Bipolar VP 0.83 (0.41 - 1.66)
Bipolar TURP 0.85 (0.63 - 1.14)
Holmium LEP 1.82 (0.93 - 3.58)
0.01 0.10 1.00 10.00 100.00
fewer events with novel-method
more events with novel-methoc
UTI network odds ratio
Holmium LEP 0.29 (0.09 - 0.95)
Thulium LEP 0.68 (0.10 - 4.26)
Diode LVP 0.71 (0.36 - 1.41)
Bipolar EP 0.71 (0.36 - 1.41)
Diode LEP 0.72 (0.15 - 3.39)
Bipolar VP 0.76 (0.40 - 1.44)
Bipolar TURP 0.79 (0.57 - 1.11)
KTP LVP 1.01 (0.64 - 1.59)
0.01 0.10 1.00 10.00
fewer events with novel-method
more events with novel-method
stricture network odds ratio
Holmium LEP 0.43 (0.24 - 0.80)
Bipolar EP 0.56 (0.28 - 1.07)
Thulium LEP 0.67 (0.22 - 1.98)
Bipolar VP 0.76 (0.46 - 1.27)
Diode LVP 0.93 (0.11 - 7.56)
Bipolar TURP 0.95 (0.73 - 1.24)
KTP LVP 0.98 (0.64 - 1.51)
Diode LEP 1.14 (0.18 - 7.17)
0.10 1.00 10.00 100.00
fewer events with novel-method
more events with novel-method

Supplementary table 1: Electronic search strategy

Pubmed search
Search ((((((((((((((thulium laser)) OR (holmium laser)) OR (diode laser)) OR (eraser laser)) OR (ktp laser)) OR (greenlight laser)) OR (KTP LVP)) OR (Bipolar EP)) OR (Bipolar VP)) OR (bipolar transurethral resection)) OR (plasmakinetic))) AND ((((((prostate hyperplasia)) OR (prostate hypertrophy)) OR (prostate enlargement))) OR ("Prostatic Neoplasms"[Mesh])))) OR ((((((((((holmium laser prostate)) OR (thulium laser prostate)) OR (diode laser prostate)) OR (KTP LVP prostate)) OR (greenlight laser prostate)) OR (Bipolar TURP)) OR (Bipolar EP prostate)) OR (Bipolar VP prostate)) OR (plasmakinetic prostate))
Embase search
((bipolar AND enucleation) or (bipolar AND 'transurethral resection' AND prostate) or (greenlight AND laser AND prostate) or (‘KTP LVP' AND prostate) or (diode AND laser AND prostate) or (thulium AND laser AND prostate) or (holmium AND laser AND prostate)) or (('prostate tumor'/exp) or ('prostate hypertrophy'/exp)) AND (('KTP LVP') or(diode AND laser) or (Greenlight) or(holmium AND laser) or(thulium AND laser) or (bipolar AND vaporization) or (bipolar AND enucleation)or (Plasmakinetic) or (bipolar AND 'transurethral resection'))
Cochrane clinical trial search
((prostate hypertrophy:ti,ab,kw) or (prostate hyperplasia:ti,ab,kw)) AND ((("bipolar":ti,ab,kw) AND ("transurethral enucleation":ti,ab,kw or "transurethral resection" or transurethral vapor* or "transurethral prostatic resection)) or (thulium:ti,ab,kw) or (holmium) or (KTP laser) or ("diode"))

Supplementary table 2: Explanation of Studied outcome

	Abbrv	Full term or explanation
Functional outcome	Post-op 6 months Qmax	Postoperative 6 months maximal flow rate
	Post-op 12 months Qmax	Postoperative 12 months maximal flow rate
	Post-op 24 months Qmax	Postoperative 24 months maximal flow rate
	Post-op 36 months Qmax	Postoperative 36 months maximal flow rate
	Post-op 6 months IPSS	Postoperative 6 months international prostate symptoms score
	Post-op 12 months IPSS	Postoperative 12 months international prostate symptoms score
	Post-op 24 months IPSS	Postoperative 24 months international prostate symptoms score
	Post-op 36 months IPSS	Postoperative 36 months international prostate symptoms score
Peri-operative parameter	Catheterization duration	
	Hb-decline	Differecne of Hb between pre-operative Hb and post-operative Hb Supposed corr=0.5 for calculatoin of SD
Complication	Blood clot tamponade	Bladder tamponade caused by blood clot need cystoscopy or manual irrigation
	Blood transfusion	
	BPH recurrence	BPH recurrence need surgical treatment or redo apical resection
	Recatherization	urine retention after remove Foley and need catheterization
	Stricture	Include bladder neck contraction, urethrae stricture and meatal stenosis
	Incontinence	Include stress and urge incontinence
	Retrograde ejaculation	
	Urinary tract infection	UTI need antibiotics treatment
	Permanent incontinence	Incontinence after postop 6 or 12 months, include stress and urge incontinence, exclude vapoenucleation studies
	Shor-term transient incontinence	Incontinence before postop 1 month include stress and urge incontinence, chose the earliest incontinence rate if multiple time points was recorded, exclude vapoenucleation studies

Supplementary table 3: Description of included studies

The characteristics of 105 trial in 131 article was shown below.
Pub_year: publication year, Qmax: maximal flow rate, IPSS: international prostate symptoms score, QOL: quality of life score. NA: not available. *: the method was vapoenucleation, #: the method included vaporization with apical resection $: three arm trial and we only chose one arm of vaporization (conventional)

author	**pub_year**	**follow_up (months)**	**intervention**	**number**	**age**	**Qmax (ml/sec)**	**IPSS**	**QOL**	**prostate volume, ml**	**PSA**
Abascal Junquera, J. Ma[1]	2006	0	Monopolar TURP / Bipolar TURP	21/24	67.3/69.5	7.2/7.7	NA	NA	42.5/39.5	NA
Akcayoz, M.[2]	2006	0	Monopolar TURP / Bipolar TURP	21/21	66/67	NA	NA	NA	47/40	NA
Akman, T.[3]	2012	12	Monopolar TURP / Bipolar TURP	130/143	67.7/67.4	8/7.2	18.5/18.8	4/7.2	55.9/59.7	NA
Al-Ansari, A.[4]	2010	36	Monopolar TURP / KTP LVP120W	60/60	67.1/66.3	6.4/6.9	27.9/27.2	NA	60.3/61.8	2.8/2.6
Al-Rawashdah, Sf.[5]	2017	36	Monopolar TURP / Bipolar TURP	251/246	67.03/67.72	8.81/8.69	23.65/23.93	NA	54.11/53.95	4.14/4
Bachmann, A.[6-8]	2014	12	Monopolar TURP / KTP LVP180W	133/136	65.4/65.9	9.9/9.5	21.7/21.2	NA	46.2/48.6	2.6/2.7
Basic D,[9]	2013	12	Monopolar TURP /Holmium LEP	20/20	65.1/63.3	NA	22.9/23.1	4.7/4.8	42.6/48.8	2.9/3.1
Bhansali, M.[10]	2009	12	Monopolar TURP / Bipolar TURP	33/34	NA	4.1/4.3	24.6/26.3	NA	82.6/82.4	NA
Bouchier-Hayes, D. M.[11 12]	2010	12	Monopolar TURP / KTP LVP80W	50/59	66.3/65.0	8.8/8.8	25.4/25.2	5.0/4.7	33.3/38.7	2.4/2.3
Bozzini, G.[13]	2017	3	Bipolar TURP / Thulium LEP	106/102	70.7/72.5	6.9/7.5	18.6/19.7	NA	81.9/89.7	3.6/3.2

Capitan, C.[14]	2011	24	Monopolar TURP / KTP LVP120W	50/50	67.7/69.8	3.8/8.0	23.5/23.7	4.1/4.5	53.1/51.2	3.6/3.5
Cetinkaya, M[15]	2015	3	Monopolar TURP / Diode LVP	36/35	64.7/63.1	8.4/9.6	21.3/212.6	4.8/4.4	54.8/50.6	2.3/2.2
Chang, Ch [16]	2017	12	Monopolar TURP / Thulium LEP*	30/29	72.6/76.1	10.8/10.5	17.8/17.1	NA	64.7/57.2	8.3/5
Chen, Q.[17 18]	2010	24	Monopolar TURP / Bipolar TURP	50/50	71.2/69.7	7.9/7.1	21.8/22.8	NA	59.1/60.2	2/1.8
Chen, Y. B.[19 20]	2013	24	Bipolar TURP /Holmium LEP	140/140	73.4/72.1	7.2/7.2	23.6/23.2	4.6/4.5	60.3/56.7	2.3/2.2
De Sio, M.[21 22]	2006	18	Monopolar TURP / Bipolar TURP	35/35	61/59	6.3/7.1	24.3/24.1	3.9/4.2	47.5/51.6	2.1/2.4
Demir, A.[23]	2015	1	Monopolar TURP / Bipolar TURP	60/64	65.6/68.2	5/4.5	26.1/26.7	4.7/5.06	70.7/63.4	11.8/10.8
Demirdag, C.[24]	2016	6	Monopolar TURP / Bipolar TURP	45/36	66.8/65	8.6/9.1	25.2/25.1	4.5/4.3	73.9/71.8	4.1/3.5
Dunsmuir, W. D.[25]	2003	12	Monopolar TURP / Bipolar VP	21/30	60/63	10.4/9.6	17/24	NA	42/36	NA
Elmansy, H.[26]	2012	12	Holmium LEP/ KTP LVP80-120W	43/37	71.5/73.2	8.1/8.9	22.4/21.8	4.2/4.2	91.3/89.3	5.4/7.5
Elsakka, A. M.[27]	2016	6	Monopolar TURP / Bipolar VP	40/40	55.6/56.9	6.5/7.5	24.2/24.3	NA	53.8/50.9	0/0
Eltabey, M. A.[28]	2010	12	Monopolar TURP /Holmium LEP	40/40	68.3/67.5	8.1/8.4	25/23	NA	58.5/62.4	3.1/2.9
Erturhan, S.[29]	2007	12	Monopolar TURP / Bipolar TURP	120/120	67.4/68.5	9.2/10.9	24/23	3.0/2.0	42/43	NA

Fagerstrom, T.[30 31]	2009	18	Monopolar TURP / Bipolar TURP	87/98	72.7/69.5	NA	NA	NA	58.2/55.6	NA
Falahatkar, S.[32]	2014	3	Monopolar TURP / Bipolar TURP	39/49	70.9/69.1	8.4/5.4	26.3/26.0	NA	46.9/47.1	NA
Fayad, As [33 34]	2015	12	Bipolar TURP /Holmium LEP	60/60	60.3/60.8	6.6/6.9	23.4/23.2	NA	67.2/68.1	4.6/4.4
Feng, L [35]	2016	12	Bipolar EP / Thulium LEP	66/61	70.0/67.6	7.1/7.4	24.1/23.8	4.4/4.3	67.0/69.0	2.4/2.7
Geavlete B[36]	2015	12	Bipolar TURP / Bipolar EP*/Bipolar VP	80/80/80	69.5/68.5/67.5	6.4/6.6/6.9	25.2/24.7/24.4	4.4/4.1/4.3	121.8/122.6/126.7	7.5/8.1/8.0
Geavlete, B.[37]	2010	6	Monopolar TURP / Bipolar VP	80/75	NA	6.3/6.2	24.4/24.2	4.2/4.4	55.8/56.2	1.8/1.8
Geavlete, B.[38]	2011	18	Monopolar TURP / Bipolar TURP / Bipolar VP	170/170/170	NA	6.4/6.1/6.6	24.2/24/24.3	4.3/4.5/4.3	54.8/53.7/54.1	2.0/1.8/1.9
Geavlete, B.[39]	2013	6	Monopolar TURP / Bipolar VP/ Bipolar VP	60/60/60	68.9/68.9	6.3/6.7/6.9	23.8/23.9/24.2	4.1/4.2/4.1	52.4/50.6/51.9	2.1/2.0/2.2
Ghozzi, S.[40]	2014	12	Monopolar TURP / Bipolar TURP	29/31	68.7/70.2	7.0/8.0	23.8/22.5	NA	49.5/49.5	2.9/3.3
Giulianelli, R.[41]	2013	36	Monopolar TURP / Bipolar TURP	80/80	64.1/62.5	NA	NA	NA	50/47.8	2.8/2.2
Guibin, X.[42]	2010	3	Monopolar TURP / KTP LVP	31/32	72.4/74.1	6.5/7	28.4/29.8	NA	96.7/100.5	6.8/6.4

Gupta, N.[43]	2006	12	Monopolar TURP /Holmium LEP	50/50	65.6/65.8	4.5/5.1	23.3/23.4	NA	59.8/57.9	NA
Hafez, M.[44]	2014	0	Monopolar TURP / Bipolar TURP	25/25	68.9/69.7	NA	NA	NA	51.2/54.2	NA
Hamouda, A.[45]	2015	12	Monopolar TURP /Holmium LEP	30/30	65.6/68.3	6.8/5.9	22.1/22.3	NA	56/56.8	4.3/5.9
Ho, H. S.[46]	2007	12	Monopolar TURP / Bipolar TURP	52/48	66.5/66.6	6.5/6.8	24.6/22.6	NA	54.8/56.5	2.2/2.8
Holovko SV[47 48]	2013	12	Monopolar TURP / KTP LVP80W	60/60	67.1/66.3	6.4/6.9	27.9/27.2	NA	60.3/61.8	2.8/2.6
Hon, N. H.[49]	2006	9.5	Monopolar TURP / Bipolar VP	79/81	68.1/66.1	11.9/12	20.6/21.3	4.3/4.2	40/38	NA
Horasanli, K.[50]	2008	6	Monopolar TURP / KTP LVP	37/39	68.3/69.2	9.2/8.6	20.2/18.9	NA	88/86.1	4.7/5.2
Huang, X.[51]	2012	1	Monopolar TURP / Bipolar TURP	65/71	64.5/65.0	6.9/6.7	22.0/23.3	4.1/4.2	50.0/52.9	1.9/2.0
Iori, F.[52]	2008	12	Monopolar TURP / Bipolar TURP	26/27	63/65	8.7/7	20/21	3.6/3	48/49	NA
Jhanwar, A.[53]	2016	24	Monopolar TURP /Holmium LEP	72/72	66.7/67.7	8.7/8.4	25.8/26.0	NA	74.5/75.6	1.7/2.0
Karadag MA. [54]	2014	12	Bipolar TURP / Bipolar VP	96/87	66.7/67.9	7.3/6.5	20.5/21.4	NA	50.6/50.9	NA
Kaya, C.[55 56]	2007	36	Monopolar TURP / Bipolar VP	15/25	66/67.2	6.0/6.0	22/21	NA	51/50	NA
Kim, J. Y.[57]	2006	6	Monopolar TURP / Bipolar TURP	25/25	70.6/68.1	6.1/6.5	18.6/19.6	NA	51.7/53.2	NA
Komura, K.[58 59]	2014	36	Monopolar TURP / Bipolar TURP	62/63	67.9/69.8	7.1/6.4	22.2/23.7	5.2/5.2	53.1/50.9	6.3/4.6

Kong, C. H.[60]	2009	1	Monopolar TURP / Bipolar TURP	51/51	68.5/68.4	4.6/4.9	23.9/23.3	4.5/4.4	43.1/41.8	NA
Kumar, A.[61 62]	2013	12	Monopolar TURP / Bipolar TURP KTP LVP120W	60/57/58	63.6/62.3/64.5	7/7.0/6.6	20.7/19.7/20.0	3.7/3.5/3.6	52.2/50.2/52.7	2.6/2.9/2.4
Kuntz, R. M.[63 64]	2004	36	Monopolar TURP /Holmium LEP	100/100	68.7/68	5.9/4.9	21.4/22.1	NA	49.9/53.5	NA
Li, K.[65]	2017	36	Bipolar TURP / Bipolar EP	44/42	69.89/73.33	6.9/6.3	21.32/20.19	5.3/5.12	88.02/87.5	7.07/6.33
Lin, M. S.[66]	2006	12	Monopolar TURP / Bipolar TURP	18/22	69/69	6.0/7.0	29.5/29.5	NA	NA	2.8/2.9
Liu, L.[67]	2014	3	Bipolar TURP / KTP LVP80W	23/25	82.3/82.1	7.1/7.3	23.8/26.3	4.8/5.1	53.2/51.1	NA
Liu, J. F.[68 69]	2013	6	Bipolar TURP / Bipolar EP	40/40	70.5/70.4	8.1/7.6	23.1/22.9	4.7/4.5	74.7/78.2	4.0/3.6
Liu, Z.[70]	2017	60	Monopolar TURP / Bipolar TURP	350/340	67.1/66.3	7.5/7.3	23.7/24.2	4.7/4.6	67.4/65.6	1.5/1.4
Lukacs, B.[71]	2012	12	Monopolar TURP / KTP LVP120W	70/68	67.6/66.9	7.7/7.7	20.0/22.1	NA	50.1/50.5	2.7/2.4
Luo, Y. H.[72]	2014	24	Bipolar TURP / Bipolar EP	155/155	69.8/70	7.8/8	21.9/22.8	4.9/5	61.7/61.8	NA
Lusuardi, L.[73]	2011	6	Bipolar TURP / Diode LEP	30/30	65.7/66.5	6.4/6.8	25.4/26.9	4.9/5.1	59.1/59.5	3.9/3.5
Mamoulakis, C.[74-77]	2012	36	Monopolar TURP / Bipolar TURP	138/141	68.9/69.4	8.7/8.9	23/23.3	4.2/4.3	68.9/64	5.3/5.7
Mavuduru, R. M[78]	2007	9	Monopolar TURP /Holmium LEP	15/15	66.4/69.8	6.9/5.7	21.4/22.5	NA	36.3/36.5	1.3/1.8

Mendez-Probst, C. E.[79]	2011	6	Monopolar TURP / Bipolar TURP	21/22	67/68	7/9.2	23.4/23.2	4.7/4.1	50.2/57.9	4.9/4.5
Michielsen, D. P.[80 81]	2007	18	Monopolar TURP / Bipolar TURP	120/118	73.1/73.8	NA	NA	NA	NA	NA
Mohanty, N. K.[82]	2012	12	Monopolar TURP / KTP LVP80W	57/60	65.7/66.6	6.7/7.4	20.8/19.9	3.9/3.9	49.0/44.7	2.7/2.4
Montorsi, F.[83-86]	2004	12	Monopolar TURP /Holmium LEP	48/52	64.5/65.1	7.8/8.2	21.9/21.6	4.7/4.6	56.2/70.3	2.5/2.3
Neill, M. G.[87]	2006	12	Bipolar EP /Holmium LEP	20/20	67/68.9	7.5/7.4	24.4/25.7	NA	51/57	NA
Netsch, C.[88]	2017	1	Holmium LEP / Thulium LEP	46/48	71.5/74	12.1/9.6	22/20	4/4	77.5/82.5	4.1/4.1
Nuhoglu, B.[89]	2006	12	Monopolar TURP / Bipolar TURP	30/27	65.2/64.6	7.3/6.9	17.3/17.6	NA	49/47	NA
Nuhoglu, B.[90]	2011	12	Monopolar TURP / Bipolar VP	47/43	64.7/65.4	8.5/8.1	20.9/21.3	NA	51.7/53.2	NA
Patankar, S.[91]	2006	1	Monopolar TURP / Bipolar TURP	51/52	NA	6.4/5.9	23.7/23.3	NA	52.2/51.3	NA
Peng, M.[92]	2016	12	Bipolar TURP / KTP LVP	59/61	68.7/69.3	7.2/7.7	20.4/21.5	4.6/4.5	64.7/63.7	3.5/3.03
Pereira-Correia, J. A.[93]	2011	24	Monopolar TURP / KTP LVP120W	10/10	63.5/66.4	NA	NA	NA	40/43.3	1.6/2.0
Purkait, B.[94]	2017	48	Monopolar TURP / KTP LVP120W	57/60	65.3/63.6	8.3/8.5	25.9/26.1	4.3/4.4	69.6/70.3	4.2/4.8

Ran, L.[95]	2013	0	Bipolar TURP / Bipolar EP	30/30	72.3/70.9	8.3/7.4	18.2/19.7	4.9/5	67.2/71.6	6.9/7.4
Razzaghi, M. R.[96]	2014	24	Monopolar TURP / Diode LVP	52/50	68.2/68.5	6.3/6.8	24.6/23.6	NA	59.6/61.1	2.5/2.3
Seckiner, I.[97]	2006	14	Monopolar TURP / Bipolar TURP	24/24	63.9/61.2	8.3/8.5	23.2/24.1	8.3/4.4	41.4/49.4	NA
Shao, Q.[98]	2009	3	Holmium LEP/ Thulium LEP	46/52	71.2/74.1	7.3/6.7	22.4/24.3	NA	44.7/40.3	NA
Singh, H.[99]	2005	3	Monopolar TURP / Bipolar TURP	28/27	67.9/68.9	5.1/5.8	21.6/20.5	4.4/4.6	NA	3.2/2.75
Singhania, P.[100]	2010	12	Monopolar TURP / Bipolar TURP	30/30	65.9/63.8	6.4/6.5	23.4/24.0	NA	NA	NA
Skinner, Taa. [101]	2017	3	Bipolar VP/ Diode LVP	30/25	71.8/69.4	NA	22.6/20.5	4.7/5.1	47.8/46.6	2.3/1.4
Stucki, P.[102]	2015	12	Monopolar TURP / Bipolar TURP	67/70	66/67	NA	NA	NA	35/34	NA
Sood, R.[103]	2017	3	Bipolar TURP / KTP LVP120W	42/36	65.57/65.28	NA	NA	NA	NA	2.5/2.4
Sun, N.[104]	2014	12	Monopolar TURP /Holmium LEP	82/82	71.9/72.2	5.6/5.2	24.5/24.4	4.6/4.5	56.2/55.1	5.8/5.5
Swiniarski P P[105]	2012	3	Monopolar TURP / Thulium LEP*	52/54	69.3/68.3	8.5/7.7	20.8/20.3	4.9/4.7	66.5/62.03	3.7/3.3
Tan, A. H.[106-108]	2003	12	Monopolar TURP /Holmium LEP	30/31	70.3/71.7	8.3/8.4	23.7/26	4.7/4.8	70/77.8	NA
Tefekli, A.[109 110]	2005	12	Monopolar TURP / Bipolar VP#	47/49	69.4/68.7	8.3/7.8	20.4/21.3	NA	54/50.1	NA
Telli, O.[111]	2015	24	Monopolar TURP / KTP LVP120W	62/39	69/67	12.5/10.6	19/20	NA	55/60	5.2/3.5

Wu, G.[112]	2016	12	Bipolar EP / Diode LEP	40/40	73.6/75.4	7.6/6.8	21.8/22.4	4.9/4.8	93.3/98.6	6.2/5.6
Xia, S. J.[113]	2008	12	Monopolar TURP / Thulium LEP*	48/52	69.3/68.9	8.3/8	20.8/21.9	4.5/4.7	55.1/59.2	2.3/2.1
Xie, C. Y.[114]	2012	60	Monopolar TURP / Bipolar TURP	110/110	64.9/69.9	9.6/9.8	22.7/23.7	4.4/4.4	67/65.8	1.4/1.3
Xu, abai.[115]	2013	12	Bipolar EP / Diode LEP	40/40	NA	7.7/7.9	23.7/23.5	4.5/4.4	65.7/68.7	2.6/2.7
Xue, B.[116]	2013	36	Monopolar TURP / KTP LVP120W	100/100	71/72.1	8.2/8	23.2/23	4.3/4.2	67.3/65.8	2.8/2.8
Yang, S. [117]	2004	3	Monopolar TURP / Bipolar TURP	59/58	NA	10.9/10.4	21.6/20.8	4/3.7	48.9/45.8	NA
Yang, Z.[118 119]	2013	18	Bipolar TURP / Thulium LEP*	79/79	61.4/62.4	9.1/8.7	23.4/22.7	4.9/3.9	69.2/72.4	2.3/2.4
Yee, CH.[120 121]	2015	6	Monopolar TURP / Bipolar VP#	84/84	65.7/64.3	8.4/8.8	21.5/21.8	3.8/4	66.1/57.2	9.2/7.2
Yip, S. K.[122]	2011	1	Bipolar TURP / Bipolar VP#	40/46	69.2/69.2	7.9/7.9	21.6/22.9	NA	61/61.5	9.5/8.7
Yousef, A. A.[123]	2010	24	Monopolar TURP / Bipolar TURP	120/120	60.7/62	NA	NA	NA	NA	NA
Zhang, F, B.[124]	2013	3	Thulium LEP* / Diode LEP *	30/33	73.4/75.6	7/6.8	24.6/23.1	NA	46.5/47.2	NA
Zhang, F.[125]	2012	18	Holmium LEP/ Thulium LEP /	62/71	73.4/76.2	7.3/6.8	22.8/24.6	NA	43.5/46.6	2.0/2.5
Zhang, K.[126]	2015	3	Bipolar TURP / Bipolar EP*	56/56	67.4/68.2	6.3/6	21.4/22.5	4.7/4.7	119/121.8	0/0

Zhang, S. Y.[127]	2012	6	Monopolar TURP / Bipolar VP#	15/15	71.9/70.9	5.1/5.1	27.3/24.6	NA	70.1/59	NA
Zhao, G. D.[128]	2011	1	Bipolar TURP / Bipolar EP	41/41	72.7/75.1	NA	23.8/24.2	NA	50.9/60.0	NA
Zhao, Z.[129]	2010	36	Monopolar TURP / Bipolar EP	102/102	67.8/67.3	8/8.3	22.4/23.2	4.8/4.5	67.9/69.2	2.2/2.2
Zhu, L.[130]	2013	60	Bipolar TURP / Bipolar EP	40/40	64.8/64.1	4.4/4.7	25/24.6	4	109.4/113.8	2.8/3
Zou, Z.[131]	2018	12	Bipolar EP / Diode LEP	57/57	69.4/67.3	5.4/6.9	22.8/23.1	43225	63.4/59.5	7.7/6.8

Supplementary table 4: Studied outcome of included studies

author	year	follow_up (months)	Qmax _6m	Qmax _12m	Qmax _24m	Qmax _36m	IPSS _6m	IPSS _12m	IPSS _24m	IPSS _36m	blood transfusion	TUR syndrome	Recath ~erization	Blood clot tamponade	Incont ~inence	UTI	stricture	recurrence	Retrograde ejaculation	Catheterization duration	Hb-decline
Abascal Junquera, J. Ma	2006	0									✓	✓	✓							✓	✓
Akcayoz, M.	2006	0									✓	✓									
Akman, T.	2012	12		✓				✓			✓	✓		✓	✓		✓			✓	✓
Al-Ansari, A.	2010	36									✓	✓		✓			✓	✓		✓	✓
Al-Rawashdah, Sf	2017	36		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓			✓			✓	✓
Bachmann, A.	2014	12	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	
Basic D,	2013	12					✓	✓			✓		✓		✓		✓			✓	✓
Bhansali, M.	2009	12		✓							✓	✓					✓			✓	
Bouchier-Hayes, D. M.	2010	12	✓	✓			✓	✓			✓	✓	✓	✓		✓	✓	✓		✓	✓
Bozzini, G.	2017	3									✓		✓	✓	✓		✓			✓	✓
Capitan, C.	2011	24									✓	✓	✓	✓		✓	✓		✓	✓	✓
Cetinkaya, M.	2015	3									✓	✓								✓	
Chang, Ch	2017	12	✓	✓			✓	✓			✓	✓	✓	✓		✓				✓	✓
Chen, Q.	2010	24	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓		✓		✓		✓
Chen, Y. B.	2013	24	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓		✓	✓	✓

de Sio, M.	2006	18		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓			✓	✓			
Demir, A.	2015	1																			✓
Demirdag, C.	2016	6	✓				✓				✓	✓		✓			✓			✓	✓
Dunsmuir, W. D.	2003	12	✓	✓			✓	✓			✓		✓	✓							✓
Elmansy, H.	2012	12	✓	✓			✓	✓					✓	✓	✓		✓	✓	✓	✓	
Elsakka, A. M.	2016	6	✓				✓				✓	✓	✓	✓	✓	✓	✓	✓		✓	
Eltabey, M. A.	2010	12	✓	✓			✓	✓			✓				✓		✓			✓	✓
Erturhan, S.	2007	12		✓				✓			✓	✓	✓	✓	✓		✓			✓	
Fagerstrom, T.	2009	18										✓				✓	✓	✓			
Falahatkar, S.	2014	3									✓	✓	✓	✓		✓	✓	✓		✓	✓
Fayad, As	2015	12	✓	✓			✓	✓			✓	✓	✓		✓		✓	✓			✓
Feng, L	2016	12	✓	✓			✓	✓			✓		✓	✓	✓	✓	✓			✓	✓
Geavlete, B.	2010	6	✓				✓				✓		✓	✓		✓					✓
Geavlete, B.	2011	18									✓	✓	✓	✓	✓	✓	✓				
Geavlete, B.	2013	6											✓				✓				
Geavlete B	2015	12	✓	✓			✓	✓			✓		✓		✓	✓	✓			✓	✓
Ghozzi	2014	12									✓	✓	✓				✓				✓
Giulianelli, R.	2013	36										✓	✓	✓		✓	✓			✓	
Guibin, X.	2010	3									✓		✓			✓				✓	
Gupta, N.	2006	12	✓	✓			✓	✓			✓	✓	✓		✓		✓			✓	✓

Hafez M	2014	0																			✓
Hamouda, A.	2015	12	✓	✓			✓	✓			✓			✓	✓		✓			✓	
Ho, H. S.	2007	12									✓	✓	✓	✓		✓	✓				✓
Holovko SV	2013	12									✓	✓		✓	✓		✓	✓		✓	
Hon, N. H.	2006	10	✓				✓				✓			✓			✓			✓	✓
Horasanli, K.	2008	6	✓				✓				✓	✓	✓			✓	✓	✓	✓	✓	
Huang, X.	2012	1												✓							✓
Iori, F.	2008	12		✓				✓			✓	✓	✓	✓		✓	✓			✓	✓
Jhanwar, A.	2016	24	✓	✓	✓		✓	✓	✓		✓		✓		✓	✓	✓			✓	✓
Karadag MA	2014	12		✓				✓					✓		✓	✓		✓		✓	✓
Kaya, C.	2007	36			✓	✓			✓	✓							✓	✓	✓		
Kim, J. Y.	2006	6	✓				✓					✓			✓	✓	✓			✓	✓
Komura, K.	2014	36				✓				✓	✓	✓	✓	✓		✓				✓	✓
Kong, C. H.	2009	1									✓	✓	✓							✓	✓
Kumar, A.	2013	12	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓	✓
Kuntz, R. M.	2004	36	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓		✓	✓
Li, K.	2017	36	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓		✓	✓
Lin, M. S.	2006	12	✓	✓			✓	✓									✓				✓
Liu, J. F	2014	6	✓				✓						✓		✓		✓			✓	
Liu, Z.	2017	60		✓		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Liu L	2014	3										✓			✓		✓	✓		✓	
Lukacs, B.	2012	12	✓	✓			✓	✓			✓				✓	✓			✓		

Luo, Y. H.	2014	24	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓			✓	
Lusuardi, L.	2011	6	✓				✓				✓		✓		✓	✓	✓			✓	✓
Mamoulakis, C.	2012	36		✓	✓			✓	✓		✓	✓	✓	✓		✓	✓	✓		✓	✓
Mavuduru, R. M	2007	9	✓				✓				✓	✓	✓	✓	✓		✓			✓	
Mendez-Probst, C. E.	2011	6	✓				✓				✓	✓	✓	✓		✓	✓				
Michielsen, D. P.	2007	18									✓	✓	✓	✓			✓			✓	✓
Mohanty, N. K.	2012	12	✓	✓			✓	✓			✓	✓	✓	✓		✓	✓			✓	✓
Montorsi, F.	2004	12	✓	✓			✓	✓			✓	✓	✓	✓	✓		✓			✓	✓
Neill, M. G.	2006	12	✓	✓			✓	✓			✓				✓	✓	✓			✓	
Netsch, C.	2017	1									✓	✓	✓	✓	✓	✓				✓	✓
nuhoglu	2006	12		✓				✓			✓	✓	✓		✓		✓			✓	✓
Nuhoglu, B.	2011	12		✓				✓			✓	✓	✓		✓		✓	✓		✓	✓
Patankar, S.	2006	1									✓	✓		✓		✓				✓	
Pawel Swiniarski P	2012	3									✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Peng, M.	2016	12	✓	✓			✓	✓			✓			✓	✓		✓		✓	✓	
Pereira-Correia, J. A.	2011	24									✓										
Purkait, B.	2017	48		✓	✓	✓		✓	✓	✓	✓		✓			✓	✓	✓		✓	
Ran, L.	2013	0									✓	✓								✓	✓
Razzaghi, M. R.	2014	24	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓		✓	✓	✓		✓	✓

Seckiner, I.	2006	14	✓	✓			✓	✓				✓		✓			✓			✓	✓
Shao, Q.	2009	3									✓	✓									✓
Singh, H.	2005	3									✓	✓			✓	✓	✓			✓	✓
Singhania, P.	2010	12	✓	✓			✓	✓			✓			✓		✓	✓				✓
Skinner, Taa	2017	3												✓			✓	✓			
Sood, R.	2017	3									✓	✓	✓	✓	✓		✓			✓	✓
Stucki, P.	2015	12									✓	✓		✓			✓				
Sun, N.	2014	12		✓				✓			✓						✓			✓	✓
Tan, A. H.	2003	12	✓	✓	✓		✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	
Tefekli, A.	2005	12	✓	✓			✓	✓			✓		✓		✓		✓	✓	✓	✓	
Telli, O.	2015	24	✓	✓	✓						✓	✓	✓			✓	✓	✓			
Wu, G	2016	12	✓	✓			✓	✓			✓		✓	✓	✓		✓		✓	✓	✓
Xia, S. J.	2008	12	✓	✓			✓	✓			✓	✓	✓		✓	✓	✓		✓	✓	✓
Xie, C. Y.	2012	60		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓
Xu abai	2013	12	✓	✓			✓	✓			✓	✓	✓	✓	✓		✓			✓	✓
Xue, B.	2013	36									✓	✓	✓		✓	✓	✓		✓	✓	✓
Yang, S	2004	3									✓	✓	✓	✓	✓		✓			✓	
Yang, Z.	2013	18	✓	✓		✓	✓	✓		✓	✓	✓		✓			✓			✓	✓
Yee CH	2015	6	✓				✓				✓	✓	✓	✓						✓	✓
Yip, S. K.	2011	1									✓		✓	✓						✓	✓
Yousef, A. A.	2010	6									✓	✓	✓	✓						✓	
Zhang, F.	2012	18	✓	✓			✓	✓			✓	✓	✓		✓		✓			✓	✓

Zhang, K.	2015	3									✓				✓		✓			✓	✓
Zhang, S. Y.	2012	6																		✓	
Zhang FB	2013	3										✓	✓			✓	✓				✓
Zhao, G. D.	2011	1												✓			✓			✓	
Zhao, Z.	2010	36	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Zhu, L.	2013	60	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓	✓
Zou, Z.	2018	12	✓	✓			✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

✓Had reported outcome for analysis

Supplementary table 5: Results of network meta-analysis

Estimated are presented as mend difference and 95% confidence intervals. Comparison between treatments should be read from column to row and the estimate is in the cell in common between the column-defining treatment and the row-defining treatment. Mean difference more than 0 favor the column-defining treatment for maximal flow rate and row-defining treatment for IPSS. Significant results are in bold and underlined.

Supplementary table 5a: network estimated mean difference (95% confidence intervals) of postop 6 months maximal flow rate

Diode LVP								
1.47 (-3.24 to 6.17)	KTP LVP							
0.99 (-3.74to 5.72)	-0.47 (-2.92 to 1.97)	Bipolar VP						
-1.81 (-7.02 to 3.39)	<u>**-3.28**</u> <u>**(-6.45 to -0.10)**</u>	-2.80 (-5.99 to 0.38)	Diode LEP					
-1.02 (-6.04 to 4.00)	-2.48 (-5.38 to 0.41)	-2.01 (-4.97 to 0.96)	0.79 (-2.62 to 4.21)	Thulium LEP				
0.01 (-4.59 to 4.61)	-1.45 (-3.53 to 0.62)	-0.98 (-3.19 to 1.23)	1.82 (-1.11 to 4.76)	1.03 (-1.48 to 3.54)	Holmium LEP			
-2.01 (-6.83 to 2.64)	<u>**-3.56**</u> <u>**(-5.89 to -1.23)**</u>	<u>**-3.09**</u> <u>**(-5.41 to -0.76)**</u>	-0.28 (-2.71 to 2.14)	-1.08 (-3.66 to 1.50)	-2.11 (-4.07 to 0.15)	Bipolar EP		
-0.20 (-4.79to 4.39)	-1.67 (-3.64 to 0.31)	-1.19 (-3.28 to 0.90)	-1.61 (-1.00 to 4.22)	0.82 (-1.68 to 3.32)	-0.21 (-1.86 to 1.44)	<u>**1.90**</u> <u>**(0.32 to 3.47)**</u>	Bipolar TURP	
0.80 (-3.58to 5.18)	-0.67 (-2.38to 1.05)	-0.19 (-1.98 to 1.59)	2.61 (-0.20 to 5.42)	1.82 (-0.64 to 4.27)	0.79 (-0.61 to 2.19)	<u>**2.90**</u> <u>**(1.11 to 4.69)**</u>	1.00 (-0.37 to 2.37)	Monopolar TURP

Supplementary table 5b: network estimated mean difference (95% confidence intervals) of postop 12 months maximal flow rate

Diode LVP								
-1.79 (-4.55 to 1.60)	KTP LVP							
-2.22 (-5.17 to 1.26)	-0.43 (-2.35 to 1.48)	Bipolar VP						
-5.05 **(-9.08 to -1.02)**	**-3.26** **(-6.04 to-0.49)**	-2.83 (-5.61 to 0.05)	Diode LEP					
-2.80 (-6.40 to 0.81)	-1.01 (-3.13 to 1.11)	-0.58 (-2.80 to 1.65)	2.25 (-0.60 to 5.10)	Thulium LEP				
-3.03 **(-6.33 to -0.27)**	-1.24 (-2.78 to 0.30)	-0.61 (-2.55 to 0.93)	2.02 (-0.58 to 4.63)	-0.32 (-2.06 to 1.60)	Holmium LEP			
-4.70 **(-8.12 to -1.27)**	**-2.91** **(-4.70 to -1.12)**	**-2.48** **(-4.28 to-0.67)**	0.36 (-1.76 to 2.47)	-1.90 (-3.81to 0.01)	**-1.67** **(-3.19 to-0.15)**	Bipolar EP		
-2.74 (-5.98 to 0.49)	-0.96 (-2.33 to 0.41)	-0.52 (-2.03 to 0.98)	2.31 (-0.17 to 4.79)	0.05 (-1.74 to 1.85)	0.28 (-0.83 to 1.40)	**1.95** **(0.66 to 3.25)**	Bipolar TURP	
-1.90 (-5.04 to 1.24)	-0.11 (-1.37 to 1.14)	0.32 (-1.17 to 1.81)	**3.15** **(0.63 to 5.67)**	0.90 (-0.86 to 2.66)	**1.13** **(0.13 to 2.13)**	**2.80** **(1.43 to 4.16)**	**0.84** **(0.08 to 1.61)**	Monopolar TURP

Supplementary table 5c: network estimated mean difference (95% confidence intervals) of postop 24 months maximal flow rate

Diode LVP						
-2.40 (-6.43 to 1.63)	KTP LVP					
5.70 (0.63 to 10.77)	**-8.10 (3.92 to 12.29)**	Bipolar VP				
-3.46 (-7.45 to0.53)	-1.06 (-3.08 to 1.68)	**-9.16 (-13.30 to -5.01)**	Holmium LEP			
-6.36 (-10.55 to-2.18)	**-3.96 (-6.91 to -1.01)**	**-12.06 (-16.40 to -7.73)**	-2.90 (-5.73 to -0.07)	Bipolar EP		
-3.02 (-6.82 to -0.78)	-0.62 (-2.96 to 1.72)	**-8.72 (-12.69 to -4.75)**	0.44 (-1.72 to 2.60)	**3.34 (1.34 to 5.34)**	Bipolar TURP	
-2.6 (-6.10 to 0.90)	-0.20 (-2.20 to 1.80)	**-8.30 (-11.97 to -4.63)**	0.86 (-1.06 to 2.78)	**3.76 (1.46to 6.06)**	0.42 (-1.07 to 1.92)	Monopolar TURP

Supplementary table 5d: network estimated mean difference (95% confidence intervals) of postop 36 months maximal flow rate

KTP LVP						
7.80 (4.73 to 10.87)	Bipolar VP					
-0.63 (-6.20 to 4.94)	**-8.43 (-14.39 to -2.47)**	Thulium LEP				
-0.26 (-2.62 to 2.10)	**-8.06 (-11.22to -4.90)**	0.37 (-5.16 to 5.91)	Holmium LEP			
-5.34 (-7.86 to 2.81)	**-13.14 (-14.43 to -9.85)**	-4.70 (-10.29 to 0.88)	**-5.07 (-7.60 to -2.55)**	Bipolar EP		
-0.03 (-1.80 to 2.02)	**-7.83 (-10.60 to -5.07)**	0.60 (-4.68to 5.88)	0.23 (-1.43 to 1.89)	**5.30 (3.49 to 7.12)**	Bipolar TURP	
0.40 (-1.24 to 2.04)	**-7.40 (-10.00 to -4.80)**	1.03 (-4.33 to 6.40)	0.66 (-1.13 to 2.46)	**5.74 (3.72to 7.76)**	0.43 (-0.51 to 1.38)	Monopolar TURP

Supplementary table 5e: network estimated mean difference (95% confidence intervals) of postop 6 months IPSS

Diode LVP									
0.27 (-3.11 to 3.64)	KTP LVP								
0.21 (-3.16 to 3.57)	-0.06 (-1.88 to 1.76)	Bipolar VP							
1.46 (-2.18 to 5.09)	1.46 (-2.18 to 5.09)	1.25 (-1.01to 3.39)	Diode LEP						
1.17 (-2.29 to 4.62)	0.90 (-1.03 to 2.83)	0.96 (-0.97 to 2.89)	-0.29 (-2.50 to 1.92)	Thulium LEP					
0.65 (-2.59 to 3.89)	0.38 (-1.09 to 1.86)	0.44 (-1.08 to 1.97)	-0.81 (-2.77 to 1.16)	-0.52 (-2.10 to 1.07)	Holmium LEP				
1.40 (-1.94 to 4.74)	1.13 (-0.55 to 2.82)	1.19 (-0.44 to 2.83)	-0.05 (-1.65 to 1.54)	0.23 (-1.43 to 1.90)	0.75 (-0.59 to 2.09)	Bipolar EP			
0.62 (-2.62 to 3.87)	0.36 (-1.07 to 1.78)	0.42 (-1.06 to 1.89)	-0.83 (-2.59 to 0.93)	-0.54 (-2.09 to 1.01)	0.02 (-1.12 to 1.07)	-0.78 (-1.86 to 0.31)	Bipolar TURP		
0.70 (-2.41 to 3.81)	0.43 (-0.88 to 1.75)	0.49 (-0.88 to 1.75)	-0.76 (-2.64 to 1.13)	-0.47 (-1.97 to 1.04)	0.05 (-0.84 to0.95)	-0.70 (-1.92 to 0.52)	0.08 (-0.84 to0.99)	Monopolar TURP	

Supplementary table 5f: network estimated mean difference (95% confidence intervals) of postop 12 months IPSS

Diode LVP								
0.88 (-1.78 to 3.53)	KTP LVP							
1.54 (-1.18 to 4.25)	0.66 (-0.78 to 2.11)	Bipolar VP						
2.55 (-0.45 to 5.55)	1.67 (-0.24 to 3.59)	1.01 (-0.91 to 2.94)	Diode LEP					
2.13 (-0.60 to 4.86)	1.25 (-0.22 to 2.72)	0.59 (-0.97 to 2.14)	-0.42 (-2.34 to 1.49)	Thulium LEP				
2.14 (-0.42 to 4.70)	1.26 (0.16 to 2.36)	0.60 (-0.67 to 1.87)	-0.41 (-2.17 to 1.35)	0.01 (-1.21 to 1.24)	Holmium LEP			
2.22 (-0.44 to 4.48)	1.34 (-0.02 to 2.67)	0.68 (-0.66 to 2.02)	-0.33 (-1.72 to 1.05)	0.09 (-1.23 to 1.42)	0.08 (-1.01 to 1.16)	Bipolar EP		
1.51 (-1.03 to 4.05)	0.63 (-0.39 to 1.66)	-0.03 (-1.17 to 1.11)	-1.04 (-2.71 to 0.63)	-0.62 (-1.80 to 0.56)	-0.63 (-1.42 to 0.15)	-0.71 (-1.65 to 0.23)	Bipolar TURP	
1.30 (-1.17 to 3.77)	0.42 (-0.54to 1.39)	-0.24 (-1.35 to 0.88)	-1.25 (-2.95 to 0.45)	-0.83 (-1.98 to 0.33)	**-0.84 (-1.51 to -0.17)**	-0.92 (-1.90 to 0.07)	-0.21 (-0.78to0.36)	Monopolar TURP

Supplementary table 5g: network estimated mean difference (95% confidence intervals) of postop 24 months IPSS

Diode LVP						
2.37 (-1.32 to 6.07)	KTP LVP					
0.80 (-3.27 to 4.87)	-1.57 (-4.41 to 1.26)	Bipolar VP				
3.05 (-0.48 to 6.57)	0.67 (-1.27 to 2.62)	2.25 (-0.37 to 4.86)	Holmium LEP			
4.25 (0.67 to 7.84)	1.88 (-0.10 to 3.87)	**3.45 (0.77 to 6.14)**	1.21 (-0.47 to 2.88)	Bipolar EP		
2.98 (-0.46 to 6.42)	0.61 (-1.07 to 2.28)	2.18 (-0.32 to 4.67)	-0.07 (-1.37 to 1.24)	**-1.28 (-2.54to -0.10)**	Bipolar TURP	
2.70 (-0.63 to 6.03)	0.33 (-1.27 to 1.93)	1.90 (-0.44to 4.24)	-0.35 (-1.50 to 0.81)	-1.55 (-2.88 to 0.23)	-0.28 (-1.14 to 0.58)	Monopolar TURP

Supplementary table 5h: network estimated mean difference (95% confidence intervals) of postop 36 months IPSS

KTP LVP						
-2.29 (-4.46 to -0.11)	Bipolar VP					
-0.81 (-3.01 to 1.40)	1.48 (-1.13to 4.09)	Thulium LEP				
0.07 (-1.65 to 1.79)	**2.36 (0.17 to 4.55)**	0.88 (-1.30 to 3.05)	Holmium LEP			
1.79 (-0.18 to 3.40)	**4.08 (1.97 to 6.19)**	**2.60 (0.53 to 4.67)**	1.72 (0.13 to 3.31)	Bipolar EP		
-0.11 (-1.40 to 1.19)	**2.18 (0.27 to 4.09)**	0.70 (-1.08 to 2.48)	-0.18 (-1.42 to 1.07)	-1.90 (-2.95to -0.84)	Bipolar TURP	
-0.39 (-1.63 to 0.85)	**1.90 (0.11 to 3.69)**	0.42 (-1.49 to 2.33)	-0.46 (-1.73 to 0.81)	**-2.18 (-3.30 to -1.06)**	-0.28 (-0.95 to 0.39)	Monopolar TURP

Supplementary table 5i: network estimated mean difference (95% confidence intervals) of postop 6 months catheterization duration

Diode LVP								
-16.42 (-36.53 to 3.69)	KTP LVP							
-26.06 (-47.13 to -5.00)	-9.64 (-21.54 to 2.26)	Bipolar VP						
-12.18 (-36.08 to 11.72)	4.24 (-11.98 to 20.45)	13.88 (-3.15 to 30.91)	Diode LEP					
-16.84 (-38.18to 4.51)	-0.42 (-12.71 to 11.88)	9.23 (-4.53，22.99)	-4.65 (-21.89 to 12.58)	Thulium LEP				
-24.14 (-44.29 to -3.98)	-7.71 (-17.67 to2.24)	1.93 (-10.05 to 13.91)	**-11.95 (-28.05 to -4.15)**	-7.30 (-18.54 to 3.95)	Holmium LEP			
-23.90 (-44.47 to -3.34)	-7.48 (-18.21 to 3.25)	2.16 (-9.69 to 14.01)	-11.72 (-24.95 to 1.51)	-7.07 (-19.12 to 4.99)	0.23 (-10.19 to 10.65)	Bipolar EP		
-37.22 (-56.57 to -17.87)	**-20.80 (-28.83 to -12.76)**	**-11.15 (-21.04 to -1.27)**	**-25.03 (-39.35 to -10.72)**	**-20.38 (-21.41 to -4.76)**	**-13.08 (-21.41 to -4.76)**	**-13.31 (-21.01to -5.62)**	Bipolar TURP	
-48.72 (-67.46 to -29.99)	**-32.30 (-39.62 to -24.98)**	**-22.66 (-32.30 to -13.32)**	**-36.54 (-51.38 to -21.70)**	**-31.89 (-42.11 to -21.66)**	**-24.59 (-32.02 to -17.15)**	**-34.82 (-33.31 to -16.33)**	**-11.50 (-16.37 to -6.64)**	Monopol ar TURP

Supplementary table 5j: network estimated mean difference (95% confidence intervals) of postop 6 months Hb-decline

Diode LVP								
0.85 (-0.37 to 2.07)	KTP LVP							
0.24 (-0.95 to 1.44)	**-0.61** **(-1.13 to -0.08)**	Bipolar VP						
0.55 (-0.70 to 1.80)	-0.30 (-0.94to 0.34)	0.31 (-0.27 to 0.89)	Diode LEP					
0.40 (-0.80 to 1.59)	-0.45 (-0.98 to 0.07)	0.15 (-0.31 to 0.62)	-0.15 (-0.68 to 0.38)	Thulium LEP				
0.21 (-0.97to 1.40)	**-0.64** **(-1.14 to -0.13)**	-0.03 (-0.48 to 0.42)	-0.34 (-0.90 to 0.22)	-0.18 (-0.56 to 0.19)	Holmium LEP			
0.24 (-0.97 to 1.44)	**-0.62** **(-1.15 to -0.08)**	-0.01 (-0.46 to 0.44)	-0.32 (-0.76 to 0.13)	-0.16 (-0.58 to 0.26)	-0.02 (-0.42 to 0.46)	Bipolar EP		
-0.21 (-1.37 to 0.95)	**-1.06** **(-1.50to -0.63)**	**-0.45** **(-0.80 to -0.11)**	**-0.76** **(-1.25 to -0.28)**	**-0.61** **(-0.95 to -0.27)**	**-0.42** **(-0.75 to -010)**	**-0.45** **(-0.78 to -0.11)**	Bipolar TURP	
-0.40 (-1.55 to 0.75)	**-1.25** **(-1.68 to -0.84)**	**-0.64** **(-0.98 to -0.31)**	**-0.95** **(-1.45 to -0.45)**	**-0.80** **(-1.13 to -0.46)**	**-0.61** **(-0.92 to -0.31)**	**-0.64** **(-0.99 to -0.28)**	**-0.19** **(-0.37 to -0.01)**	Monopolar TURP

Supplementary table 6: Results of meta-analysis of direct comparison

Estimated are presented as mend difference (or odds ratio) and 95% confidence intervals. Significant results are in bold and underlined.

Supplementary table 6a: Pairwise meta-analysis of mean difference (95% CI) for post-op 6 months flow rate

Comparison		Pairwias meta-analysis mean difference	No. of participants	No. of trials	Heterogeneity I2
Bipolar TURP	Monopolar TURP	1.34 (-0.10 to 2.78)	533	8	49.90%
Bipolar EP		**<u>4.7 (2.71 to 6.69)</u>**	204	1	-
Holmium LEP		0.97 (-0.75 to 2.70)	749	8	91.10%
Thulium LEP		-2.13 (-8.84 to 4.58)	159	2	80.50%
Bipolar VP		-0.03 (-2.4 to 2.33)	646	6	88.70%
KTP LVP		-0.71 (-2.24 to 0.83)	632	6	79.50%
Diode LVP		0.80 (-0.55 to 2.15)	102	1	-
Bipolar EP	Bipolar TURP	1.94 (-1.10 to 4.98)	692	5	97.7%
Holmium LEP		0.23 (-0.26 to 0.73)	340	2	0%
Thulium LEP		-0.4 (-4.31 to 3.51)	158	1	-
KTP LVP		0.41 (-0.97 to 1.78)	232	2	0%
Bipolar VP		-2.10 (-3.25 to -0.95)	146	1	-
Diode LEP		-0.03 (-0.92 to 0.86)	60	1	-
Holmium LEP	Bipolar EP	**<u>-3.20 (-4.63 to -1.77)</u>**	40	1	-
Diode LEP		0.31 (-1.02 to 1.65)	274	3	0%
Bipolar VP		-2.90 (-4.00 to -1.80)	147	1	-
Thulium LEP		0.45 (-0.83 to 1.73)	127	1	-
Thulium LEP	Holmium LEP	**<u>4.37 (3.08 to 5.66)</u>**	133	1	
KTP LVP		**<u>-5.60 (-9.70 to -1.50)</u>**	80	1	

Supplementary table 6b : Pairwise meta-analysis of mean difference (95% CI) for post-op 12 months flow rat

Comparison		Pairwise meta-analysis mean difference	No. of participants	No. of trials	Heterogeneity I2
Bipolar TURP	Monopolar TURP	**1.16 (0.14 to 2.08)**	2126	14	80.50%
Bipolar EP		1.40 (-0.95 to 3.75)	204	1	-
Holmium LEP		1.18 (0.22 to 2.15)	875	8	70.4%
Thulium LEP		-1.43 (-3.82 to 0.96)	159	2	32.90%
Bipolar VP		0.54 (-0.61 to 1.70)	226	3	0%
KTP LVP		-0.29 (-0.95 to -0.28)	655	6	5.30%
Diode LVP		***-1.90 (-3.21 to -0.59)***	102	1	
Bipolar EP	Bipolar TURP	2.05 (-2.02 to 6.13)	605	4	98.4%
Holmium LEP		**0.49 (0.11 to 0.87)**	386	2	0%
Thulium LEP		-0.70 (-4.73 to 3.33)	158	1	
Bipolar VP		-0.92 (-3.21 to 1.36)	329	2	87.1%
KTP LVP		-0.08 (-1.44 to 1.28).	227	2	0%
Holmium LEP	Bipolar EP	**-3.10 (-5.23 to -0.97)**	40	1	
Thulium LEP		0.37 (-0.92 to 1.66)	127	1	
Diode LEP		0.27 (-0.93to 1.47)	274	3	0%
Bipolar VP		**-2.80 (-3.87 to -1.73)**	147	1	-
Thulium LEP	Holmium LEP	0.85 (-0.71 to 2.41)	133	1	
KTP LVP		**-6.40 (-10.85 to -1.95)**	80	1	

Supplementary table 6c :Pairwise meta-analysis of mean difference (95% CI) for post-op 24 months flow rate

Comparison		Pairwias meta-analysis mean difference	No. of participants	No. of trials	Heterogeneity I2
Bipolar TURP	Monopolar TURP	**0.08(0.06 to 0.10)**	1138	5	0%
Bipolar EP		**4.30 (1.66 to 6.94)**	180	1	0%
Holmium LEP		1.22 (0.28 to 2.15)	347	3	25.5%
Bipolar VP		**-8.30 (-9.77 to -6.83)**	40	1	0%
Diode LVP		**-2.60 (-3.53 to -1.67)**	102	1	0%
KTP LVP		-0.20 (-2.36 to 1.97)	324	3	90.7%
Bipolar EP	Bipolar TURP	3.21 (-2.21 to 8.63)	439	3	97.6%
Holmium LEP		0.42 (-0.67 to 1.51)	280	1	0%
KTP LVP		-0.08 (-1.98 to 1.82)	101	1	0%

Supplementary table 6d: Pairwise meta-analysis of mean difference (95% CI) for post-op 36 months flow rate

Comparison		Pairwise meta-analysis mean difference	No. of participants	No. of trials	Heterogeneity I2
Bipolar TURP	Monopolar TURP	0.63 (-0.15 to 1.14)	1554	5	71.6%
Bipolar EP		**3.70 (0.97 to 6.43)**	170	1	0%
Holmium LEP		1.50 (-1.91 to 4.91)	144	1	0%
Bipolar VP		**-7.40 (-9.27 to -5.53)**	40	1	0%
KTP LVP		0.44 (-0.73 to 1.61)	220	2	0%
Bipolar EP	Bipolar TURP	**5.38 (1.76 to 9.00)**	159	2	75.3%
Thulium LEP		0.60 (-4.36 to 5.56)	118	1	0%
KTP LVP		-0.11 (-2.02 to 1.80)	98	1	0%

Table 6e: Pairwise meta-analysis of mean difference (95% CI) for post-op 6 months IPSS

Comparison		Pairwias meta-analysis mean difference	No. of participants	No. of trials	Heterogeneity I2
Bipolar TURP	Monopolar TURP	0.01 (-0.27 to 0.29)	533	8	0%
Bipolar EP		**-1.60 (-2.52 to -0.68)**	204	1	0
Holmium LEP		-0.28 (-1.18 to 0.63)	789	9	95.10%
Thulium LEP		0.13 (-0.80 to 1.07)	159	2	0%
Bipolar VP		0.37 (-2.48 to 3.22)	646	6	97.30%
Diode LVP		0.70 (-0.13 to 1.53)	102	1	0%
KTP LVP		0.90 (-0.51 to 2.31)	531	5	79.00%
Bipolar EP	Bipolar TURP	-0.43 (-1.10 to 0.24)	692	5	81.2%
Holmium LEP		-0.21 (-0.91 to 0.50)	340	2	67.40%
Thulium LEP		**-0.80 (-1.27 to -0.33)**	158	1	0%
Diode LEP		-0.23 (-0.79 to 0.33)	60	1	0%
Bipolar VP		-0.20 (-0.80 to 0.40)	146	1	-
KTP LVP		-0.11 (-0.51 to 0.30)	232	2	0%
Holmium LEP	Bipolar EP	**3.30 (2.55 to 4.05)**	40	1	0%
Thulium LEP		-0.46 (-1.25 to 0.33)	127	1	0%
Diode LEP		-0.20 (-0.70 to 0.30)	274	3	0%
Bipolar VP		0.40 (-0.17 to 0.97)	147	1	-
Thulium LEP	Holmium LEP	-0.38 (-0.80 to 0.04)	133	1	0%
KTP LVP		-1.10 (-2.44 to 0.24)	80	1	0%

Supplementary table 6f :Pairwise meta-analysis of mean difference (95% CI) for post-op 12 months IPSS

Comparison		Pairwias meta-analysis mean difference	No. of participants	No. of trials	Heterogeneity I2
Bipolar TURP	Monopolar TURP	**-0.32 (-0.34 to -0.30)**	2556	13	0%
Bipolar EP		**-1.70 (-2.67 to -0.73)**	204	1	0%
Holmium LEP		**-1.17 (-1.93 to -0.41)**	915	9	94.60%
Thulium LEP		-0.19 (-1.13 to 0.75)	159	2	0%
Bipolar VP		0.07 (-0.95 to 1.09)	226	3	53.30%
Diode LVP		**1.30 (0.29 to 2.31)**	102	1	0%
KTP LVP		0.74 (-0.65to 2.12)	564	5	90.1%
Bipolar EP	Bipolar TURP	-0.55 (-1.36 to 0.26)	605	4	81.1%
Holmium LEP		-0.74 (-1.88 to 0.41)	386	2	90.20%
Thulium LEP		**0.60 (0.02 to 1.18)**	158	1	0%
Bipolar VP		0.02 (-0.46 to 0.51)	329	2	0%
KTP LVP		0.11 (-0.29 to 0.51)	227	2	0%
Holmium LEP	Bipolar EP	0.30 (-0.90 to 1.50)	40	1	0%
Thulium LEP		-0.16 (-1.02 to 0.70)	127	1	0%
Diode LEP		-0.34 (-0.77 to 0.09)	274	3	0%
Bipolar VP		0.30 (-0.20 to 0.80)	147	1	-
Thulium LEP	Holmium LEP	**-2.07 (-2.53 to -1.61)**	133	1	0%
KTP LVP		0.40 (-0.72 to 1.52)	80	1	0%

Supplementary table 6g : Pairwise meta-analysis of mean difference (95% CI) for post-op 24 months IPSS

Comparison		Pairwise meta-analysis mean difference	No. of participants	No. of trials	Heterogeneity I2
Bipolar TURP	Monopolar TURP	-0.27 (-0.77 to 0.23)	1138	5	76.40%
Bipolar EP		**-2.20 (-2.89 to -1.51)**	180	1	0%
Holmium LEP		-0.37 (-1.72 to 0.98)	347	3	94.0%
Bipolar VP		**1.90 (1.09 to 2.71)**	40	1	0%
Diode LVP		**2.70 (0.19 to 5.21)**	102	1	0%
KTP LVP		0.31 (-0.77 to 1.40)	223	2	53.3%
Bipolar EP	Bipolar TURP	-1.07 (-3.31 to 1.18)	435	3	96.7%
Holmium LEP		-0.01 (-0.42 to 0.40)	280	1	0%
KTP LVP		0.12 (-0.34 to 0.58)	101	1	0%

Supplementary table 6h: Pairwise meta-analysis of mean difference (95% CI) for post-op 36 months IPSS

Comparison		Pairwise meta-analysis mean difference	No. of participants	No. of trials	Heterogeneity I2
Bipolar TURP	Monopolar TURP	-0.36 (-0.85 to 0.12)	1554	5	88.6%
Bipolar EP		**-1.90 (-2.68 to -1.12)**	170	1	0%
Holmium LEP		-0.60 (-1.61 to 0.41)	144	1	0%
Bipolar VP		**1.90 (1.08 to 2.72)**	40	1	0%
KTP LVP		-0.29 (-0.72to 0.14)	220	2	0%
Bipolar EP	Bipolar TURP	-2.01 (-4.60 to 0.59)	73	2	94.8%
Thulium LEP		0.70 (-0.12 to 1.52)	118	1	0%
KTP LVP		0.00 (-0.47 to 0.47)	98	1	0%

Supplementary table 6i : Pairwise meta-analysis of mean difference (95% CI) for post-op Hb-decline

Comparison		Pairwise meta-analysis mean difference	No. of participants	No. of trials	Heterogeneity I2
Bipolar TURP	Monopolar TURP	-0.24 (-0.47 to 0.01)	2945	22	96.6%
Bipolar EP		**-0.44 (-0.63 to -0.26)**	498	5	72.1%
Holmium LEP		**-0.52 (-0.82 to -0.23)**	828	7	78.00%
Thulium LEP		**-0.54 (-0.93 to -0.15)**	265	3	67.40%
Bipolar VP		**-0.46 (-0.72 to -0.20)**	624	5	79.40%
Diode LVP		-0.40 (-1.11 to 0.31)	102	1	0%
KTP LVP		**-1.32 (-1.75 to -0.89)**	764	6	75.50%
Bipolar EP	Bipolar TURP	**-0.38 (-0.57 to -0.18)**	412	4	64.90%
Holmium LEP		-0.60 (-1.34 to 0.13)	400	2	94.6%
Thulium LEP		-1.25 (-3.44 to 0.93)	366	1	99.1%
Diode LEP		**-0.37 (-0.63 to -0.11)**	60	1	0%
Bipolar VP		**-0.60 (-0.91 to -0.29)**	429	3	80.0%
KTP LVP		**-0.71 (-1.06 to -0.37)**	764	6	75.5%
Thulium LEP	Bipolar EP	**-0.19 (-0.37 to -0.01)**	127	1	0%
Diode LEP		**-0.30 (-0.60 to -0.00)**	274	3	72.2%
Bipolar VP		**-0.70 (-0.92 to -0.48)**	160	1	-
Thulium LEP	Holmium LEP	-0.21(-0.61 to 0.18)	325	2	81.0%
Diode LEP	Thulium LEP	**-0.60 (-1.10 to -0.10)**	63	1	0%

Supplementary table 6j : Pairwise meta-analysis of mean difference (95% CI) for catheterization duration

Comparison		Pairwise meta-analysis mean difference	No. of participants	No. of trials	Heterogeneity I2
Bipolar TURP	**Monopolar TURP**	**-13.76 (-18.19 to 9.32)**	3945	16	97.5%
Bipolar EP		**-28.80 (-36.78 to -20.82)**	204	1	-
Holmium LEP		**-21.11 (-25.68 to 16.54)**	979	9	74.4%
Thulium LEP		**-16.57 (-37.08 to 3.95)**	265	3	94.6%
Bipolar VP		**-16.89 (-26.95 to -6.82)**	624	6	90.8%
Diode LVP		**-48.60 (-88.27 to -8.93)**	173	2	98.6%
KTP LVP		**-34.69 (-43.03 to -26.34)**	1140	8	96.3%
Bipolar EP	Bipolar TURP	**-13.12 (-21.02 to -5.22)**	970	3	98.3%
Holmium LEP		**-5.91 (-11.67 to -0.15)**	280	1	-
Thulium LEP		**-57.8 (-107.16 to -0.45)**	366	1	94.9%
Diode LEP		**-32.93 (-38.75 to -27.11)**	60	1	-
Bipolar VP		-19.80 (-28.76 to 10.83)	429	3	76.0%
KTP LVP		**-13.58 (-22.45 to -7.35)**	283	3	82.3%
Holmium LEP	Bipolar EP	0.30 (-3.99 to 4.59)	40	1	-
Thulium LEP		**-10.32 (-19.92 to -0.72)**	127	1	-
Diode LEP		**-9.18 (-21.78 to -3.41)**	160	2	85.9%
Bipolar VP		**-7.20 (-12.89 to -1.51)**	160	1	-
Thulium LEP	Holmium LEP	-1.40 (-7.66 to 4.85)	227	2	-
KTP LVP	Holmium LEP	4.80 (-6.26 to 15.86)	80	1	-

Supplementary table 6k: Pairwise meta-analysis of mean difference (95% CI) for blood clot tamponade

Comparison		Pairwise meta-analysis odds ratio (95% CI)	No. of participants	No. of trials	No. of events	Heterogeneity I2
Bipolar TURP	Monopolar TURP	**<u>0.49 (0.33 to 0.73)</u>**	4455	23	124	16.8 %
Bipolar EP		0.20 (0.01 to 4.14)	204	1	2	-
Holmium LEP		0.40 (0.13 to 1.19)	451	5	15	0%
Thulium LEP		1.01 (0.25 to 4.10)	165	2	8	0%
Bipolar VP		**<u>0.40 (0.19 to 0.84)</u>**	954	6	39	0%
KTP LVP		**<u>0.17 (0.04 to 0.79)</u>**	684	6	52	64.30%
Diode LVP		0.13 (0.02 to 1.11)	102	1	8	-
Bipolar EP	Bipolar TURP	0.40 (0.01 to 20.25)	168	1	7	-
Thulium LEP		0.14 (0.02 to 1.08)	366	1	14	-
Bipolar VP		0.93 (0.17 to 5.17)	426	2	6	0%
KTP LVP		0.71 (0.05 to 10.52)	235	2	3	32%
KTP LVP	Holmium LEP	0.22 (0.01 to 4.76)	80	1	2	-
Thulium LEP	Bipolar EP	0.36 (0.01 to 8.88)	127	1	1	--

Supplementary table 6l: Pairwise meta-analysis of mean difference (95% CI) for blood transfusion

Comparison		Pairwise meta-analysis odds ratio (95% CI)	No. of participants	No. of trials	No. of events	Heterogeneity I2
Bipolar TURP	Monopolar TURP	**0.45 (0.30 to 0.69)**	4639	24	92	2.9%
Bipolar EP		0.14 (0.01 to 2.72)	204	1	3	-
Holmium LEP		**0.18 (0.07 to 0.47)**	979	10	26	0%
Thulium LEP		0.35 (0.11 to 1.07)	265	3	16	0%
Bipolar VP		**0.21 (0.08 to 0.55)**	1140	7	28	0%
Diode LVP		0.18 (0.02 to 1.58)	173	2	5	0%
KTP LVP		**0.20 (0.09 to 0.43)**	1399	12	55	0%
Bipolar EP	Bipolar TURP	0.27 (0.06 to 1.02)	808	4	9	0%
Holmium LEP		0.14 (0.01 to 2.83)	366	1	3	0%
KTP LVP		0.60 (0.07 to 4.98)	235	2	3	0%
Bipolar VP		0.76 (0.18 to 3.11)	586	3	7	0%
Bipolar VP	Bipolar EP	0.33 (0.01 to 8.20)	160	1	1	-
Diode LEP		0.33 (0.01 to 8.22)	160	1	1	-
Thulium LEP		0.36 (0.01 to 8.88)	127	1	1	-

Supplementary table 6m:Pairwise meta-analysis of mean difference (95% CI) for Incontinence

Comparison		Pairwise meta-analysis odds ratio (95% CI)	No. of participants	No. of trials	No. of events	Heterogeneity I2
Bipolar TURP	Monopolar TURP	0.77 (0.45 to 1.31)	1922	5	58	0%
Bipolar EP		1.00 (0.14 to 7.24)	204	1	4	-
Holmium LEP		1.11 (0.46 to 2.70)	815	9	22	0%
Thulium LEP		0.25 (0.04 to 1.55)	206	2	6	0%
Bipolar VP		0.63 (0.10 to 4.07)	606	3	8	26.90%
KTP LVP		1.38 (0.56 to 3.39)	458	3	31	13.60%
Bipolar EP	Bipolar TURP	1.56 (0.64 to 3.82)	742	5	77	57.20%
Holmium LEP		2.02 (0.60 to 6.79)	400	2	25	43.80%
Diode LEP		0.48 (0.04 to 5.63)	60	1	3	-
Bipolar VP		0.40 (0.09 to 1.74)	683	3	8	0%
Holmium LEP	Bipolar EP	0.47 (0.04 to 5.69)	40	1	3	-
Diode LEP		0.91 (0.38 to 2.15)	274	3	23	0%
Thulium LEP		1.37 (0.49 to 3.82)	208	1	16	-
Thulium LEP	Holmium LEP	0.57 (0.07 to 74.71)	227	2	3	-
KTP LVP		0.43 (0.08 to 2.38)	80	1	7	-

Supplementary table 6n :Pairwise meta-analysis of mean difference (95% CI) for retrograde ejaculation

Comparison		Pairwise meta-analysis odds ratio (95% CI)	No. of participants	No. of trials	No. of events	Heterogeneity I2
Bipolar TURP	Monopolar TURP	0.83 (0.61 to 1.11)	790	2	262	0%
Bipolar EP		0.81 (0.43 to 1.53)	204	1	50	-
Holmium LEP		1.74 (0.59 to 5.14)	61	1	20	-
Thulium LEP		0.60 (0.33 to 1.10)	206	2	65	0%
Bipolar VP		0.83 (0.41 to 1.66)	136	2	82	0%
KTP LVP		**0.51 (0.32 to 0.81)**	514	4	212	38.10%
Holmium LEP	Bipolar TURP	1.26 (0.33 to 4.79)	280	1	9	-
Diode LEP	Bipolar EP	0.88 (0.22 to 3.48)	194	2	63	76.5%
KTP LVP	Holmium LEP	**0.18 (0.06 to 0.53)**	80	1	28	-

Supplementary table 6o :Pairwise meta-analysis of mean difference (95% CI) for recatheterization

Comparison		Pairwise meta-analysis odds ratio (95% CI)	No. of participants	No. of trials	No. of events	Heterogeneity I2
Bipolar TURP	Monopolar TURP	0.74 (0.52 to 1.04)	3926	21	150	0%
Holmium LEP		0.85 (0.36 to 1.99)	675	6	28	0%
Thulium LEP		0.83 (0.02 to 33.08)	265	2	5	66.10%
Bipolar VP		1.03 (0.35 to 3.01)	1100	8	50	52.50%
Diode LVP		2.17 (0.38 to 12.43)	102	1	6	
KTP LVP		1.21 (0.70 to 2.11)	1001	9	60	0%
Bipolar EP	Bipolar TURP	0.43 (0.16 to 1.12)	716	5	21	0%
Holmium LEP		**<u>0.26 (0.11 to 0.60)</u>**	400	2	35	0%
Bipolar VP		0.97 (0.35 to 2.72)	769	4	39	48.80%
KTP LVP		1.70 (0.39 to 7.46)	115	1	8	-
Thulium LEP	Bipolar EP	1.08 (0.07 to 17.71)	127	1	2	-
Bipolar VP		3.08 (0.31 to 30.24)	160	1	4	-
Diode LEP		0.99(0.23 to 4.29)	274	2	8	-
Thulium LEP	Holmium LEP	0.47 (0.08to 2.75)	227	2	6	-
KTP LVP		5.09 (0.54 to 47.74)	80	1	5	-
Diode LEP	Thulium LEP	0.90 (0.12 to 6.85)	63	1	4	-

Supplementary table 6p: Pairwise meta-analysis of mean difference (95% CI) for recurrence

Comparison		Pairwise meta-analysis odds ratio (95% CI)	No. of participants	No. of trials	No. of events	Heterogeneity I2
Bipolar TURP	Monopolar TURP	0.74 (0.34 to 1.61)	1532	6	27	0%
Bipolar EP		0.20 (0.01 to 4.14)	204	1	2	-
Holmium LEP		0.55 (0.11 to 2.68)	261	2	6	0%
Thulium LEP		5.00 (0.23 to 106.68)	106	1	2	-
Bipolar VP		2.44 (0.55 to 10.76)	306	3	9	0%
Diode LVP		4.43 (0.48 to 41.13)	102	1	5	-
KTP LVP		2.07 (0.80 to 5.37)	643	6	36	24.9%
Bipolar EP	Bipolar TURP	0.20 (0.02 to 1.71)	166	2	4	-
Holmium LEP		0.19 (0.01 to 4.11)	120	1	2	
Bipolar VP		0.82 (0.18 to 3.78)	183	1	7	-
KTP LVP	Holmium LEP	6.13 (0.28 to 131.79)	80	1	2	-

Supplementary table 6q :Pairwise meta-analysis of mean difference (95% CI) for stricture

Comparison		Pairwise meta-analysis odds ratio (95% CI)	No. of participants	No. of trials	No. of events	Heterogeneity I2
Bipolar TURP	Monopolar TURP	0.94 (0.70to 1.26)	4227	25	213	0%
Bipolar EP		0.33 (0.03 to 3.19)	204	1	4	-
Holmium LEP		0.56(0.29 to 1.10)	979	9	41	0%
Thulium LEP		1.25 (0.05 to 29.17)	206	2	7	64.40%
Bipolar VP		0.69 (0.37 to 1.30)	926	7	47	0%
Diode LVP		0.14 (0.01 to 2.78)	102	1	3	-
KTP LVP		0.95 (0.59 to 1.53)	1178	10	83	0%
Bipolar EP	Bipolar TURP	0.75 (0.38 to 1.50)	910	6	35	0%
Holmium LEP		0.26 (0.04 to 1.71)	400	2	7	0%
Bipolar VP		0.78 (0.28 to 2.15)	500	2	38	49.90%
KTP LVP		1.33 (0.46 to 3.85)	361	4	14	0%
Holmium LEP	Bipolar EP	0.26 (0.04 to 1.71)	400	2	7	-
Thulium LEP		0.25 (0.03 to 2.03)	366	1	5	-
Bipolar VP		2.46 (0.61 to 9.88)	160	1	10	-
Diode LEP		1.97 (0.33 to 11.67)	274	2	6	-

Supplementary table 6r: Pairwise meta-analysis of mean difference (95% CI) for urinary tract infection

Comparison		Pairwise meta-analysis odds ratio (95% CI)	No. of participants	No. of trials	No. of events	Heterogeneity I2
Bipolar TURP	Monopolar TURP	0.81 (0.56 to 1.15)	2668	15	137	0%
Bipolar EP		0.66 (0.11 to 4.04)	204	1	5	-
Holmium LEP		0.24 (0.06 to 1.02)	205	2	11	0%
Thulium LEP		0.45 (0.13 to 1.55)	265	2	12	0%
Bipolar VP		0.71 (0.33 to 1.54)	575	3	29	0%
Diode LVP		0.68 (0.11 to 4.25)	102	1	5	-
KTP LVP		1.04 (0.64 to 1.68)	1139	10	77	0%
Bipolar EP	Bipolar TURP	0.93 (0.43 to 2.03)	550	3	27	0%
Diode LEP		3.10 (0.12 to 79.23)	60	1	1	-
Bipolar VP		0.90 (0.36 to 2.25)	683	2	19	0%
KTP LVP		0.63 (0.17 to 2.36)	115	1	10	-
Holmium LEP	Bipolar EP	1.00 (0.06 to 17.18)	40	1	2	-
Thulium LEP		0.53 (0.05 to 6.03)	127	1	3	-
Bipolar VP		1.71 (0.39 to 7.41)	160	1	8	-

Supplementary table 7: Sensitivity analysis

Supplementary table 7a: network estimated mean difference (95% confidence intervals) of postop maximal flow rate adjusted by prostate volume

Post-op 6 months Qmax	Mean PV		>70 gm	<70 gm	*P* for interaction	>60 gm	<60 gm	*P* for interaction
	Trials (N=) / Methods	43	10	33		17	26	
	Bipolar resection	0.66 (-0.60 to 1.92)	0.36 (-3.02 to 3.73)	0.70 (-0.53 to 1.92)	0.015	0.21 (-2.35 to2.77)	0.86 (-0.51, 2.23)	0.024
	Enucleation	**1.52 (0.36 to 2.69)**	2.37 (-0.65 to 5.38)	0.62 (-0.57 to 1.82)		1.85 (-0.41 to 4.1)	0.29 (-1.07, 1.65)	
	vaporization	-0.44 (-1.61 to 0.73)	-3.12 (-7.15 to 0.89)	0.10 (-0.97 to 1.17)		-2.49 (-5.39 to -0.41)	0.20 (-0.88 to 1.29)	
	Enucleation vs vaporization	1.98(0.55 to 3.41)	5.47 (2.03 to 8.91)	0.54(-1.01 to 2.08)		4.32(1.69 to 6.95)	0.09(-1.65 to 1.83)	
Post-op 12 months Qmax	Mean PV		>70 gm	<70 gm	*P* for interaction	>60 gm	<60 gm	*P* for interaction
	Trials (N=) / Methods trials	45	7	38		17	28	
	Bipolar resection	0.63 (-0.16 to 1.42)	0.05 (-3.36 to 3.45)	**0.85 (0.21 to1.49)**	0.002	0.98 (-0.67 to 2.63)	0.73 (0.03 to 1.42)	0.047
	Enucleation	**1.49 (0.59 to 2.40)**	2.83 (-0.21 to 5.87)	0.65 (-0.17 to 1.48)		**2.51 (0.83 to 4.19)**	0.39 (-0.56 to 1.33)	
	vaporization	-0.21 (-1.19 to 0.76)	-1.77 (-6.43 to 2.88)	0.13 (-0.65 to 0.92)		-0.35 (-2.78 to 2.09)	-0.03 (-0.81 to 0.76)	
		1.71 (0.53 to 2.88)	4.60 (0.85 to 8.34)	0.52 (-0.58 to 1.62)		2.85(0.50 to 5.20)	0.41 (-0.81 to 1.62)	

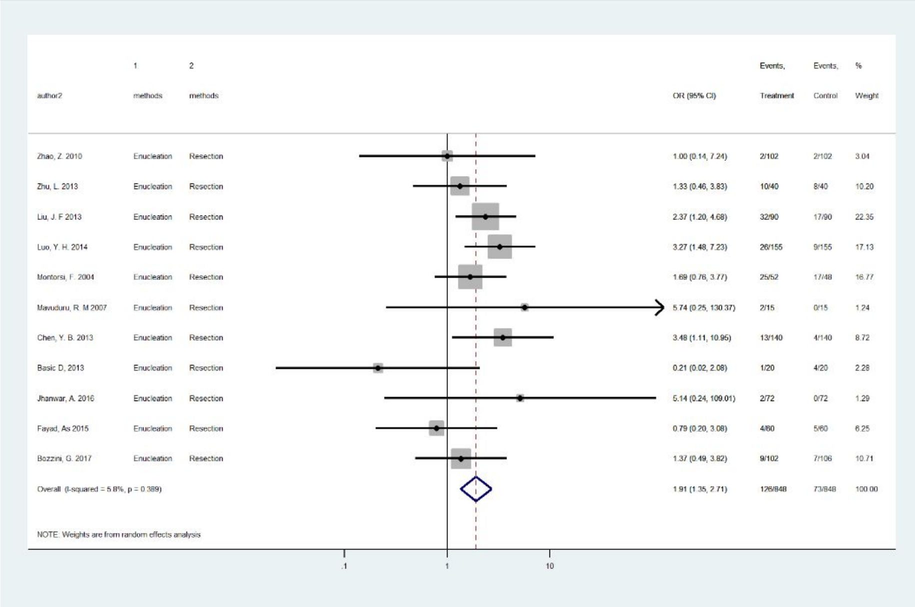
Results are mean differences (95% confidence intervals)
PV: prostate volume; TURP: transurethral resection of the prostate; Qmax: maximal flow rate
Enucleation: includes bipolar EP, holmium LEP, thulium LEP and diode LEP, vaporization: include bipolar VP, KTP LVP, diode LVP
Significant results are in bold and underlined

Supplementary table 7b: network estimated mean difference (95% confidence intervals) of postop IPSS adjusted by prostate volume

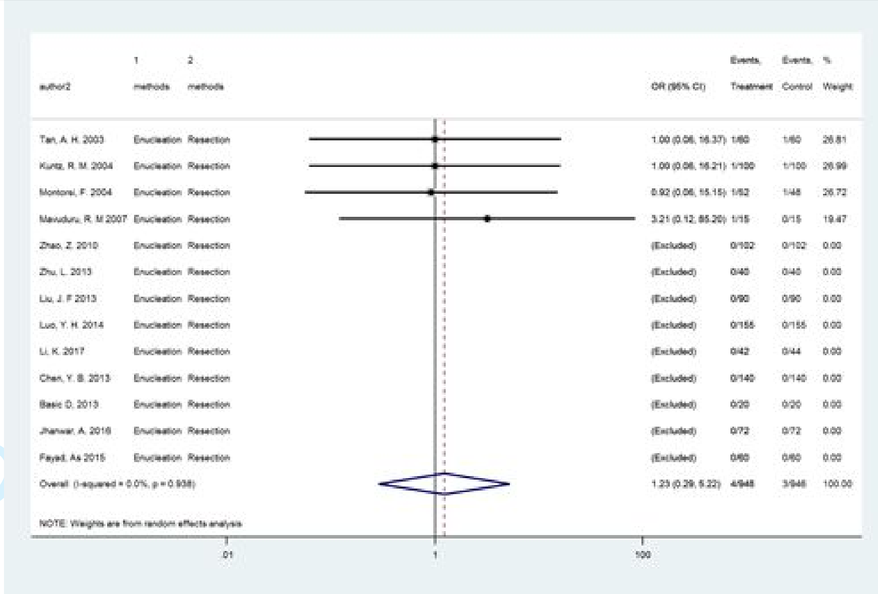
Post-op 6 months IPSS	Mean PV		>70 gm	<70 gm	*p* for interaction	>60 gm	<60 gm	*p* for interaction
	Trials (N=) Methods	43	10	33		17	26	
	Bipolar resection	0.22 (-0.58 to 1.03)	1.38 (-0.12 to 2.89)	0.05 (-0.95 to 1.05)	0.21	0.90 (-0.08 to 1.89)	0.03 (-1.30 to 1.35)	0.40
	Enucleation	-0.17 (-0.89 to 0.54)	1.14 (-0.22 to 2.50)	-0.52 (-1.43 to 0.39)		0.57 (-0.28 to 1.41)	-0.72 (-1.96 to 0.51)	
	vaporization	0.52 (-0.32 to 1.37)	1.69 (-0.32 to 3.70)	0.39 (-0.61 to1.39)		1.00 (-0.25 to 2.25)	0.32 (-0.91 to 1.56)	
Post-op 12 months IPSS	Mean PV							
	Trials (N=) Methods trials	44	6	38		16	28	
	Bipolar resection	-0.17 (-0.72 to 0.37)	0.21 (-1.12 to 1.54)	-0.22 (-0.84 to 0.40)	0.73	0.12 (-0.70 to 0.95)	-0.18 (-0.98 to 0.62)	0.46
	Enucleation	**-0.84 (-1.40 to -0.27)**	**-0.45 (-1.45 to -0.56)**	**-0.99 (-1.71 to -0.27)**		-0.34 (-1.`1 to 0.44)	**-1.21 (-2.14 to -0.28)**	
	vaporization	0.24 (-0.45 to 0.94)	-0.04 (-1.42 to 1.49)	0.36 (-0.46 to 1.19)		0.84 (-0.29 to 1.97)	0.06 (-0.91 to 1.02)	

Results are mean differences (95% confidence intervals)
PV: prostate volume; TURP: transurethral resection of the prostate; Qmax: maximal flow rate
Enucleation: includes bipolar EP, holmium LEP, thulium LEP and diode LEP, vaporization: include bipolar VP, KTP LVP, diode LVP
Significant results are in bold and underlined

Supplementary table 7c

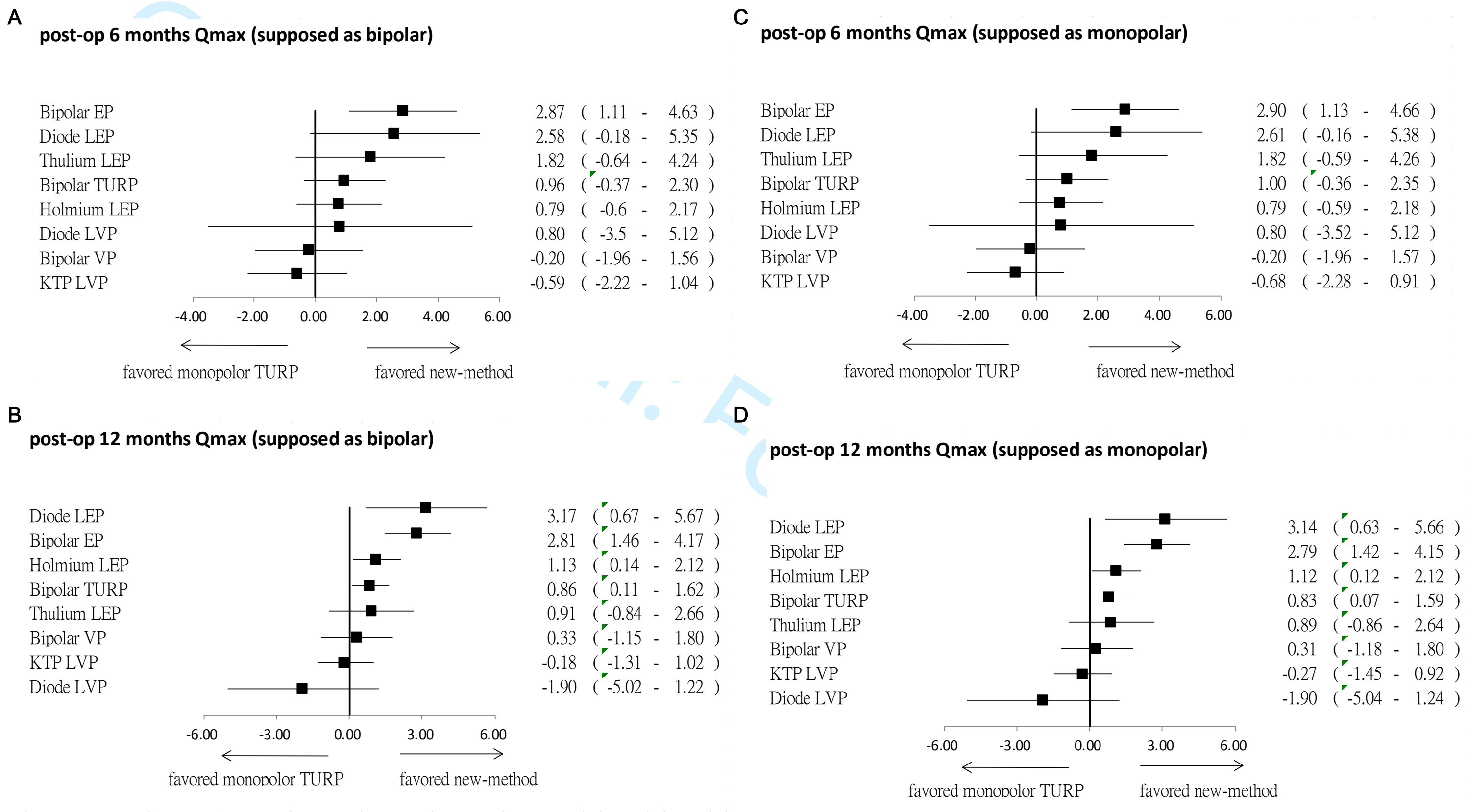


Short-term transient incontinence: used the earliest reported incontinence events if multiple time points



Permanent incontinence

Supplementary table 7d: network meta-analysis supposed Bach et al trial as monopolar or bipolar TURP



A, B : TURP groups in Bach et al trial is viewed as bipolar group
C, D: TURP group in Bach et al trial is viewed as monopolar group
The ranking and results tare he same nomatter included or excluded Bach et al trial in the analysis.

Supplementary Table 8: Assessment of inconsistency

Supplementary table 8a: Design inconsistency

	chi-square	*P* value for test of global inconsistency
IPSS_6m	4.92	0.97
IPSS_12m	6.38	0.93
IPSS_24m	0.72	0.95
IPSS_36m	0.15	1.0
Flow_6m	11.22	0.59
Flow_12m	13.5	0.41
Flow_24m	0.55	0.99
Flow_36m	1.64	0.80
catheterization duration	14.22	0.43
Hb-decline	10.5	0.66
	F-value	
Blood clot tamponade	0.69	0.77
Incontinence	0.58	0.86
Recurrence	0.56	0.69
Retrograde ejaculation	0.56	0.57
Blood transfusion	0.35	0.98
Urinary tract infection	0.27	0.97
stricture	0.52	0.90
recatherization	1.18	0.28

Supplementary table 8b: Loop inconsistency

	chi-square	P value for test of global inconsistency
Post-op 6 months Qmax	10.7	0.38
Post-op 12 months Qmax	11.6	0.24
Post-op 24 months Qmax	0.087	0.96
Post-op 36 months Qmax	3.1	0.22
Post-op 6 months IPSS	4.88	0.90
Post-op 12 months IPSS	6.46	0.69
Post-op 24 months IPSS	0.41	0.82
Post-op 36 months IPSS	0.13	0.94
catheterization duration	10.55	0.39
Hb-decline	8.1	0.53

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