EUROPEAN UROLOGY 67 (2015) 1066–1096

available at www.sciencedirect.com
journal homepage: www.europeanurology.com

European Association of Urology

Platinum Priority – Collaborative Review – Benign Prostatic Obstruction

*Editorial by Hashim Hashim and Paul Abrams on pp. 1097–1098 of this issue*

# A Systematic Review and Meta-analysis of Functional Outcomes and Complications Following Transurethral Procedures for Lower Urinary Tract Symptoms Resulting from Benign Prostatic Obstruction: An Update

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**Article info**

***Article history:***
Accepted June 12, 2014

***Keywords:***
Benign prostatic obstruction
Meta-analysis
Transurethral procedures
Laser
Prostate

**Abstract**

***Context:*** A number of transurethral ablative techniques based on the use of innovative medical devices have been introduced in the recent past for the surgical treatment of benign prostatic obstruction (BPO).

***Objective:*** To conduct a systematic review of the literature and a meta-analysis of available randomized controlled trials (RCTs), and to evaluate the efficacy and safety of transurethral ablative procedures for BPO.

***Evidence acquisition:*** A systematic literature search was performed for all RCTs comparing any transurethral surgical technique for BPO to another between 1992 and 2013. Efficacy was evaluated after a minimum follow-up of 1 yr based on International Prostate Symptom Score, maximum flow rate, and postvoid residual volume. Efficacy at midterm follow-up, prostate volume, perioperative data, and short-term and long-term complications were also assessed. Data were analyzed using RevMan software.

***Evidence synthesis:*** A total of 69 RCTs (8517 enrolled patients) were included. No significant difference was found in terms of short-term efficacy between bipolar transurethral resection of the prostate (B-TURP) and monopolar transurethral resection of the prostate (M-TURP). However, B-TURP was associated with a lower rate of perioperative complications. Better short-term efficacy outcomes, fewer immediate complications, and a shorter hospital stay were found after holmium laser enucleation of the prostate (HoLEP) compared with M-TURP. Compared with M-TURP, GreenLight photoselective vaporization of the prostate (PVP) was associated with a shorter hospital stay and fewer complications but no different short-term efficacy outcomes.

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http://dx.doi.org/10.1016/j.eururo.2014.06.017

***Conclusions:*** This meta-analysis shows that HoLEP is associated with more favorable outcomes than M-TURP in published RCTs. B-TURP and PVP have resulted in better perioperative outcomes without significant differences regarding efficacy parameters after short-term follow-up compared with M-TURP. Further studies are needed to provide long-term comparative data and head-to head comparisons of emerging techniques.

***Patient summary:*** Bipolar transurethral resection of the prostate, photovaporization of the prostate, and holmium laser enucleation of the prostate have shown efficacy outcomes comparable with conventional techniques yet reduce the complication rate. The respective role of these new options in the surgical armamentarium needs to be refined to propose tailored surgical treatment for benign prostatic obstruction relief.



## 1. Introduction

Lower urinary tract symptoms (LUTS) are a common complaint in older men [1]. Surgical intervention is the standard treatment for patients with bothersome LUTS due to benign prostatic obstruction (BPO) unwilling to try medical therapies, in cases where medical therapies were not effective, and in cases of complicated LUTS [1]. In the past 2 decades, a wide range of innovative transurethral procedures have challenged the supremacy of the two standard surgical options (monopolar transurethral resection of the prostate [M-TURP] and open prostatectomy [OP]) [2]. These alternative transurethral procedures embrace all laser therapies, encompassing the various types of lasers and modalities of prostatic tissue ablation (enucleation, vaporization, and resection) and bipolar devices permitting bipolar TURP (B-TURP) or bipolar enucleation.

A number of systematic reviews have summarized the growing evidence supporting the use of these new techniques [2–6]. In this rapidly moving field, our objective was to conduct an updated systematic review and meta-analysis gathering all the level of evidence (LE) 1 information available in the literature about transurethral procedures for surgical management of LUTS/BPO, by focusing on commercially available and emerging techniques.

## 2. Evidence acquisition

### 2.1. *Literature search and inclusion of studies*

A systematic review was conducted, based on a literature search through the PubMed/Medline, Embase, Scopus, and ISI Web of Knowledge. Three authors participated in the process of literature search and data acquisition process (J.N.C., G.N., and S.M.). The literature search aimed at identifying all the papers reporting the results of randomized controlled trials (RCTs) in full-length articles published in English, German, Dutch, Italian, or French between 1992 (date of the first publications relative to laser prostatectomy) and September 2013. The following keywords were used in the databases just cited: (randomized OR randomised) AND prostate (in title or abstract fields) AND (Transurethral resection OR TURP OR monopolar OR Bipolar OR Gyrus OR TURis OR Vista CTR OR TUVis OR plasmakinetic OR PkEP OR vaporization or vaporisation OR electrovaporization OR electrovaporisation OR TUVP OR vaporesection OR TUVRP OR ablation OR enucleation OR laser OR Nd:YAG OR VLAP OR CLAP OR photovaporisation OR photovaporization OR PVP OR KTP OR LBO Holmium OR HoLEP OR HoLRP OR HoLAP OR thulium OR TmLRP OR diode [in text]). The search was completed by a PubMed/Medline search for the *Prostatic hyperplasia/Surgery* Medical Subject Heading term, limited to the "randomized controlled trials" category. The reference lists of all systematic reviews in the field were also screened for additional references. After the removal of duplicates and the exclusion of conference abstracts, a first selection was made based on the title and abstract of the papers. Only the RCTs comparing two ablative transurethral techniques were considered, thus excluding studies about transurethral needle ablation, transurethral microwave therapy, transurethral ethanol ablation of the prostate, water-induced thermotherapy, high-intensity focused ultrasound, intraprostatic injections, as well as hybrid/combination procedures. We included studies reporting main functional outcomes (International Prostate Symptom Score [IPSS] or maximum flow rate [$Q_{max}$]) or postoperative complications. Based on expert agreement, a number of transurethral procedures were excluded from the present report because they were no longer used in clinical practice and/or linked to all references well studied in previous systematic reviews [2,4] without new data available in the literature: visual laser ablation of the prostate, contact laser ablation/vaporization of the prostate, holmium laser resection of the prostate, and holmium laser ablation of the prostate.

Once selected, the full text of the articles were studied to gather information about study design, inclusion criteria, baseline patient characteristics, operative parameters, immediate, short-term (≤12 mo), and long-term complications, as well as short-term (12 mo) and medium- to long-term functional outcomes (defined as ≥24 mo). Functional data earlier than 12 mo were not considered, in accordance with current standard guidelines for the evaluation of BPO surgery [1]. Quality of the studies was assessed by the Jadad score [7].

### 2.2. *Statistical analysis*

A meta-analysis was considered for each outcome including perioperative data, efficacy, or complications for every head-to-head comparison. For an optimal consistency of the results, subgroups meta-analyses were conducted within each category of devices. Meta-analysis was conducted using RevMan software v.5.1 (Cochrane Collaboration, Oxford, UK). Specifically, statistical heterogeneity was tested using the chi-square test. A value of $p < 0.10$ was used to indicate heterogeneity. In the case of a lack of heterogeneity, fixed-effects model was used for the meta-analyses. The results were expressed as weighted mean difference with 95% confidence interval (CI) for continuous outcomes and as an odds ratio (OR) with a 95% CI for dichotomous variables. Evaluation of potential publication bias was done by funnel plots analysis for each outcome. Meta-analysis of continuous variables was possible only for studies reporting them as means and standard deviations.

## 3. Evidence synthesis

The initial search yielded 1719 records. After removal of duplicates, 1161 articles were considered and reviewed based on title and abstract. At the end of the process, 170 papers were reviewed in full text and 69 RCTs were finally included [8–76]. Figure 1 shows the flow diagram. Table 1 summarizes the data about study design, Jadad score, and inclusion criteria for all studies. Analysis of funnels plots showed no significant evidence of publication bias on the outcome studied. Overall the quality of studies was low, with a lot of missing data, primary hypothesis often not specified, and showing some caveats in the methodology. Supplemental Table 1 includes the baseline data for each study considered including number of patients in each arm, age, IPSS, $Q_{max}$, postvoid residual volume (PVR), prostate size, quality of life (QoL), and sexual function data, if available.

### 3.1. *Bipolar devices for transurethral surgery*

To date, five types of bipolar resection devices have been developed and marketed: the plasmakinetic (PK) system (Gyrus-PK), the Vista Coblation/CTR (controlled tissue resection) system (ACMI) (withdrawn), the transurethral resection in saline (TURis) system (Olympus), the Karl Storz bipolar device, and the Richard Wolf bipolar device. The devices differ in the way in which bipolar current flow is delivered to achieve cut, coagulation, and vaporization of the prostatic tissue.

Forty independent RCTs evaluating bipolar devices were identified in our systematic review (Table 1). Bipolar techniques were mostly compared with M-TURP ($n = 33$) but also with holmium laser enucleation of the prostate (HoLEP) ($n = 2$) and emerging alternative devices ($n = 7$). Bipolar technologies were separated for the analysis into three modalities: bipolar resection (B-TURP), bipolar vapor resection (bipolar transurethral vaporization of the prostate [B-TUVP]), and bipolar enucleation (plasmakinetic enucleation of the prostate [PKEP]).

### 3.2. *Bipolar resection techniques*

#### 3.2.1. *Bipolar transurethral resection of the prostate versus monopolar transurethral resection of the prostate*

Only four devices have been evaluated through published RCTs: ACMI Vista CTR (two studies) [9,10], Gyrus-PK

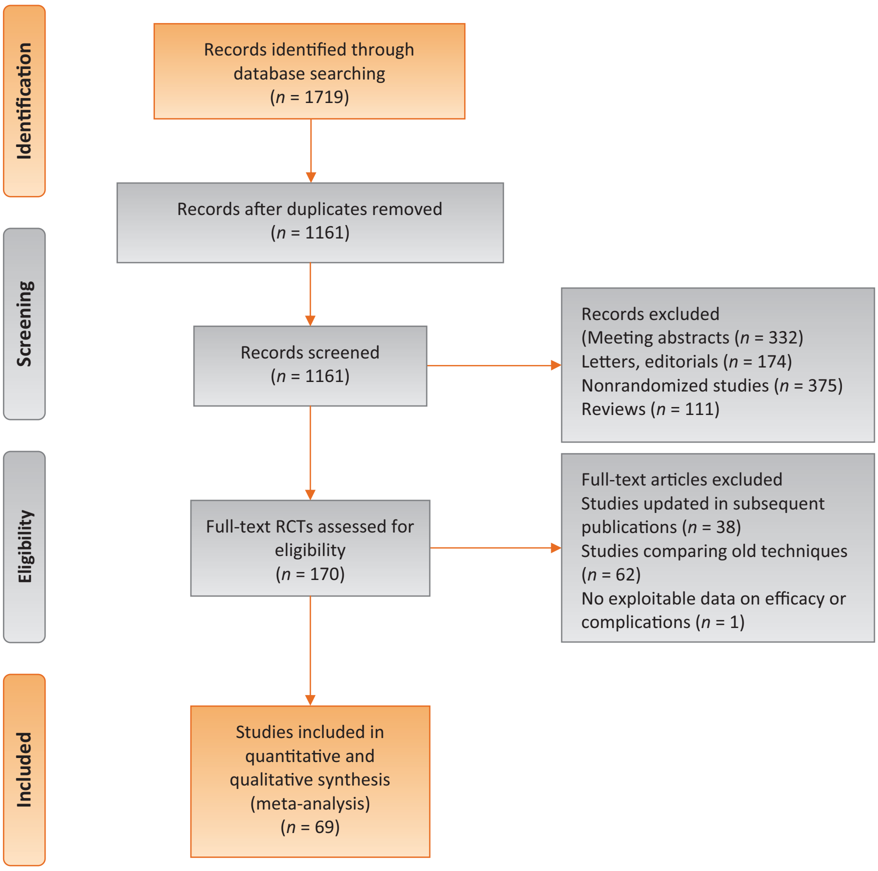



**Fig. 1 – Preferred Reporting Items for Systematic Reviews and Meta-analysis flowchart. RCT = randomized controlled trial.**

**Table 1 – Characteristics and design of the studies**

| Study | Study design | | | | | | | Inclusion criteria | | | | | | Jadad score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Study arms | Techniques | | | Hypothesis | Main outcome criterion | Follow-up, mo | Prostate size, ml | Anticoagulation | Age, yr | Minimal IPSS | Maximal $Q_{max}$ | Urinary retention at baseline | |
| Geavlete et al. [8] | 2 | Bipolar enucleation | vs | OP | Unclear | Unclear | 12 | >80 | N/A | N/A | 19 | 10 | N/A | 2 |
| Méndez-Probst et al. [9] * | 2 | B-TURP (Vista CTR) | vs | M-TURP | IPSS difference | IPSS | 6 | N/A | Excluded | N/A | 12 | 12 | Included | 1 |
| Singh et al. [10] | 2 | B-TURP (Vista CTR) | vs | M-TURP | Tolerance | Unclear | 3 | N/A | N/A | >50 | 7 | 12 | Included | 2 |
| Iori et al. [20] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Efficacy | IPSS: urodynamics | 12 | N/A | N/A | N/A | N/A | N/A | N/A | 2 |
| Erturhan et al. [19] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Efficacy | Unclear | 12 | N/A | N/A | N/A | 18 | N/A | Included | 1 |
| Chen et al. [23] | 2 | B-TURP (Gyrus PK) | vs | HoLEP | Efficacy | Operation time | 24 | N/A | Excluded | N/A | N/A | N/A | N/A | 2 |
| Seckiner I et al. [17] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Efficacy | Unclear | 12 | 30–70 | N/A | >50 | 8 | 15 | Included | 1 |
| Yang et al. [22] | 2 | B-TURP (Gyrus PK) | vs | ThuLEP | Efficacy and safety | Unclear | 18 | 30–100 | N/A | <85 | N/A | 15 | N/A | 2 |
| Giulianelli et al. [24] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Unclear | Unclear | 36 | N/A | N/A | N/A | N/A | N/A | N/A | 3 |
| Yang et al. [14] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Efficacy | Unclear | 3 | N/A | N/A | N/A | N/A | N/A | N/A | 1 |
| Singhania et al. [18] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Unclear | Unclear | 12 | N/A | N/A | N/A | N/A | N/A | N/A | 1 |
| Patankar et al. [12] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Efficacy-safety | Unclear | 1 | 35–70 | N/A | >45 | 18 | 10 | Included | 3 |
| Bhansali et al. [16] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Unclear | Unclear | 12 | >60 | N/A | N/A | 18 | 12 | N/A | 1 |
| Nuhoglu et al. [21] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Efficacy-safety | Unclear | 12 | N/A | N/A | N/A | 15 | 10 | N/A | 1 |
| Huang et al. [11] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Hemostasis | Blood loss and coagulation depth | 1 | 30–80 | N/A | >50 | 16 | 15 | N/A | 1 |
| Kim et al. [15] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Efficacy | Unclear | 6 | N/A | N/A | N/A | N/A | N/A | N/A | NA |
| Xie et al. [26] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Unclear | Unclear | 60 | >20 | N/A | >45 | 12 | 15 | N/A | 2 |
| Kong et al. [13] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Unclear | Unclear | 1 | N/A | N/A | N/A | N/A | N/A | Included | 1 |
| Autorino et al. [25] | 2 | B-TURP (Gyrus PK) | vs | M-TURP | Efficacy B-TURP superior | Time of catheterization | 48 | >30 | Excluded | >50 | 18 | 15 | Included | 3 |
| Mamoulakis et al. [27] * | 2 | B-TURP (Karl Storz AUTOCON II 400ESU) | vs | M-TURP | B-TURP reduces decline of sodium levels | Sodium level change after surgery | 36 | N/A | Unclear | N/A | N/A | 15 | Included | 2 |
| Fagerström et al. [31] | 2 | B-TURP (Olympus TURis Surgmaster) | vs | M-TURP | Fluid absorption | Unclear | 18 | 30–100 | Included | N/A | N/A | N/A | Included | 1 |
| Fagerstrom et al. [28] | 2 | B-TURP (Olympus TURis Surgmaster) | vs | M-TURP | Safety | Blood loss | 1 | 30–100 | N/A | N/A | N/A | N/A | Included | 1 |
| Ho et al. [30] | 2 | B-TURP (Olympus TURis Surgmaster) | vs | M-TURP | Efficacy | Unclear | 12 | N/A | N/A | >50 | 19 | 15 | Included | 1 |
| Michielsen et al. [76] | 2 | B-TURP (Olympus TURis Surgmaster) | vs | M-TURP | Complications | Perioperative data | 1 | N/A | N/A | N/A | 13 | 15 | N/A | 2 |
| Chen et al. [33] | 2 | B-TURP (Olympus TURis Surgmaster) | vs | M-TURP | Efficacy | Unclear | 24 | >50 | N/A | >55 | 18 | 15 | N/A | 2 |
| Geavlete et al. [32] | 3 | B-TURP (Olympus TURis Surgmaster) | vs | M-TURP vs B-TUVP (Olympus) | Efficacy | Unclear | 18 | 30–80 | N/A | N/A | 19 | 10 | N/A | 1 |
| Akman et al. [29] | 2 | B-TURP (Olympus TURis Surgmaster) | vs | M-TURP | Erectile function | IIEF | 12 | N/A | N/A | N/A | N/A | N/A | N/A | 1 |
| Geavlete et al. [36] | | B-TUVP (Olympus mushroom electrode) | vs | M-TURP | Unclear | Unclear | 6 | 30–80 | N/A | N/A | 19 | 10 | N/A | 1 |
| Yip et al. [34] | 2 | B-TUVP (Olympus mushroom electrode) | vs | B-TURP (Olympus TURis Surgmaster) | Catheter time | Catheter time | 1 | N/A | N/A | >50 | 18 | 15 | Included | 3 |
| Zhang et al. [35] | 2 | B-TUVP (Olympus mushroom electrode) | vs | M-TURP | Unclear | Unclear | 6 | 25–125 | N/A | N/A | N/A | 10 | N/A | 2 |
| Nuhoglu et al. [21] | 2 | B-TUVP (Olympus mushroom electrode) | vs | M-TURP | Unclear | Unclear | 12 | N/A | Included | N/A | 8 | 15 | Included | 2 |
| Muslumanoglu et al. [38] | 2 | B-TUVP (PK Gyrus VRP hybrid technique) | vs | M-TURP | Unclear | Unclear | 100 | N/A | N/A | N/A | 16 | N/A | Included | 1 |
| Hon et al. [39] | | B-TUVP (PKVP Gyrus plasma V) | vs | M-TURP | Efficacy | Unclear | 9 | <80 | N/A | N/A | N/A | N/A | N/A | 1 |
| Dunsmuir et al. [41] | | B-TUVP (PKVP Gyrus) | vs | M-TURP | Unclear | Catheterization time | 12 | <80 | Excluded | <80 | N/A | N/A | Excluded | 1 |
| Fung et al. [40] | 2 | B-TUVP (PKVP Gyrus) | vs | M-TURP | Efficiency-safety | Unclear | 3 | N/A | Excluded | N/A | 20 | 10 | Included | 2 |
| Kaya et al. [42] | 2 | B-TUVP (PKVP Gyrus) | vs | M-TURP | Efficacy | IPSS $Q_{max}$ | 36 | <60 | N/A | N/A | N/A | 15 | N/A | 2 |
| Xu et al. [43] | 2 | DiLEP | vs | PKERP | Unclear | Unclear | 12 | N/A | N/A | >50 | 7 | 15 | N/A | 4 |

**Table 1** (*Continued*)

| Study | Study design | | | | | | | Inclusion criteria | | | | | | Jadad score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Study arms | Techniques | | | Hypothesis | Main outcome criterion | Follow-up, mo | Prostate size, ml | Anticoagulation | Age, yr | Minimal IPSS | Maximal $Q_{max}$ | Urinary retention at baseline | |
| Lusuardi et al. [44] | 2 | ELEP (ERASER) | vs | B-TURP (Gyrus PK) | Safety | Catherization time | 6 | N/A | Excluded | N/A | N/A | N/A | N/A | 3 |
| Salonia et al. [45] | 2 | HoLEP | vs | OP | Cost analysis | Costs | 1 | 70–220 | N/A | <75 | N/A | 15 | N/A | 1 |
| Naspro et al. [53] | 2 | HoLEP | vs | OP | Efficacy | Unclear | 24 | >70 | N/A | N/A | N/A | 15 | N/A | 2 |
| Fayad et al. [47] | 2 | HoLEP | vs | B-TURP (Olympus TURis Surgmaster) | Efficacy | Unclear | 6 | >20 | Excluded | N/A | 8 | 15 | Included | 2 |
| Eltabey et al. [51] | 2 | HoLEP | vs | M-TURP | Unclear | IPSS $Q_{max}$ PVR | 12 | 30–100 | N/A | N/A | 12 | 15 | N/A | 2 |
| Mavuduru et al. [46] | 2 | HoLEP | vs | M-TURP | Efficacy | Unclear | 3 | N/A | N/A | N/A | N/A | N/A | Included | 2 |
| Kuntz et al. [55] | 2 | HoLEP | vs | OP | Efficacy | Unclear | 60 | >100 | N/A | N/A | 8 | 12 | Included | 3 |
| Ahyai et al. [54] | 2 | HoLEP | vs | M-TURP | Efficacy | Unclear | 36 | <100 | N/A | N/A | 12 | 12 | Included | 3 |
| Neill et al. [50] | 2 | HoLEP | vs | PKEP | Efficacy | Catheterization time | 12 | 20–200 | N/A | N/A | 12 | 15 | Included | 1 |
| Briganti et al. [52] * | 2 | HoLEP | vs | M-TURP | Sexual function | IIEF | 24 | <100 | N/A | <75 | N/A | 15 | Excluded | 1 |
| Elmansy et al. [49] | 2 | HoLEP | vs | PVP-120W | Unclear | Unclear | 12 | >60 | Included | N/A | 9 | 15 | N/A | 1 |
| Montorsi et al. [48] * | 2 | HoLEP | vs | M-TURP | Efficacy + sexual symptoms | | 12 | <100 | N/A | <75 | N/A | 15 | Excluded | 1 |
| Gilling et al. [56] | 2 | HoLEP | vs | M-TURP | 10% difference in hospital stay and catheterization time | Hospital stay/ Catheterization time/Transfusion rate | 92 | 40–200 | N/A | N/A | 8 | 15 | Excluded | 1 |
| Zhu et al. [58] | 2 | PKEP | vs | B-TURP (Gyrus PK) | Time of catheterization is inferior for PKEP | Time of catheterization | 60 | 70–200 | N/A | 50–70 | 20 | 10 | N/A | 5 |
| Zhao et al. [57] | 2 | PKEP | vs | M-TURP | Unclear | Unclear | 36 | >20 | N/A | >45 | 12 | 15 | Included | 3 |
| Ou et al. [60] | 2 | PKEP | vs | OP | Unclear | IPSS and $Q_{max}$ | 12 | >80 | Excluded | N/A | N/A | N/A | Included | 2 |
| Rao et al. [59] | 2 | PKEP | vs | OP | Unclear | Unclear | 12 | >80 | N/A | >50 | N/A | 15 | N/A | 2 |
| Lukacs et al. [62] * | 2 | PVP-120W | vs | M-TURP | Noninferiority on IPSS; superiority on hospital stay | IPSS 12 mo, hospital stay | 12 | <80 | Excluded | N/A | 12 | 12 | Excluded | 3 |
| Pereira-Correia et al. [63] | 2 | PVP-120W | vs | M-TURP (mannitol) | Unclear | Unclear | 24 | <60 | N/A | N/A | N/A | N/A | Excluded | 2 |
| Kumar et al. [61] | 3 | PVP-120W | vs | B-TURP (Gyrus PK) vs M-TURP | Unclear | Multiple | 12 | [20–80] | Excluded | >50 | 7 | 15 | Excluded | 2 |
| Xue et al. [66] | 2 | PVP-120W | vs | M-TURP | Unclear | Unclear | 36 | <100 | N/A | N/A | 15 | 15 | Excluded | N/A |
| Al-Ansari et al. [65] | 2 | PVP-120W | vs | M-TURP | Efficacy | Unclear | 36 | <100 | Excluded | N/A | 16 | 15 | Included | 3 |
| Capitan et al. [64] | 2 | PVP-120W | vs | M-TURP | Superiority on IPSS | IPSS | 24 | <80 | Included | N/A | 15 | 15 | Included | 3 |
| Alivizatos et al. [68] | 2 | PVP-80W | vs | OP | Efficacy | IPSS, $Q_{max}$ | 12 | >80 | N/A | >50 | 12 | 2 | Excluded | 1 |
| Mohanty et al. [69] | 2 | PVP-80W | vs | M-TURP | Efficacy | Unclear | 12 | 20–80 | N/A | >50 | 7 | 15 | Excluded | 4 |
| Horasanli et al. [67] | 2 | PVP-80W | vs | M-TURP | Postoperative data | Unclear | 6 | [70–100] | N/A | N/A | 7 | 15 | Excluded | 1 |
| Bouchier-Hayes et al. [70] | 2 | PVP-80W | vs | M-TURP | Efficacy-equivalence | Objective and subjective criteria | 12 | N/A | Excluded | >50 | 12 | 15 | Included | 3 |
| Zhang et al. [35] | 2 | TmLEP | vs | HoLEP | Unclear | Unclear | 18 | 0–80 | N/A | <85 | N/A | 15 | N/A | 3 |
| Peng et al. [72] | 2 | TmLRP | vs | B-TURP (Olympus) | Unclear | Unclear | 3 | N/A | N/A | N/A | N/A | N/A | N/A | 4 |
| Xia et al. [73] | 2 | TmLRP | vs | M-TURP | Efficacy | IPSS | 12 | <100 | N/A | <85 | N/A | 15 | Excluded | 2 |
| Yan et al. [74] | 2 | TmLRP | vs | M-TURP (mannitol) | Unclear | PiCCO monitoring system | 3 | N/A | OK | N/A | N/A | N/A | N/A | 2 |
| Gupta et al. [75] | 3 | TUVRP | vs | M-TURP vs HoLEP | Efficacy | Unclear | 12 | >40 | N/A | N/A | N/A | N/A | Included | 2 |

B-TURP = Bipolar transurethral resection of the prostate; B-TUVP = bipolar transurethral vaporization of the prostate; DiLEP = diode laser enucleation; HoLEP = holmium laser enucleation of the prostate; IIEF = International Index of Erectile Function; IPSS = International Prostate Symptom Score; N/A = not available; M-TURP = monopolar transurethral resection of the prostate; OP = Open prostatectomy; PiCCO = transpulmonary thermodilution hemodynamic monitoring; PKEP = plasmakinetic enucleation of the prostate; PVP = photovaporization of the prostate; PVR = postvoid residual; $Q_{max}$ = maximum flow rate; TmLEP = thulium laser enucleation of the prostate; TmLRP = thulium laser resection of the prostate; TUVRP = transurethral vapor resection of the prostate.

* Multicenter study.

(16 studies) [11–26], Olympus TURis (seven studies) [28–33,76], and Karl Storz AUTOCON device (one study) [27]. For clarity and completeness, we decided to conduct the analyses comparing B-TURP with M-TURP in two ways. The first is a global analysis of B-TURP (all devices) against M-TURP, and the second is a separate analysis of published data for each bipolar resection modality/manufacturer.

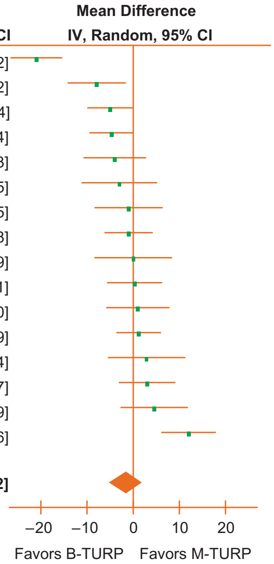
### 3.3. *Global analysis of bipolar transurethral resection of the prostate versus monopolar transurethral resection of the prostate*

Only four studies included results over long-term follow-up [24–27]. The vast majority of the papers were limited to a 12-mo follow-up, with significant dropout rates.

A.

| Study or Subgroup | B-TURP (all modalities) Mean | SD | Total | M-TURP Mean | SD | Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Xie et al | 36 | 19 | 120 | 57 | 24 | 120 | 6.6% | –21.00 [–26.48, –15.52] |
| Erturhan et al | 49.99 | 12.35 | 53 | 57.88 | 18.95 | 51 | 6.3% | –7.89 [–14.06, –1.72] |
| Chen et al | 55.03 | 16.3 | 110 | 60.01 | 20.1 | 110 | 6.8% | –4.98 [–9.82, –0.14] |
| Seckiner et al | 54 | 21 | 127 | 58.7 | 16.8 | 130 | 6.8% | –4.70 [–9.36, –0.04] |
| Singh et al | 62 | 23 | 95 | 66 | 23 | 90 | 6.1% | –4.00 [–10.63, 2.63] |
| Kim et al | 54 | 13.6 | 25 | 57 | 15.4 | 25 | 5.6% | –3.00 [–11.05, 5.05] |
| Patankar et al | 59 | 19 | 50 | 60 | 18 | 50 | 5.9% | –1.00 [–8.25, 6.25] |
| Kumar et al | 58 | 14.6 | 80 | 59 | 18 | 80 | 6.7% | –1.00 [–6.08, 4.08] |
| Fagerström et al | 52.9 | 12.8 | 24 | 52.9 | 16.3 | 24 | 5.5% | 0.00 [–8.29, 8.29] |
| Giulianelli et al | 46.03 | 16.72 | 57 | 45.73 | 15.29 | 60 | 6.4% | 0.30 [–5.51, 6.11] |
| Michielsen et al | 59 | 18 | 48 | 58 | 16 | 52 | 6.1% | 1.00 [–5.70, 7.70] |
| Mamoulakis et al | 52 | 21.17 | 141 | 50.8 | 18.8 | 139 | 6.8% | 1.20 [–3.49, 5.89] |
| Akman et al | 39.8 | 17.8 | 30 | 36.9 | 14.6 | 30 | 5.5% | 2.90 [–5.34, 11.14] |
| Huang X et al | 55 | 9.7 | 27 | 52 | 13.2 | 30 | 6.4% | 3.00 [–2.97, 8.97] |
| Nuhoglu et al | 75.77 | 22.63 | 71 | 71.22 | 19.85 | 65 | 5.9% | 4.55 [–2.59, 11.69] |
| Ho et al | 56 | 25 | 118 | 44 | 20 | 120 | 6.5% | 12.00 [6.24, 17.76] |
| **Total (95% CI)** | | | **1176** | | | **1176** | **100.0%** | **–1.51 [–5.15, 2.12]** |

Heterogeneity: Tau² = 44.63; $\chi^2$ = 86.48, df = 15 ($p$ < 0.00001); I² = 83%
Test for overall effect: Z = 0.82 ($p$ = 0.41)




B.

| Study or Subgroup | B-TURP Events | Total | M-TURP Events | Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Akman et al | 3 | 127 | 8 | 130 | 12.1% | 0.37 [0.10, 1.42] |
| Autorino et al | 1 | 35 | 0 | 35 | 0.8% | 3.09 [0.12, 78.41] |
| Chen et al | 1 | 50 | 3 | 50 | 4.6% | 0.32 [0.03, 3.18] |
| Erturhan et al | 1 | 120 | 7 | 120 | 10.9% | 0.14 [0.02, 1.12] |
| Fagerström et al | 4 | 95 | 10 | 90 | 15.4% | 0.35 [0.11, 1.16] |
| Geavlete et al | 3 | 170 | 11 | 170 | 16.9% | 0.26 [0.07, 0.95] |
| Giulianelli et al | 0 | 80 | 3 | 80 | 5.4% | 0.14 [0.01, 2.71] |
| Ho et al | 1 | 48 | 1 | 52 | 1.5% | 1.09 [0.07, 17.84] |
| Iori et al | 0 | 27 | 0 | 26 | | Not estimable |
| Kong et al | 0 | 51 | 2 | 51 | 3.9% | 0.19 [0.01, 4.11] |
| Kumar et al | 1 | 57 | 7 | 60 | 10.5% | 0.14 [0.02, 1.14] |
| Mamoulakis et al | 9 | 141 | 4 | 139 | 5.9% | 2.30 [0.69, 7.66] |
| Mendez-Probst et al | 0 | 22 | 0 | 21 | | Not estimable |
| Michielsen et al | 4 | 118 | 1 | 120 | 1.5% | 4.18 [0.46, 37.92] |
| Nuhoglu et al | 1 | 27 | 2 | 30 | 2.9% | 0.54 [0.05, 6.30] |
| Patankar et al | 0 | 53 | 1 | 51 | 2.4% | 0.31 [0.01, 7.90] |
| Singhania et al | 0 | 30 | 0 | 30 | | Not estimable |
| Xie et al | 0 | 110 | 2 | 110 | 3.9% | 0.20 [0.01, 4.14] |
| Yang et al | 1 | 58 | 1 | 59 | 1.5% | 1.02 [0.06, 16.66] |
| **Total (95% CI)** | | **1419** | | **1424** | **100.0%** | **0.49 [0.32, 0.74]** |
| Total events | 30 | | 63 | | | |

Heterogeneity: $\chi^2$ = 17.64, df = 15 ($p$ = 0.28); I² = 15%
Test for overall effect: Z = 3.32 ($p$ = 0.0009)

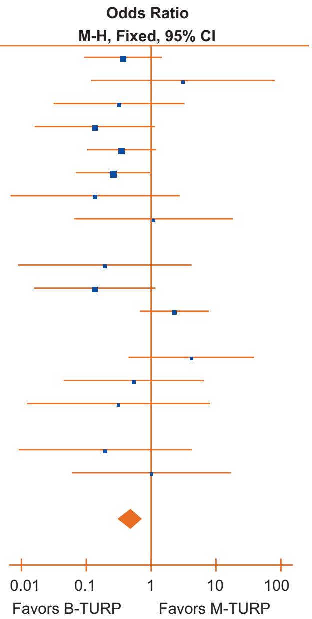
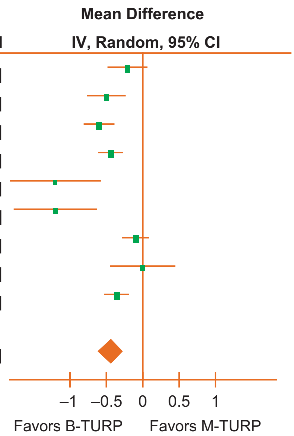



**Fig. 2 – Meta-analysis of efficacy and complications in studies comparing any bipolar device with monopolar transurethral resection of the prostate. (A–L) Perioperative data and complications: (A) interventional duration, min); (B) transfusion rate; (C) hemoglobin loss; (D) sodium decrease; (E) urinary tract infections; (F) immediate acute urinary retention; (G) clot retention; (H) catheterization time; (I) recatheterization; (J) immediate reoperation rate; (K) transurethral resection syndrome; (L) length of stay. (M–Q) Efficacy at 12 mo: (M) International Prostate Symptom Score (IPSS) at 12 mo; (N) maximum flow rate ($Q_{max}$) at 12 mo; (O) quality of life at 12 mo; (P) prostate volume at 12 mo; (Q) postvoid residual (PVR) at 12 mo. (R–T) Complications at 12 mo: (R) strictures at 12 mo; (S) incontinence rate at 12 mo; (T) reoperation at 12 mo. (U–W) Long-term efficacy: (U) long-term IPSS; (V) long-term $Q_{max}$; (W) long-term PVR. (X–Z) Long-term complications: (X) strictures; (Y) bladder neck contracture; (Z) reoperation rate.**
**B-TURP = bipolar transurethral resection of the prostate; CI = confidence interval; M-TURP = monopolar transurethral resection of the prostate; SD = standard deviation.**

C.

| Study or Subgroup | B-TURP Mean | B-TURP SD | B-TURP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Akman et al | 1.2 | 0.9 | 127 | 1.41 | 1.23 | 130 | 11.9% | –0.21 [–0.47, 0.05] |
| Chen et al | 1.1 | 0.6 | 50 | 1.6 | 0.7 | 50 | 12.1% | –0.50 [–0.76, –0.24] |
| Ho et al | 1.2 | 0.6 | 48 | 1.8 | 0.4 | 52 | 13.4% | –0.60 [–0.80, –0.40] |
| Huang X et al | 0.71 | 0.42 | 71 | 1.15 | 0.53 | 65 | 14.4% | –0.44 [–0.60, –0.28] |
| Kim et al | 1.5 | 1 | 25 | 2.7 | 1.2 | 25 | 5.4% | –1.20 [–1.81, –0.59] |
| Kong et al | 0.6 | 1.48 | 51 | 1.8 | 1.41 | 51 | 6.1% | –1.20 [–1.76, –0.64] |
| Mamoulakis et al | 0.8 | 0.7 | 141 | 0.9 | 0.8 | 139 | 14.0% | –0.10 [–0.28, 0.08] |
| Singh et al | 1.2 | 1 | 30 | 1.2 | 0.7 | 30 | 8.1% | 0.00 [–0.44, 0.44] |
| Xie et al | 1.22 | 0.54 | 110 | 1.58 | 0.65 | 110 | 14.4% | –0.36 [–0.52, –0.20] |
| **Total (95% CI)** | | | **653** | | | **652** | **100.0%** | **–0.43 [–0.61, –0.26]** |

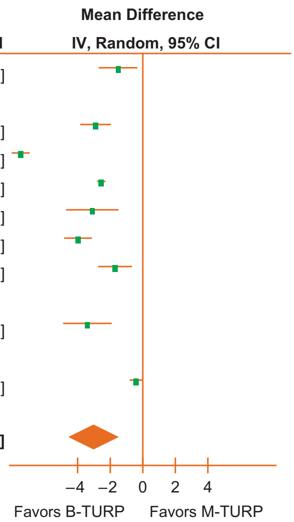
Heterogeneity: Tau² = 0.05; $\chi^2$ = 35.32, df = 8 ($p$ < 0.0001); I² = 77%
Test for overall effect: Z = 4.87 ($p$ < 0.00001)




D.

| Study or Subgroup | B-TURP Mean | B-TURP SD | B-TURP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Akman et al | 1.3 | 3.8 | 143 | 2.82 | 5.8 | 143 | 10.9% | –1.52 [–2.66, –0.38] |
| Autorino et al | 0.6 | 0 | 35 | 0.9 | 0 | 35 | | Not estimable |
| Chen et al | 3.4 | 1.4 | 50 | 6.3 | 2.9 | 50 | 11.2% | –2.90 [–3.79, –2.01] |
| Ho et al | 3.2 | 0.5 | 48 | 10.7 | 1.8 | 52 | 11.5% | –7.50 [–8.01, –6.99] |
| Huang X et al | 2.02 | 0.53 | 71 | 4.57 | 0.71 | 65 | 11.6% | –2.55 [–2.76, –2.34] |
| Kim et al | 1.1 | 2.5 | 25 | 4.2 | 3.1 | 25 | 10.4% | –3.10 [–4.66, –1.54] |
| Kong et al | 1.03 | 2.36 | 51 | 5.01 | 1.77 | 51 | 11.3% | –3.98 [–4.79, –3.17] |
| Mamoulakis et al | 0.8 | 3.2 | 146 | 2.5 | 5.3 | 149 | 11.1% | –1.70 [–2.70, –0.70] |
| Michielsen et al | 1.47 | 0 | 118 | 2.23 | 0 | 120 | | Not estimable |
| Singh et al | 1.2 | 2.7 | 30 | 4.6 | 3 | 30 | 10.6% | –3.40 [–4.84, –1.96] |
| Singhania et al | 1.3 | 0 | 30 | 4.12 | 0 | 30 | | Not estimable |
| Xie et al | 1.62 | 1.31 | 110 | 2.03 | 1.35 | 110 | 11.5% | –0.41 [–0.76, –0.06] |
| **Total (95% CI)** | | | **857** | | | **860** | **100.0%** | **–3.01 [–4.56, –1.46]** |

Heterogeneity: Tau² = 5.38; $\chi^2$ = 524.50, df = 8 ($p$ < 0.00001); I² = 98%
Test for overall effect: Z = 3.81 ($p$ = 0.0001)




E.

| Study or Subgroup | B-TURP Events | B-TURP Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Chen et al | 0 | 50 | 0 | 50 | | Not estimable |
| Geavlete et al | 5 | 170 | 6 | 170 | 17.2% | 0.83 [0.25, 2.77] |
| Giulianelli et al | 2 | 80 | 0 | 80 | 1.4% | 5.13 [0.24, 108.51] |
| Ho et al | 2 | 48 | 2 | 52 | 5.4% | 1.09 [0.15, 8.04] |
| Iori et al | 1 | 27 | 0 | 26 | 1.4% | 3.00 [0.12, 77.03] |
| Kim et al | 1 | 25 | 1 | 25 | 2.8% | 1.00 [0.06, 16.93] |
| Kumar et al | 6 | 57 | 5 | 60 | 12.9% | 1.29 [0.37, 4.50] |
| Mamoulakis et al | 1 | 141 | 2 | 139 | 5.9% | 0.49 [0.04, 5.46] |
| Mendez-Probst et al | 1 | 22 | 0 | 21 | 1.4% | 3.00 [0.12, 77.83] |
| Patankar et al | 6 | 53 | 7 | 51 | 18.7% | 0.80 [0.25, 2.57] |
| Singh et al | 3 | 30 | 4 | 30 | 10.7% | 0.72 [0.15, 3.54] |
| Singhania et al | 0 | 30 | 0 | 30 | | Not estimable |
| Xie et al | 8 | 110 | 8 | 110 | 22.0% | 1.00 [0.36, 2.77] |
| **Total (95% CI)** | | **843** | | **844** | **100.0%** | **1.03 [0.64, 1.66]** |
| Total events | 36 | | 35 | | | |

Heterogeneity: $\chi^2$ = 2.89, df = 10 ($p$ = 0.98); I² = 0%
Test for overall effect: Z = 0.13 ($p$ = 0.90)

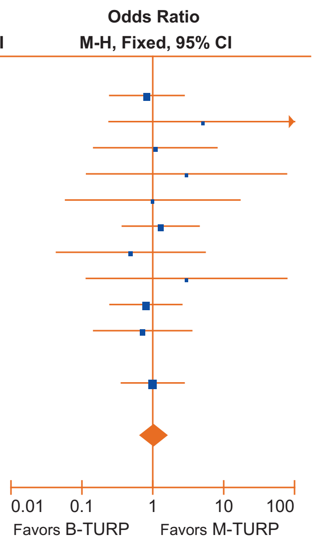
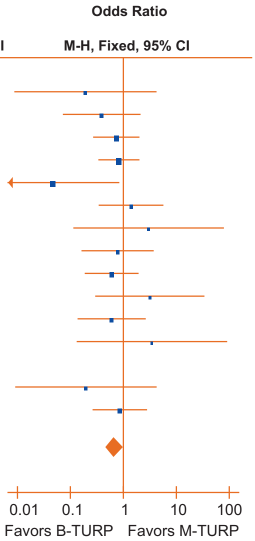



**Fig. 2. (*Continued*)**

F.

| Study or Subgroup | B-TURP Events | B-TURP Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Autorino et al | 0 | 35 | 0 | 35 | | Not estimable |
| Chen et al | 0 | 50 | 2 | 50 | 3.7% | 0.19 [0.01, 4.10] |
| Erturhan et al | 2 | 120 | 5 | 120 | 7.3% | 0.39 [0.07, 2.05] |
| Fagerström et al | 8 | 95 | 10 | 90 | 13.9% | 0.74 [0.28, 1.96] |
| Geavlete et al | 10 | 170 | 12 | 170 | 16.7% | 0.82 [0.35, 1.96] |
| Giulianelli et al | 0 | 80 | 9 | 80 | 13.9% | 0.05 [0.00, 0.82] |
| Ho et al | 5 | 48 | 4 | 52 | 5.1% | 1.40 [0.35, 5.53] |
| Iori et al | 1 | 27 | 0 | 26 | 0.7% | 3.00 [0.12, 77.03] |
| Kumar et al | 3 | 57 | 4 | 60 | 5.4% | 0.78 [0.17, 3.64] |
| Mamoulakis et al | 5 | 141 | 8 | 139 | 11.5% | 0.60 [0.19, 1.89] |
| Mendez-Probst et al | 3 | 22 | 1 | 21 | 1.3% | 3.16 [0.30, 33.07] |
| Michielsen et al | 3 | 118 | 5 | 120 | 7.1% | 0.60 [0.14, 2.57] |
| Nuhoglu et al | 1 | 27 | 0 | 30 | 0.7% | 3.45 [0.13, 88.40] |
| Singhania et al | 0 | 30 | 0 | 30 | | Not estimable |
| Xie et al | 0 | 110 | 2 | 110 | 3.7% | 0.20 [0.01, 4.14] |
| Yang et al | 6 | 58 | 7 | 59 | 9.2% | 0.86 [0.27, 2.72] |
| **Total (95% CI)** | | **1188** | | **1192** | **100.0%** | **0.68 [0.47, 0.98]** |
| Total events | 47 | | 69 | | | |

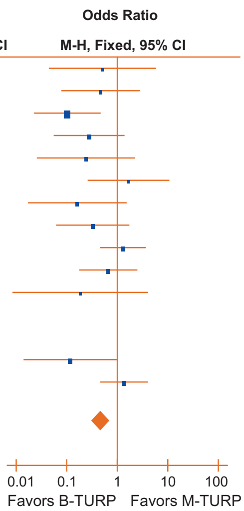
Heterogeneity: $\chi^2$= 10.03, df = 13 ($p$ = 0.69); I² = 0%
Test for overall effect: Z = 2.04 ($p$ = 0.04)




G.

| Study or Subgroup | B-TURP Events | B-TURP Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Akman et al | 1 | 127 | 2 | 130 | 2.6% | 0.51 [0.05, 5.67] |
| Autorino et al | 2 | 35 | 4 | 35 | 5.1% | 0.47 [0.08, 2.75] |
| Erturhan et al | 2 | 120 | 17 | 120 | 22.5% | 0.10 [0.02, 0.46] |
| Geavlete et al | 2 | 170 | 7 | 170 | 9.3% | 0.28 [0.06, 1.35] |
| Giulianelli et al | 1 | 80 | 4 | 80 | 5.3% | 0.24 [0.03, 2.20] |
| Ho et al | 3 | 48 | 2 | 52 | 2.4% | 1.67 [0.27, 10.43] |
| Iori et al | 1 | 27 | 5 | 26 | 6.6% | 0.16 [0.02, 1.49] |
| Kumar et al | 2 | 57 | 6 | 60 | 7.6% | 0.33 [0.06, 1.69] |
| Mamoulakis et al | 9 | 141 | 7 | 139 | 8.9% | 1.29 [0.47, 3.55] |
| Michielsen et al | 4 | 118 | 6 | 120 | 7.7% | 0.67 [0.18, 2.43] |
| Patankar et al | 0 | 53 | 2 | 51 | 3.4% | 0.19 [0.01, 3.95] |
| Seckiner et al | 0 | 24 | 0 | 24 | | Not estimable |
| Singhania et al | 0 | 30 | 0 | 30 | | Not estimable |
| Xie et al | 1 | 110 | 8 | 110 | 10.7% | 0.12 [0.01, 0.95] |
| Yang et al | 9 | 58 | 7 | 59 | 7.9% | 1.36 [0.47, 3.95] |
| **Total (95% CI)** | | **1198** | | **1206** | **100.0%** | **0.47 [0.31, 0.70]** |
| Total events | 37 | | 77 | | | |

Heterogeneity: $\chi^2$ = 17.69, df = 12 ($p$ = 0.13); I² = 32%
Test for overall effect: Z = 3.72 ($p$ = 0.0002)




H.

| Study or Subgroup | B-TURP Mean | B-TURP SD | B-TURP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Akman et al | 57.6 | 24 | 127 | 62.4 | 30 | 130 | 7.0% | –4.80 [–11.43, 1.83] |
| Bhansali et al | 19.05 | 3.92 | 34 | 39.25 | 10.223 | 33 | 7.5% | –20.20 [–23.93, –16.47] |
| Erturhan et al | 72 | 26.4 | 120 | 108 | 26.4 | 120 | 7.0% | –36.00 [–42.68, –29.32] |
| Giulianelli et al | 24 | 12 | 80 | 48 | 48 | 80 | 6.1% | –24.00 [–34.84, –13.16] |
| Iori et al | 23 | 4 | 27 | 31.9 | 4 | 26 | 7.7% | –8.90 [–11.05, –6.75] |
| Kim et al | 56 | 29 | 25 | 88 | 36 | 25 | 4.4% | –32.00 [–50.12, –13.88] |
| Kong et al | 37.2 | 15.03 | 51 | 57.7 | 17.31 | 51 | 7.1% | –20.50 [–26.79, –14.21] |
| Kumar et al | 35.07 | 7.14 | 57 | 36.56 | 6.77 | 60 | 7.6% | –1.49 [–4.01, 1.03] |
| Mamoulakis et al | 72 | 28.8 | 141 | 74 | 28.8 | 139 | 7.0% | –2.00 [–8.75, 4.75] |
| Michielsen et al | 96 | 72 | 118 | 108 | 84 | 120 | 4.1% | –12.00 [–31.87, 7.87] |
| Nuhoglu et al | 47 | 5.6 | 27 | 75.7 | 12.5 | 30 | 7.3% | –28.70 [–33.65, –23.75] |
| Patankar et al | 18.44 | 2.7 | 53 | 42.4 | 15.12 | 51 | 7.5% | –23.96 [–28.17, –19.75] |
| Seckiner et al | 75.4 | 8.4 | 24 | 75.4 | 33.6 | 24 | 5.4% | 0.00 [–13.86, 13.86] |
| Singh et al | 60 | 12 | 30 | 81.84 | 12.72 | 30 | 7.1% | –21.84 [–28.10, –15.58] |
| Xie et al | 64.8 | 19.2 | 110 | 86.64 | 27.6 | 110 | 7.1% | –21.84 [–28.12, –15.56] |
| **Total (95% CI)** | | | **1024** | | | **1029** | **100.0%** | **–17.14 [–22.94, –11.35]** |

Heterogeneity: Tau² = 112.65; $\chi^2$ = 266.68, df = 14 ($p$ < 0.00001); I² = 95%
Test for overall effect: Z = 5.80 ($p$ < 0.00001)

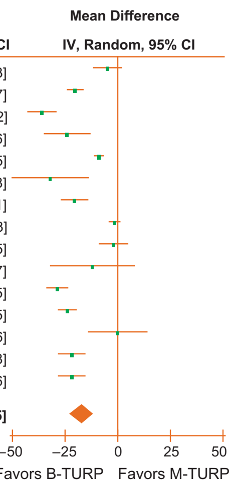


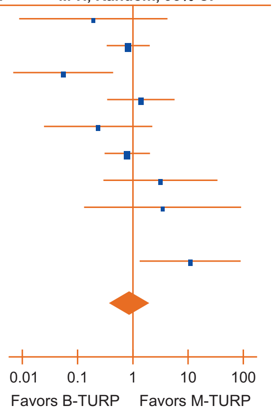

**Fig. 2. (*Continued*)**

**I.**

| Study or Subgroup | All B-TURP Events | All B-TURP Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Chen et al | 0 | 50 | 2 | 50 | 5.7% | 0.19 [0.01, 4.10] |
| Geavlete et al | 10 | 170 | 12 | 170 | 19.1% | 0.82 [0.35, 1.96] |
| Giulianelli et al | 1 | 80 | 15 | 80 | 9.8% | 0.05 [0.01, 0.43] |
| Ho et al | 5 | 48 | 4 | 52 | 14.6% | 1.40 [0.35, 5.53] |
| Kong et al | 1 | 51 | 4 | 51 | 8.9% | 0.23 [0.03, 2.18] |
| Mamoulakis et al | 9 | 141 | 11 | 139 | 18.7% | 0.79 [0.32, 1.98] |
| Mendez-Probst et al | 3 | 22 | 1 | 21 | 8.3% | 3.16 [0.30, 33.07] |
| Nuhoglu et al | 1 | 27 | 0 | 30 | 5.2% | 3.45 [0.13, 88.40] |
| Singhania et al | 0 | 30 | 0 | 30 | | Not estimable |
| Xie et al | 10 | 110 | 1 | 110 | 9.7% | 10.90 [1.37, 86.68] |
| **Total (95% CI)** | | **729** | | **733** | **100.0%** | **0.86 [0.37, 1.99]** |
| Total events | 40 | | 50 | | | |

Heterogeneity: Tau² = 0.76; $\chi^2$ = 17.38, df = 8 ($p$ = 0.03); I² = 54%

Test for overall effect: Z = 0.35 ($p$ = 0.73)

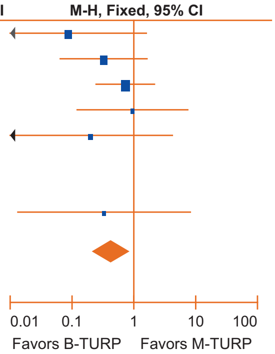



**J.**

| Study or Subgroup | B-TURP Events | B-TURP Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Erturhan et al | 0 | 120 | 5 | 120 | 22.0% | 0.09 [0.00, 1.59] |
| Geavlete et al | 2 | 170 | 6 | 170 | 23.8% | 0.33 [0.06, 1.64] |
| Mamoulakis et al | 6 | 141 | 8 | 139 | 30.9% | 0.73 [0.25, 2.15] |
| Mendez-Probst et al | 2 | 22 | 2 | 21 | 7.5% | 0.95 [0.12, 7.44] |
| Michielsen et al | 0 | 118 | 2 | 120 | 9.9% | 0.20 [0.01, 4.21] |
| Nuhoglu et al | 0 | 27 | 0 | 30 | | Not estimable |
| Singhania et al | 0 | 30 | 0 | 30 | | Not estimable |
| Xie et al | 0 | 110 | 1 | 110 | 6.0% | 0.33 [0.01, 8.20] |
| **Total (95% CI)** | | **738** | | **740** | **100.0%** | **0.43 [0.21, 0.88]** |
| Total events | 10 | | 24 | | | |

Heterogeneity: $\chi^2$ = 3.01, df = 5 ($p$ = 0.70); I² = 0%

Test for overall effect: Z = 2.31 ($p$ = 0.02)




**K.**

| Study or Subgroup | B-TURP Events | B-TURP Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Akman et al | 0 | 127 | 2 | 130 | 10.2% | 0.20 [0.01, 4.24] |
| Autorino et al | 0 | 35 | 0 | 35 | | Not estimable |
| Erturhan et al | 0 | 120 | 2 | 120 | 10.3% | 0.20 [0.01, 4.14] |
| Geavlete et al | 0 | 170 | 3 | 170 | 14.4% | 0.14 [0.01, 2.74] |
| Giulianelli et al | 0 | 80 | 2 | 80 | 10.3% | 0.20 [0.01, 4.13] |
| Ho et al | 0 | 48 | 2 | 52 | 9.8% | 0.21 [0.01, 4.45] |
| Iori et al | 0 | 27 | 0 | 26 | | Not estimable |
| Kim et al | 0 | 25 | 0 | 25 | | Not estimable |
| Kong et al | 0 | 51 | 0 | 51 | | Not estimable |
| Kumar et al | 0 | 57 | 1 | 60 | 6.0% | 0.34 [0.01, 8.64] |
| Mamoulakis et al | 0 | 141 | 1 | 139 | 6.2% | 0.33 [0.01, 8.08] |
| Mendez-Probst et al | 0 | 22 | 0 | 21 | | Not estimable |
| Michielsen et al | 0 | 118 | 1 | 120 | 6.1% | 0.34 [0.01, 8.34] |
| Nuhoglu et al | 0 | 27 | 0 | 30 | | Not estimable |
| Patankar et al | 0 | 53 | 2 | 51 | 10.4% | 0.19 [0.01, 3.95] |
| Singh et al | 0 | 30 | 0 | 30 | | Not estimable |
| Singhania et al | 0 | 30 | 0 | 30 | | Not estimable |
| Xie et al | 0 | 110 | 2 | 110 | 10.3% | 0.20 [0.01, 4.14] |
| Yang et al | 0 | 58 | 1 | 59 | 6.1% | 0.33 [0.01, 8.35] |
| **Total (95% CI)** | | **1329** | | **1339** | **100.0%** | **0.22 [0.09, 0.56]** |
| Total events | 0 | | 19 | | | |

Heterogeneity: $\chi^2$ = 0.38, df = 10 ($p$ = 1.00); I² = 0%

Test for overall effect: Z = 3.17 ($p$ = 0.002)

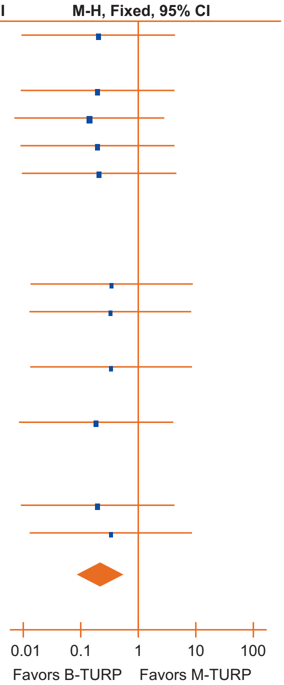



**Fig. 2. (*Continued*)**

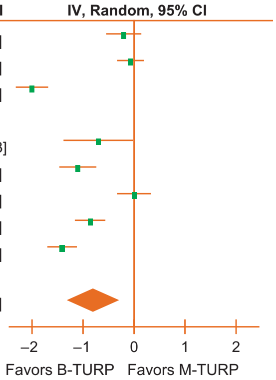
*3.3.1. Perioperative data and immediate complications*

Perioperative data and immediate complications are shown in Figure 2A–2L. Intervention duration was not significantly different between the two groups ($p = 0.41$). Bipolar techniques were associated with a shorter catheterization time (mean difference: 17.14 min; $p < 0.00001$) and a shorter length of hospital stay (mean difference: 0.79 d; $p = 0.003$). However, even if statistically significant, those data did not have the magnitude to reach clinical relevance. Immediate complications were also reduced in the B-TURP arms, with a significant difference noted on the transfusion rate (OR: 0.49; $p = 0.0009$), hemoglobin drop (mean difference: 0.43; $p < 0.00001$), clot urinary retention (OR: 0.47; $p = 0.0002$), and overall immediate reoperation rate (OR: 0.43; $p = 0.02$). Decline of serum sodium was less important after B-TURP, and no transurethral resection syndrome was

**L.**

| Study or Subgroup | B-TURP Mean | B-TURP SD | B-TURP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Akman et al | 2.5 | 1.3 | 127 | 2.7 | 1.4 | 130 | 12.6% | −0.20 [−0.53, 0.13] |
| Bhansali et al | 3.3 | 0.59 | 34 | 3.37 | 0.43 | 33 | 12.9% | −0.07 [−0.32, 0.18] |
| Erturhan et al | 3 | 1.2 | 120 | 5 | 1.2 | 120 | 12.7% | −2.00 [−2.30, −1.70] |
| Iori et al | 2 | 0.05 | 27 | 2.11 | 0.12 | 26 | | Not estimable |
| Kim et al | 3.3 | 1.1 | 25 | 4 | 1.3 | 25 | 10.9% | −0.70 [−1.37, −0.03] |
| Kong et al | 1.5 | 0.88 | 51 | 2.6 | 0.92 | 51 | 12.5% | −1.10 [−1.45, −0.75] |
| Mamoulakis et al | 3.5 | 1.5 | 141 | 3.5 | 1.2 | 139 | 12.7% | 0.00 [−0.32, 0.32] |
| Singh et al | 3.02 | 0.55 | 30 | 3.88 | 0.58 | 30 | 12.8% | −0.86 [−1.15, −0.57] |
| Xie et al | 4.18 | 0.89 | 110 | 5.59 | 1.17 | 110 | 12.8% | −1.41 [−1.68, −1.14] |
| **Total (95% CI)** | | | **638** | | | **638** | **100.0%** | **−0.79 [−1.32, −0.27]** |

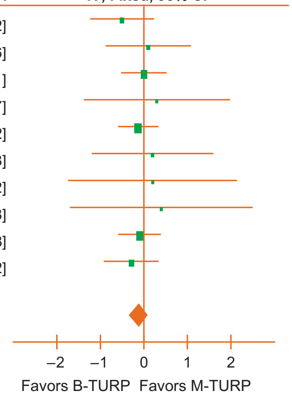
Heterogeneity: Tau² = 0.54; $\chi^2$ = 152.59, df = 7 ($p$ < 0.00001); I² = 95%
Test for overall effect: Z = 2.97 ($p$ = 0.003)




**M.**

| Study or Subgroup | B-TURP Mean | B-TURP SD | B-TURP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Akman et al | 10.3 | 3 | 127 | 10.8 | 2.9 | 130 | 9.4% | −0.50 [−1.22, 0.22] |
| Chen et al | 4.2 | 2.6 | 50 | 4.1 | 2.3 | 50 | 5.3% | 0.10 [−0.86, 1.06] |
| Erturhan et al | 4 | 2 | 120 | 4 | 2 | 120 | 19.2% | 0.00 [−0.51, 0.51] |
| Iori et al | 7 | 1.7 | 27 | 6.7 | 4 | 26 | 1.8% | 0.30 [−1.37, 1.97] |
| Kumar et al | 6.94 | 1.25 | 57 | 7.07 | 1.22 | 60 | 24.5% | −0.13 [−0.58, 0.32] |
| Mamoulakis et al | 7.7 | 4 | 88 | 7.5 | 4.8 | 73 | 2.6% | 0.20 [−1.18, 1.58] |
| Nuhoglu et al | 5.4 | 3.7 | 24 | 5.2 | 3.2 | 26 | 1.3% | 0.20 [−1.72, 2.12] |
| Seckiner et al | 8.7 | 4.1 | 23 | 8.3 | 2.9 | 21 | 1.1% | 0.40 [−1.68, 2.48] |
| Singhania et al | 6.13 | 0.94 | 30 | 6.23 | 0.94 | 30 | 21.7% | −0.10 [−0.58, 0.38] |
| Xie et al | 6.5 | 2.03 | 110 | 6.79 | 2.59 | 110 | 13.0% | −0.29 [−0.90, 0.32] |
| **Total (95% CI)** | | | **656** | | | **646** | **100.0%** | **-0.12 [-0.34, 0.11]** |

Heterogeneity: $\chi^2$ = 2.58, df = 9 ($p$ = 0.98); I² = 0%
Test for overall effect: Z = 1.02 ($p$ = 0.31)




**N.**

| Study or Subgroup | B-TURP Mean | B-TURP SD | B-TURP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Akman et al | 17.1 | 3.1 | 127 | 16.3 | 4.7 | 130 | 15.2% | 0.80 [−0.17, 1.77] |
| Bhansali et al | 16.6 | 2.64 | 34 | 15.9 | 3.126 | 3 | 4.9% | 0.70 [−2.95, 4.35] |
| Chen et al | 23.2 | 8.1 | 50 | 22.2 | 8.8 | 50 | 5.6% | 1.00 [−2.32, 4.32] |
| Erturhan et al | 19.5 | 3.5 | 120 | 18.5 | 33 | 120 | 2.2% | 1.00 [−4.94, 6.94] |
| Giulianelli et al | 26.7 | 2.2 | 80 | 23.2 | 9 | 80 | 9.9% | 3.50 [1.47, 5.53] |
| Iori et al | 24.2 | 5 | 27 | 23.2 | 9 | 26 | 4.4% | 1.00 [−2.94, 4.94] |
| Kumar et al | 19.93 | 5.17 | 57 | 18.8 | 4.88 | 60 | 10.8% | 1.13 [−0.69, 2.95] |
| Mamoulakis et al | 19.3 | 8.1 | 88 | 19.8 | 8.9 | 73 | 7.5% | −0.50 [−3.15, 2.15] |
| Nuhoglu et al | 17.1 | 2.7 | 24 | 17.9 | 3.1 | 26 | 11.9% | −0.80 [−2.41, 0.81] |
| Seckiner et al | 18.8 | 6.9 | 23 | 15.7 | 6.3 | 21 | 4.5% | 3.10 [−0.80, 7.00] |
| Singhania et al | 18.52 | 2.07 | 30 | 15.42 | 2.31 | 30 | 14.5% | 3.10 [1.99, 4.21] |
| Xie et al | 28.05 | 8.69 | 110 | 27.37 | 8.91 | 110 | 8.7% | 0.68 [−1.65, 3.01] |
| **Total (95% CI)** | | | **770** | | | **729** | **100.0%** | **1.26 [0.31, 2.21]** |

Heterogeneity: Tau² = 1.30; $\chi^2$ = 25.17, df = 11 ($p$ = 0.009); I² = 56%
Test for overall effect: Z = 2.60 ($p$ = 0.009)

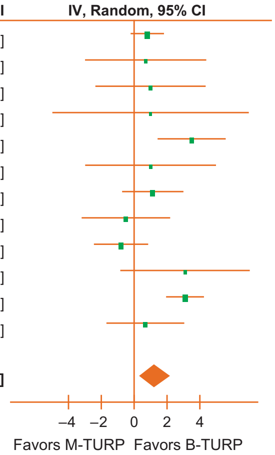


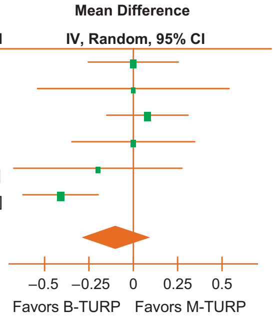

**Fig. 2. (*Continued*)**

O.

| Study or Subgroup | Experimental Mean | Experimental SD | Experimental Total | Control Mean | Control SD | Control Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Erturhan et al | 2 | 1 | 120 | 2 | 1 | 120 | 20.2% | 0.00 [–0.25, 0.25] |
| Iori et al | 1 | 1 | 27 | 1 | 1 | 26 | 9.1% | 0.00 [–0.54, 0.54] |
| Kumar et al | 1.67 | 0.61 | 57 | 1.59 | 0.65 | 60 | 21.7% | 0.08 [–0.15, 0.31] |
| Mamoulakis et al | 1.1 | 1 | 88 | 1.1 | 1.2 | 73 | 15.6% | 0.00 [–0.35, 0.35] |
| Seckiner et al | 1.8 | 0.8 | 23 | 2 | 0.8 | 21 | 10.8% | –0.20 [–0.67, 0.27] |
| Xie et al | 2.15 | 0.58 | 110 | 2.56 | 0.97 | 110 | 22.6% | –0.41 [–0.62, –0.20] |
| **Total (95% CI)** | | | **425** | | | **410** | **100.0%** | **-0.10 [-0.29, 0.10]** |

Heterogeneity: Tau² = 0.03; $\chi^2$ = 11.81, df = 5 ($p$ = 0.04); I² = 58%

Test for overall effect: Z = 0.99 ($p$ = 0.32)

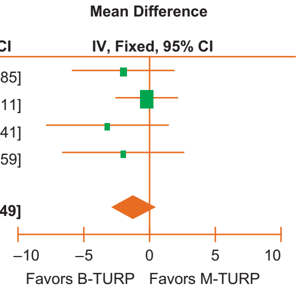



P.

| Study or Subgroup | B-TURP Mean | B-TURP SD | B-TURP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Iori et al | 22 | 6.8 | 24 | 24 | 7.1 | 26 | 19.4% | –2.00 [–5.85, 1.85] |
| Kumar et al | 24.8 | 6.3 | 57 | 25.01 | 6.53 | 60 | 53.3% | –0.21 [–2.53, 2.11] |
| Nuhoglu et al | 25.3 | 8.1 | 23 | 28.5 | 7.5 | 21 | 13.6% | –3.20 [–7.81, 1.41] |
| Seckiner et al | 29 | 8 | 27 | 31 | 9 | 26 | 13.7% | –2.00 [–6.59, 2.59] |
| **Total (95% CI)** | | | **131** | | | **133** | **100.0%** | **–1.21 [–2.91, 0.49]** |

Heterogeneity: $\chi^2$ = 1.70, df = 3 ($p$ = 0.64); I² = 0%

Test for overall effect: Z = 1.39 ($p$ = 0.16)

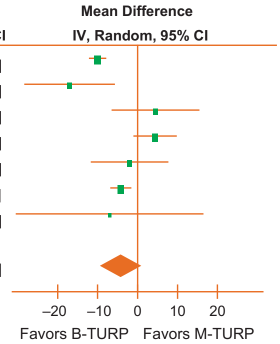



Q.

| Study or Subgroup | B-TURP Mean | B-TURP SD | B-TURP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Erturhan et al | 15 | 5 | 120 | 25 | 10 | 120 | 21.7% | –10.00 [–12.00, –8.00] |
| Giulianelli et al | 10 | 10 | 80 | 27 | 50 | 80 | 10.9% | –17.00 [–28.17, –5.83] |
| Iori et al | 24.7 | 32.5 | 88 | 20.2 | 36.8 | 73 | 11.2% | 4.50 [–6.33, 15.33] |
| Kumar et al | 31.09 | 14.14 | 57 | 26.71 | 14.87 | 60 | 18.2% | 4.38 [–0.88, 9.64] |
| Mamoulakis et al | 33 | 19 | 24 | 35 | 15 | 26 | 12.6% | –2.00 [–11.54, 7.54] |
| Nuhoglu et al | 12.02 | 7.49 | 110 | 16.2 | 10.89 | 110 | 21.4% | –4.18 [–6.65, –1.71] |
| Xie et al | 20 | 35 | 27 | 27 | 50 | 26 | 4.0% | –7.00 [–30.32, 16.32] |
| **Total (95% CI)** | | | **506** | | | **495** | **100.0%** | **–4.15 [–9.27, 0.98]** |

Heterogeneity: Tau² = 30.37; $\chi^2$ = 39.80, df = 6 ($p$ < 0.00001); I² = 85%

Test for overall effect: Z = 1.59 ($p$ = 0.11)




R.

| Study or Subgroup | B-TURP Events | B-TURP Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Akman et al | 8 | 127 | 6 | 130 | 13.1% | 1.39 [0.47, 4.12] |
| Autorino et al | 1 | 35 | 1 | 35 | 2.3% | 1.00 [0.06, 16.65] |
| Erturhan et al | 5 | 120 | 4 | 120 | 9.1% | 1.26 [0.33, 4.81] |
| Fagerström et al | 2 | 95 | 1 | 90 | 2.4% | 1.91 [0.17, 21.48] |
| Geavlete et al | 17 | 170 | 16 | 170 | 34.0% | 1.07 [0.52, 2.19] |
| Ho et al | 3 | 48 | 1 | 52 | 2.1% | 3.40 [0.34, 33.86] |
| Iori et al | 1 | 27 | 1 | 26 | 2.3% | 0.96 [0.06, 16.22] |
| Kim et al | 1 | 25 | 2 | 25 | 4.5% | 0.48 [0.04, 5.65] |
| Kumar et al | 0 | 57 | 1 | 60 | 3.4% | 0.34 [0.01, 8.64] |
| Mamoulakis et al | 9 | 121 | 8 | 135 | 16.5% | 1.28 [0.48, 3.42] |
| Nuhoglu et al | 1 | 27 | 0 | 30 | 1.1% | 3.45 [0.13, 88.40] |
| Seckiner et al | 2 | 24 | 1 | 24 | 2.2% | 2.09 [0.18, 24.73] |
| Singh et al | 1 | 30 | 1 | 30 | 2.3% | 1.00 [0.06, 16.76] |
| Yang et al | 1 | 58 | 2 | 59 | 4.6% | 0.50 [0.04, 5.67] |
| **Total (95% CI)** | | **964** | | **986** | **100.0%** | **1.20 [0.80, 1.80]** |
| Total events | 52 | | 45 | | | |

Heterogeneity: $\chi^2$ = 3.38, df = 13 ($p$ = 1.00); I² = 0%

Test for overall effect: Z = 0.86 ($p$ = 0.39)

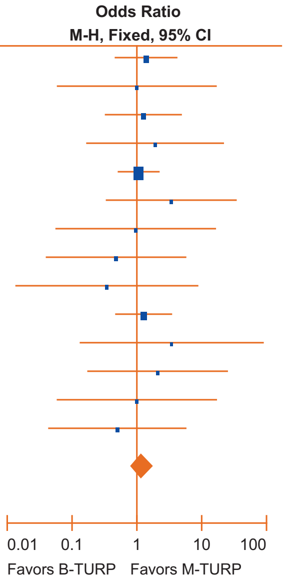
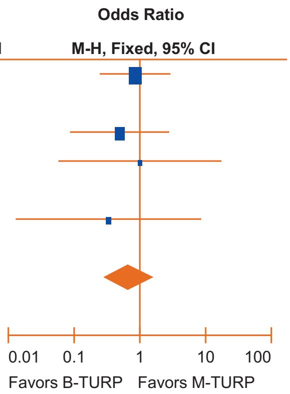



**Fig. 2.** (***Continued***)

S.

| Study or Subgroup | B-TURP Events | B-TURP Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Akman et al | 5 | 127 | 6 | 130 | 47.1% | 0.85 [0.25, 2.85] |
| Erturhan et al | 0 | 120 | 0 | 120 | | Not estimable |
| Geavlete et al | 2 | 170 | 4 | 170 | 32.7% | 0.49 [0.09, 2.73] |
| Kim et al | 1 | 25 | 1 | 25 | 7.9% | 1.00 [0.06, 16.93] |
| Nuhoglu et al | 0 | 27 | 0 | 30 | | Not estimable |
| Yang et al | 0 | 58 | 1 | 59 | 12.2% | 0.33 [0.01, 8.35] |
| **Total (95% CI)** | | **527** | | **534** | **100.0%** | **0.68 [0.28, 1.65]** |
| Total events | 8 | | 12 | | | |

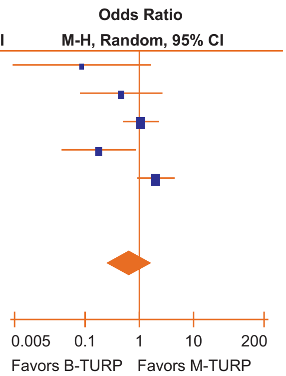
Heterogeneity: $\chi^2 = 0.52$, df = 3 ($p = 0.91$); $I^2 = 0\%$
Test for overall effect: Z = 0.85 ($p = 0.40$)




T.

| Study or Subgroup | B-TURP Events | B-TURP Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Erturhan et al | 0 | 120 | 5 | 120 | 8.3% | 0.09 [0.00, 1.59] |
| Fagerström et al | 2 | 95 | 4 | 90 | 16.4% | 0.46 [0.08, 2.59] |
| Geavlete et al | 16 | 170 | 15 | 170 | 28.7% | 1.07 [0.51, 2.25] |
| Giulianelli et al | 2 | 80 | 10 | 80 | 18.2% | 0.18 [0.04, 0.85] |
| Mamoulakis et al | 20 | 121 | 12 | 135 | 28.4% | 2.03 [0.95, 4.35] |
| Nuhoglu et al | 0 | 27 | 0 | 30 | | Not estimable |
| **Total (95% CI)** | | **613** | | **625** | **100.0%** | **0.66 [0.25, 1.72]** |
| Total events | 40 | | 46 | | | |

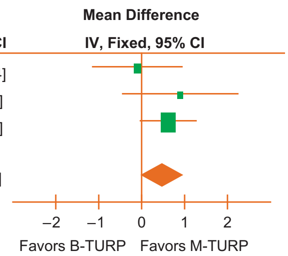
Heterogeneity: Tau² = 0.69; $\chi^2 = 11.81$, df = 4 ($p = 0.02$); $I^2 = 66\%$
Test for overall effect: Z = 0.86 ($p = 0.39$)




U.

| Study or Subgroup | Experimental Mean | Experimental SD | Experimental Total | Control Mean | Control SD | Control Total | Weight | Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Chen et al | 3.7 | 2.7 | 50 | 3.8 | 2.6 | 50 | 24.0% | –0.10 [–1.14, 0.94] |
| Mamoulakis et al | 8 | 4.4 | 82 | 7.1 | 4 | 69 | 14.4% | 0.90 [–0.44, 2.24] |
| Xie et al | 7.2 | 1.65 | 78 | 6.58 | 2.43 | 79 | 61.6% | 0.62 [–0.03, 1.27] |
| **Total (95% CI)** | | | **210** | | | **198** | **100.0%** | **0.49 [–0.02, 1.00]** |

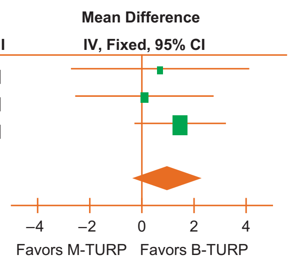
Heterogeneity: $\chi^2 = 1.75$, df = 2 ($p = 0.42$); $I^2 = 0\%$
Test for overall effect: Z = 1.88 ($p = 0.06$)




V.

| Study or Subgroup | B-TURP Mean | B-TURP SD | B-TURP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Chen et al | 25.5 | 9 | 50 | 24.8 | 8.3 | 50 | 15.3% | 0.70 [–2.69, 4.09] |
| Mamoulakis et al | 19.5 | 7.3 | 82 | 19.4 | 8.9 | 69 | 25.5% | 0.10 [–2.53, 2.73] |
| Xie et al | 26.41 | 5.22 | 78 | 24.94 | 5.8 | 79 | 59.2% | 1.47 [–0.26, 3.20] |
| **Total (95% CI)** | | | **210** | | | **198** | **100.0%** | **1.00 [–0.32, 2.33]** |

Heterogeneity: $\chi^2 = 0.77$, df = 2 ($p = 0.68$); $I^2 = 0\%$
Test for overall effect: Z = 1.48 ($p = 0.14$)




W.

| Study or Subgroup | Experimental Mean | Experimental SD | Experimental Total | Control Mean | Control SD | Control Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Mamoulakis et al | 27.8 | 27.3 | 82 | 20.2 | 36.9 | 69 | 37.0% | 7.60 [–2.92, 18.12] |
| Xie et al | 11.72 | 4.85 | 78 | 14.44 | 8.31 | 79 | 63.0% | –2.72 [–4.85, –0.59] |
| **Total (95% CI)** | | | **160** | | | **148** | **100.0%** | **1.10 [–8.67, 10.87]** |

Heterogeneity: Tau² = 38.25; $\chi^2 = 3.55$, df = 1 ($p = 0.06$); $I^2 = 72\%$
Test for overall effect: Z = 0.22 ($p = 0.83$)

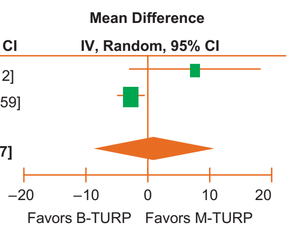



**Fig. 2. (*Continued*)**

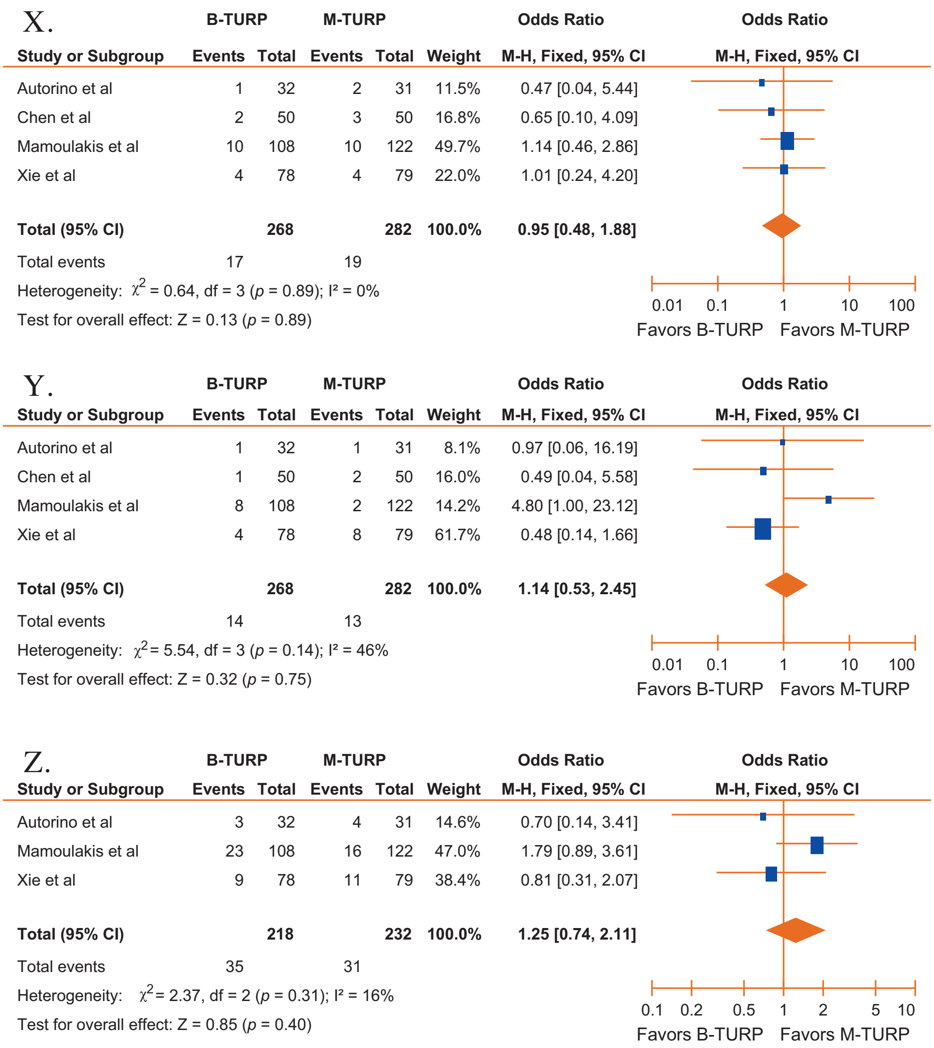



**Fig. 2. (*Continued*).**

seen in any study in the B-TURP arm. There was a significant lower rate of postoperative urinary retention (OR: 0.68; $p = 0.04$) in the B-TURP group. The rate of postoperative urinary tract infection (UTI) was similar in both groups.

*3.3.2. Efficacy*

At 12 mo, a meta-analysis of RCTs evaluating bipolar devices showed no significant difference between B-TURP and M-TURP on IPSS, QoL score, PVR, and prostate volume. B-TURP procedures, however, seemed to be associated with a higher $Q_{max}$ (Fig. 2M–2Q).

Long-term data were very scarce in the literature, with only three studies available for meta-analysis [26,27,33]. There was a trend for a significantly lower IPSS after M-TURP but no significant differences on objective parameters (PVR volume and $Q_{max}$) (Fig. 2U–2W). Due to the heterogeneity of the data, high dropout rate, and variable length of follow-up in the three studies selected for meta-analysis, these results should be considered with caution. Stronger data with long-term follow-up are needed.

*3.3.3. Short- and long-term complications*

Data on short- and long-term complications are shown in Figure 2R–2T and 2X–2Z. At 12-mo follow-up, rate of urethral stricture/bladder neck contracture and incontinence (defined in most papers as stress urinary incontinence that appeared after the intervention) were similar following M-TURP and B-TURP. Overall reoperation rate at 1 yr was low and not significantly different between groups. Other complications, such as sexual dysfunction and storage symptoms, were not suitable for meta-analysis due to lack of reliable data. Only four studies reported complications between 24 mo and 60 mo. No difference was seen between groups for the incidence of urethral strictures, bladder neck contractures, and reoperations. Other outcomes were underreported.

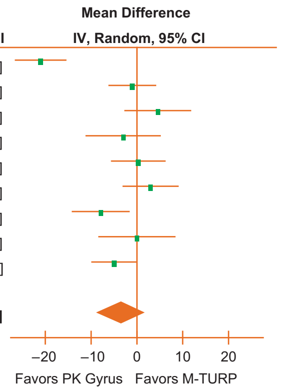
***3.4. Separate analyses for bipolar transurethral resection of the prostate devices versus monopolar transurethral resection of the prostate***

The literature contained enough data to compare efficacy and complications end points after the Gyrus-PK device versus

A.

| Study or Subgroup | PK Gyrus Mean | PK Gyrus SD | PK Gyrus Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Erturhan et al | 36 | 19 | 120 | 57 | 24 | 120 | 11.6% | –21.00 [–26.48, –15.52] |
| Giulianelli et al | 58 | 14.6 | 80 | 59 | 18 | 80 | 11.8% | –1.00 [–6.08, 4.08] |
| Huang X et al | 75.77 | 22.63 | 71 | 71.22 | 19.85 | 65 | 10.7% | 4.55 [–2.59, 11.69] |
| Kim et al | 54 | 13.6 | 25 | 57 | 15.4 | 25 | 10.1% | –3.00 [–11.05, 5.05] |
| Kumar et al | 46.03 | 16.72 | 57 | 45.73 | 15.29 | 60 | 11.4% | 0.30 [–5.51, 6.11] |
| Nuhoglu et al | 55 | 9.7 | 27 | 52 | 13.2 | 30 | 11.3% | 3.00 [–2.97, 8.97] |
| Patankar et al | 49.99 | 12.35 | 53 | 57.88 | 18.95 | 51 | 11.2% | –7.89 [–14.06, –1.72] |
| Seckiner et al | 52.9 | 12.8 | 24 | 52.9 | 16.3 | 24 | 10.0% | 0.00 [–8.29, 8.29] |
| Xie et al | 55.03 | 16.3 | 110 | 60.01 | 20.1 | 110 | 11.9% | –4.98 [–9.82, –0.14] |
| **Total (95% CI)** | | | **567** | | | **565** | **100.0%** | **–3.47 [–8.76, 1.81]** |

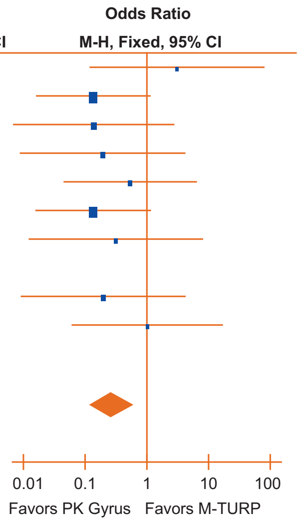
Heterogeneity: Tau² = 54.87; $\chi^2$ = 53.86, df = 8 ($p$ < 0.00001); I² = 85%
Test for overall effect: Z = 1.29 ($p$ = 0.20)




B.

| Study or Subgroup | PK Gyrus Events | PK Gyrus Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Autorino et al | 1 | 35 | 0 | 35 | 1.8% | 3.09 [0.12, 78.41] |
| Erturhan et al | 1 | 120 | 7 | 120 | 25.8% | 0.14 [0.02, 1.12] |
| Giulianelli et al | 0 | 80 | 3 | 80 | 12.9% | 0.14 [0.01, 2.71] |
| Iori et al | 0 | 51 | 2 | 51 | 9.2% | 0.19 [0.01, 4.11] |
| Kong et al | 1 | 27 | 2 | 30 | 6.8% | 0.54 [0.05, 6.30] |
| Kumar et al | 1 | 57 | 7 | 60 | 24.9% | 0.14 [0.02, 1.14] |
| Nuhoglu et al | 0 | 53 | 1 | 51 | 5.6% | 0.31 [0.01, 7.90] |
| Patankar et al | 0 | 30 | 0 | 30 | | Not estimable |
| Singhania et al | 0 | 110 | 2 | 110 | 9.3% | 0.20 [0.01, 4.14] |
| Xie et al | 1 | 58 | 1 | 59 | 3.6% | 1.02 [0.06, 16.66] |
| Yang et al | 0 | 27 | 0 | 26 | | Not estimable |
| **Total (95% CI)** | | **648** | | **652** | **100.0%** | **0.27 [0.12, 0.61]** |
| Total events | 5 | | 25 | | | |

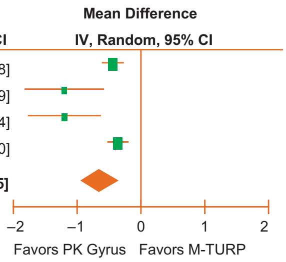
Heterogeneity: $\chi^2$ = 4.46, df = 8 ($p$ = 0.81); I² = 0%
Test for overall effect: Z = 3.16 ($p$ = 0.002)




C.

| Study or Subgroup | Gyrus PK Mean | Gyrus PK SD | Gyrus PK Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Huang X et al | 0.71 | 0.42 | 71 | 1.15 | 0.53 | 65 | 34.5% | –0.44 [–0.60, –0.28] |
| Kim et al | 1.5 | 1 | 25 | 2.7 | 1.2 | 25 | 14.6% | –1.20 [–1.81, –0.59] |
| Kong et al | 0.6 | 1.48 | 51 | 1.8 | 1.41 | 51 | 16.2% | –1.20 [–1.76, –0.64] |
| Xie et al | 1.22 | 0.54 | 110 | 1.58 | 0.65 | 110 | 34.7% | –0.36 [–0.52, –0.20] |
| **Total (95% CI)** | | | **257** | | | **251** | **100.0%** | **–0.65 [–0.94, –0.35]** |

Heterogeneity: Tau² = 0.06; $\chi^2$ = 13.88, df = 3 ($p$ = 0.003); I² = 78%
Test for overall effect: Z = 4.27 ($p$ < 0.0001)




D.

| Study or Subgroup | PK Gyrus Mean | PK Gyrus SD | PK Gyrus Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Autorino et al | 0.6 | 0 | 35 | 0.9 | 0 | 35 | | Not estimable |
| Huang X et al | 2.02 | 0.53 | 71 | 4.57 | 0.71 | 65 | 27.0% | –2.55 [–2.76, –2.34] |
| Kim et al | 1.1 | 2.5 | 25 | 4.2 | 3.1 | 25 | 21.1% | –3.10 [–4.66, –1.54] |
| Kong et al | 1.03 | 2.36 | 51 | 5.01 | 1.77 | 51 | 25.2% | –3.98 [–4.79, –3.17] |
| Singhania et al | 1.3 | 0 | 30 | 4.12 | 0 | 30 | | Not estimable |
| Xie et al | 1.62 | 1.31 | 110 | 2.03 | 1.35 | 110 | 26.7% | –0.41 [–0.76, –0.06] |
| **Total (95% CI)** | | | **322** | | | **316** | **100.0%** | **–2.45 [–3.97, –0.94]** |

Heterogeneity: Tau² = 2.20; $\chi^2$ = 128.34, df = 3 ($p$ < 0.00001); I² = 98%
Test for overall effect: Z = 3.18 ($p$ = 0.001)

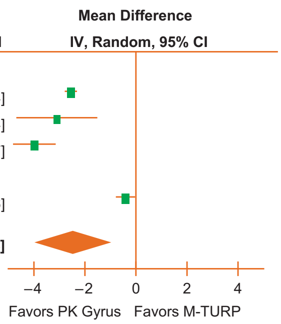



**Fig. 3 – Meta-analysis of efficacy and complications is studies comparing Gyrus plasmakinetic bipolar resection with monopolar transurethral resection of the prostate. (A) Intervention duration; (B) transfusion rate; (C) hemoglobin loss; (D) sodium decrease; (E) immediate acute urinary retention; (F) clot retention; (H) recatheterization; (I) length of stay; (J) International Prostate Symptom Score at 12 mo; (K) maximum flow rate at 12 mo; (L) prostate volume at 12 mo; (M) stricture at 12 mo.**
**CI = confidence interval; M-TURP = monopolar transurethral resection of the prostate; PK Gyrus, Gyrus plasmakinetic bipolar resection; SD = standard deviation.**

M-TURP and after the transurethral resection in saline (TURis) procedure versus M-TURP for short-term outcomes only. Most reports dealt with the Gyrus-PK device (Table 1). When the data were fit for meta-analysis (that was the case for all immediate- and short-term outcomes except UTI rate, re-operation rates, and incontinence at 1-yr follow-up), Gyrus-PK versus M-TURP comparison led to exactly the same results as obtained here for global B-TURP procedures (Fig. 3). The opposite head-to-head comparison of TURis versus M-TURP showed no significant difference between the two techniques for the duration of intervention, clot retention, and catheterization time (Fig. 4). These results may be due to weaker data quality compared with Gyrus-PK, and a lack of power cannot be excluded to explain those results.

The advantages of the Karl Storz B-TURP device were detailed in the high-quality RCT published by Mamoulakis et al. [27]. This trial showed comparable advantages of the bipolar arm regarding perioperative outcomes, as well as no

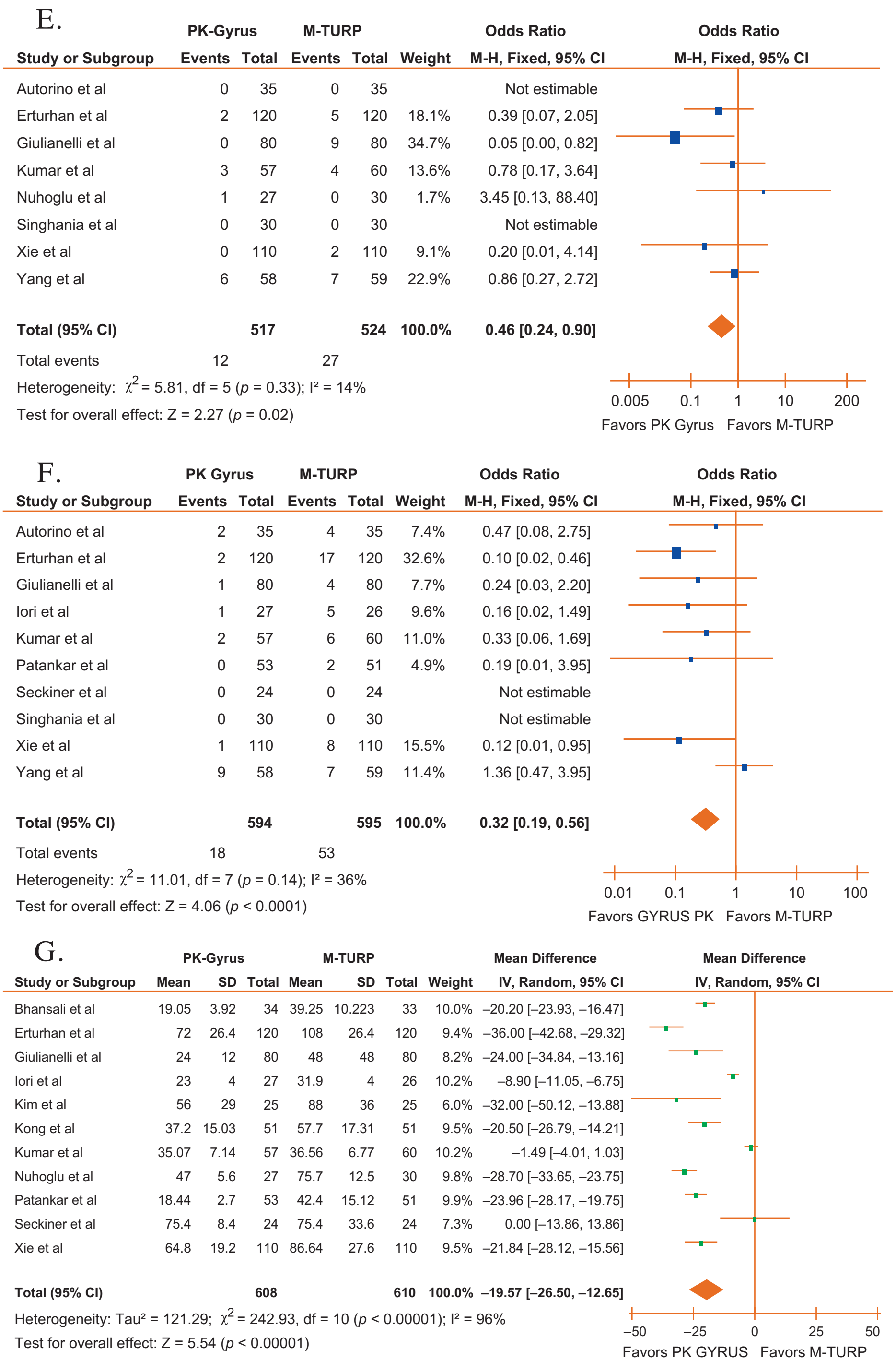



**Fig. 3. (*Continued*)**

significant differences between B-TURP and M-TURP arms after a medium follow-up of 24–36 mo. Only two studies evaluated the ACMI Vista CTR (no longer marketed) with short-term follow-up <1 yr; thus no specific analysis was conducted for this device.

### 3.5. *Bipolar transurethral resection of the prostate versus other technologies*

B-TURP has been compared with HoLEP [23,47], thulium laser enucleation of the prostate (ThuLEP) [22], Eraser laser enucleation of the prostate (ELEP) [44], B-TUVP [32,34], and PKEP [58]. Chen et al. showed similar functional results (on IPSS, $Q_{max}$, and QoL score) for B-TURP and HoLEP after 2-yr follow-up in a large RCT including 280 patients, with HoLEP associated with shorter catheterization and hospitalization durations and lower risk of bleeding [23]. Fayad et al., in a smaller study, found no significant differences in postoperative parameters between the two groups [47].

In a long-term RCT, Zhu et al. showed that PKEP was superior to B-TURP on IPSS reduction and $Q_{max}$ improvement after 5 yr in patients with prostates >70 ml, as well as better perioperative outcomes [58].

Yang et al. reported no difference in functional parameters between ThuLEP and Gyrus-PK B-TURP after a follow-up of 18 mo, but favorable short-term outcomes with ThuLEP (reduced hospital stay, catheterization time, and bleeding) [22]. The same conclusions were obtained in favor of ELEP compared with Gyrus-PK B-TURP after 6-mo follow-up [44].

Olympus TURis and B-TUVP using a button-type vapor-resection electrode were compared by Geavlete et al. in a three-arm RCT, showing better functional results for the TURis arm, as well as fewer postoperative complications [32].

None of these comparisons was suitable for meta-analysis, and the paucity of the data must lead to cautious interpretation of the results.

### 3.6. *Holmium laser enucleation of the prostate*

Fifteen RCTs involving HoLEP were retrieved and analyzed. HoLEP was compared with M-TURP in five independent studies [46,48,51,54,56], with M-TURP and transurethral

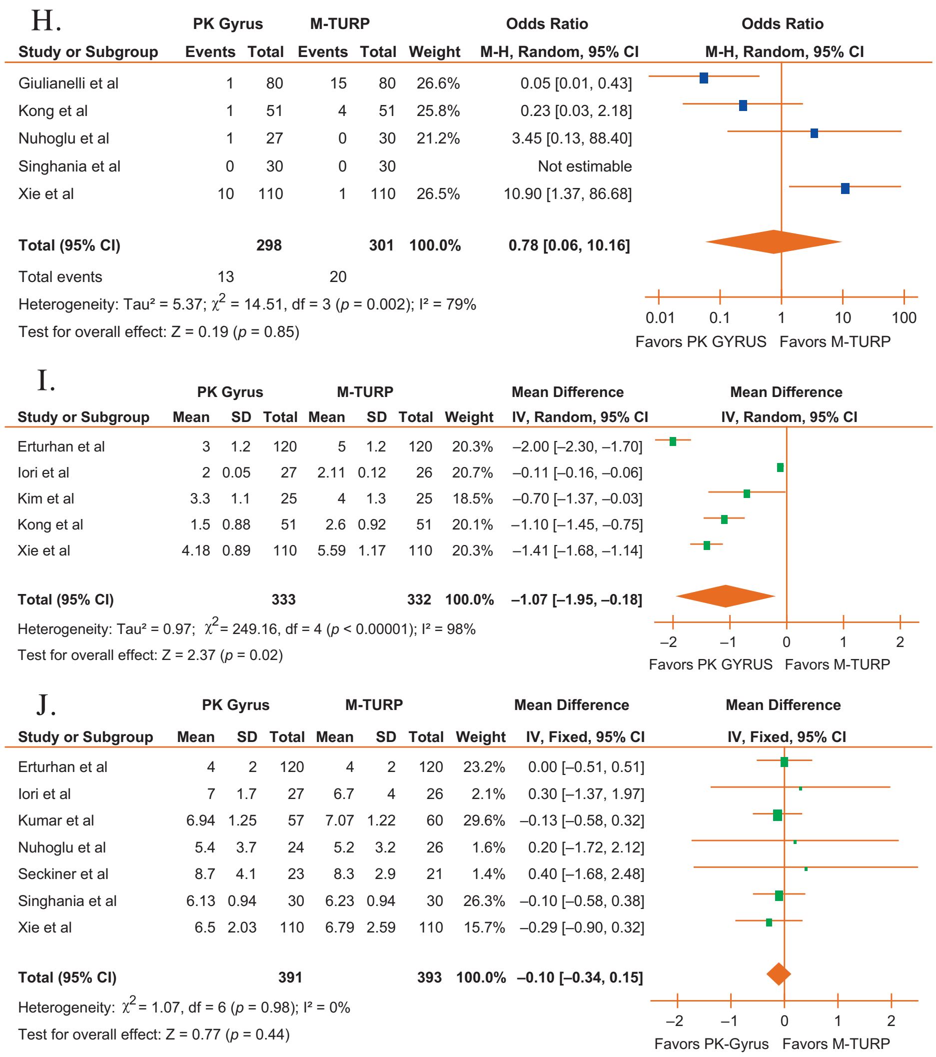



**Fig. 3.** (*Continued*)

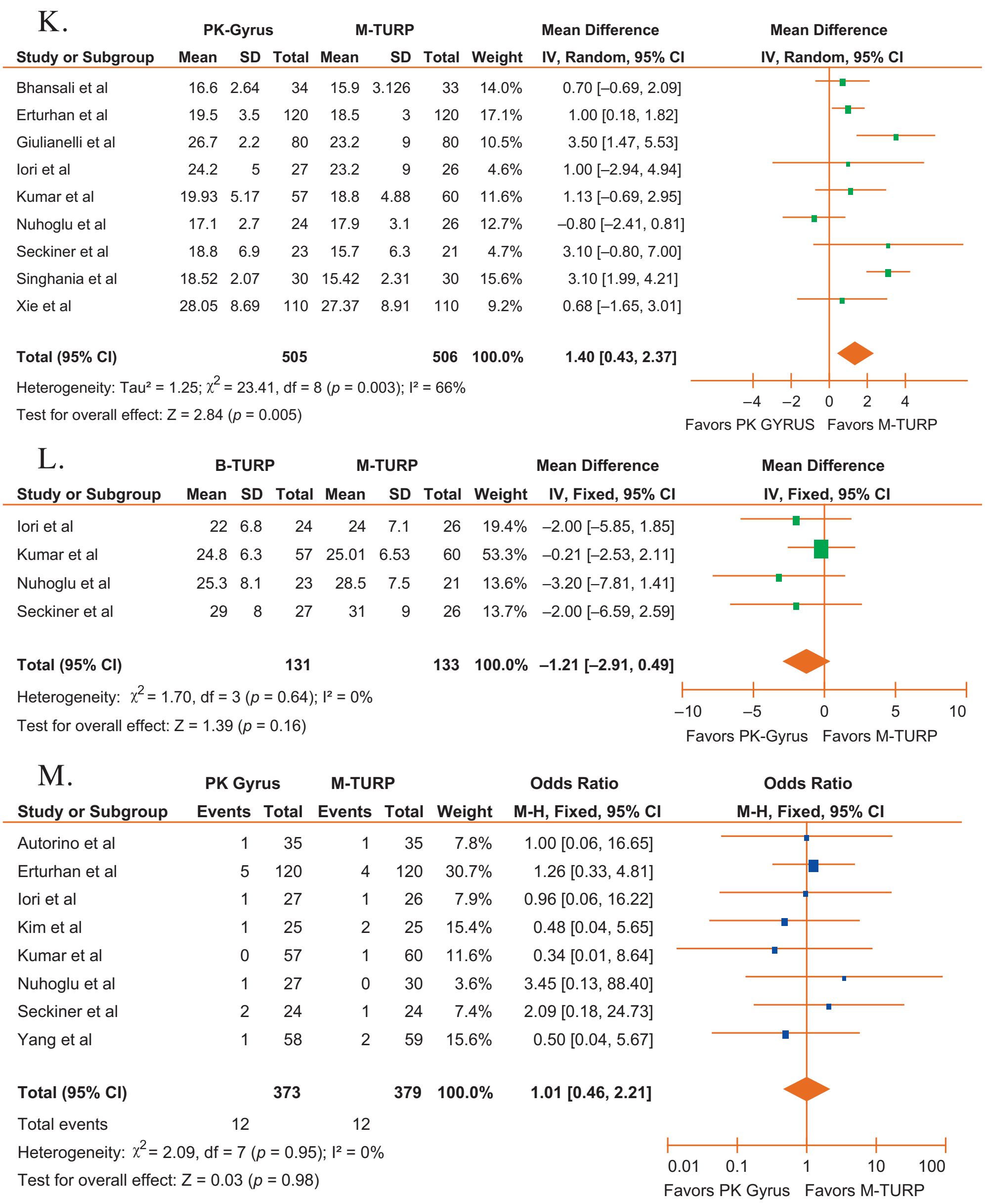



**Fig. 3. (*Continued*).**

vapor resection of the prostate in one study [75], with OP in three studies [45,53,55], with PKEP in one study [50], with PVP in one study [49], and with B-TURP in one study [47] (Table 1 and Supplemental Table 1). Only the data comparing HoLEP and M-TURP were suitable for meta-analysis.

*3.6.1. Holmium laser enucleation of the prostate versus monopolar transurethral resection of the prostate*

Data derived from six independent studies were considered for meta-analysis containing data on 570 patients. Results are detailed in Figure 2. HoLEP (including enucleation and morcellation) was associated with longer operative time (mean difference of 14.9 min; $p < 0.00001$). Immediate complications were less numerous with HoLEP. No patient required blood transfusion after HoLEP compared with 8 of 235 after M-TURP; sodium serum levels as well as hemoglobin levels decreased less after HoLEP (Fig. 5). The rate of acute urinary retention, clot retention, recatheterization, short-term reoperation, postoperative UTIs, postoperative storage symptoms, and urethral strictures were not significantly different in the two groups. Overall, HoLEP was associated with a shorter catheterization duration (mean difference: 22.2 h; $p < 0.00001$) and shorter length of hospital stay (mean difference: 1.4 d; $p = 0.0009$).

At 1-yr follow-up, efficacy analyses revealed better results for HoLEP compared with M-TURP in terms of IPSS (mean difference: 0.91; $p = 0.003$), $Q_{max}$ (mean difference: 1.59 ml/s; $p = 0.02$), and PVR (mean difference: 18.69; $p < 0.00001$), but difference on QoL score was not significant (Fig. 6A–6D). Although only based on two studies, long-term results after 3–8 yr still seemed to favor HoLEP

(Fig. 6E and 6F). Very few data were available on long-term complications.

*3.6.2. Holmium laser enucleation of the prostate versus open prostatectomy*

Three RCTs compared HoLEP and OP [45,53,55], with one focused on cost analysis [45]. All these trials included patients with prostates >100 ml. These studies showed significantly longer operation duration for HoLEP (mean difference: 24.9 min; $p = 0.01$) compared with OP. However, HoLEP was associated with a shorter catheterization duration (mean difference: 98 h; $p = 0.01$) as well as a shorter hospital stay (mean difference: 4.3 d; $p = 0.004$). Evaluation of immediate complications has shown that the risk of perioperative blood transfusion was higher after OP than HoLEP (relative risk: 6.09; $p < 0.0001$). Based on the two clinical trials focused on efficacy and complications, the results were comparable in the two groups for both IPSS and $Q_{max}$, after short-term and long-term follow-up. Complications were also similar in terms of reoperation, strictures, and incontinence [53,55].

*3.6.3. Holmium laser enucleation of the prostate compared with other techniques*

Fayad et al. compared HoLEP with B-TURP (TURis SurgMaster, Olympus) in a small short-term RCT including 60 patients with medium-size prostates. The two techniques were found to be safe with HoLEP having a longer operative time [47]. Neill et al. compared HoLEP with PKEP in a small RCT with 1-yr follow-up, suggesting that comparable results could be obtained in terms of complications and functional outcomes [50]. Based on this single trial, no firm statement could be made on the comparison between B-TURP or PKEP and HoLEP, and additional studies are warranted.

Finally, HoLEP was compared with PVP-120W in a recent RCT from Elmansy et al., who included only patients with

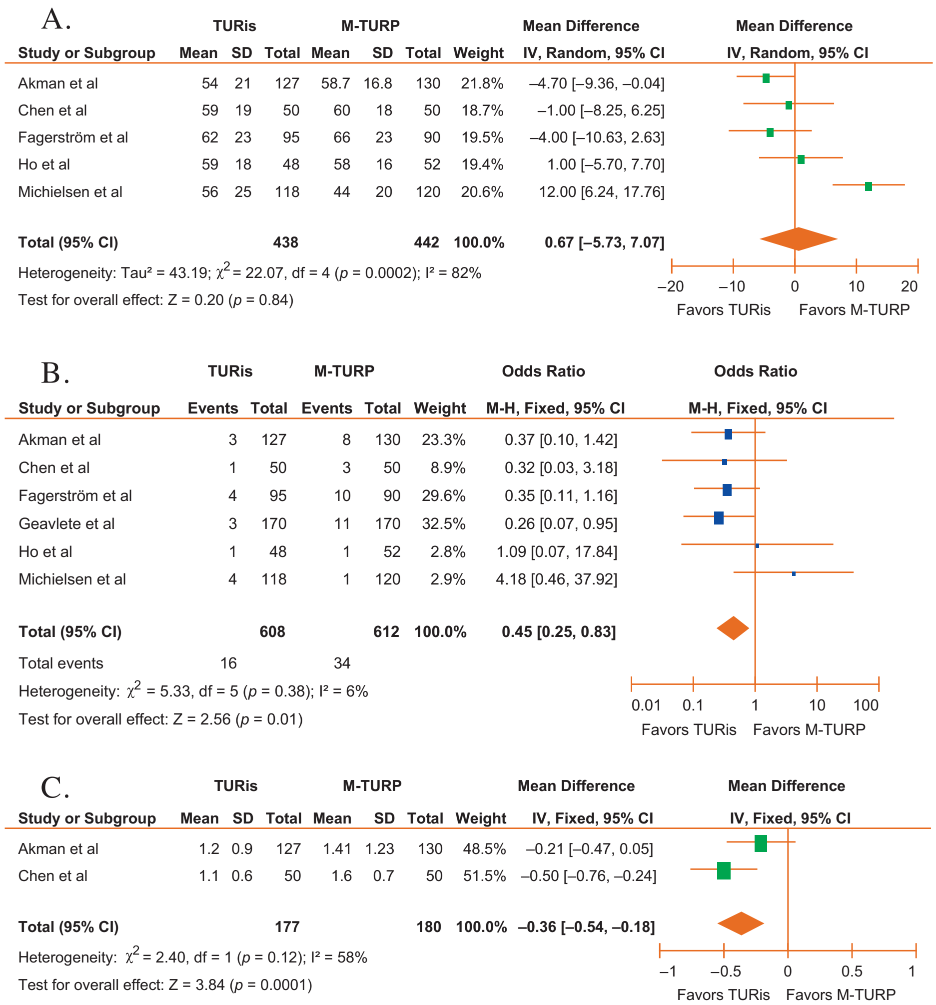



**Fig. 4 – Meta-analysis of efficacy and complications in studies comparing transurethral resection in saline bipolar resection with monopolar transurethral resection of the prostate (M-TURP). (A) Intervention duration; (B) blood transfusion; (C) hemoglobin loss; (D) sodium decrease; (E) immediate acute urinary retention; (F) clot retention; (G) catheterization time; (H) recatheterization; (I) International Prostate Symptom Score at 12 mo; (J) maximum flow rate at 12 mo; (K) strictures at 12 mo.**
**CI = confidence interval; M-TURP = monopolar transurethral resection of the prostate; SD = standard deviation; TURis = transurethral resection in saline.**

prostates >60 ml [49]. Despite significant limitations (unusually high rate of conversion of PVP procedure to TURP, use of the HPS device that is no longer marketed, as well as methodological flaws), the results obtained in the short term suggest that HoLEP may be more adequate for BPO relief when due to larger prostates. Once again, further evaluations are needed against the GreenLight XPS device, with a better design to generate more relevant comparative data for these two techniques.

### 3.7. *GreenLight photovaporization of the prostate*

The literature search retrieved 10 RCTs on PVP, evaluating the GreenLight 80W device in four studies [67–70] and the GreenLight HPS 120W device in six studies [61–66]. No RCT published to date was conducted with the GreenLight XPS 180W, except the recently published Goliath study, with only a 6-mo follow-up [77]. For better consistency of the results, the meta-analysis was conducted by including only studies using the GreenLight 120W HPS. Six RCTs compared PVP-120W with M-TURP including 697 patients [61–66].

Results of the meta-analysis are shown in Fig. 7. Operating time was slightly longer with PVP-120W (mean difference: 9.37 min; $p < 0.0001$). Immediate outcome significantly favored PVP with a lower risk of perioperative transfusion (OR: 0.10; $p < 0.00001$), reduced time of postoperative catheterization (mean difference: 32.36 h; $p < 0.0001$), and shorter length of stay (mean difference: 1.85 d; $p < 0.00001$ [1.59–2.09]). The rate of postoperative acute urinary retention and UTI was not different between the two groups. The remaining immediate outcomes were not suitable for meta-analysis.

Functional outcomes at 12 mo were not significantly different between groups (Fig. 7J–7L). These results advocate for comparative outcomes for PVP and TURP in the short term. Unfortunately, no midterm data were available to compare the efficacy of the two techniques after 12 mo. Three studies reporting the complication rate at midterm follow-up, however, showed that intervention for urethral

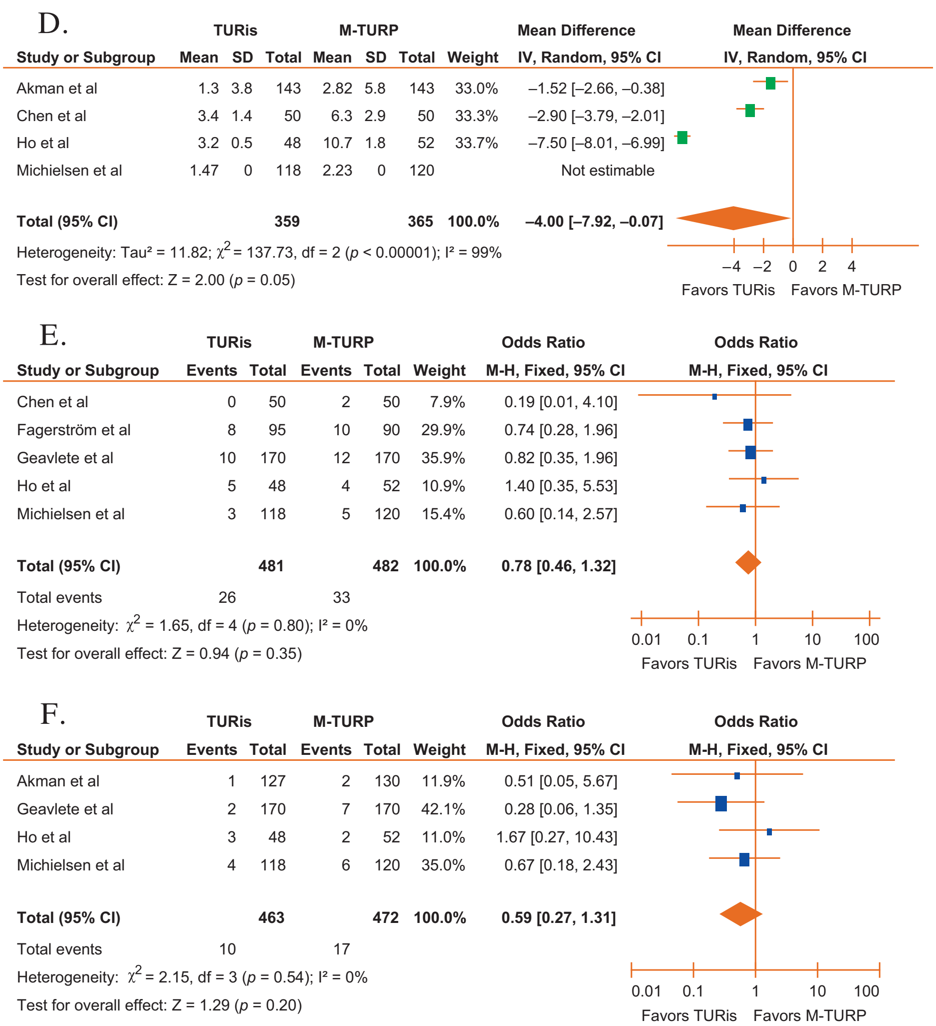



**Fig. 4.** (*Continued*)

G.

| Study or Subgroup | TURis Mean | TURis SD | TURis Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Akman et al | 57.6 | 24 | 127 | 62.4 | 30 | 130 | 90.0% | –4.80 [–11.43, 1.83] |
| Michielsen et al | 96 | 72 | 118 | 108 | 84 | 120 | 10.0% | –12.00 [–31.87, 7.87] |
| **Total (95% CI)** | | | **245** | | | **250** | **100.0%** | **–5.52 [–11.82, 0.77]** |

Heterogeneity: $\chi^2$ = 0.45, df = 1 ($p$ = 0.50); I² = 0%
Test for overall effect: Z = 1.72 ($p$ = 0.09)

H.

| Study or Subgroup | TURis Events | TURis Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Chen et al | 0 | 50 | 2 | 50 | 14.4% | 0.19 [0.01, 4.10] |
| Geavlete et al | 10 | 170 | 12 | 170 | 65.6% | 0.82 [0.35, 1.96] |
| Ho et al | 5 | 48 | 4 | 52 | 20.0% | 1.40 [0.35, 5.53] |
| **Total (95% CI)** | | **268** | | **272** | **100.0%** | **0.85 [0.42, 1.70]** |
| Total events | 15 | | 18 | | | |

Heterogeneity: $\chi^2$ = 1.41, df = 2 ($p$ = 0.49); I² = 0%
Test for overall effect: Z = 0.47 ($p$ = 0.64)

I.

| Study or Subgroup | TURis Mean | TURis SD | TURis Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Akman et al | 10.3 | 3 | 127 | 10.8 | 2.9 | 130 | 64.0% | –0.50 [–1.22, 0.22] |
| Chen et al | 4.2 | 2.6 | 50 | 4.1 | 2.3 | 50 | 36.0% | 0.10 [–0.86, 1.06] |
| **Total (95% CI)** | | | **177** | | | **180** | **100.0%** | **–0.28 [–0.86, 0.29]** |

Heterogeneity: $\chi^2$ = 0.96, df = 1 ($p$ = 0.33); I² = 0%
Test for overall effect: Z = 0.96 ($p$ = 0.33)

J.

| Study or Subgroup | B-TURP Mean | B-TURP SD | B-TURP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Akman et al | 17.1 | 3.1 | 127 | 16.3 | 4.7 | 130 | 92.1% | 0.80 [–0.17, 1.77] |
| Chen et al | 23.2 | 8.1 | 50 | 22.2 | 8.8 | 50 | 7.9% | 1.00 [–2.32, 4.32] |
| **Total (95% CI)** | | | **177** | | | **180** | **100.0%** | **0.82 [–0.12, 1.75]** |

Heterogeneity: $\chi^2$ = 0.01, df = 1 ($p$ = 0.91); I² = 0%
Test for overall effect: Z = 1.72 ($p$ = 0.09)

K.

| Study or Subgroup | TURis Events | TURis Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Akman et al | 8 | 127 | 6 | 130 | 25.4% | 1.39 [0.47, 4.12] |
| Fagerström et al | 2 | 95 | 1 | 90 | 4.6% | 1.91 [0.17, 21.48] |
| Geavlete et al | 17 | 170 | 16 | 170 | 65.9% | 1.07 [0.52, 2.19] |
| Ho et al | 3 | 48 | 1 | 52 | 4.1% | 3.40 [0.34, 33.86] |
| **Total (95% CI)** | | **440** | | **442** | **100.0%** | **1.29 [0.74, 2.25]** |
| Total events | 30 | | 24 | | | |

Heterogeneity: $\chi^2$ = 1.06, df = 3 ($p$ = 0.79); I² = 0%
Test for overall effect: Z = 0.88 ($p$ = 0.38)

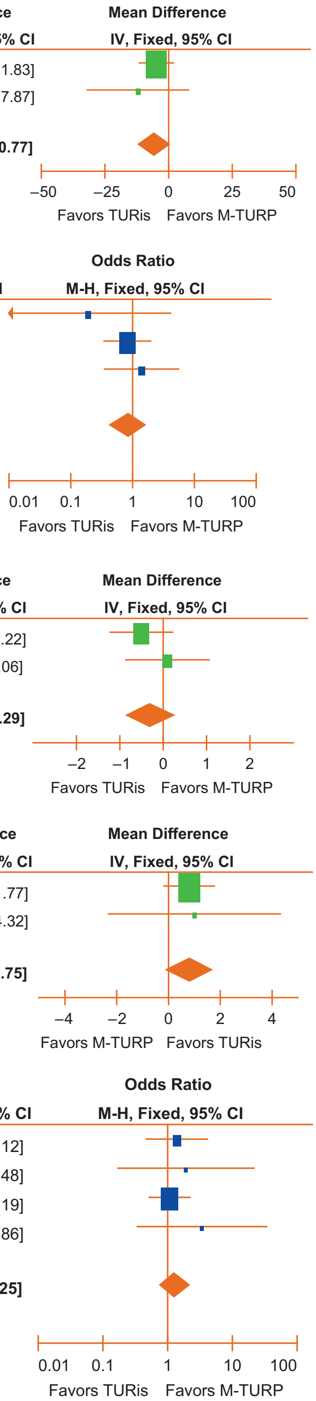



**Fig. 4. (*Continued*).**

stricture and for bladder neck contractures were comparable in the two groups [65,66]. The rate of reoperation for BPO recurrence seemed slightly higher after PVP, but the small size of the samples has to be considered for interpretation of these results.

### *3.8. Other transurethral techniques*

Several other techniques have been investigated in the literature, based on enucleation (bipolar enucleation [8], Gyrus-PK enucleation [50,57–60], diode enucleation [43], Eraser enucleation [44], ThuLEP [35]), electrovaporization or vapor resection (with Olympus mushroom electrode [21,32,34,35]), Wing loop manufactured by Wolf [75], Gyrus-PK [38–42], or thulium [72–74]. All these techniques have been compared with various surgical alternatives, without enough consistent data suitable for meta-analysis (Table 1).

Gyrus-PK enucleation (PKEP) has been investigated as an alternative to M-TURP [57], B-TURP [58], HoLEP [50], and OP [59,60] in large prostates. This technique showed promising results, as efficacious as OP with fewer complications in some reports [59], but further data are needed to compare PKEP with HoLEP to be considered the standard enucleation technique. Enucleation using an Olympus bipolar device

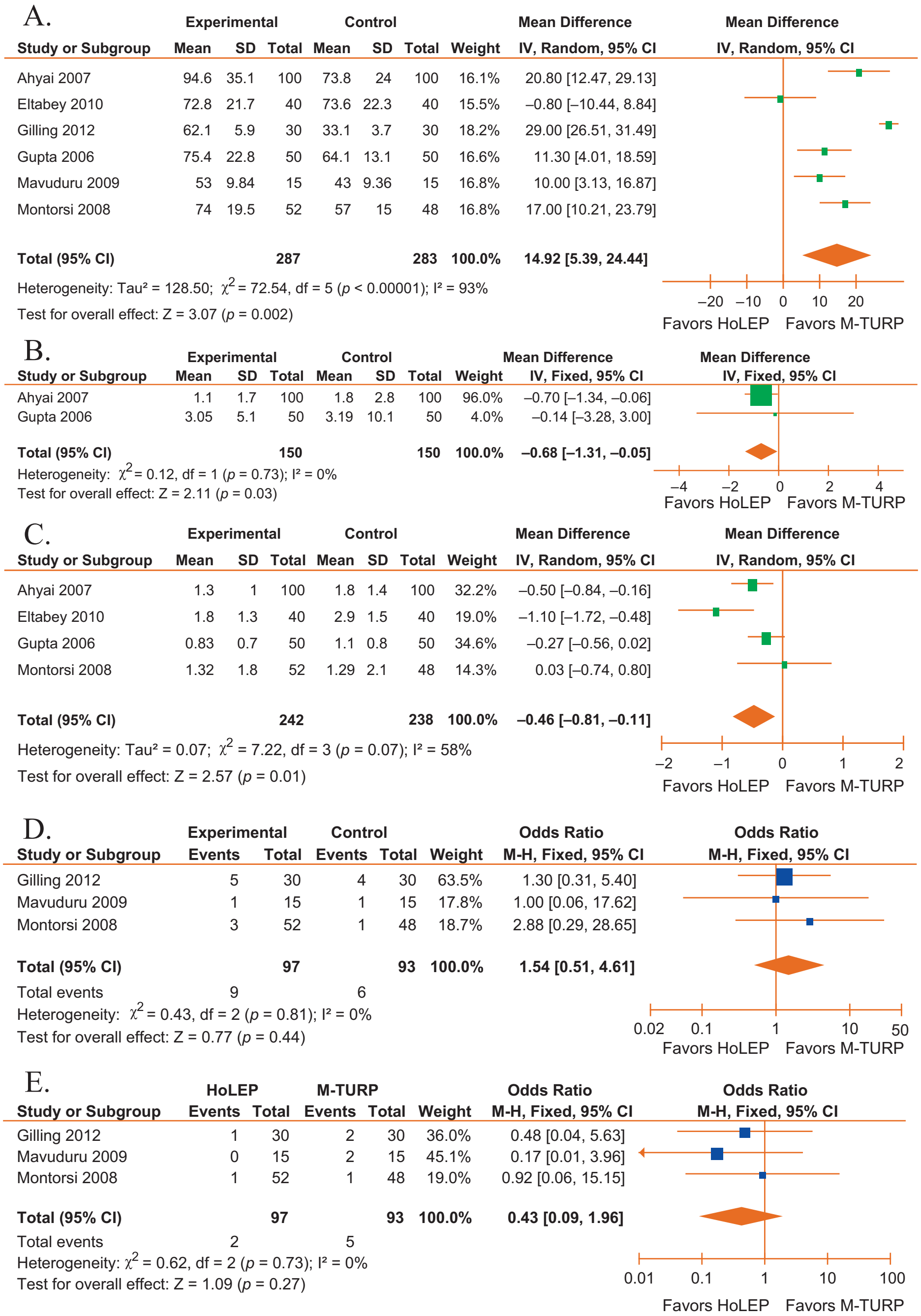



**Fig. 5 – Meta-analysis of short-term complications after holmium laser enucleation of the prostate compared with monopolar transurethral resection of the prostate. (A) Intervention duration; (B) sodium decrease; (C) hemoglobin decrease; (D) acute urinary retention; (E) clot retention; (F) recatheterization; (H) reoperation; (I) catheter duration; (J) length of stay; (K) storage symptoms; (L) strictures after 1 yr; (M) urinary tract infections. CI = confidence interval; HoLEP = holmium laser enucleation of the prostate; M-TURP = monopolar transurethral resection of the prostate; SD = standard deviation.**

was compared with OP in a single short-term RCT at the moment [8], as well as enucleation techniques using thulium [22,71], Diode [43], or Eraser [44], so that these procedures can still be considered under development.

Studies about vapor-resection hybrid techniques using the Olympus system were all short-term trials with <1-yr follow-up [34–37]. TUVP using the Gyrus device was mainly compared with M-TURP [38–42] in rather small prostates through five independent studies with follow-up up to 100 mo. Main functional results were contradictory, and the heterogeneity of the trials, nonstandardized technique, as well as the methodological limitations of these reports, do not allow any firm conclusions. ThuLEP using the Revolix laser was compared with TURP in three heterogeneous short-term trials [72–74], suggesting favorable outcomes, but further studies are warranted.

### 3.9. *Sexual adverse events after transurethral techniques*

Evaluation of sexual function after transurethral procedures for BPO relief is difficult for a number of reasons. First, the pathophysiology of erectile dysfunction and ejaculation dysfunction is still poorly understood, even following the historical techniques that have been largely evaluated [78]. Second, the evaluation of sexuality covers not only erection and ejaculation, but a number of other domains (eg, satisfaction, orgasm, desire). Third, several confounding factors have been shown to interact with sexual symptoms,

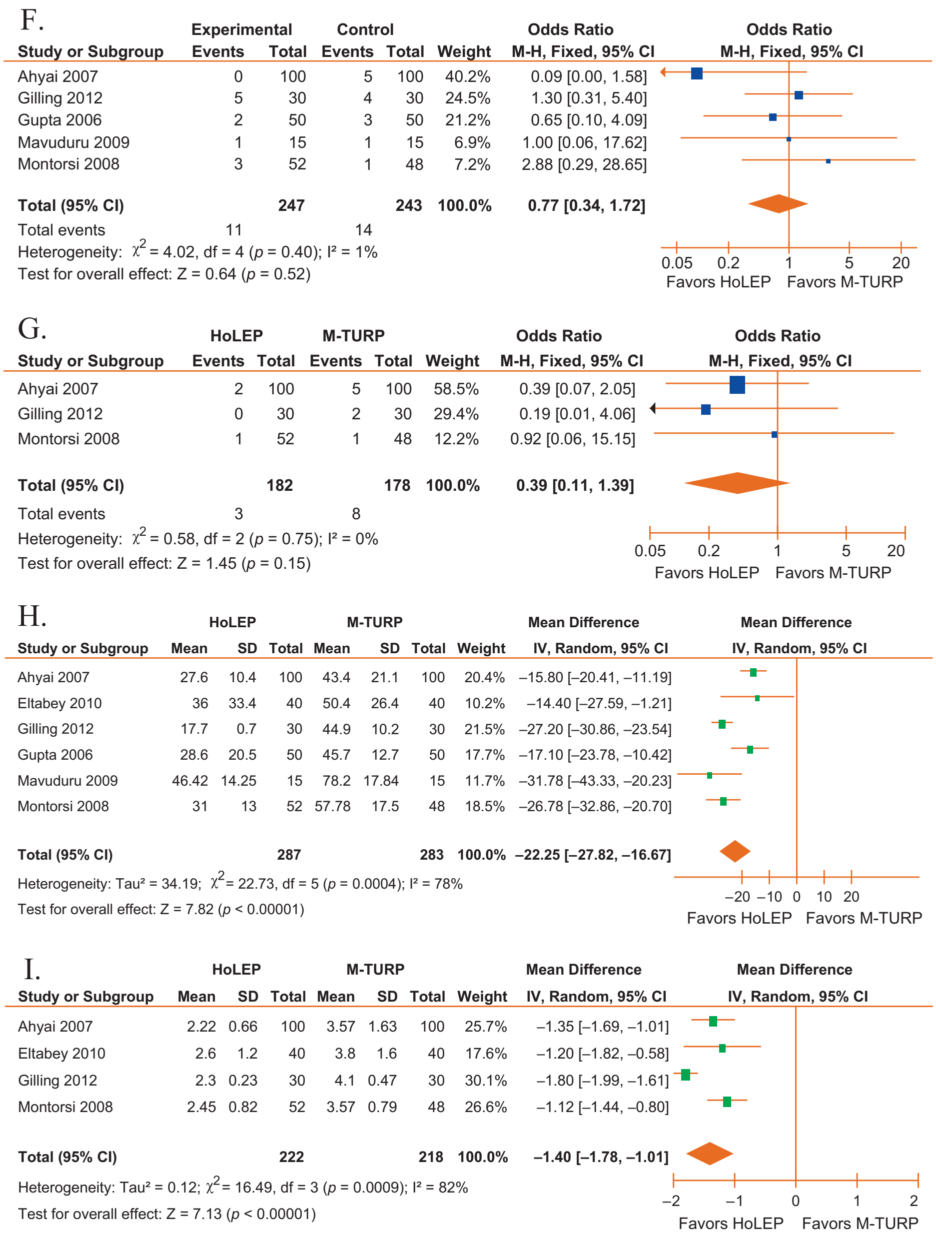


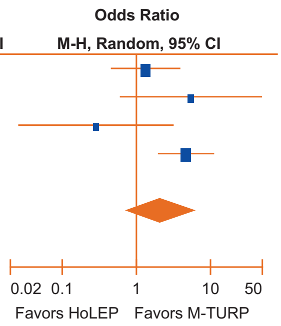

**Fig. 5. (*Continued*)**

J.

| Study or Subgroup | HoLEP Events | HoLEP Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Eltabey 2010 | 10 | 40 | 8 | 40 | 32.7% | 1.33 [0.46, 3.83] |
| Gupta 2006 | 5 | 50 | 1 | 50 | 16.3% | 5.44 [0.61, 48.40] |
| Mavuduru 2009 | 1 | 15 | 3 | 15 | 14.4% | 0.29 [0.03, 3.12] |
| Montorsi 2008 | 33 | 52 | 13 | 48 | 36.6% | 4.68 [2.00, 10.95] |
| **Total (95% CI)** | | **157** | | **153** | **100.0%** | **2.12 [0.71, 6.33]** |
| Total events | 49 | | 25 | | | |

Heterogeneity: Tau² = 0.66; $\chi^2$ = 7.09, df = 3 ($p$ = 0.07); I² = 58%

Test for overall effect: Z = 1.35 ($p$ = 0.18)

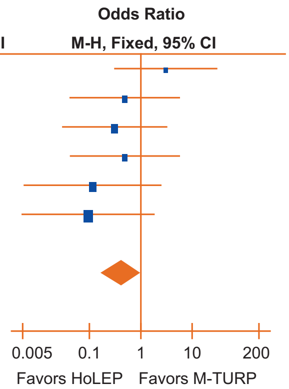



K.

| Study or Subgroup | HoLEP Events | HoLEP Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Ahyai 2007 | 3 | 100 | 1 | 100 | 6.1% | 3.06 [0.31, 29.95] |
| Eltabey 2010 | 1 | 40 | 2 | 40 | 12.3% | 0.49 [0.04, 5.60] |
| Gilling 2012 | 1 | 30 | 3 | 30 | 18.4% | 0.31 [0.03, 3.17] |
| Gupta 2006 | 1 | 50 | 2 | 50 | 12.4% | 0.49 [0.04, 5.58] |
| Mavuduru 2009 | 0 | 15 | 3 | 15 | 21.5% | 0.12 [0.01, 2.45] |
| Montorsi 2008 | 0 | 52 | 4 | 48 | 29.3% | 0.09 [0.00, 1.80] |
| **Total (95% CI)** | | **287** | | **283** | **100.0%** | **0.42 [0.17, 1.03]** |
| Total events | 6 | | 15 | | | |

Heterogeneity: $\chi^2$= 4.69, df = 5 ($p$ = 0.46); I² = 0%

Test for overall effect: Z = 1.91 ($p$ = 0.06)




L.

| Study or Subgroup | HoLEP Events | HoLEP Total | M-TURP Events | M-TURP Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Ahyai 2007 | 1 | 100 | 1 | 100 | 4.6% | 1.00 [0.06, 16.21] |
| Eltabey 2010 | 8 | 40 | 12 | 40 | 44.3% | 0.58 [0.21, 1.63] |
| Gilling 2012 | 1 | 30 | 0 | 30 | 2.2% | 3.10 [0.12, 79.23] |
| Gupta 2006 | 1 | 50 | 1 | 50 | 4.5% | 1.00 [0.06, 16.44] |
| Mavuduru 2009 | 2 | 15 | 0 | 15 | 1.9% | 5.74 [0.25, 130.37] |
| Montorsi 2008 | 25 | 52 | 17 | 48 | 42.4% | 1.69 [0.76, 3.77] |
| **Total (95% CI)** | | **287** | | **283** | **100.0%** | **1.25 [0.71, 2.19]** |
| Total events | 38 | | 31 | | | |

Heterogeneity: $\chi^2$ = 3.91, df = 5 ($p$ = 0.56); I² = 0%

Test for overall effect: Z = 0.76 ($p$ = 0.45)

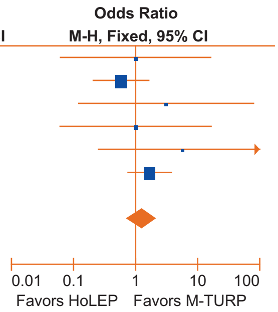



**Fig. 5. (*Continued*).**

with LUTS and their related bother being one of them [79]. Finally, several methodological issues have to be considered when analyzing the literature: (1) Sexual symptom scales are multiple not similar in all studies, and often limited to International Index of Erectile Function (IIEF)-5, (2) sexuality is rarely the main evaluation criterion in benign prostate surgery, studies being focused on efficacy, and (3) a lot of data were generated from nonrandomized studies or case series, providing only limited evidence. Studies on BPO-related procedures do not systematically include patients with baseline sexual dysfunction. For all these reasons, LE 1 evidence on sexual adverse events after BPO-related procedures is scarce.

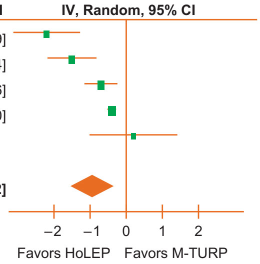
Among the 69 independent trials included in the present review, 18 reports included data on sexual function, often using IIEF-5, and rarely Danish Sexual Function [62] score or IIEF-15 [48,52]. A total of 50% of manuscripts do not specify the number of sexually active patients, further complicating the analysis. A few additional reports include raw data about so-called retrograde ejaculation, or erectile dysfunction in assessing complications of the procedures (always secondary outcomes) in a nonstandardized fashion that limits the interpretability of the results. Thus only a rough evaluation could be drawn from the present work, with data not suitable for meta-analysis.

Three studies have generated comprehensive results on HoLEP compared with OP and M-TURP [48,52,53]. Focusing on sexual symptoms as the primary outcome, Briganti et al. showed that M-TURP and HoLEP were associated with a decrease of orgasmic function due to ejaculation dysfunction but no significant impact of the procedures was noted on erection [52]. Approximately 78% of patients in both groups reported loss of ejaculation (ie, no visible sperm when achieving orgasm), with no difference between groups. These results are further supported by the retrograde ejaculation rate after HoLEP mentioned in other RCTs (74% for Ahyai et al.

A.

| Study or Subgroup | HoLEP Mean | HoLEP SD | HoLEP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Ahyai 2007 | 1.7 | 1.8 | 89 | 3.9 | 3.9 | 86 | 16.6% | –2.20 [–3.11, –1.29] |
| Eltabey 2010 | 2.2 | 1.4 | 40 | 3.7 | 1.6 | 40 | 20.2% | –1.50 [–2.16, –0.84] |
| Gilling 2012 | 4.3 | 0.7 | 25 | 5 | 0.9 | 27 | 23.5% | –0.70 [–1.14, –0.26] |
| Gupta 2006 | 5.2 | 0.17 | 50 | 5.6 | 0.32 | 50 | 26.7% | –0.40 [–0.50, –0.30] |
| Montorsi 2008 | 4.1 | 2.3 | 52 | 3.9 | 3.6 | 48 | 12.9% | 0.20 [–0.99, 1.39] |
| **Total (95% CI)** | | | **256** | | | **251** | **100.0%** | **–0.91 [–1.51, –0.32]** |

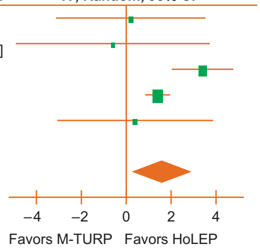
Heterogeneity: Tau² = 0.34; $\chi^2$ = 27.46, df = 4 ($p$ < 0.0001); I² = 85%
Test for overall effect: Z = 3.01 ($p$ = 0.003)




B.

| Study or Subgroup | HoLEP Mean | HoLEP SD | HoLEP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Ahyai 2007 | 27.9 | 9.9 | 89 | 27.7 | 12.2 | 86 | 11.7% | 0.20 [–3.10, 3.50] |
| Eltabey 2010 | 24.9 | 11.7 | 40 | 25.5 | 7.4 | 40 | 7.8% | –0.60 [–4.89, 3.69] |
| Gilling 2012 | 21.8 | 2.1 | 25 | 18.4 | 2.8 | 27 | 29.6% | 3.40 [2.06, 4.74] |
| Gupta 2006 | 25.1 | 1.06 | 50 | 23.7 | 1.58 | 50 | 39.8% | 1.40 [0.87, 1.93] |
| Montorsi 2008 | 25.1 | 7.2 | 52 | 24.7 | 10 | 48 | 11.0% | 0.40 [–3.04, 3.84] |
| **Total (95% CI)** | | | **256** | | | **251** | **100.0%** | **1.59 [0.26, 2.91]** |

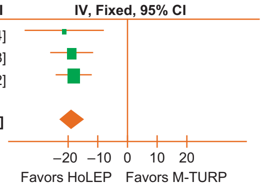
Heterogeneity: Tau² = 1.08; $\chi^2$ = 9.66, df = 4 ($p$ = 0.05); I² = 59%
Test for overall effect: Z = 2.34 ($p$ = 0.02)




C.

| Study or Subgroup | HoLEP Mean | HoLEP SD | HoLEP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Ahyai 2007 | 5.3 | 15.3 | 89 | 26.6 | 60.4 | 86 | 10.5% | –21.30 [–34.46, –8.14] |
| Eltabey 2010 | 5.3 | 15.2 | 40 | 24.1 | 16.8 | 40 | 36.9% | –18.80 [–25.82, –11.78] |
| Gilling 2012 | 33.7 | 5.5 | 25 | 51.8 | 14.5 | 27 | 52.6% | –18.10 [–23.98, –12.22] |
| **Total (95% CI)** | | | **154** | | | **153** | **100.0%** | **–18.69 [–22.96, –14.43]** |

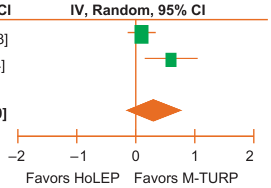
Heterogeneity: $\chi^2$ = 0.19, df = 2 ($p$ = 0.91); I² = 0%
Test for overall effect: Z = 8.59 ($p$ < 0.00001)




D.

| Study or Subgroup | HoLEP Mean | HoLEP SD | HoLEP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Gilling 2012 | 1.5 | 0.5 | 25 | 1.4 | 0.3 | 27 | 57.3% | 0.10 [–0.13, 0.33] |
| Montorsi 2008 | 1.4 | 0.9 | 52 | 0.8 | 1.28 | 48 | 42.7% | 0.60 [0.16, 1.04] |
| **Total (95% CI)** | | | **77** | | | **75** | **100.0%** | **0.31 [–0.17, 0.80]** |

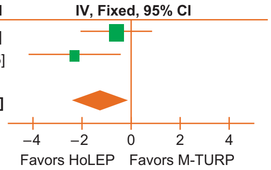
Heterogeneity: Tau² = 0.09; $\chi^2$ = 3.97, df = 1 ($p$ = 0.05); I² = 75%
Test for overall effect: Z = 1.27 ($p$ = 0.20)




E.

| Study or Subgroup | HoLEP Mean | HoLEP SD | HoLEP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Ahyai 2007 | 2.7 | 3.2 | 36 | 3.3 | 3 | 36 | 62.5% | –0.60 [–2.03, 0.83] |
| Gilling 2012 | 8 | 5.2 | 92 | 10.3 | 7.42 | 92 | 37.5% | –2.30 [–4.15, –0.45] |
| **Total (95% CI)** | | | **128** | | | **128** | **100.0%** | **–1.24 [–2.37, –0.10]** |

Heterogeneity: $\chi^2$ = 2.03, df = 1 ($p$ = 0.15); I² = 51%
Test for overall effect: Z = 2.14 ($p$ = 0.03)




F.

| Study or Subgroup | HoLEP Mean | HoLEP SD | HoLEP Total | M-TURP Mean | M-TURP SD | M-TURP Total | Weight | Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Ahyai 2007 | 29 | 11 | 36 | 27.5 | 9.9 | 36 | 35.9% | 1.50 [–3.33, 6.33] |
| Gilling 2012 | 22.09 | 15.47 | 92 | 17.83 | 8.61 | 92 | 64.1% | 4.26 [0.64, 7.88] |
| **Total (95% CI)** | | | **128** | | | **128** | **100.0%** | **3.27 [0.37, 6.17]** |

Heterogeneity: $\chi^2$ = 0.80, df = 1 ($p$ = 0.37); I² = 0%
Test for overall effect: Z = 2.21 ($p$ = 0.03)

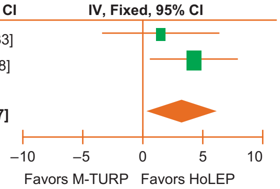



**Fig. 6 – Efficacy of holmium laser enucleation of the prostate compared with monopolar transurethral resection of the prostate. (A) International Prostate Symptom Score (IPSS) difference after 1-yr follow-up; (B) maximum flow rate ($Q_{max}$) difference after 1-yr follow-up; (C) postvoid residual difference after 1-yr follow-up; (D) quality of life difference after 1-yr follow-up; (E) IPSS difference after long-term follow-up; (F) $Q_{max}$ difference after long-term follow-up.**
**CI = confidence interval; HoLEP = holmium laser enucleation of the prostate; M-TURP = monopolar transurethral resection of the prostate; SD = standard deviation.**

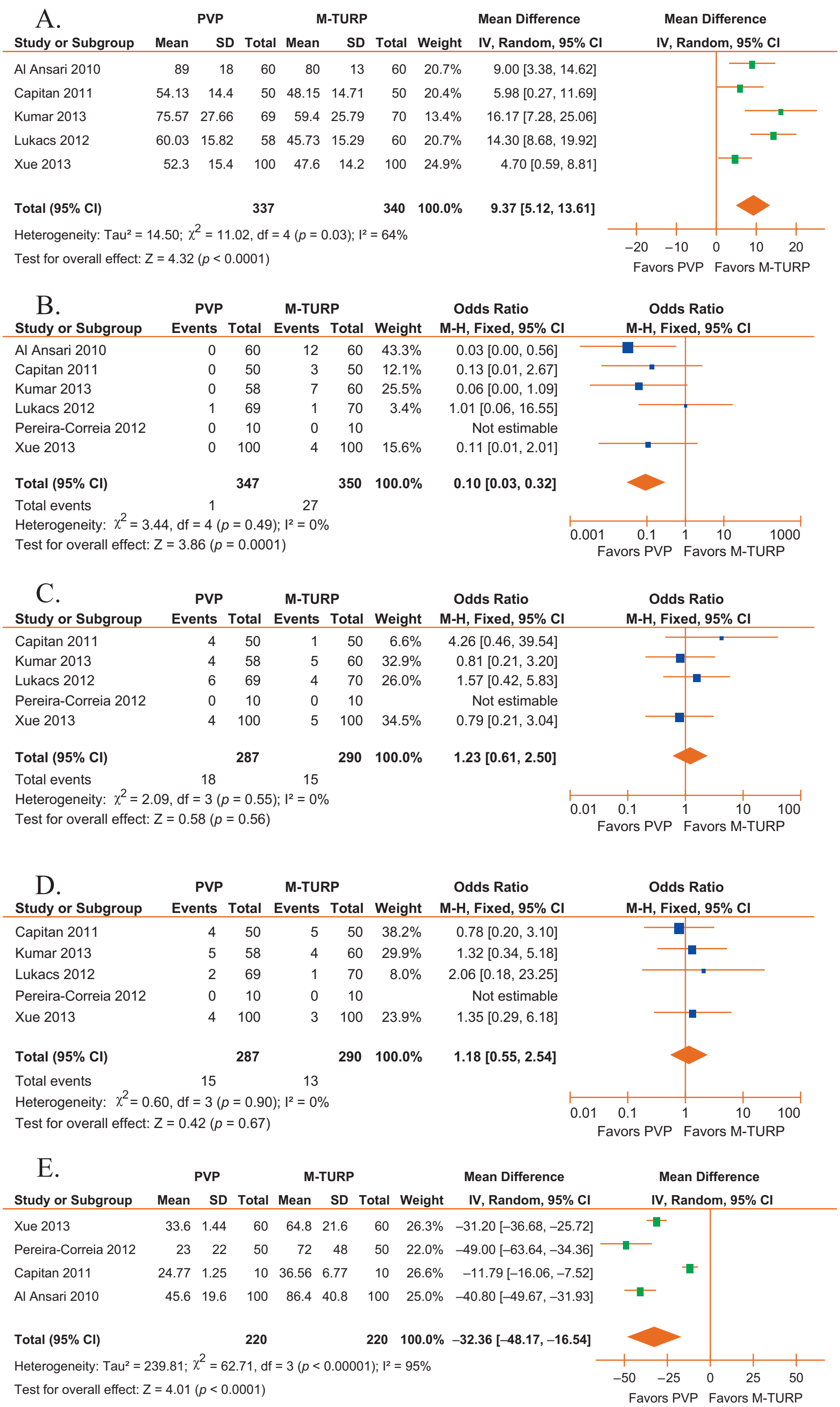



**Fig. 7 – Meta-analysis of efficacy and complications in studies comparing photovaporization of the prostate with monopolar transurethral resection of the prostate. (A) Intervention duration; (B) transfusion rate; (C) urinary tract infection; (D) acute urinary retention; (E) catheter duration; (F) length of stay; (G) bladder neck contracture (long term); (H) stricture (long-term rate); (I) reoperation for bladder outlet obstruction relief (long-term rate); (J) International Prostate Symptom Score at 12 mo; (K) maximum flow rate at 12 mo; (L) postvoid residual at 12 mo.**
**CI = confidence interval; M-TURP = monopolar transurethral resection of the prostate; PVP = photovaporization of the prostate; SD = standard deviation.**

[54], 70% for Kuntz et al. [55], and 88% for Elmansy et al. [49]). Overall, loss of ejaculation is surely the main complication of HoLEP, in accordance with the complete removal of the prostatic tissue inherent to the surgical technique.

With regard to PVP, the loss of ejaculation occurred less often than after HoLEP (22% vs 88% [49]), probably because of incompleteness of the procedure. Other studies have shown no difference between M-TURP and PVP based on IIEF-5 evaluation, advocating for an absence of erectile dysfunction following the two procedures [61,63]. These results were in line with those presented by Lukacs et al. based on individual items of the Danish Prostatic Symptom Score sex questionnaire (DAN-PSSsex) [62].

RCTs comparing PVP with M-TURP showed a lower rate of retrograde ejaculation among the PVP groups (30% after PVP vs 60.5% after TURP for Xue et al. [66], and 34.7% after PVP vs 65% after TURP for Capitan et al. [64]). Lukacs et al. pointed out a worsening of the ejaculation subscore of the DAN-PSSsex in 38% of cases compared with 61.5% after TURP [62]. These results are in favor of a favorable profile of PVP concerning sexual outcomes but still have to be confirmed with the 180-W XPS device compared with other standards.

Sexual adverse events after B-TURP seemed comparable with those seen after M-TURP, according to six RCTs that assessed IIEF-5 changes as secondary outcome. The most

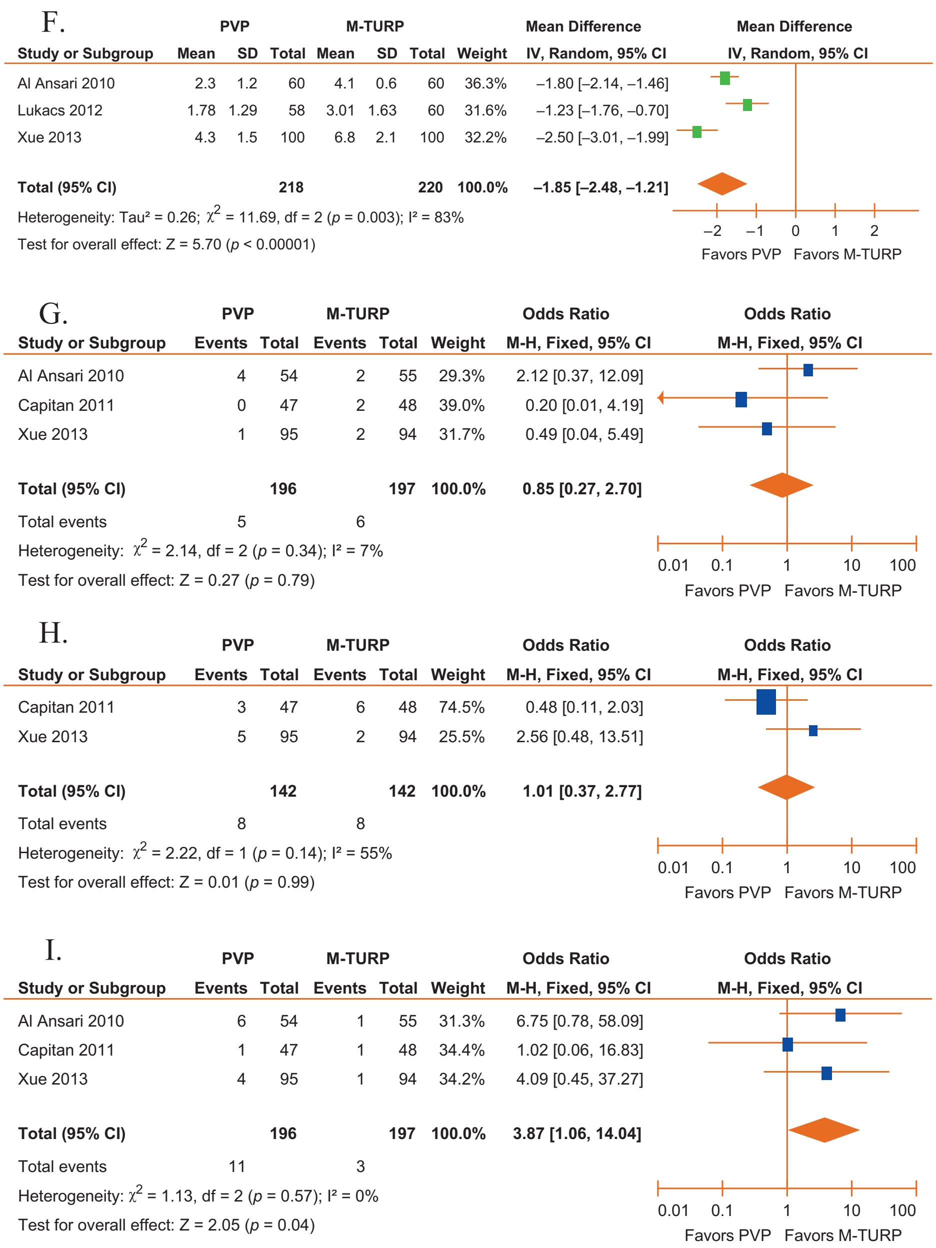



**Fig. 7. (*Continued*)**

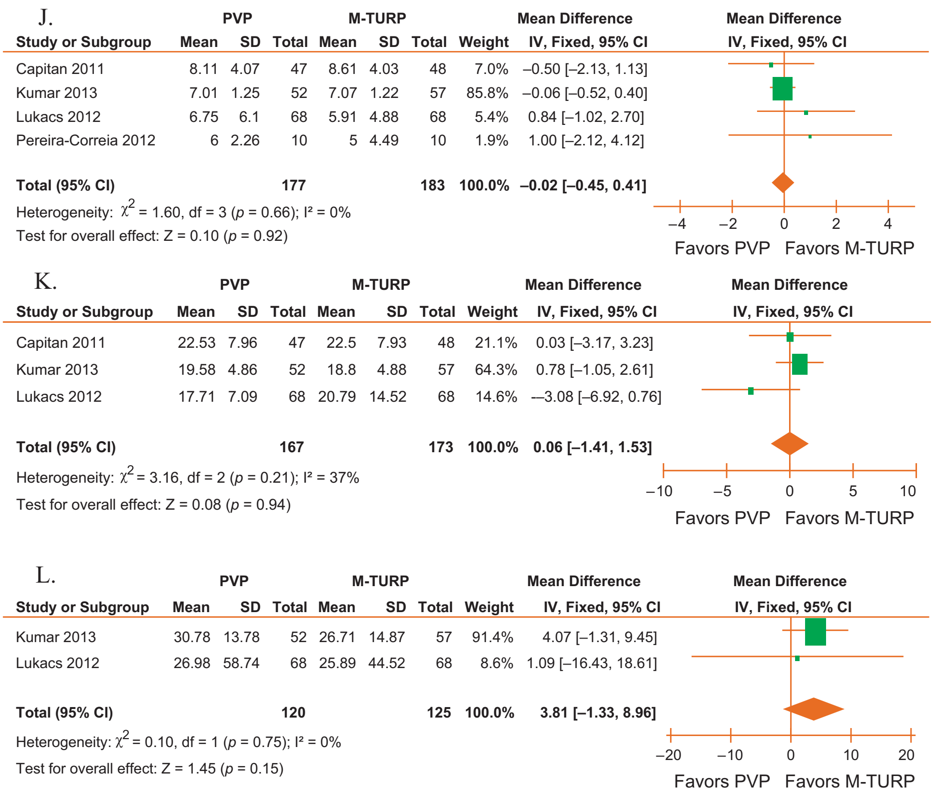



**Fig. 7. (*Continued*).**

relevant data come from the study conducted by Akman et al., who compared M-TURP with B-TURP (Olympus Surgmaster) in a 12-mo RCT focused on the IIEF-erectile function (EF) score [29]. The authors concluded that IIEF-EF variations were similar in each group, being stable overall. Most of the patients were unchanged, whereas 28.2% and 17%, respectively, improved and worsened their erectile function during follow-up. Furthermore, Mamoulakis et al. recently published a comprehensive evaluation of sexual function by the IIEF-15 in a RCT comparing M-TURP with B-TURP (AUTOCON II 400 ESU and Storz endourologic devices) [80]. Again, because some patients were improved, worsened, or were unchanged on the various sexual domains analyzed, the surgical procedure was not a predictor of any sexual function change during follow-up. All these data favor the noninferiority of B-TURP compared with M-TURP.

PKEP was recently compared with OP [59], B-TURP [58], and M-TURP [57]. As assessed by IIEF-5, no impact on erectile function was noted by the procedure in any trial, up to midterm follow-up, and was not significantly different from the comparator arms. The retrograde ejaculation rate after PKEP was found to be high (64.7% for Rao et al. [59] and 59% for Zhu et al. [58]), consistent with the results found with other enucleation techniques. Data about thulium laser techniques were limited to one study comparing M-TURP with thulium laser resection of the prostate [73], and it found no negative impact on erectile function, with a 55% rate of retrograde ejaculation, not significantly different from TURP. No data about sexual adverse events were available for ELEP and the diode laser.

### *3.10. Discussion*

Based on available studies published in the literature, with M-TURP the reference comparator, B-TURP showed comparable efficacy outcomes in the short term with a lower rate of complications. PVP was also shown to lead to similar short-term efficacy compared with M-TURP in patients with prostate volume <100 ml, with a reduced complication rate and potential advantages in patients at high risk of bleeding. HoLEP has been shown to provide durable efficacy, at least as good as conventional TURP in smaller prostates and similar to OP in larger prostates, with a lower risk of complications. The upcoming challenge is thus to optimize patient stratification, that is, to assess which technique should be preferred based on patient characteristics (prostate size, risk of bleeding, life expectancy, sexual symptoms). Current knowledge could justify the following approach for decision making:

- GreenLight photovaporization of the prostate should be offered for patients with prostate volume <100 ml and is seen as promising in patients at high risk of bleeding or high risk of complications.
- Enucleation (ie, HoLEP, which has the highest LE) should be offered for patients in whom complete enucleation of

the adenoma is required, especially in big prostates >100 ml.
- Resection using bipolar devices (B-TURP) should be considered as an alternative to M-TURP.

Further patient selection, regarding sexual outcomes, for example, cannot be based on strong evidence and is one of the most important challenges in the future regarding tailored treatment. Another issue is the accessibility and the diffusion of each surgical technique because not all centers have full access and expertise on all the available options.

Although an important number of LE 1 studies have been published to assess efficacy and complications of transurethral ablative procedures for BPO relief, our review highlighted several caveats in the available literature. First, the vast majority of the studies were conducted without specifically testing a scientific hypothesis; they simply compared functional outcomes and complications, often not even specifying a primary outcome criterion for comparison. Learning curve, which is a very important issue for new techniques, could not be taken into account because very few papers display adequate details about the level of training of the surgeons. Prostate size, a key factor for translating results into clinical practice and decision making, is not rigorously displayed in all studies. Several papers concluded with a statement of similar efficacy between two techniques, and very few reported a noninferiority trial, which may be misleading regarding data interpretation [5]. Inclusion criteria, including for critical parameters such as urinary retention at baseline, IPSS, and $Q_{max}$ data, patient age, prostate size, and anticoagulation therapies are not systematically reported. Furthermore, because LUTS are a chronic disease, and recurrence/reoperation is a very important issue in the field, only 21 studies exhibited a follow-up >24 mo (Table 1). Intermediate- and long-term studies often harbored a high rate of dropouts, as already underlined by Ou and Zimmern [81]. These issues, rather basic and methodological, should lead to clear recommendations for future research in the field to minimize study flaws and encourage authors to publish high-quality trials.

Indeed, despite the high number of trials available, some questions remain unsolved:

- As the use of PVP is currently expanding, the functional long-term results of the technique compared with TURP are unknown in the 180W era. No studies compared this technique with B-TURP, or HoLEP, that have also been depicted as reference techniques.
- There is no adequate LE 1 evidence to date addressing the results of current alternatives to TURP in patients with anticoagulant therapy.
- No study has compared promising alternatives (180W PVP, HoLEP, and B-TURP) in the specific population of men with large prostates.
- Sexual outcomes after promising emerging procedures such as PVP are not adequately studied in terms of erection and also ejaculation and sexual satisfaction. Sexual symptoms are exceptionally the main outcome criterion of published studies, and they are not systematically evaluated despite their recognized importance in LUTS management [78].
- Long-term retreatment rates are poorly documented.
- Cost effectiveness of those competing techniques globally but also given local and national conditions of cost and reimbursement remains to be assessed.

All this information, based on strong and reliable studies, would clarify treatment decision making as well as medicoeconomic issues.

## 4. Conclusions

The literature contains numerous LE 1 trials assessing efficacy and complications of transurethral procedures for BPO relief. However, the quality of the studies is rather low. Long-term assessment is lacking, evaluation of sexual adverse events is not sufficient, and no data allow the choice of a particular technique based on patient characteristics.

As TURP is still seen as the reference treatment, bipolar TURP has shown favorable outcomes with lower short-term complications. PVP shows results comparable with M-TURP with potential advantages regarding short-term perioperative complications, but supplemental evidence is needed to compare the PVP 180W XPS device and modern competitors (including B-TURP and HoLEP). HoLEP is the standard enucleation technique, with satisfactory midterm results and a low complication rate. Supplementary evidence is needed to establish the potential advantages of the PVP 180WXPS device against modern competitors including B-TURP and HoLEP. The other numerous alternative emerging surgical options require further evaluation.

***Author contributions:*** Jean-Nicolas Cornu had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

*Study concept and design:* Cornu, Ahyai, Bachmann, de la Rosette, Gilling, Gratzke, McVary, Novara, Woo, Madersbacher
*Acquisition of data:* Cornu, Novara, Madersbacher.
*Analysis and interpretation of data:* Cornu, Ahyai, Bachmann, de la Rosette, Gilling, Gratzke, McVary, Novara, Woo, Madersbacher.
*Drafting of the manuscript:* Cornu.
*Critical revision of the manuscript for important intellectual content:* Ahyai, Bachmann, de la Rosette, Gilling, Gratzke, McVary, Novara, Woo, Madersbacher.
*Statistical analysis:* Cornu, Novara, Madersbacher.
*Obtaining funding:* None.
*Administrative, technical, or material support:* None.
*Supervision:* Madersbacher.
*Other* (specify): None.

***Financial disclosures:*** Jean-Nicolas Cornu certifies that all conflicts of interest, including specific financial interests and relationships and affiliations relevant to the subject matter or materials discussed in the manuscript (eg, employment/affiliation, grants or funding, consultancies, honoraria, stock ownership or options, expert testimony, royalties, or patents filed, received, or pending), are the following: Jean-Nicolas Cornu has served on advisory boards for Biocompatibles UK and Takeda, and he has received consultancies/honorarium or travel grants from

Bard, AMS, Astellas, EDAP-TMS, Coloplast, Pfizer, and Bouchara-Recordati. Sascha Ahyai receives consultancies/honorarium from Lumenis and research grants from GSK. Alexander Bachmann is an advisor/speaker and principal investigator for AMS. Jean de la Rosette conducts workshops and symposia for Storz and Olympus. Peter Gilling is an investigator for Starmedtec and Procept Biorobotics. Christian Gratzke has received honoraria/served on advisory boards/acted an a consultant for AMS, Astellas, Bayer, GSK, Lilly, MSD, Neotract, Pfizer, Recordati, Rottapharm Madaus, and Steba. Kevin McVary is a consultant/advisor, conducts scientific study/trials, receives honorarium, and is a principal investigator for Allergan and Lilly/ICOS; consultant/advisor, conducts scientific studies/trials, and receives honorarium from NxThera; consultant/advisor and receives honoraria from Watson Pharmaceuticals; consultant/advisor and principal investigator for Neotract and principal investigator for NIDDK; and a meeting participant/lecturer for GSK. Giacomo Novara is an advisory board member or speaker for Astellas, GlaxoSmithKline, Lilly, Menarini, Nycomed, Pfizer, Pierre Fabre, and Recordati. Henry Woo has no conflicts of interest to disclose. Stephan Madersbacher receives consultancies/honorarium from AMS, Astellas, Pfizer, GSK, and Lilly.

*Funding/Support and role of the sponsor:* None.

## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.eururo.2014.06.017.

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