# A Systematic Review of Green-Light Laser Vaporization for Superficial Bladder Cancer

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# Abstract

**Background:** The related research of green-light laser vaporization in the treatment of non-muscle invasive bladder cancer (NMIBC) is limited. This study focused on analyzing the effectiveness and safety of it from the perspective of an extensive literature review.

**Methods:** A comprehensive search of CNKI, WanFang, VIP, PubMed, Embase, and CENTRAL databases for photoselective vaporization of bladder tumor and transurethral resection of bladder tumor treatment of non-muscle invasive bladder cancer (NMIBC). The search included studies from January 1996 to December 2019. Two reviewers independently screened literature, extracted data, assessed the risk of bias of included studies. RevMan 5.3 software was used for Meta-analysis.

**Results:** A total of 18 RCTs involving 1648 patients met the predefined criteria. Meta-analysis data demonstrated that the PVBT group exhibited a significant advantage over the TURBT group in intraoperative obturator nerve reflex and bladder perforation and postoperative 1-year recurrence. The PVBT procedure has advantages over TURBT in the amount of surgical bleeding and the length of hospital stay, bladder irrigation time, and catheter indwelling time. There was no difference between the two types of surgery in the incidence of postoperative urethral stricture and the length of surgery.

**Conclusion:** Our systematic review and meta-analysis suggests that PVBT is better than TURBT as an alternative treatment for patients with NMIBC in safe aspect. However, whether it is equally effective in terms of oncological control remains to be elucidated, and additional high quality RCTs are needed to confirm our findings.


# Background

By incidence, bladder cancer ranks seventh among systemic malignancies and first among urinary tumors [1]. With an emphasis on painless gross hematuria and the extensive use of ultrasound, CT (computerized tomography), cystoscopy, and urine, the early diagnosis of bladder cancer has been significantly improved [1]. Under the new lymph node, tumor, metastasis (NTM) staging method, bladder cancer can be divided into non-muscle-invasive bladder cancer (stages Tis, Ta, T1) and muscle-invasive bladder cancer (stages T2 or higher). Approximately 70–80% of patients with bladder cancer present with non-muscle-invasive bladder cancer NMIBC (formerly known as superficial bladder cancer) [2]. NMIBC has a high recurrence rate, and the recurrence rate after the first operation can exceed 50%. The treatment and prognosis of bladder cancer are closely related to the stage classification. The treatment of NMIBC is mainly based on partial surgery and complete resection of the tumor plus intravesical adjuvant treatment to prevent recurrence. At present, the surgical treatment recommended by the guidelines domestically and abroad is transurethral resection of the bladder tumor (TURBT)[3, 4] and is the preferred treatment of NMIBC. TURBT is a high-frequency electric transurethral resection of tumor tissue which requires no incision on the body surface. It can be repeated, and it involves less trauma and is subject to a quicker recovery than other surgical methods. However, TURBT is prone to intraoperative obturator nerve reflex, bladder perforation, and other problems such as dilutive hyponatremia and transurethral resection syndrome, and the recurrence rate is high [5]. TURBT can also cause microvascular and lymphatic vessels to rupture, and the cut tumor tissue can become disseminated within the bladder, increasing the probability of tumor lymphatic metastasis and distant implantation in vivo [6].Since the

end of the last century, laser technology has been used throughout urology. This technology has been widely used in clinical practice due to its safety, minimal invasiveness, and a positive therapeutic effect [7]. In 2002, Laserscope pioneered the 80W green laser surgery system and applied it to benign prostatic hyperplasia. Since then, green laser has emerged as a new technology for the treatment of urinary diseases [8]. The green laser (KTP laser) is easily absorbed by oxidized hemoglobin, but it is not easily absorbed by water, so it is called "selective light." As a result, it can better utilize its energy in human tissues to generate thermal energy, thus causing a vaporization effect. The green laser surgery system is mainly limited to the shallow surface of the tissue surface with a depth of approximately 0.8 mm. At the same time the tissue is vaporized, a solidification zone of 1–2 mm is formed on the surface of the tissue, which facilitates a strong hemostasis. Another advantage of the green laser is that it does not produce an electric field effect. In theory, it can avoid the stimulation of the obturator nerve by the current as well as induce nerve reflex, which reduces the incidence of bladder perforation [9, 10]. We performed a systematic review of RCTs using meta-analysis to determine whether there are any differences between the intraoperative and postoperative outcomes, in addition to oncologic outcomes, between these two approaches, in order to determine whether transurethral laser treatment techniques can be appropriate alternatives to TURBT.

# Methods

The search terms and search strategies were developed according to the Cochrane Handbook for Systematic Reviews of Interventions [11]. The search languages were Chinese and English, and the CNKI, VIP, WangFang, CBM, PubMed, EMBase, and the Cochrane Library databases were utilized for this study. The databases were searched from January 1996 until December 2019. The corresponding search terms were “laser,” “KTP laser,” “electric resection,” “bladder tumor,” “green laser” and “urinary bladder neoplasms.” Some of the search terms had no subject word correspondence, such as “NMIBC,” so the search was supplemented by free words and synonyms, such as "green laser", "greenlight laser", "PVBT", "KTP", "urinary bladder neoplasms", "bladder neoplasm", "bladder tumor", "urinary bladder cancer" and "bladder cancer". Additionally, search terms were linked together via using the appropriate logical operators, synonyms were connected with “or”, “and” was applied to search terms with different meanings (**Supplementary file-search strategy**).

For a study to be considered eligible, it had to meet the following criteria: (1) It was a randomized controlled clinical trial; (2) The study subjects were patients diagnosed with NMIBC; (3) The experimental group was treated with transurethral bladder tumor green laser selective vaporization (PVBT group) and the control group was treated with transurethral resection of bladder tumor (TURBT group). (4) Research indicators must include at least four or more of the following indicators, such as the amount of surgical bleeding and the length of hospital stay, bladder irrigation time, and catheter indwelling time, urethral stricture, obturator nerve reflex and bladder perforation and postoperative recurrence rate. Studies were excluded if they met the following criteria: (1) Non-randomized controlled trials; (2) Too small of a total sample size (< 40 cases rendered the complication index difficult to observe); (3) The original research data could not be obtained. Even if you contact the original author by email or other means. The study was a repeat publication, or the original data record was incomplete; (4) Presence of upper urinary tract tumors and other operations at the same time; (5) Non-green lasers such as helium neon, holmium laser, red laser, 2 μm laser, and semiconductor laser, among others; (6) There were too few outcome indicators. After contacting the author, if these problems could not be rectified, no further research was conducted.

The search process was completed by two independent researchers (researcher Xu, researcher Wu). If there was any disagreement in the search process, Professor Chen would provide professional advice and a re-search may have been completed. In the end, Professor Chen will check whether the retrieval process and the retrieval results are correct. The quality of the included research literature was evaluated based on the improved Jadad scale. The evaluation of literature quality is mainly based on the following aspects: random sequence generation, random hiding, blind method implementation, exit and loss of follow-up.

Study parameters included duration of surgery, intraoperative blood loss, length of hospital stay, duration of catheterization, bladder irrigation, obturator nerve reflex, bladder perforation, tumor recurrence, and urethral stricture. Meta-analysis was performed using RevMan 5.3 statistical software (London, United Kingdom). The count data used Relative Risk (RR) as the effect index, and the measurement data used Mean Difference (MD) as the effect index. Each effect amount provided a point estimate and a 95% Confidence Interval (CI). First, heterogeneity analysis was carried out for each study. The $\chi^2$ test was also carried out (the test level was set to $\alpha = 0.1$), and the heterogeneity was judged by $I^2$. If the studies were homogenous ($I^2 < 50\%$), a meta-analysis was performed using a fixed effect model. If the studies were heterogeneous ($I^2 > 50\%$), a random effects model was used for meta-analysis. For obvious heterogeneity, sensitivity analysis and other methods were used for processing. The test level for the meta-analysis was $\alpha = 0.05$.

Sensitivity analysis was not performed on the research indicators with good homogeneity in the included studies. For the indicators with greater heterogeneity, two methods, single-removal method and selection model analysis method, were used for sensitivity analysis. If there is no difference in the results of two methods, the meta-analysis is reliable. If there are differences in the results of the sensitivity analysis, it is suggested that there are factors that affect the effectiveness of the intervention, and caution must be exercised when interpreting the results and drawing conclusions.

For research indicators with more than 10 included articles, funnel charts were used to determine whether there is publication bias. If the points are evenly distributed on both sides of the midline in the funnel chart, it indicates that there is no publication bias. On the contrary, there is publication bias. If there is too little relevant literature for an index, no funnel chart was made.

# Results

Through the preliminary search, 560 literatures were obtained, and 18 literatures were obtained by reading the title, abstract and full text of the articles and referring to the inclusion and exclusion criteria [12–29]. The total number of cases was 1,648, including 835 in the PVBT group and 813 in the TURBT group. The specific search process is shown in Fig. 1.

According to the original data obtained from the literature, baseline data, such as surgical grouping, age, gender, tumor staging/grading, tumor number, and position, were plotted and compared, and all the studies were consistent with baseline data (Table 1). Tumor staging in different articles at different time period was based on different AJCC staging versions which are 5th, 6th, and 7th, respectively. Nevertheless, the staging of superficial bladder cancer was consistent in these tumor staging criteria. Therefore, the AJCC staging doesn’t affect our results.

Table 1
List of basic characteristics of the incorporated literature

| Inclusive study | Number of cases PVBT/TURBT | Average age (years) PVBT/TURBT | Male patient PVBT/TURBT | Female patient PVBT/TURBT | Base-line comparability | Follow-up outcome |
|---|---|---|---|---|---|---|
| Xu et al. 2015 [29] | 99/94 | 63.06/62.82 | 80/76 | 19/18 | Yes | □□□□□□□ |
| Li et al. 2017 [12] | 34/30 | 49.6/50.7 | 20/16 | 14/14 | Yes | □□□□□□□ |
| Zhang et al. 2016 [13] | 43/43 | 56.41/52.29 | 28/26 | 15/17 | Yes | □□□□□ |
| Wang et al. 2016 [14] | 60/60 | 57.23/57.65 | 33/32 | 27/28 | Yes | □□□□□□□□ |
| Liu 2015 [15] | 43/43 | 62.3/60.5 | 31/29 | 12//14 | Yes | □□□□□□ |
| Han et al. 2015 [16] | 59/59 | 65.29/65.76 | 32/31 | 27/28 | Yes | □□□□□□ |
| Liu et al. 2015 [17] | 31/30 | 53.20/51.93 | 23/21 | 8//9 | Yes | □□□□□□ |
| Shen et al. 2015 [18] | 120/120 | 54.2* | 108* | 132* | Yes | □□□□□□□□□ |
| Wen et al. 2014 [19] | 30/30 | 56/57 | 23/22 | 7//8 | Yes | □□□□□□□□ |
| Ge et al. 2011 [20] | 24/24 | 46.5* | 27* | 21* | Yes | □□□□ |
| Luo et al. 2011 [21] | 28/28 | 60.5* | 43* | 13* | Yes | □□□□□□□□ |
| Cao and Cao 2011 [22] | 46/47 | 56/58 | 25/26 | 21/21 | Yes | □□□□□ |

Note: (1) *data is recorded in the index document but not grouped; (2) Outcome indicators: □ obturator nerve reflex; □ bladder perforation; □ urethral stricture; □ recurrence; □ time required for surgery; □ surgical bleeding volume; □ hospitalization time; □ catheter indwelling time; □ bladder irrigation time. Abbreviations: PVBT, photoselective vaporization of bladder tumor; TURBT, transurethral resection of bladder tumor.

| Inclusive study | Number of cases<br><br>PVBT/TURBT | Average age (years) PVBT/TURBT | Male patient PVBT/TURBT | Female patient PVBT/TURBT | Base-line comparability | Follow-up outcome |
|---|---|---|---|---|---|---|
| Li et al. 2010 [23] | 35/35 | 65/62 | 26/25 | 9//10 | Yes | □□□□□□□□ |
| Wang et al. 2009 [24] | 44/51 | 59.71/58.6 | 29/42 | 15//9 | Yes | □□□ |
| Huo et al. 2008 [25] | 35/32 | 56/52 | 26/26 | 9//6 | Yes | □□□□□□□□ |
| Deng et al. 2008 [26] | 42/42 | 62/58 | 23/24 | 19/18 | Yes | □□□□□ |
| Liu and Li 2007 [27] | 20/20 | 65.5/62.5 | 15/15 | 5/5 | Yes | □□□□□ |
| Jiang et al. 2006 [28] | 42/25 | 65* | 57* | 10* | Yes | □□□□□□□ |

Note: (1) *data is recorded in the index document but not grouped; (2) Outcome indicators: □ obturator nerve reflex; □ bladder perforation; □ urethral stricture; □ recurrence; □ time required for surgery; □ surgical bleeding volume; □ hospitalization time; □ catheter indwelling time; □ bladder irrigation time. Abbreviations: PVBT, photoselective vaporization of bladder tumor; TURBT, transurethral resection of bladder tumor.

The quality of 18 included articles was evaluated according to the modified Jadad scale. Among them, there were 2 high quality documents and 16 general quality documents (Table 2).

Table 2
List of quality evaluation of the incorporated literature

| Inclusion study | Generation of random sequences | Randomized hiding | Blind method | Withdrawal and loss of follow-up | Score |
|---|---|---|---|---|---|
| Yansheng Xu,2015 | Computer generated randomly | Sealed envelope | Single blind | Described and processed | 7 |
| Yijian Li,2017 | Random test without describing method | No clear | Not described | Not described | 2 |
| Jianchao Zhang,2016 | Computer generated randomly | computer control | Not described | Not described | 4 |
| Zhancheng Wang,2016 | Random test without describing method | No clear | Not described | Not described | 2 |
| Kun Liu,2015 | Random number table method | No clear | Not described | Not described | 3 |
| Qianhe Han,2015 | Random number table method | No clear | Not described | Not described | 2 |
| Zhifeng Liu,2015 | Random test without describing method | No clear | Not described | Not described | 2 |
| Yizhen Shen,2015 | Random number table method | No clear | Not described | Not described | 3 |
| Yongan Wen,2014 | Random test without describing method | No clear | Not described | Not described | 2 |
| Guangcheng Ge,2011 | Random test without describing method | No clear | Single blind | Not described | 3 |
| Bin Luo,2011 | Random test without describing method | No clear | Not described | Not described | 2 |
| Shiyi Cao,2011 | Random test without describing method | No clear | Single blind | Not described | 3 |
| Jian Li,2010 | Random test without describing method | No clear | Not described | Not described | 2 |
| Li Wang,2009 | Random test without describing method | No clear | Not described | Describe the loss of follow-up | 3 |
| Lizhi Huo,2008 | Random test without describing method | No clear | Not described | Not described | 2 |
| Gang Deng,2008 | Random test without describing method | No clear | Single blind | Not described | 3 |
| Weijun Liu,2007 | Random test without describing method | No clear | Not described | Not described | 2 |

Note: 1–3 points are considered general quality and 4–7 points are considered high quality.

| Inclusion study | Generation of random sequences | Randomized hiding | Blind method | Withdrawal and loss of follow-up | Score |
|---|---|---|---|---|---|
| Shaobo Jiang,2006 | Random test without describing method | No clear | Not described | Not described | 2 |
| Note: 1–3 points are considered general quality and 4–7 points are considered high quality. | | | | | |

There were 14 publications [11, 13–17, 19, 20, 22–24, 26–28] met the criteria of obturator nerve reflex inclusion. The heterogeneity analysis results ($I^2 = 0$, $P = 0.72$) indicated good homogeneity among various studies. Meta-analysis of them revealed that the obturator nerve reflex in the operation was lower in the PVBT group than in the TURBT group and the result was statistical significant (RR = 0.09, 95% CI [0.04, 0.18], Z = 6.91, P < 0.00001, Fig. 2A). Funnel plot showed no publication bias (Fig. 4A).

Quantitative analysis of 14 researches [15–18, 20–29] uncovered the probability of bladder perforation in the PVBT group was lower than in the TURBT group (RR = 0.14, 95% CI [0.07, 0.28], Z = 5.35, P < 0.00001, Fig. 2B) in a statistically relevant manner. These articles were in good homogeneity ($I^2 = 0$, $P = 1.00$) and no publication bias was found (Fig. 4B).

Quantitative analysis of the basic data of 13 articles [12–19, 21, 23, 25, 27] (MD = − 2.46, 95% CI [− 5.37, 0.46], Z = 1.65, $P = 0.10$) indicated that the difference was not statistically significant, and there was no difference in the time required for surgery between the PVBT group and TURBT group (Fig. 2C). There was a strong heterogeneity among included articles for surgical time ($I^2 = 91\%$, $P < 0.00001$) and publication bias was found (Fig. 4C). Sensitivity analysis revealed that the results of removal single study and change effect model are inconsistent, which indicated that the results and conclusions of the index is of poor reliability.

Quantitative analysis of 8 studies [14, 16, 18, 19, 21, 23, 25, 27] (MD = − 17.27, 95% CI [− 24.73, − 9.81], Z = 4.54, $P < 0.00001$) showed that the amount of surgical bleeding of PVBT group was significantly less than TURBT group (Fig. 2D). Since there was a strong heterogeneity ($I^2 = 99\%$, $P < 0.00001$), sensitivity analysis was performed and no difference between results of removal single study and change effect model was found, suggesting that the analysis of intraoperative blood loss was reliable.

Of the 18 articles included in the study, only three specifically described the urethral stricture after surgery [18, 20, 28]. Quantitative analysis of the data regarding urethral stricture post-surgery in these three papers was performed [18, 20, 28] (RR = 0.53, 95% CI [0.15, 1.83], Z = 1.00, $P = 0.32$, Fig. 3A). Hence, there was no difference in the incidence of postoperative urethral stricture between the PVBT group and the TURBT group.

Quantitative analysis of the basic data of 17 RCT studies [12–15, 17–30] that met the criteria (RR = 0.52, 95% CI [0.40, 0.67], Z = 5.11, $P < 0.0001$) demonstrated statistical significance. The rate of recurrence of bladder tumors after PVBT was lower than that of the TURBT group (Fig. 3B). The included studies represented a good homogeneity ($I^2 = 0$, $P = 0.66$) and no publication bias (Fig. 4D).

Quantitative analysis of the length of hospital stay of the 10 works [12–14, 16, 18, 19, 21, 23, 25, 30] (MD = − 2.80, 95% CI [− 3.82, − 1.87], Z = 5.37, $P < 0.00001$) illustrated that the length of hospital stay of PVBT group

was significantly less than TURBT group (Fig. 3C). The heterogeneity analysis results ($I^2$ = 98%, $P$ < 0.00001) indicated there was strong heterogeneity existed. However, sensitivity analysis suggested the meta-analysis was reliable as there was no difference between results of removal single study and change effect model. Funnel plot showed that the distribution of each point was diffuse and uneven, so publication bias was considered (Fig. 4E).

Quantitative analysis of the underlying data of 12 studies [12–19, 21, 23, 25, 30] (MD = − 2.60, 95% CI [− 3.30, − 1.90], Z = 7.29, $P$ < 0.00001) indicated that the duration of catheter indwelling of PVBT group was significantly less than TURBT group (Fig. 3D). There was a strong heterogeneity depending on the heterogeneity analysis results ($I^2$ = 98%, $P$ < 0.00001). The sensitivity analysis suggested there was no difference between results of removal single study and change effect model. A considered publication bias was shown in funnel plot (Fig. 4F).

Postoperative bladder irrigation time data from the remaining 7 studies [12, 14, 17–19, 21, 25] were analyzed (MD = − 0.95, 95% CI [− 1.49, − 0.42], Z = 3.48, $P$ < 0.0005), and the difference between the PVBT group and the TURBT group in the postoperative bladder irrigation time was statistically significant. That is, postoperative bladder irrigation time was significantly shorter in the PVBT group than in the TURBT group (Fig. 3E). Heterogeneity was considered according to the heterogeneity analysis results ($I^2$ = 99%, $P$ < 0.00001). After sensitivity analysis, no difference between results of removal single study and change effect model was shown, so the analysis was still reliable.

Through analysis, it was found that obturator nerve reflex, bladder perforation, urethral stricture, and tumor recurrence all showed good homogeneity. However, the amount of surgical bleeding, the duration of operation, length of hospital stay, the duration of catheter indwelling, postoperative bladder irrigation time showed greater heterogeneity. The inconsistency of measurement tools, measurement units and measurement accuracy should be regarded as the source of heterogeneity.

Sensitivity analysis of the operation time were inconsistent, so the reliability of its related results and conclusions should be doubted. The amount of surgical bleeding, length of hospital stay, catheter indwelling time and bladder irrigation time all showed high heterogeneity. But after sensitivity analysis, the results were still statistically significant, indicating that the results were reliable.

# Discussion

Although societal and living standards have improved, the incidence of bladder cancer has increased, trending toward a younger age of diagnosis [1]. Bladder cancer ranks third among global male cancers, with NMIBC accounting for 70% of cases [1]. TURBT is the preferred surgical method for the treatment of NMIBC. However, with the continuous improvement of medical technology, TURBT has come to be criticized for its various drawbacks [30]. TURBT uses a high-frequency current to cut tumor tissue, and it is easy for thermal penetrating injuries to take place during the cutting process. It can also damage surrounding tissues and form eschar and scar tissue [30]. Due to its electric field effect, it is apt to obturator nerve reflex, especially bladder wall tumors, thereby increasing clinical complications that include bladder perforation and adhesion formation [30]. The rate of recurrence following TURBT is also high [1]. In TURBT, the tumor tissue is repeatedly cut into pieces,

which violates the principle of surgical tumor-free, i.e., in order to prevent the spread of the tumor, the tumor should be removed as a whole, rather than from many individual tissues.

Green laser vaporization is already widely used in the treatment of bladder tumors, mainly in NMIBC. It is also used in muscle invasive bladder cancer[31]. PVBT has obvious advantages over TURBT with regards to surgical complications including obturator nerve reflex, bladder perforation, and surgical bleeding. This is because the green laser does not produce an electric field effect, so it does not induce nerve reflection. At the same time, the tissue penetration is shallow, the incidence of bladder perforation is small, and its selective absorption causes almost no bleeding during intraoperative bleeding. Long-term follow-up studies have also demonstrated it to be superior to traditional resection in terms of postoperative recurrence rate [30]. The green laser directly vaporizes the tumor tissue, reducing the probability that the tumor cells will be scattered in the bladder and cause distal implantation. The green laser vaporizes tissue at the same time to form a vaporization zone on the surface of the tissue, which effectively blocks the microvessels and lymphatic vessels and reduces the possibility of cancer cells entering the lumen [32].

This article includes a total of 18 studies [12–29] that have been published thus far, with a combined sample size of 1,648 patients. Meta-analysis showed PVBT has obvious advantages over TURBT in the treatment of obturator nerve reflex and bladder perforation (the heterogeneity test was $I^2 < 50\%$, $P < 0.05$). This is basically consistent with the current view, and the safety of PVBT has been verified repeatedly [29].

Regarding the amount of surgical bleeding, hospitalization time, the duration of bladder irrigation and catheter indwelling, this meta-analysis showed that PVBT is superior to TURBT. Because of the heterogeneity, sensitivity analysis was carried out and showed that the conclusions of the four indicators are reliable. Therefore, the efficiency and safety of PVBT were verified. Heterogeneous sources are often considered inconsistent with the familiarity of the green laser surgery system and the inconsistent measurement methods.

In the incidence of postoperative urethral stricture and duration of the operation, the meta-analysis showed that there was no difference between the two surgical methods ($P > 0.05$), and the sensitivity analysis suggested that the results are stable and the conclusion is reliable. Overall, the efficiency and safety of PVBT has once again been verified [29]. Based upon these findings, we surmise that PVBT is worth promoting as a standard procedure for the treatment of NMIBC.

Limitations of this study are as follows. 1) Although the incorporated literature is described as a randomized controlled clinical trial, most of the research literature does not specifically describe the methods of random sequence generation or concealing randomization. The implementation of blinding, withdrawal and follow-up were not described, leading to the possibility of selection bias, implementation bias, and measurement bias. 2) In some of these studies, the ending indicators are not comprehensive. 3) Heterogeneity was found among some of the reports. Most of the included studies didn't underscore whether they applied monopolar or bipolar TURBT. Not all the agents performing the experiments had the same degree of familiarity with the green laser surgery system. The measurement tools were also not the same. 4)The bladder intravesical adjuvant treatment differed in several studies, the drugs and the intravesical adjuvant treatment time were different. And the duration of postoperative follow-up time was different. Finally, These factors may affect the outcome indicators, which in turn affect the reliability of the conclusions [33], especially regarding to the recurrence rate

of tumor. Hence, although the recurrence rate of tumor showed that PVBT was better than TURBT in the analysis of forest map, the analysis of recurrence rate was biased and the conclusion was not reliable.

# Conclusions

Based on the data included in our meta-analysis, PVBT is safer than TURBT for patients with NMIBC, but whether it is equally effective in terms of oncological control remains to be elucidated. However, additional randomized controlled trials with longer follow-up periods and larger sample sizes should be performed to verify our findings.

# Abbreviations

PVBT, photoselective vaporization of bladder tumor;

TURBT, transurethral resection of the bladder tumor;

NMIBC, non-muscle-invasive bladder cancer.

# Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Availability of data and material

The data and materials can be obtained by contacting the first author.

### Competing interests

All the authors declare that there are no competing interests

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### Authors' contributions

ZX and GW performed the literature search, statistical analysis and wrote the manuscript. GC stratified the data. GG provided meaningful discussion key points. GW revised and edited the manuscript. All authors have read and approved the manuscript, and ensure that this is the case.

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# Figures

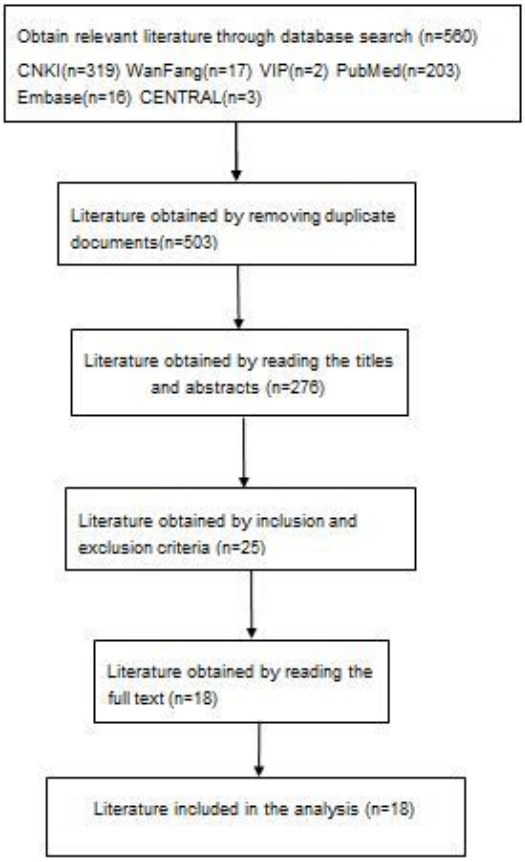
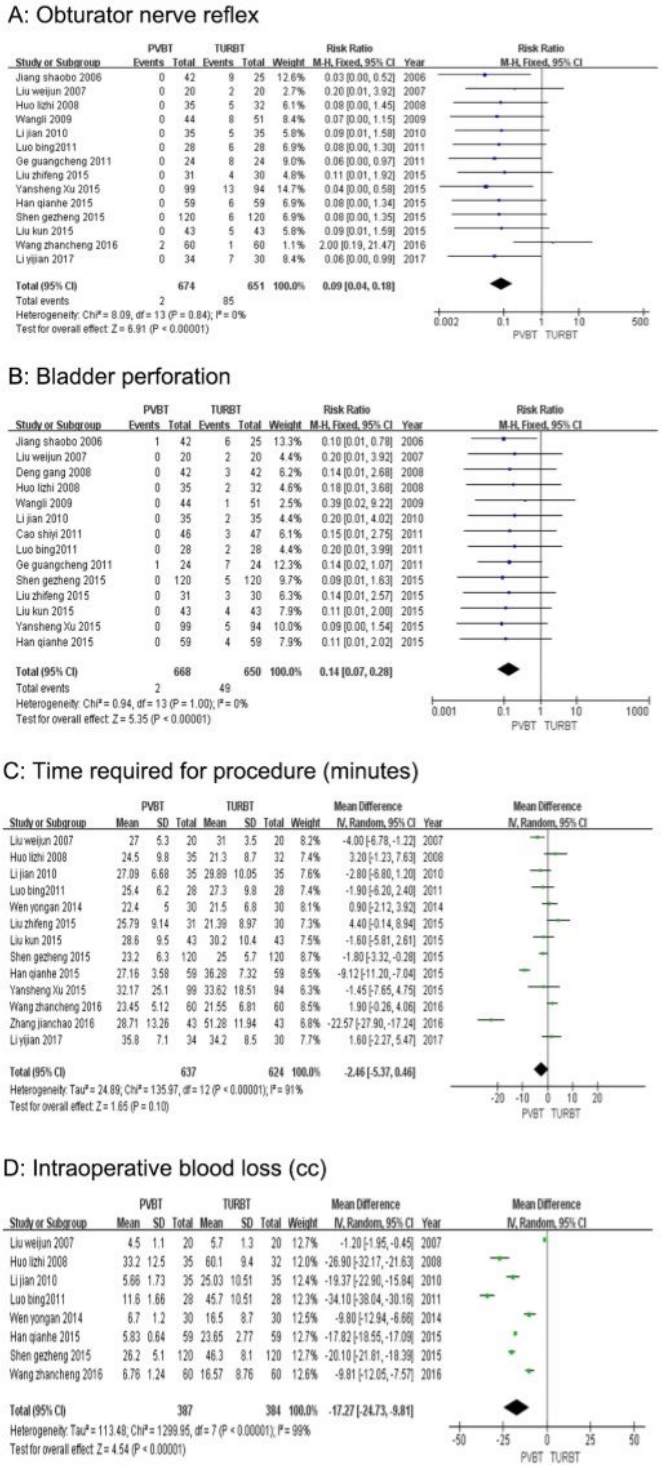


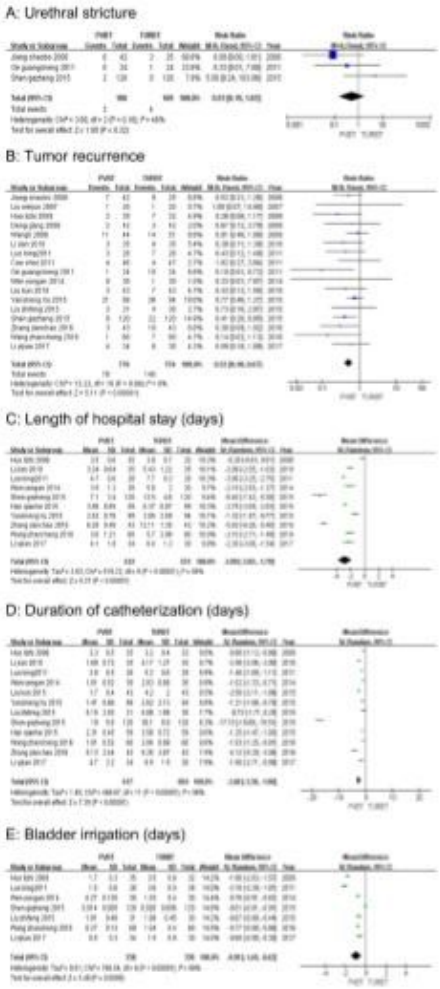

**Figure 1**

Studies identified, included and excluded.




## Figure 2

Meta-analysis comparing PVBT and TURBT in NMIBC with respect to the issues following the procedure. (A) Obturator nerve reflex. (B) Bladder perforation. (C) Time required for surgery (minutes). (D) Intraoperative blood loss (cc). PVBT: photoselective vaporization of bladder tumor; TURBT: transurethral resection of bladder tumor; NMBIC: non-muscle invasive bladder cancer.




## Figure 3

Meta-analysis comparing PVBT and TURBT in NMIBC with respect to the issues post-procedure. (A) Urethral stricture. (B) Tumor recurrence. (C) Length of hospital stay (days). (D) Duration of catheterization (days). (E) Bladder irrigation (days). PVBT: photoselective vaporization of bladder tumor; TURBT: transurethral resection of bladder tumor; NMBIC: non-muscle invasive bladder cancer.

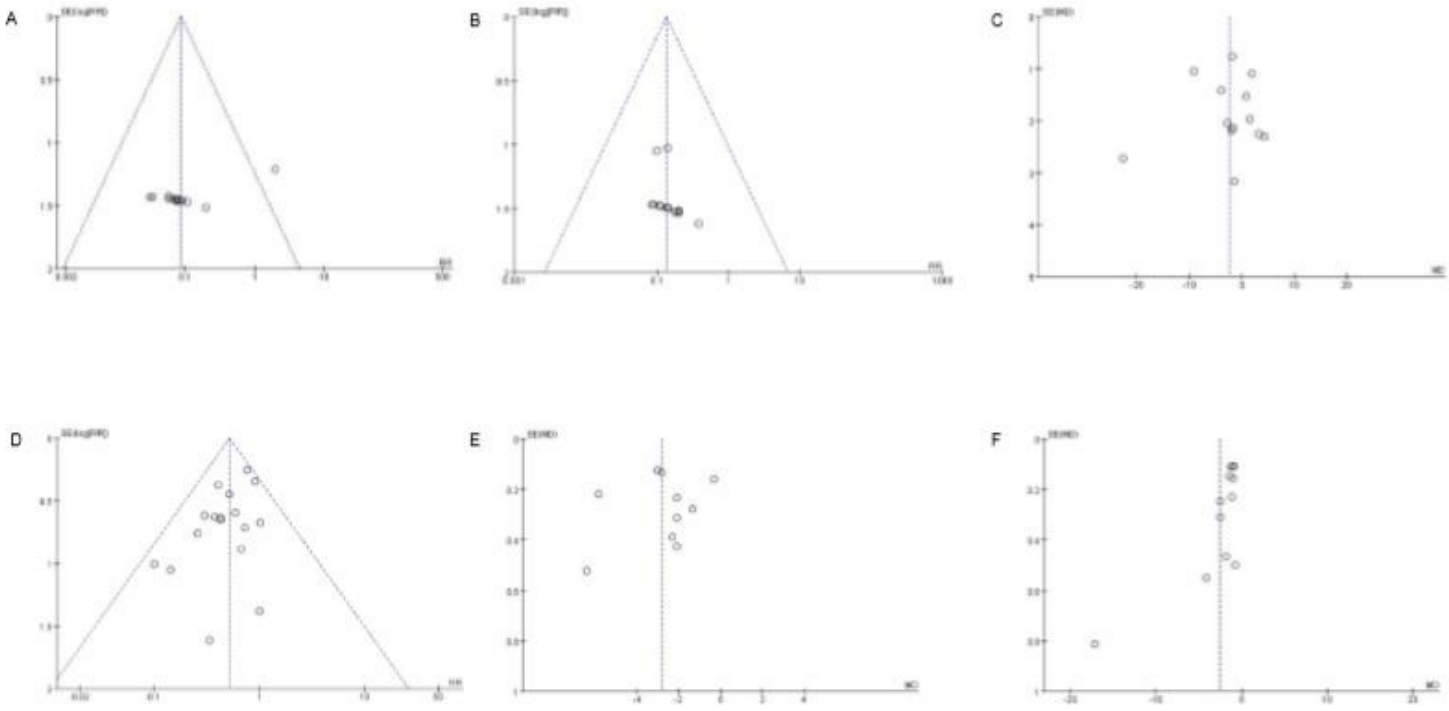



**Figure 4**

Publication bias analysis, funnel plot. (A) Obturator nerve reflection. (B) Bladder perforation. (C) The duration of operation (days). (D) The rate of recurrence of bladder tumors. (E) The length of hospital stay (days). (F) The duration of catheter indwelling (days).

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