REVIEW

The Efficacy and Safety of Laser and Electrosurgical Transurethral Procedures for the Treatment of BPO in High-Risk Patients: A Systematic Review

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Objective: To compare efficacy and safety outcomes of GreenLight, Holmium and Thulium laser techniques with standard monopolar and bipolar transurethral resection of the prostate (TURP) in high-risk patients with lower urinary tract symptoms (LUTS) secondary to benign prostatic obstruction (BPO).

Methods: We conducted a systematic literature review of studies in patients undergoing BPO surgeries who may be considered high-risk for standard TURP, with higher risk defined as follows: large prostates (≥80 mL) and/or taking antithrombotic agents and/or urinary retention and/or age >80 years and/or significant comorbidity. Outcomes summarised included bleeding complications, re-intervention rates, hospital length of stay, and standard measures of disease and symptom severity for all available timepoints.

Results: A total of 276 studies of 32,722 patients reported relevant data. Studies were heterogeneous in methodology, population and outcomes reported. IPSS reduction, Qmax improvement and PVR were similar across all interventions. Mean values at baseline and after 12 months across interventions were 13.2−29 falling to 2.3−10.8 for IPSS, 0−19 mL/s increasing to 7.5−34.1 mL/s for Qmax and 41.4−954 mL falling to 5.1−138.3 mL for PVR. Laser treatments show some advantages compared with monopolar and bipolar TURP for some adverse events and safety parameters such as bleeding complications. Duration of hospital stay, reinterventions and recatheterisations were lower with GreenLight, HoLEP, Thulium lasers, and bipolar enucleation than TURP.

Conclusions: Laser therapies are effective and well-tolerated treatment options in high-risk patients with BPO compared with monopolar or bipolar TURP. The advantageous safety profile of laser treatments means that patients with a higher bleeding risk should be offered laser surgery preferentially to mTURP or bTURP.

Keywords: benign prostatic hyperplasia, high-risk, GreenLight, Holmium laser enucleation of the prostate, HoLEP, Laser, transurethral resection of the prostate, TURP

Introduction

GreenLight, Holmium and Thulium lasers are supported with evidence to treat benign prostatic obstruction (BPO) and are routinely used for vapourisation, vaporesection or anatomical enucleation of the prostate. Laser energy has potential haemostatic advantages over electrosurgical resection and may help prevent bleeding-related adverse events.[1] These techniques were introduced to provide alternatives to, and address some of the limitations of, electrosurgical resection.[2] This may be of particular importance in "high risk patients", a term which is often poorly defined but in the context of BPO surgery most closely relates to the characteristics of patients who are at higher risk of complications or adverse events if they underwent monopolar TURP (mTURP). TURP with glycine irrigation fluid results in a tissue removal rate of around 1 g/minute,[3] with a higher risk of TUR syndrome with prolonged operative time,[4] creating a size limitation for tissue removal.[5] Patients with large glands were therefore subjected to risk of TUR syndrome if a full resection was attempted or underwent sub-optimal removal of tissue. Post-operative bleeding, the need for continued or lengthy irrigation and

catheterisation and an appreciable risk of blood transfusion in patients means that the technique is less frequently attempted in patients taking antithrombotic agents,[6,7] while other comorbidities also increase the risk of complications after surgery for BPO.[8]

Thus, there is a group of patients in whom monopolar resection of the prostate tissue may result in increased adverse events or poorer functional outcomes. Given that the laser techniques were introduced partly to overcome these limitations of TURP and increase the availability of BPO surgery to patients who would be deemed higher risk if undergoing mTURP, it is reasonable to assess whether they have lived up to their promise. However, given evidence of some benefits already in the literature, there are very few randomised controlled trials in high-risk patients, due to ethical considerations.

Level 1 evidence of the safety of laser technologies for BPO treatment in high-risk populations is therefore lacking, but there have been numerous cohort studies that have included high-risk patients. The results of these studies and some prior evidence syntheses suggest some benefits of laser therapies in high-risk populations.[9] Where RCT evidence is lacking, as it is with high-risk men with BPO, patient management decisions are made on no evidence or on an assimilation of evidence from observational studies. This review was conducted to address this latter option and is an important addition to the body of knowledge on the best way to manage this subpopulation.

Prostate size increases with age, as do the prevalence of comorbidities and the resultant polypharmacy, including an increased incidence of antithrombotic (anti-platelet aggregation and oral anticoagulants, OACs) agent utilisation.[10,11] Age, therefore, although not necessarily a risk factor on its own, is a proxy measure for these other risk factors. Average prostate size at surgical intervention is also increasing[12] and in some geographies more patients present for surgery in acute urinary retention or with an indwelling catheter.[11,13] A greater understanding of any potential benefit that laser treatment might bring to high-risk patients could help doctors and patients in a shared decision-making process.

This systematic literature review was conducted to identify relevant observational and comparative studies of GreenLight (120 and 180 W), Holmium and Thulium laser therapies, and other enucleation and vapourisation therapies, versus standard electrosurgical transurethral resection of the prostate (TURP) in high-risk patients and determine any differences in efficacy and safety. The definitions of high-risk populations in this review were based on those agreed for a submission to the National Institute for Health and Care Excellence (NICE) in the UK. It is worth noting, however, that the level of risk associated with each of these characteristics may be modified by the surgical procedure undertaken. Urologists in practice select the intervention that they think will provide the greatest benefit and/or smallest risk to the individual patient. The aim of this review is to provide surgeons and patients with as comprehensive an evidence base as possible upon which to make these decisions.

Material and Methods

In this review, the following high-risk groups were included:

1. Increased bleeding risk, including anticoagulant and anti-platelet drug use;
2. Large prostate size (>80 mL);
3. A history of urinary retention or presence of an in-dwelling catheter;
4. Older age (>80 years);
5. Significant comorbidity.

These groups of patients would be considered at higher risk from complications if they were undergoing mTURP.

Search Strategy and Study Selection

We searched Medline, PubMed and Embase on 28th March 2022, as well as manually searching for relevant grey literature, for randomised and single-arm clinical trials and observational studies of laser vapourisation and enucleation or TURP in high-risk men with BPO (see Supplementary Information, Tables S1–S3). These records were each screened independently by two researchers according to the inclusion criteria in Table S4, and disagreements reconciled by discussion. All studies potentially meeting the inclusion criteria were retrieved and the full text screened for relevance by two senior researchers independently, with disagreements resolved by discussion. Studies were included in the review

only if relevant data were reported for a population who were all at high risk. For example, many studies included men with a mean prostate size >80 mL, but were only included in the review if data were reported for a subgroup who all had a prostate size of >80 mL, or where the lower value of the 95% confidence interval was above this threshold. The citation lists of systematic reviews were searched to identify additional relevant publications. Reasons for excluding publications from the review after full-text screening are reported in Table S5. Data were extracted from the publications for all outcomes of interest by one researcher and checked by a second, with disagreements resolved by the project leader.

Types of Participants and Interventions Included

Efficacy and safety outcome measures with comparable data in high-risk populations were extracted, including International Prostate Symptom Score (IPSS), maximum urinary flow rate (Qmax), post-void residual volume of urine (PVR), bleeding complications, re-intervention rates and hospital length of stay. Data were extracted for all available timepoints and where specific definitions of outcomes, eg bleeding or hematuria, were given, these were also recorded. Absolute post-operative values and mean changes from baseline were extracted for continuous variables with measures of variance and statistical significance. Other details including baseline characteristics and funding were also extracted.

Assessment of Risk of Bias

Risk of bias was assessed by two researchers independently using the Cochrane RoB2 tool for RCTs and questionnaires from the Joanna Briggs Institute for cohort and cross-sectional studies. Due to the expected heterogeneity in study methodology, populations and assessment of outcomes, no formal statistical synthesis or sensitivity analyses of the results, assessment of publication bias or of the certainty of the body of evidence for each outcome was planned, but data were summarised in tables and charts using R software functions.

Results

After deduplication, the searches identified 5980 records, of which 268 studies had relevant data for the selected interventions and outcomes for this publication, from a total of 31,862 patients (Figure S1). The data are presented according to the different sub-groups of high-risk men. Different procedures have different risk-benefit ratios within these sub-groups and so presenting the data in this way should help inform clinical practice where patients present with a particular high-risk characteristic.

A total of 147 studies contained data on 19,342 patients who were recruited primarily for having large prostates, 37 reported on 4287 men selected for having urinary retention or an indwelling catheter and 53 studies reported data on 5757 men who were recruited because they were taking antithrombotic agents (Table S6, Supplementary Information). Few studies assessed outcomes in men who were selected for having other comorbidities (21 studies, 1923 patients), for being aged ≥80 years or for being assessed as ASA grade III–IV (12 studies, 1175 patients). In the studies selected, patients may have multiple high-risk features (Table S7). For consistency, analysis of specific risk factors has been based on the primary high-risk category the source study reported, that is, the feature for which the patients were included in the study. Table 1 shows the number of studies and patients reporting data for each intervention using the study methodology and primary high-risk categories. The patient numbers in most cases were underestimated as many studies that were only available as abstracts did not report the sample size.

Efficacy Outcomes
Functional Outcomes

Across all high-risk sub-groups, most studies reported IPSS (Table S8), Qmax (Table S9) and PVR measurements (Table S10) over time (Figure 1), however follow-up times were less commonly reported beyond 12 months. For each outcome, there was considerable variability across studies for each intervention. All interventions showed similar efficacy in IPSS reduction, Qmax improvement and PVR reduction over the time periods observed. Mean baseline IPSS scores per study ranged from 13.2 to 29 across interventions, falling to 2.3 to 10.8 at 12 months. Mean baseline Qmax ranged from 0 to 19 mL/s across studies, increasing to 7.5 to 34.1 mL/s at 12 months. Mean baseline PVR was 41.4 to 954 mL, falling to 5.1 to 138.3 mL at 12 months.

Table 1 Summary of the Total Number of Patients from the Studies Included in the Full Systematic Literature Review by Intervention, Study Methodology, and Primary High-Risk Category

Interventions	Study Methodologies Number of Patients [a](Number of Studies)				Main Category of "High-Risk" Population Number of Patients [a](Number of Studies)				
	RCT	Single-Arm Trial [b]	Prospective Observational	Retrospective Observational	Large Prostate (≥80 mL)	Urinary Retention	Anticoagulants/ Antiplatelets	Comorbidities	Mixed Risk-Factors
GreenLight 120W	-	5 (277)	11 (770)	19 (1502)	13 (1288)	4 (188)	11 (549)	2 (149)	5 (375)
GreenLight 180W	1 (10)	6 (837)	6 (1060)	31 (4267)	17 (2911)	6 (448)	9 (1198)	3 (270)	7 (967)
GreenLight (other) [c]	3 (157)	4 (255)	12 (1378)	17 (1338)	17 (1697)	2 (101)	10 (564)	3 (368)	4 (398)
HoLEP	13 (759)	3 (276)	11 (1049)	60 (10,703)	50 (5492)	12 (1613)	17 (4688)	4 (338)	4 (656)
ThuLEP	3 (253)	1 (93)	3 (495)	7 (644)	10 (892)	2 (236)	-	2 (357)	-
Thulium (other) [d]	1 (58)	3 (273)	6 (2080)	9 (671)	12 (2505)	1 (93)	5 (446)	-	1 (38)
DiLEP	1 (40)	-	-	1 (49)	1 (40)	-	1 (49)	-	-
Enucleation	7 (434)	-	3 (192)	7 (525)	15 (1108)	-	1 (24)	1 (19)	-
BiVAP	-	-	2 (94)	3 (163)	3 (189)	-	1 (54)	1 (14)	-
b-TURP	16 (918)	2 (100)	10 (864)	8 (723)	24 (1609)	3 (95)	3 (338)	3 (151)	3 (412)
TURP	16 (984)	3 (312)	21 (2357)	12 (774)	17 (1534)	18 (1271)	5 (461)	4 (389)	7 (695)

Notes: [a]Number of participants was not reported in many studies, so these values may be an underestimation of the total number of patients. [b]Includes randomised control trials with only one relevant intervention arm. [c]Includes older GreenLight 80W systems, GreenLEP, and undefined interventions. [d]Includes undefined thulium lasers, ThuVEP, ThuVAP, and ThuVARP.

Figure 1 Mean and median baseline and follow-up IPSS score, Qmax (mL/s), and PVR (mL) over time, by intervention group and primary high-risk category. Different colours indicate the different population risk groups. Filled in circles are mean values and outlined circles are median values. Horizontal lines represent the weighted averages.

Some differences were seen in the response to different interventions across high-risk subgroups. Patients with large prostate glands showed a significant reduction in IPSS scores across treatment modalities, with no major differences in durability. In men with indwelling catheters, post-operative IPSS was good across all modalities, with greater hetero-geneity of IPSS response to GreenLight 180 W compared with other treatments at the 1-month and 3-month time points but generally being a little higher than other modalities at 6 months and 1 year. Holmium laser enucleation of the prostate (HoLEP) and bipolar enucleation therapies demonstrated the best sustained reduction in IPSS at 24 months; however, data for bipolar enucleation were limited (Table S8).

In patients with large prostates, HoLEP gave the greatest improvement in Qmax, other enucleation therapies showed similarly substantial improvements although much less data was available, and a slightly lower reduction can be seen following GreenLight or bTURP. In men taking anticoagulants or antiplatelets, HoLEP and GreenLight 180 W report consistent clinically significant high improvements in Qmax from baseline to all follow-up points. Thulium shows the greatest improvement, but data were only available from 3 studies. In men with indwelling catheters, Qmax improve-ments seem similar across techniques, and are sustained up to the 2-year time point across therapies (Table S9). All interventions show relatively similar improvements in PVR up to the 2-year follow-up, and this improvement is consistent across the different high-risk categories (Table S10).

Peri-Operative Outcomes
Mean operative time was greatest in patients with larger glands across all treatments when compared with other high-risk classes. In patients taking anticoagulant and anti-platelet drugs, operating time appears a little longer with Holmium laser compared with other modalities.

Hospital length of stay is a proxy marker for bleeding and other complications after surgical interventions for BPO. The weighted mean length of stay (shown by the horizontal lines in Figure S2) was similar to GreenLight 120 W, GreenLight 180 W, HoLEP and Thulium lasers at between 1 and 3 days, and was slightly higher with enucleation and significantly higher with TURP (Table S11, and Figure S2). Up to 72% and 76% of high-risk patients were treated with GreenLight 180 W and 120 W, respectively, as day cases. Up to 86% of patients treated with HoLEP are reported to have been treated as day cases and up to 95% are reported to have a hospital stay of no more than 1 day; however, it is unclear in this study whether these are truly day cases. Day-case rates were not reported for any other intervention (Table S11).

Duration of hospital stay was greater for bTURP and mTURP overall. GreenLight, HoLEP and Thulium laser treatments are associated with substantially shorter stays than both mTURP and bTURP in patients with large glands, patients taking anticoagulants and anti-platelet drugs and "other high risk groups".

Safety Outcomes
The overall adverse event reporting in the studies retrieved was inconsistent.

Serious Adverse Events
Reporting of serious adverse events (Clavien-Dindo grade ≥3) was inconsistent across the studies and in many cases was not reported at all. In studies not reporting adverse events by severity, we cannot assume that there were no cases. More serious
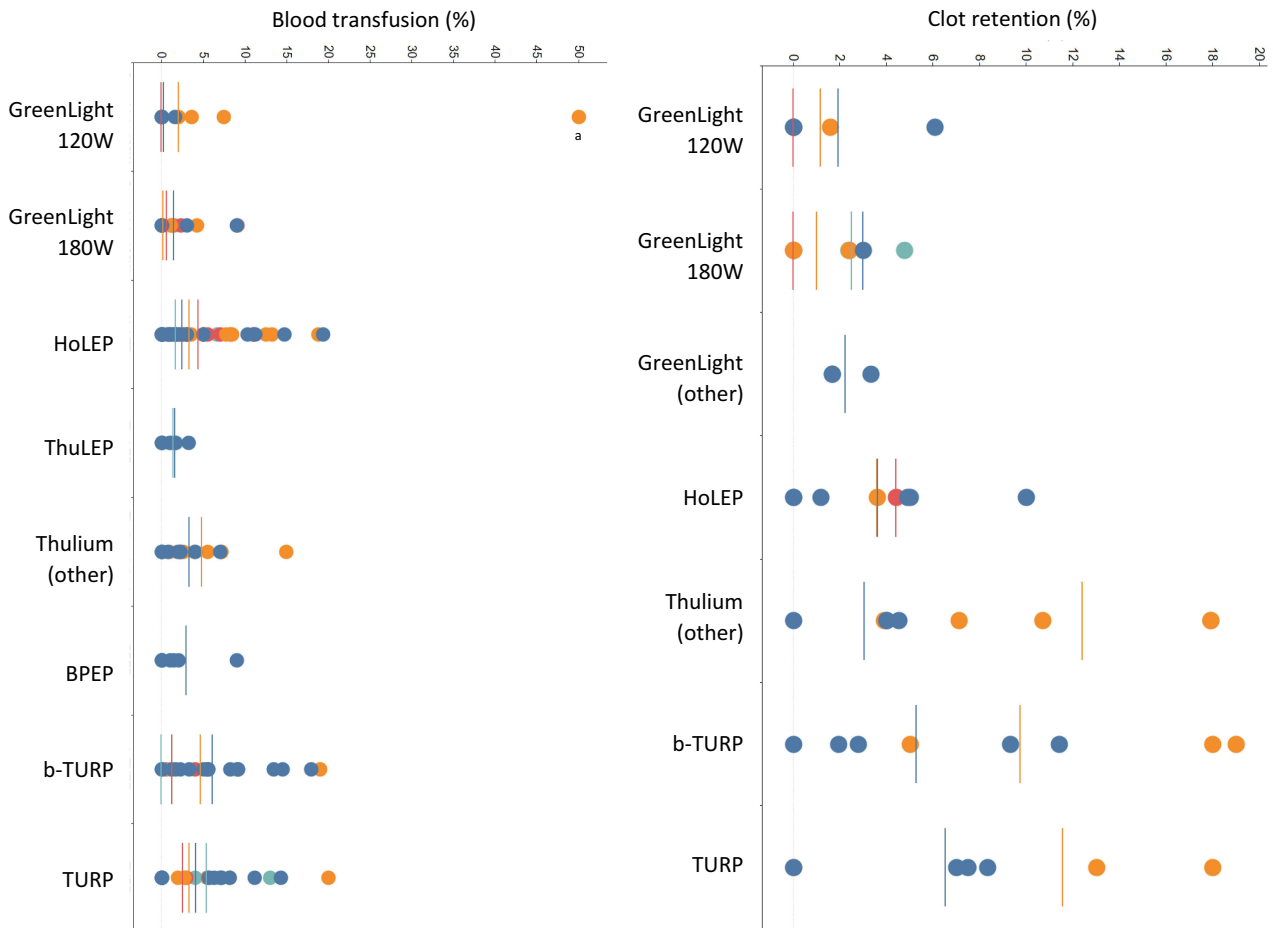

Figure 2 Clot retention and blood transfusion rates, by intervention group and primary high-risk category. Different colours indicate the different population risk groups. Filled in circles are mean values and outlined circles are median values. Horizontal lines represent the weighted averages. [a]One study reported 50% blood transfusion from a sample of 2 patients on anticoagulants.
Notes: Population high-risk group: ■Large prostate, ■Anticoagulant or antiplatelet therapy, ■Urinary retention, ■Other. Data type: ●Mean, ○Median.

adverse events tend to be the least common and therefore with smaller sample sizes there is less chance these events will occur. Moreover, the majority of the studies included in the review were observational, in which clinicians may have chosen what they consider to be the safest intervention based on the patients' risk profile. Subsequently, interventions preferred by the clinicians have a greater chance of encountering more severe adverse events and may paradoxically be interventions with the highest complication rates. Due to heterogeneity across the studies in terms of the population baseline characteristics and inconsistent reporting, it is difficult to get an accurate interpretation of the true rate of events.

Clavien grade 5 outcomes were reported for mTURP and bTURP in patients with large glands and for GreenLight, bTURP and HoLEP in patients taking antiplatelet and anticoagulant drugs. Overall rates of Clavien grade 5 adverse events were very low across all studies (4 deaths reported in 10,747 patients with HoLEP (0.04%), 4 out of 9341 patients with GreenLight (0.04%), 3 out of 4449 patients with Thulium lasers (0.07%), 19 out of 3334 patients with TURP (0.57%) and none reported out of 1778 patients with bTURP, 1109 patients with bipolar enucleation or 281 patients with bipolar vapourisation.

Clavien grade 3 and 4 complications were also low across all interventions and all high-risk population groups. Clavien grade 4 complications were reported for 18 out of 1501 patients with data for GreenLight (1.2%), 7 out of 1035 patients with data for HoLEP (0.7%), 8 out of 1813 with Thulium lasers (0.4%), 0 out of 53 patients with enucleation (0% from one study), and 1 out of 314 patients with bTURP or mTURP (0.3%). A similar pattern of results was evident with the reporting of Clavien grade 3 adverse events, with higher rates reported for laser interventions than TURP and enucleation.

Bleeding Complications

The range in proportion of patients with more objectively measured bleeding outcomes is summarised in Table S12. Although all included interventions had studies where no patients required blood transfusion, this was required in up to 20% of anticoagulated patients treated with TURP, up to 18.8% treated with HoLEP, 14.9% after Thulium, 7.4% after GreenLight 120 W and 4.2% after GreenLight 180 W. In patients with large glands, rates of blood transfusion were up to 19.3% after HoLEP, 17.9% after bTURP, 14.2% after mTURP, 9% after each of GreenLight 180 W and bipolar enucleation, and 7% after Thulium. Similar results were shown in patients with urinary retention or comorbidities, with mTURP, bTURP and HoLEP having the highest rates of blood transfusion. The weighted mean blood transfusion rates were lowest with GreenLight 120 or 180 W, compared with the other interventions (Figure 2). In patients with urinary retention, none of those treated with Greenlight or mTURP required transfusion, compared with 2.78% of patients after HoLEP and 1.7% after Thulium laser.

The maximum reported proportion of patients with clot retention was also lower with GreenLight than the other interventions (Figure 2), although again all interventions included studies where no patients developed this complication. Up to 6.3% of patients had clot retention after GreenLight 120 W and 4.8% after GreenLight 180 W, compared with up to 10% with HoLEP, 17.9% after Thulium laser, 18% with mTURP and 19% after bTURP. The weighted mean values for clot retention were <2% with GreenLight 120 W, <3% with GreenLight 180 W, but >3% with HoLEP and Thulium lasers, and >6% with bTURP or mTURP (Figure 2).

Re-intervention rates for clot retention and haematuria were not well reported across the studies (Table S12, Figure S3). Re-intervention rates were only included in the review if they were reported after a 3-month follow-up as this would indicate a failure of the original intervention or a long-term complication. Haematuria, clot retention and reintervention for bleeding were highest after mTURP. Haematuria occurs most frequently after mTURP and least often after HoLEP.

Other Outcomes and High-Risk Subgroups

Data for urethral stricture, bladder neck contracture and recurrent BPO are summarised in Table S13, and data for urinary retention-related outcomes are summarised in Table S14 and readmission rates by reason of readmission are shown in Figure S4 in the supplement.

Discussion

There are ethical concerns in randomising high-risk patients between different surgical treatments for BPO.[14] This is due to concerns about exposing high-risk patients to TURP, which would be an obvious comparator in any randomised controlled trial. As a result, there is a paucity of direct comparative evidence on the respective benefits or risks of

different energy sources in these populations. Concerns over complications from mTURP mean that many patients are not offered surgery, even when in urinary retention; a recent study showed that older patients with comorbidity make up the majority of community-based patients with long-term in-dwelling catheters. Long-term catheterisation is associated with a significant risk of urinary infection and adverse events.[15]

Principal Findings

This review addressed this evidence gap by synthesising observational evidence on the treatment of high-risk men with BPO. It therefore provides important new information to guide the management of these hard-to-treat patients.

While a number of different surgical treatments are clinically proven, the patient's treatment choice is likely to be driven by their risk tolerance of potential adverse events and complications. This paper provides a distillation of the available evidence to help guide patients and urologists in this shared decision process.

All surgical techniques reviewed provide good symptomatic relief, improvement in urinary flow rate and reduction in post-void residual urine volume. In these high-risk populations, the benefits of treatment persist for at least 4 years with GreenLight, Thulium laser therapy and TURP, and for at least 3 years for HoLEP, suggesting that the need for re-intervention due to recurrent lower-urinary tract symptoms will be low over these time periods following any of these procedures. This is important since reducing the need for any future surgery reduces exposure of these patients to further surgical risk. However, for many high-risk men, their life expectancy will be limited by their underlying comorbidities, so longer term benefits from reduced need for further surgery may not be achieved.

Although the heterogeneity of the data and the lack of comparative studies means that a formal statistical comparison of outcomes is not feasible, the data identified in this review suggest that certain surgical interventions may be preferable to others in men with different reasons for being considered high-risk. In patients with in-dwelling catheters or a history of urinary retention, HoLEP provides the greatest improvement in post-void residual volume of urine and the greatest improvement in Qmax. It also offers the greatest likelihood of remaining reintervention-free. In patients with large prostate glands, the laser modalities out-perform mTURP and bTURP for safety outcomes. In patients taking antithrombotic agents, the risk of bleeding-related complications is lowest with GreenLight and highest for Thulium, mTURP and bTURP. In all subgroups, procedures utilising laser energy result in shorter hospital stays and shorter periods of catheterisation than electrosurgical procedures. However, given that many high-risk patients have multiple comorbidities, the selection of the most appropriate surgical technique will always have to be determined on a case-by-case basis. Overall, laser treatments were beneficial compared with TURP in terms of safety and adverse events, and duration of hospital stay, re-interventions and re-catheterisations were lower with lasers than TURP.

Our study agrees with other systematic literature reviews of specific high-risk subgroups. Liang et al[9] found that the risk of bleeding complications was 2.58 times greater in men treated with TURP who were taking anticoagulants or antiplatelets than not, but that those treated with HoLEP or photoselective vapourisation of the prostate (PVP), such as GreenLight, had a bleeding risk that was not significantly different from the control group. Albisinni et al[16] concluded that laser prostate vapourisation or enucleation with GreenLight PVP or HoLEP was safe in frail, elderly men, while Pascoe et al[17] found no increase in complications after PVP in men with prostates larger than 100 mL compared with in those with smaller glands, although operative time and retreatment rates were higher. In general, systematic reviews of high-risk men with benign prostatic hyperplasia concur that all available interventions have comparable efficacy, particularly with IPSS, Qmax, and PVR outcomes, but that laser enucleation and vapourisation therapies have a more favourable perioperative profile, in terms of length of stay, blood loss, and catheterisation time.[18–22]

The few RCTs identified in this review also support these assertions. RCTs of GreenLight and HoLEP versus TURP report significant benefits with the laser treatments in terms of catheterisation time and hospital length of stay.[23,24] GreenLight is also shown to have significantly lower perioperative bleeding compared to TURP,[23] while HoLEP does not but does have significantly shorter operative time compared to TURP.[24] Similar results have been reported for HoLEP versus bipolar enucleation,[25] and bipolar enucleation has been shown to be superior to bTURP with respect to operative time, catheterisation time, postoperative bleeding complications and bladder neck contracture.[26]

Strengths and Limitations

This systematic review has a number of limitations, most of which relate to the generally incomplete and inconsistent reporting of data from observational studies. Statistical comparisons were not feasible due to the heterogeneity in both the study methodology and baseline characteristics. There is no universally agreed definition of "high risk", so thresholds for reporting prostate size, in particular, varied across studies. We have included studies where outcomes were reported for a group of patients who all had a prostate size of 80 mL or more, or where the mean prostate volume and the lower margin of the 95% confidence interval for the study population were all above 80 mL, but our subgroup of men at high risk due to prostate size is heterogeneous for this feature. There was also heterogeneity in whether urinary retention was historical or patients had indwelling catheter at the time of admission, and in the type and severity of comorbidities or of anticoagulant and antiplatelet use.

Studies conducted on a particular subgroup of patients used different cut-off values to determine whether patients met the specified high-risk criteria, and this has led to heterogeneity within these groups of studies. In addition, participants in studies who were all selected for having a specific risk factor (eg large prostate) frequently also have other risk factors (eg existing cardiovascular disease or taking antiplatelets/anticoagulants). This makes it difficult to provide a precise analysis of a homogeneous subgroup with a specific risk factor, but it does mean that the results reflect clinical practice, where the concept of a high-risk patient is also not well defined.

Although IPSS, Qmax and PVR were reported by most studies, follow-up times ranged from 1 to 60 months. Measures of complications, in particular bleeding events, varied and were usually poorly defined, the timepoints at which "perioperative" and "postoperative" outcomes were reported were often not stated, and whether complications required re-intervention were also frequently unclear. This inconsistent and incomplete reporting is of concern, as it hinders the ability of high-risk patients to be fully informed about their treatment options. This is particularly the case since RCTs can be unethical in this population and so treatment and reimbursement decisions are dependent on observational evidence to supplement the relatively few RCTs that have been done for newer interventions. This lack of comparative data, and the heterogeneity of the observational data, means it is not possible to perform a meta-analysis. In the absence of such an analysis, this synthesis is necessary to provide insight when trying to decide how best to manage high-risk patients. Future research should aim to report outcomes and complications in a more standardised way so the relative benefits and harms of these and new interventions can be better determined.

Conclusion

In this systematic review, we asked whether the current laser interventions for BPO are better than TURP, in the patients for whom TURP is known to be associated with a high-risk of adverse events or poor functional outcomes. Ethical considerations mean that high-quality RCT data directly comparing techniques in high-risk groups are likely to continue to be lacking. The heterogeneity of the observational studies reviewed, both in inclusion criteria and outcome measures means that only directional qualitative conclusions are possible. In high-risk patients, the data available generally support the conclusion that laser therapies are able to provide comparable functional outcomes to electrosurgery and have an overall safety benefit and favorable perioperative outcomes, with specific benefits in high-risk subgroups. This data should help urologists and patients in their shared decision process.

Acknowledgments

Author Contributions

Glyn Burtt and Emily Woodward were responsible for the conception of the literature review. Alison Martin and Cassandra Springate contributed to the study design, execution, data acquisition and synthesis, and drafting of the manuscript. Paul Zantek contributed to the interpretation of the data. Feras Al Jaafari, Gordon Muir, and Vincent Misrai

contributed to the interpretation of the data and the writing of the manuscript. All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval for the version to be published; and agreed to be accountable for all aspects of the work.

Disclosure

Glyn Burtt, Emily Woodward and Paul Zantek are employed by Boston Scientific. Cassandra Springate and Alison Martin are employed by Crystallise Ltd, who received funding from Boston Scientific to conduct the research. Feras Al Jaafari has worked as a consultant for Boston Scientific. Gordon Muir has worked as a consultant for Boston Scientific, PROCEPT and Olympus GMBh. Vincent Misrai has worked as a consultant for Boston Scientific. The authors report no other conflicts of interest in this work.

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