Efficacy and safety of transurethral split of prostate for benign prostatic hyperplasia: a meta-analysis

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Abstract

Background: Transurethral resection of the prostate (TURP) is the first choice for the treatment of benign prostatic hyperplasia. However, Transurethral split of prostate (TUSP) also seems to have clear clinical efficacy and clinical promotion value. To better clarify the potential and limitations of this treatment of prostate hyperplasia. This study objectively evaluated the clinical efficacy and safety of TUSP.

Methods: The Pubmed, Cochrane Library, Embase, China National Knowledge Infrastructure (CNKI), Database for Chinese Technical Periodicals (VIP), Wanfang (Wanfang data), and SinoMed databases were searched for relevant studies. We then used Revman Manager 5.3 to perform a meta-analysis of all randomized controlled trials that evaluated the efficacy and safety of TUSP versus the classic surgical procedures commonly used in the clinic.

Results: A total of 7 studies involving 592 patients were included. The combined data showed that TUSP can shorten the operation time [MD: -33.68; 95% CI: -38.45 to -28.91; P < 0.001], reduce intraoperative blood loss [MD: -56.06; 95% CI: -62.68 to -49.43; P < 0.001], shorten the time of indwelling catheter [MD: -1.83; 95% CI: -1.99 to -1.67; P < 0.001], shorten the postoperative hospital stay length [MD: -1.61; 95% CI: -1.90 to -1.32; P < 0.001] and improved postoperative quality of life score (QOL) [MD: 0.16; 95% CI: 0.02 to 0.29; P = 0.02] compared to traditional surgical approaches. There were no statistically significant differences in international prostate symptom score (IPSS), maximum urinary flow rate (Qmax), residual urine volume (RUV), or complications between TUSP and traditional approaches.

Conclusion: TUSP can be an effective alternative for clinical treatment of benign prostatic hyperplasia. Given the limitations of the included studies, more high-quality randomized controlled trials are needed in the future to validate or update the results of this analysis.

Keywords: Transurethral split of prostate, TUSP, Benign prostatic hyperplasia, BPH, Meta-analysis
Background
Benign prostatic hyperplasia (BPH) is one of the most common benign diseases in middle-aged men. The incidence of the disease is positively correlated with age. According to statistics, the histological prevalence rates is approximately 10% for men aged 30–40, 20% for men aged 41–50, 50 to 60% for men aged 60–70, and 80 to 90% for men aged 70–90. Lower urinary tract symptoms (LUTS), such as frequent urination, urgency, and dysuria, are the main pathological features of BPH [1]. Extremely high morbidity and the resultant LUTS have brought much pain to the lives of male patients. If the treatment is not appropriate or timely, it may also be complicated with upper urinary tract damage or even affect dual renal function [2]. Currently, transurethral resection of the prostate (TURP) is the clinically preferred treatment [3, 4]. However, there are still complications such as hemorrhage, transurethral resection syndrome (TURS) and retrograde ejaculation [5]. New surgical methods, such as bipolar transurethral electrovaporization of the prostate (TUPKP) and transurethral plasmakinetic enucleation of the prostate (TUEKP), have emerged and have been shown to have relatively few complications. However, these methods also have the problem of expensive equipment and high technical requirements for doctors, which is not conducive to clinical promotion [6]. Therefore, it is necessary to find an effective, relatively safe and inexpensive surgical method. Professor Guo Yinglu from the First Hospital of Peking University, China, has been working on the transurethral split of prostate (TUSP) method for many years and finally developed a variety of models of double-chambered water balloon expansion catheters. They standardized the surgical procedure, making the surgery more mature in the treatment of BPH, and proved that the operation is safe and effective through related research [7, 8].

Although some Chinese scholars have conducted randomized controlled trials (RCTs) on using TUSP to treat BPH and found that it has relatively clear clinical efficacy and clinical promotion value, small sample size made it is impossible to provide a comprehensive evaluation. To date, there has been no systematic review and meta-analysis of the efficacy and safety of TUSP in the treatment of BPH. Therefore, we systematically searched and analyzed existing literature to assess the efficacy and potential advantages of TUSP.

Methods
This meta-analysis were following the Cochrane Handbook of Systematic Reviews of Interventions and was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines [9, 10].
Statistical analysis

Meta-analysis of the data was performed using RevMan 5.3 (Cochrane Collaboration, Oxford, UK) [11] provided by the Cochrane Collaboration. The relative risk (risk ratio, RR) and the 95% confidence interval (95% CI) were used to calculate the effect size of the dichotomous data. The effect sizes for continuous variable were presented as the mean difference (MD) and 95% CI. Heterogeneity test was assessed by the chi-square test, and the test efficiency was set to $\alpha = 0.05$. When the heterogeneity test result was not statistically significant ($P > 0.05$, $I^2 < 50\%$), the fixed effect model (FEM) was used. When the heterogeneity test results were statistically significant ($P < 0.05$, $I^2 > 50\%$), a random effects model (REM) was used. Sensitivity analysis was used if necessary to find the sources of heterogeneity, and subgroup analyses were used to reduce heterogeneity.

Results

Description of studies

Figure 1 shows the flow chart for the search process and study selection. Through a comprehensive search, a total of 318 articles were obtained. After excluding 163 duplicate articles, 155 articles were included. After screening the titles and abstract, 145 articles were excluded because they did not meet the inclusion criteria for the following reasons: retrospective analysis (60), non-clinical studies (3), and irrelevant studies (76). Finally, we carefully read the full text of the remaining 10 articles, and 3 articles were excluded because they did not use random assignment.

Study characteristics and quality of evidence

A total of 7 studies involving 592 patients were included in the meta-analysis [12–18]. Table 1 describes the basic characteristics of the included studies. These studies

![Flow diagram of literature searches](image)
were published between 2017 and 2019. Four of the studies compared TUSP with TUPKP [13, 14, 16, 17], two of studies compared TUSP with TUKEP [12, 18], and another study compared TUSP with TURP [15]. The outcome measures involved in this meta-analysis included operation time, intraoperative blood loss, postoperative indwelling catheter time, postoperative hospital stay length, IPSS score at 3 months postoperatively, QOL at 3 months postoperatively, Qmax at 3 months postoperatively, RUV at 3 months postoperatively and complications. All of these tests were conducted in China.

For the included 7 studies, the bias was largely unclear. Figure 2 shows a summary of the methodological quality of each of the included studies. The judgment of the reviewers for each item of risk of bias tool is shown in Fig. 3 as a percentage.

### Operation time
A total of 6 trials [12–17] reported on the operation time, involving a total of 510 patients (259 in the observation group and 251 in the control group). The results showed that TUSP required a shorter time for surgery than traditional clinical surgery \[MD: -33.68; 95\% CI: -38.45 \text{ to} -28.91; P < 0.001\], but there was a large amount of heterogeneity \(P < 0.001, \hat{I}^2 = 88\%\). We performed a sensitivity analysis, which revealed that the source of the heterogeneity may have been trials conducted by Kong Min [12]. By reading the full text, we found that the study group underwent endoscopic observation of the surgical field after TUSP treatment, leading to prolonged operation time in the observation group, which may have resulted in heterogeneity. After eliminating these trials, we found no heterogeneity between the groups \(P = 0.71, \hat{I}^2 = 0\%), so a fixed effect model was adopted for the meta-analysis. The time required for TUSP in the treatment of benign prostatic hyperplasia was shorter, and the difference was statistically significant \[MD: -37.21; 95\% CI: -41.87 \text{ to} -35.65; P < 0.001\] (Fig. 4).

### Intraoperative blood loss
A total of 5 trials [12–14, 16, 17] described intraoperative blood loss, involving a total of 300 patients (152 in the observation group and 148 in the control group). The heterogeneity test indicated that the data had high level of heterogeneity \(P = 0.005, \hat{I}^2 = 73\%\), but the sensitivity analysis did not find any sources of heterogeneity, and the meta-analysis results were more stable. Therefore, the random effects model was used for analysis. The results showed that the amount of bleeding in the treatment of benign prostatic hyperplasia was lower in the TUSP group, and the difference was statistically significant \[MD: -56.06; 95\% CI: -62.68 \text{ to} -49.43; P < 0.001\].

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**Table 1 Characteristics of the included studies**

| Author            | Year | Sample size | Age(Y) | Intervention methods | Follow-times | outcomes |
|-------------------|------|-------------|--------|----------------------|--------------|----------|
| Kong Min [12]     | 2017 | 40/40       | NA     | TUSP                 | 3 months     | Operation time (min); Intraoperative blood loss (ml); IPSS; Qmax; |
| Wang Qi [13]      | 2017 | 50/50       | 74.4 ± 9.8 | TUSP                 | 3 months     | Operation time (min); Intraoperative blood loss (ml); Postoperative indwelling catheter time(d); Postoperative hospital stay length(d); IPSS; Qmax; QOL; RUV; Complications |
| Zhou Jin [14]     | 2018 | 30/30       | 79.21 ± 15.37 | TUSP                 | NA           | Operation time (min); Intraoperative blood loss (ml); Complications |
| Kong Qingkuo [15] | 2018 | 107/103     | NA     | TUSP                 | 3 months     | Operation time (min); Postoperative indwelling catheter time(d); Postoperative hospital stay length(d); IPSS; Qmax; QOL; RUV; Complications |
| Li Hong [16]      | 2018 | 15/15       | 67.4 ± 10.1 | 69.1 ± 10.5          | TUSP         | Operation time (min) extra-indwelling catheter time(d); Postoperative hospital stay length(d); IPSS; Qmax; QOL; RUV; Complications |
| Liu Shuzhi [17]   | 2018 | 10/10       | 72.58 ± 12.42 | TUSP                 | 12 months    | Operation time (min) extra-indwelling catheter time(d); Postoperative hospital stay length(d); |
| Wang Bo [18]      | 2019 | 46/46       | 69.3 ± 3.8  | 69.8 ± 3.7           | TUSP         | Operation time (min) extra-indwelling catheter time(d); Postoperative hospital stay length(d); IPSS; Qmax; QOL; RUV; Complications |

**Qmax** maximum urinary flow rate, **RUV** residual urine volume, **IPSS** international prostate symptom score, **QOL** quality of life
Subgroup analysis based on the different surgical methods of the control group showed that TUSP can reduce intraoperative blood loss compared with TUPKP or TUKEP (Fig. 5).

**Postoperative indwelling catheter time**

A total of 5 trials [13, 15–18] recorded postoperative urinary catheter indwelling time, including 228 patients in the observation group and 224 patients in the control group. The meta-analysis showed that compared with traditional clinical surgery, the time of indwelling catheter after TUSP was shorter, and the difference was statistically significant [MD: -1.83; 95% CI: −1.99 to −1.67; \( P < 0.001 \)] (Fig. 6). There was no heterogeneity among the studies (\( P = 0.93, I^2 = 0\% \)).

**Postoperative hospital stay length**

A total of 5 trials [13,15–18] reported on postoperative hospital stay length, involving a total of 452 patients (228 in the observation group and 224 in the control group). The final results showed that compared with traditional clinical surgical treatment, patients with benign prostatic hyperplasia after TUSP treatment had a significantly shorter postoperative hospital stay length [MD: -1.61; 95% CI: −1.90 to −1.32; \( P < 0.001 \)] (Fig. 7). There was no heterogeneity between the studies (\( P = 0.88, I^2 = 0\% \)).

**IPSS score at 3 months postoperatively**

Five of the included trials [12, 13, 15, 16, 18] recorded the patient’s IPSS score at 3 months postoperatively, involving a total of 512 patients. The results showed that there was no significant difference in the IPSS score between TUSP and traditional clinical surgery at 3 months.
postoperatively [MD: -2.01; 95% CI: -4.16 to -0.14; \( P = 0.07 \)] (Fig. 8).

**Qmax at 3 months postoperatively**
A total of 5 trials [12, 13, 15, 16, 18] compared the patient’s Qmax at 3 months postoperatively, with 258 patients in the observation group and 254 patients in the control group. There was no significant difference in the Qmax between TUSP and traditional clinical surgery at 3 months postoperatively [MD: 3.59; 95% CI: -2.38 to 9.56; \( P = 0.24 \)] (Fig. 9).

**QOL scores at 3 months postoperatively**
There were 3 trials [13, 15, 16] that examined the QOL scores at 3 months postoperatively, involving 340 patients (172 in the observation group and 168 in the control group). The meta-analysis showed that the QOL scores of patients after TUSP were higher, and the difference was statistically significant [MD: 0.16; 95% CI: 0.02 to 0.29; \( P = 0.02 \)] (Fig. 10). There was no heterogeneity between the studies (\( P = 0.55, I^2 = 0\%\)).

**RUV at 3 months postoperatively**
There were 3 trials [13, 15, 16] that examined RUV at 3 months postoperatively, involving 340 patients (172 in the observation group and 168 in the control group). The meta-analysis results showed no significant difference in RUV between TUSP and traditional clinical surgery [MD: -0.42; 95% CI: -3.49 to 2.65; \( P = 0.79 \)] (Fig. 11).

**Complications**
Complications were recorded in 6 trials [12–16, 18]. Among them, Kong Min’s study only recorded the total incidence of complications, including 1 case of complications in the observation group and 7 cases in the control group. The incidence of complications in the treatment group was significantly lower than that of the control group. Figure 12 shows an analysis of the complications in the other five trials. The results showed that there were no statistical differences between the two types of temporary urinary incontinence, urinary
retention, bladder neck contracture, urethral stricture and secondary bleeding.

**Publication Bias analysis**
We used the Egger test of Stata 15.1 to assess the possibility of publication bias. Egger’s test of QOL indicated that there was significant publication bias ($P = 0.011$) and the other outcome indicators have no significant publication bias.

**Discussion**
Benign prostatic hyperplasia is one of the most common diseases in middle-aged men. The clinical manifestations of prostate enlargement and lower urinary tract symptoms are extremely troublesome for the patient’s life and work. As the global population ages, the incidence of this disease is increasing [19, 20]. At present, it is difficult to achieve satisfactory results using simple drug treatments; surgery is the most effective way to treat BPH, and traditional transurethral resection of the prostate is considered the gold standard for the treatment of BPH [21]. However, traditional clinical surgery is highly invasive, and it has shortcomings such as long operation time, large amounts of intraoperative blood loss, TURS and high treatment costs [22], so it is difficult to be widely used in developing countries. Therefore, we urgently need a safer and cheaper surgical method to treat BPH.

In 1984, with the development of interventional radiology, Burhenne et al. used arteriographic balloon catheters to perform prostate balloon dilatation on 10 male cadavers, which proved that the procedure can increase the diameter of the prostatic urethra. Additionally, the author used this method to perform TUDP to himself, verifying the potential value of TUDP [23]. In 1987, Castaneda performed prostate balloon dilatation on 12 BPH patients and achieved satisfactory results. The application of this surgical procedure was reported for the first time [24]. Because of the simplicity and convenience of this operation, the complications are relatively few. This has been positively received by most clinicians, prompting a large number of doctors to conduct more research on this technology [25]. Unfortunately, Gill [26] and McLoughlin [27] did not achieve satisfactory results in clinical studies of TUDP. Lepor [28] compared TUDP and cystoscopy and found that they have the same effect on symptom responses. Further clinical studies have shown that, since the therapeutic effect of TUDP on BPH is uncertain, even with a low incidence of complications, TURP is still the best choice for BPH [29]. This has led doctors and patients to gradually lose confidence in TUDP.

**Table 6**

| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Weight | Mean Difference | IV, Fixed, 95% CI |
|------------------|------|----|-------|------|----|-------|--------|----------------|------------------|
| Kong Qingkuo 2018 | 2.1  | 0.6 | 107   | 3.9  | 0.9 | 103   | 59.4%  | -1.80 [-2.01, -1.59] |
| Li Hong 2018     | 2.1  | 0.3 | 15    | 4.1  | 0.8 | 15    | 13.7%  | -2.00 [-2.43, -1.57] |
| Liu Shuzhi 2018  | 3.4  | 1.1 | 10    | 5.1  | 2.2 | 10    | 1.1%   | -1.70 [-3.22, -0.18] |
| Wang Bo 2019     | 2.2  | 0.56| 45    | 4.03 | 1.12| 46    | 19.6%  | -1.83 [-2.19, -1.47] |
| Wang Qi 2017     | 3.5  | 1.3 | 50    | 5.2  | 1.9 | 50    | 6.3%   | -1.70 [-2.34, -1.06] |

Total (95% CI): 228
Heterogeneity: Chi² = 8.86, df = 4 ($P = 0.093$), $I^2 = 0%$
Test for overall effect: $Z = 22.36 (P < 0.00001)$

**Fig. 6** Forest plot and meta-analysis of Postoperative indwelling catheter time(d). Experimental: the group of TUSP; Control: the group of traditional clinical surgery

**Table 7**

| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Weight | Mean Difference | IV, Fixed, 95% CI |
|------------------|------|----|-------|------|----|-------|--------|----------------|------------------|
| Kong Qingkuo 2018 | 4.2  | 1.1 | 107   | 5.7  | 1.7 | 103   | 56.1%  | -1.50 [-1.89, -1.11] |
| Li Hong 2018     | 4.1  | 1.2 | 15    | 6.1  | 1.4 | 15    | 9.7%   | -2.00 [-2.93, -1.07] |
| Liu Shuzhi 2018  | 4.1  | 1.6 | 10    | 5.6  | 1.8 | 10    | 3.8%   | -1.60 [-3.09, -0.11] |
| Wang Bo 2019     | 4.1  | 1.21| 46    | 5.89 | 2.3 | 46    | 15.0%  | -1.79 [-2.54, -1.04] |
| Wang Qi 2017     | 4.1  | 1.8 | 50    | 5.7  | 2  | 50    | 15.3%  | -1.60 [-2.35, -0.85] |

Total (95% CI): 228
Heterogeneity: Chi² = 1.20, df = 4 ($P = 0.88$), $P = 0%$
Test for overall effect: $Z = 10.84 (P < 0.00001)$

**Fig. 7** Forest plot and meta-analysis of Postoperative hospital stay length(d). Experimental: the group of TUSP; Control: the group of traditional clinical surgery
However, because this surgical method is relatively inexpensive and suitable for use in developing countries such as China, Huang [7, 8] has improved TUDP and redesigned the balloon catheter. The new operation can crack the prostate capsule. Therefore, it was named transurethral split of the prostate (TUSP), and the efficacy and safety of TUSP were verified in animal experiments and clinical trials.

The main principle of TUSP is to expand the prostatic capsule at the 12 o’clock position of the apex of the prostate through the internal balloon to reduce the urethral closure pressure. Then, the external balloon continues to expand the entire dorsal capsule. Finally, a wide “U”-shaped urethra extending to the 12 o’clock position is formed, which reduces the tension of the urethral wall [30]. To obtain a better curative effect, there are certain requirements. First, the appropriate catheter type should be selected strictly according to the prostate volume before operation. If necessary, surgeons should observe the prostate shape and size with and endoscope first to accurately determine the type. Second, the catheter should be stabilized to prevent slippage during the operation. The inner balloon is fixed to the membranous part, and the external balloon is fixed to the prostatic urethra [7]. Some Chinese scholars use ultrasound-guided TUSP surgery, which greatly improves the accuracy of positioning and the success rate of surgery [31]. Finally, it is advisable to stabilize the pressure of the internal and external balloon of the catheter at 0.3 MPa.

TUSP simply dilates the obstructed urethral prostate on the basis of preserving the prostate organs, and it has less trauma and simple operation. It is especially suitable for patients who require the preservation of sexual function, are accompanied by a variety of underlying diseases, are poorly tolerated by anesthesia, or are elderly. However, there are still some limitations. First, TUSP can cause mechanical laceration of the prostate urethra, which may cause bleeding during the operation. The catheter has no hemostatic function, so electrocoagulation hemostasis may be needed during the operation. Secondly, TUSP is unavailable for viewable operation [8], which may require further research and development of visual and automatic instruments. Finally, it is impossible to collect prostate tissue for histological examination because TUSP operation is performed while preserving prostate function [8].

After 328 patients were followed up for 38–99 months, Huang [8] found only 2 cases of recurrent dysuria, which
showed that TUSP had a good long-term curative effect. However, due to the limited amount of literature, it is expected that more research on long-term linkages will be published in the future.

The successful application of TUSP in the treatment of patients with BPH may be associated with a significant reduction in inflammatory infiltration and collagen content in the bladder neck, prostatic urethra and urethra. Bianchi-Frias [32] and Huang [7] found in experiments on mice and dogs that the inflammatory infiltration and collagen content in the ageing prostate is very rich. When the dog is subjected to TUSP, inflammatory infiltration and collagen in the bladder neck, prostatic urethra and urethra are significantly reduced. These factors may weaken the contraction of the prostate tissue and expand the urethra. However, the mechanism remains to be confirmed by further research.

The purpose of this review is to analyze the efficacy and safety of TUSP in the treatment of benign prostatic hyperplasia. We searched the existing literature and included 7 randomized controlled trials of TUSP in the treatment of BPH. The results of the analysis showed that compared with the traditional surgical approach, TUSP can shorten the operation time, reduce the amount of intraoperative blood loss, shorten the time of indwelling catheter and speed up the postoperative recovery. At the same time, we also compared IPSS, Qmax, RUV, QOL and complications at 3 months after the operation. The results showed that except for the higher QOL score after TURP, the IPSS, Qmax, RUV and complications of the two treatments were not statistically significant. Therefore, from a clinical point of view, TUSP leads to less trauma, can shorten the operation time, and has relatively high safety. It is suitable for patients who are intolerant or unwilling to undergo surgical resection of the prostate, such as elderly or physically weak patients.

Although this review included a systematically search and analysis, there are still some limitations. First, the sample size was small, and not all outcomes are reported in each of the included studies, which may affect the accuracy of the results. Second, due to the insufficient number of articles included in the literature, this study classified TURP, TUPKP and TUKEP into the traditional clinical surgery approach as a control group, which may lead to the emergence of heterogeneity. We hope that more research can be carried out in the future. Third, only one study had a follow-up period of 12 months, while other studies had a follow-up period of 3 months. Therefore, the long-term effectiveness and safety of TUSP could not be evaluated. It is strongly recommended that future studies use longer follow-up periods. Fourth, due to the particularity of the surgery, the surgical approach requires the consent of the patient and the family, so the included studies were not double-blind. Finally, the included studies were all from China, so the evaluation of TUSP in this review may only be applicable to Chinese people. We look forward to future clinical research in more countries.

| Study or Subgroup | Experimental Mean | SD | Total | Control Mean | SD | Total | Weight | IV, Fixed, 95% CI | Mean Difference | IV, Fixed, 95% CI |
|-------------------|------------------|----|-------|---------------|----|-------|--------|-----------------|----------------|-----------------|
| Kong Qingkuo 2018| 51.3             | 10.7| 107   | 52.4          | 15.8| 103   | 70.3   | -1.10 [-4.76, 2.56]|                |                 |
| Li Hong 2018      | 51.4             | 11.1| 15    | 52.3          | 15.3| 15    | 10.3   | -0.50 [-1.07, 0.07]|                |                 |
| Wang Qi 2017      | 46.3             | 18.2| 50    | 44            | 17.4| 50    | 19.4   | 2.30 [0.68, 0.92]|                |                 |
| Total (95% CI)    | 172              |     | 168   | 100.0%        |     |       | -0.42  [-3.49, 2.65]|                |                 |

**Fig. 10** Forest plot and meta-analysis of QOL scores at 3 months postoperatively. Experimental: the group of TUSP; Control: the group of traditional clinical surgery.

| Study or Subgroup | Experimental Mean | SD | Total | Control Mean | SD | Total | Weight | IV, Fixed, 95% CI | Mean Difference | IV, Fixed, 95% CI |
|-------------------|------------------|----|-------|---------------|----|-------|--------|-----------------|----------------|-----------------|
| Kong Qingkuo 2018| 51.3             | 10.7| 107   | 52.4          | 15.8| 103   | 70.3   | -1.10 [-4.76, 2.56]|                |                 |
| Li Hong 2018      | 51.4             | 11.1| 15    | 52.3          | 15.3| 15    | 10.3   | -0.50 [-1.07, 0.07]|                |                 |
| Wang Qi 2017      | 46.3             | 18.2| 50    | 44            | 17.4| 50    | 19.4   | 2.30 [0.68, 0.92]|                |                 |
| Total (95% CI)    | 172              |     | 168   | 100.0%        |     |       | -0.42  [-3.49, 2.65]|                |                 |

**Fig. 11** Forest plot and meta-analysis of RUV at 3 months postoperatively. Experimental: the group of TUSP; Control: the group of traditional clinical surgery.
Conclusions

Compared with traditional prostatectomy, TUSP may have a similar curative effect on BPH, and it has the advantages of reduced trauma, less intraoperative blood loss, shorter operation times and shorter hospital stays. In the Chinese population, it is an effective and safe surgical procedure for patients who are old or weak and unable to tolerate prostatectomy. It is worth promoting. However, given the small number of studies included in this meta-analysis and the low quality, this conclusion requires further validation from more high-quality clinical randomized controlled trials.

Abbreviations

BPH: Benign prostatic hyperplasia; TUSP: Transurethral split of prostate; TURP: Transurethral resection of the prostate; TUPKP: Bipolar transurethral electrovaporization of the prostate; TUKEP: Transurethral plasmakinetic enucleation of the prostate; TURS: Transurethral resection syndrome; QOL: Quality of life score; IPSS: International prostate symptom score; Qmax: Maximum urinary flow rate; RUV: Residual urine volume; MD: Mean difference; RR: Risk ratio; CI: Confidence interval; RCTs: Randomized controlled trials

Acknowledgments

We wish to thank Daozhang Yuan for his suggestions on manuscript revision and thank American Journal Experts (AJE) for its linguistic assistance during the preparation of this manuscript.
Authors’ contributions
YYH and SY drafted the study and conducted the analyses. YH and JXL performed the data extraction, carried out the meta analysis and drafted the manuscript. SSW and DZY reviewed and revised the manuscript. All authors approved the final version of the manuscript.

Funding
None.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on request.

Ethics approval and consent to participate
All analyses were based on previous published studies, thus no ethical approval and patient consent are required.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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Received: 15 July 2019 Accepted: 21 August 2020
Published online: 03 September 2020

References
1. Bushman W. Etiology, epidemiology, and natural history. Urol Clin N Am. 2009;36(4):403–15.
2. Rule AD, Lieber MM, Jacobsen SJ, et al. Is benign prostatic hyperplasia a risk factor for chronic renal failure? J Urol. 2005;173(3):691–6.
3. Peyronnet B, Pradere B, Brichart N, et al. Complications associated with Photoselective vaporization of the prostate: categorization by a panel of GreenLight users according to Clavien score and report of a single-center experience. Urology. 2014;84(3):657–64.
4. Oelke M, Bachmann A, Descazeaud A, et al. EAU guidelines on the treatment and follow-up of non-neurogenic male lower urinary tract symptoms including benign prostatic obstruction. Eur Urol. 2013;64(1):118–40.
5. Mammoulakis C, de la Rosette, Jean J.M.C.H (2015) Bipolar transurethral resection of the prostate: Darwinian evolution of an instrumental technique. Urology 85(5):1143–1150.
6. Mebust WK (2003) Transurethral surgery. In: Walsh PC, Retok AB, Vaughan ED, Wein AJ (eds) Campbell’s urology, Vol 2.8th (ed) Philadelphia: Saunders, pp 1479–1505.
7. Huang W, Guo Y, Xiao G, et al. Treatment of benign prostatic hyperplasia using transurethral Split of the prostate with a columnar balloon catheter. J Endourol. 2015;29(3):344–50.
8. Huang W, Huang Z, Xiao G, et al. Effect of transurethral split of the prostate using a double-columnar balloon catheter for benign prostatic hyperplasia. Medicine. 2016;95(40):e4657.
9. Higgins JPT, Green S (2011) Cochrane handbook for systematic reviews of interventions, version 5.1.0. The Cochrane collaboration. www.cochrane-handbook.org.
10. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ. 2009;339.
11. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials. 1986;7(3):177–88.
12. Min KONG, Jun CHEN, Wu-zhen YUAN, et al. Efficacy of modified transurethral split of prostate enlargement for the treatment of benign prostatic hyperplasia. Contemp Med. 2017;23(29):55–6.
13. Qi WANG, Chaokun LI, Liang HUANG. Efficacy of transurethral columnar balloon dilation of prostate in treatment of benign prostatic hyperplasia in high risk elderly patients. Chin J Multip Organ Dis Elderly. 2017;16(06):423–7.
14. Jin Z. Analysis of the application effect of transurethral split of prostate enlargement in patients with benign prostatic hyperplasia. Zhejiang J Traumatic Surg. 2018;23(05):590–1.
15. Kong Q, Jinguwei S, Bin L, et al. Effect of transurethral split of the prostate for the treatment of prostatic hyperplasia in the elderly. Chin J Exp Surg. 2018;35(2):361–2.
16. Hong L. Cylindrical water balloon prostate expansion catheter for the treatment of benign prostatic hyperplasia. Zhejiang J Traumatic Surg. 2018;23(05):904–5.
17. Shuzhi L, Jingren Z, Bao Z, et al. Clinical study of columnar water sac in the treatment of benign prostatic hyperplasia with neurogenic bladder. Health Guide. 2018;48:326.
18. Wang B. Clinical effect of transurethral split of prostate in the treatment of benign prostatic hyperplasia. Clin Res Pract. 2019;1(10):83–5.
19. Sivaranjan G, Boofsky MS, Shah O, et al. The role of minimally invasive surgical techniques in the Management of large-Ball gland Prostatic Hypertrophy. Rev Urol. 2015;17(3):140–9.
20. Woodard TJ, Manigault KR, Mcburnows NN, et al. Management of Benign Prostatic Hyperplasia in older adults. Consult Pharm. 2016;31(8):412–4.
21. Blankstein U, Van AB, Elterman DS. BPH update: medical versus interventional management. Canadian. J Urol. 2016;23(151):10.
22. Reich O, Gratzke C, Bachmann A, et al. Morbidity, mortality and early outcome of transurethral resection of the prostate: a prospective multicenter evaluation of 10,654 patients. J Urol. 2008;180(1):246–9.
23. Burchette HJ, Chisholm RJ, Quenville NF. Prostatic hyperplasia: radiological intervention. Work in progress. Radiology. 1984;152(3):655–7.
24. Castaneda F, Letourneau JG, Reddy P, et al. Alternative treatment of prostatic urethral obstruction secondary to benign prostatic hypertrophy. Non-surg Ball Catheter Prost Dilatation RGFs. 1987;147:426–9.
25. Wasserman NF, Reddy PK, Zhang G, et al. Experimental treatment of benign prostatic hyperplasia with transurethral balloon dilation of the prostate: preliminary study in 73 humans. Radiology. 1990;177(2):485–94.
26. Gill KP, Machan LS, Allison DJ, et al. Bladder outflow tract obstruction from benign prostatic hypertrophy treated by balloon dilatation. Br J Urol; 1989; 64(8):18–22.
27. Mcloughlin J, Keane PF, Jager R, et al. Dilatation of the prostatic uretha with 35 mm balloon. BJU Int. 1991;67(2):177–81.
28. Lepor H, Sypherd D, Machi G, et al. Randomized double blind study comparing the effectiveness of balloon dilation of the prostate and cystoscopy for the treatment of symptomatic benign prostatic hyperplasia. J Urol. 1992;147(3):539–42.
29. Vale JA. Balloon dilation of the prostate-should it have a place in the urologist’s armamentarium? J R Soc Med. 1993;86(6):283–6.
30. Weizhen B, Wang X, Wang D, et al. The application of endoscopic assisted direct vision in transurethral columnar balloon dilation of the prostate. Chin J Endourol. 2019;33(3):198–202.
31. Wang C, Xiaolin M, Wenfeng L, et al. Transurethral columnar balloon dilation of prostate under ultrasound guidance for treatment of benign prostatic hyperplasia. J Minim Invasive Urol. 2018;7(04):263–6.
32. Daniella BF, Funda VL, Coleman IM, et al. The effects of aging on the molecular and cellular composition of the prostate microenvironment. PLoS One. 2010;5(9):e12501.

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