Meta Analysis

Current Urology

OPEN

Aquablation in men with benign prostate hyperplasia: A systematic review and meta-analysis

David C. Chen[a,b], Liang Qu[a,b], Howard Webb[a], Kirby Qin[a], Bodie Chislett[a], Alan Xue[a], Sari Khaleel[c], Manuel De Jesus Escano[d], Eric Chung[e], Ahmed Adam[f], Damien Bolton[a], Marlon Perera[a,*]

[a]Department of Surgery, University of Melbourne, Austin Health, Melbourne, Australia; [b]Young Urology Researchers Organisation (YURO), Melbourne, Australia; [c]Urology Service, School of Medicine, University of Minnesota, Minneapolis, MN, USA; [d]Research Department, Universidad Iberoamericana, Santo Domingo, Dominican Republic; [e]Princess Alexandra Hospital, Woolloongabba, Brisbane, Australia; [f]Division of Urology, Department of Surgery, Faculty of Health Sciences, University of the Witwatersrand, School of Clinical Medicine, Johannesburg, South Africa

Abstract

Objective: The aim of the study is to investigate improvements in lower urinary tract symptoms in men with benign prostatic hyperplasia (BPH) treated with prostatic Aquablation.

Materials and methods: We performed a literature search of clinical trials using the MEDLINE, Embase, and Cochrane Library databases and retrieved published works on Aquablation for the treatment of BPH up to August 2021. Unpublished works, case reports, conference proceedings, editorial comments, and letters were excluded. Risk of bias was assessed using the ROBINS-I tool. Raw means and mean differences were meta-analyzed to produce summary estimates for pre- versus post-International Prostate Symptom Scores, maximum flow rate, and male sexual health questionnaire value changes. An inverse-variance weighted random effects model was used.

Results: Seven studies were included in this review (n = 551 patients) that evaluated various urological parameters. At 3 months, the International Prostate Symptom Scores raw mean difference from baseline was −16.475 (95% confidence interval [CI], −15.264 to −17.686; $p < 0.001$), with improvements sustained for 12 months. Similarly, maximum flow rate improved by +1.96 (95% CI, 10.015 to 11.878; $p < 0.001$) from pre to 3 months postoperatively. In addition, the male sexual health questionnaire change pooled effect size was −0.55 (95% CI, −1.621 to 0.531; $p = 0.321$) from preintervention to postintervention at 3 months. Meta-analyses of some outcomes showed large statistical heterogeneity or evidence of publication bias.

Conclusions: Aquablation seems to improve lower urinary tract symptoms in men with BPH while providing relatively preserved sexual function. Further research is required to confirm these preliminary results.

Keywords: Benign prostatic hyperplasia; Prostate; Aquablation; Meta-analysis

1. Introduction

Lower urinary tract symptoms (LUTS) secondary to benign prostatic hyperplasia (BPH) are estimated to affect up to 30% of men in Europe older than 50 years, presenting as moderate to severe urinary tract symptoms.[1] Up to 30% of patients are refractory to nonsurgical therapy, as unsatisfactory improvements in their LUTS lead them to require surgical intervention.[2–4] Transurethral resection of the prostate (TURP) remains the criterion standard for treating LUTS, with significant and reliable results.[4] However, TURP is associated with long-term morbidity, including ejaculatory dysfunction, erectile dysfunction, and urethral strictures.[5] In an effort to limit these adverse effects, considerable research has been undertaken to develop novel technologies to address BPH. Such technologies include minimally invasive surgical interventions, including prostatic urethral lift[6] and Rezum. While these techniques limit the destruction of native tissue with potentially less of the abovementioned potential morbidities associated with TURP, there is a reduced efficacy of International Prostate Symptom Scores (IPSS) improvement relative to TURP, as well as varying degrees of retreatment rates.[7,8] Accordingly, there is a need for a more invasive and enucleative process that is associated with improved adverse effect profiles compared with TURP.

Aquablation was performed using the AquaBeam System (AquaBeam; PROCEPT BioRobotics, Inc, Redwood Shores, Calif). Aquablation was initially described in 2015 and is a minimally invasive surgical intervention that combines programmed robotics and imaging guidance for the treatment of LUTS secondary to BPH by removing hyperplastic prostate cells. While still considered a minimally invasive procedure, Aquablation is performed in the lithotomy position under general anesthesia.[9] The AquaBeam system consists of a conformal planning unit, a console, and a robotic handpiece. This is a highly automated procedure. Aquablation delivers high-pressure and heat-free ablation, creating patency in the prostatic urethra. The conformal planning unit allows for individualized prostatic mapping by the operating surgeon, which adjusts for the angle, length, contour, and depth of penetration of the high-pressure water beam. The

*Corresponding Author: Marlon Perera, 145 Studley Rd, Heidelberg, Melbourne, VIC 3084, Australia. E-mail address: marlonLperera@gmail.com (M. Perera).

Supplemental Digital Content is available for this article.

Current Urology, (2023) 17, 1, 68–76

Received January 4, 2022; Accepted March 1, 2022.

http://dx.doi.org/10.1097/CU9.0000000000000122

procedure has been described in detail previously and allows for more controlled ablative techniques within predetermined parameters tailored to the patient.[9]

To date, several studies have reported patient outcomes after the use of Aquablation systems for the treatment of LUTS secondary to BPH. A previous systematic review has been published, although limited data are available for pooled estimates.[10] In addition, in the previously mentioned meta-analysis, a considerable proportion of patients were recruited from prospective trials. Accordingly, this study aimed to collate available data on Aquablation using a systematic search strategy and to quantify the urinary, sexual, and quality of life outcomes using meta-analysis. We intend to include patients who are representative of the "real-world" experience of Aquablation. The study was performed independently without consultation or input from PROCEPT BioRobotics, Inc.

2. Materials and methods

2.1. Registration, search strategy, and selection criteria

A systematic review of the literature was performed in accordance with the Cochrane Collaboration and Preferred Reporting Items for Systematic Review and Meta-analysis guidelines.[11] Scientific literature databases including the Web of Science (MEDLINE), Embase, and Cochrane Libraries were systematically searched in August 2021 using several keywords: ("prostate" or "benign* prostat* hyperp*" or "BPH*") and ("aquablat*" or "water jet*"). The search strategy and article selection were performed by 3 independent evaluators (D.C., H.W., and L.Q.) and any discrepancies were resolved. After screening based on the study title and abstract contents, the remaining articles were assessed based on the full text and excluded when appropriate. Unpublished works, case reports, conference proceedings, editorial comments, and letters to the editor were excluded because quality appraisal was not possible.

Studies that analyzed ablation outcomes in men with BPH were included in the analysis. Study designs considered for inclusion included randomized clinical trials, prospective studies, and retrospective cohort studies. Restrictions including English-language publications and a minimum sample size of 10 patients were used. Where duplicate study populations or analyses of repeated data were identified from the literature review, publications reporting a larger sample size were used for analysis.

2.2. Quality assessment

Quality of the studies was assessed based on the *Cochrane Handbook for Systematic Reviews of Interventions*, version *5.02*.[12–14] A quality appraisal tool was adapted for the current research meta-analysis based on the Risk of Bias in Nonrandomized Studies of Interventions (ROBINS-I) tool.[15]

2.3. Data extraction

Data extracted from the eligible studies included demographic information (patient age and prostate volume), operative details (operative time, perioperative complications, transfusion, and return to theater), and postoperative outcomes. The primary outcome measures that were assessed included prostate symptoms (IPSS, maximal urinary flow rate [Qmax], sexual health International Index of Erectile dysfunction, Sexual Health Inventory for Men, Male Sexual Health Questionnaire [MSHQ] for Ejaculatory function, and Bother [MSHQ-Bother]), and quality of life outcome measures (IPSS-QoL). Summary statistics and effect sizes were reported for scores that were measured at baseline and at postoperative intervals depending on the availability of data. The mean difference score was tested for IPSS, Qmax, and MSHQ from the preoperative score to the 3-month postprocedure score. Secondary outcome measures included complication rates, comparison of Clavien-Dindo proportions, and rates of reoperation. The extracted data were collated using Excel (Microsoft Corporation, Redmond, Calif).

2.4. Statistical analysis

Descriptive statistics were used to describe the metadata of the study. After data extraction, missing data were identified and imputed. Any missing means, standard deviations, or correlation coefficients between paired data were managed according to the methodological recommendations.[16] Algebraic recalculation methods using reported medians and interquartile ranges were used to fill in the standard deviations and means of the primary outcomes.[17] Summary statistic imputation was used when algebraic recalculation was not possible. The prognostic method was used to impute the selected standard deviations.[18] Missing correlation coefficients required for paired raw mean differences were imputed using the "interval method" approach. This involved a sensitivity analysis of the plausible range of correlation coefficient values for the paired data to assess the robustness of the calculated effect size.[18,19] In this review, it was predetermined that only outcome measures with at least 3 studies reporting on them were meta-analyzed.

Pooled estimates were calculated for each primary outcome measure at each time interval. Given the lack of comparison groups in most series and the consistent scoring systems used for each outcome measure, raw means were meta-analyzed to produce summary estimates. Raw mean differences for paired data were calculated for the pre- versus post-IPSS, Qmax, and MSHQ value changes using the following formulae[19]:

$$D = \overline{X}_1 - \overline{X}_2, \quad V_D = \frac{S_{\text{diff}}^2}{n}, \quad S_{\text{diff}} = \sqrt{S_1^2 + S_2^2 - 2 \times r \times S_1 \times S_2}^2$$

Inverse-variance weighted random effects models were applied throughout all meta-analyses, with DerSimonian-Laird estimates of τ^2. Statistical heterogeneity was assessed through the calculation of Cochran's Q and I^2 and reported for each meta-analysis outcome measure.

Throughout this review, an α level of 0.05 was deemed statistically significant. All statistical analyses were performed using StataIC v15.1 (College Station, Tex). The Stata module "Metan" was used to perform all meta-analyses hereinabove.[20]

3. Evidence synthesis

3.1. Search strategy

Using a systematic search, 305 articles were identified, of which 129 were duplicate records and were excluded. Of the remaining 176 records, 36 were not relevant to the research question upon initial screening, and 126 were conference abstracts, reviews, letters, and editorials that could not be quality assessed and were thus excluded. From the remaining 14 patients, 7 were excluded because they did not contain data relevant to the study outcomes or involved the same or extremely similar patient populations as the included studies. Thus, in total, 7 series were suitable for assessment (a summary of the search strategy is shown in Fig. 1). Across these 7 series, 551 men who underwent aquablation for BPH were included in the analysis. The included studies with their respective patients and study characteristics are summarized in Table 1.

3.2. Risk of bias

Each article was individually assessed using the ROBINS-I scoring system[27] for nonrandomized trials. None of the studies fulfilled

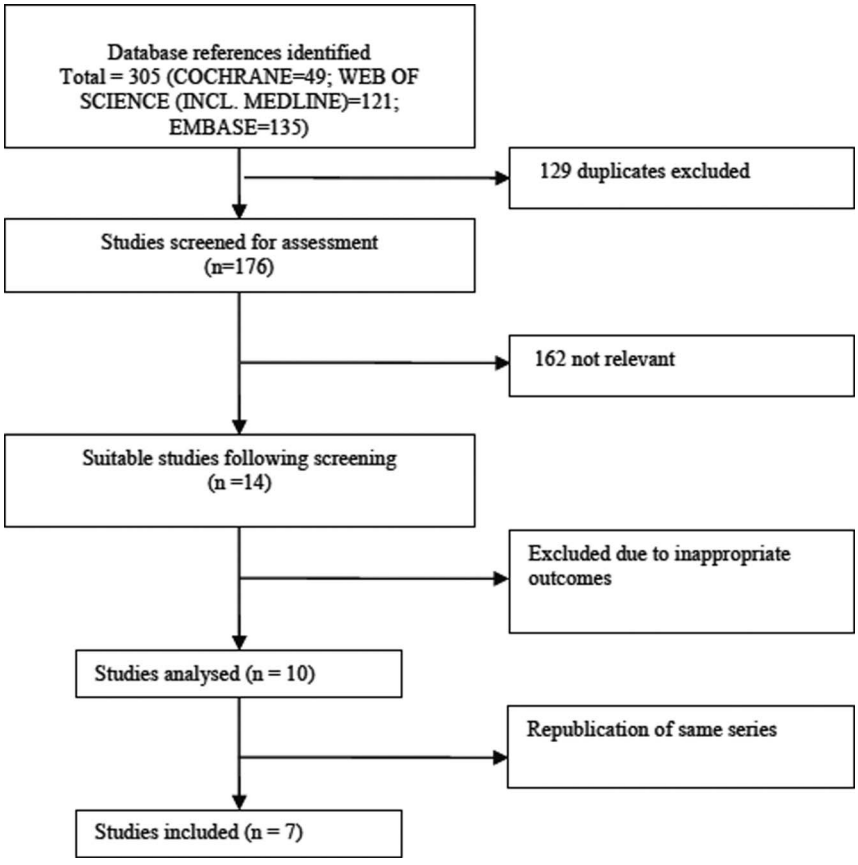

Figure 1. Search strategy.

the ideal 16 points for noncomparative studies and 24 points for comparative studies. All articles reported follow-ups, with 3 articles reporting a 5% loss to follow-up at the primary endpoint. In the study by Gilling et al.[9] (2020), all participants at the time of operation, and all assessors at the primary follow-up were blinded to their interventions received for LUTS. The scoring of each article in accordance with the ROBINS-I scoring system is reported in Supplementary Table 1, (http://links.lww.com/CURRUROL/A17).[15] This review has undergone the AMSTAR 2 appraisal of healthcare interventions and has received a moderate rating.[28]

3.3. Urinary outcomes

Regarding urinary outcomes, 7 articles reported IPSS data pre- and post-ablation treatment. Of these, only 3 studies included 6-month estimates, and only 4 studies included 12-month estimates.[9,21–26] Because of the limited data set beyond 12 months, no pooled estimates were performed after 12 months of follow-up. At 3 months after treatment, the raw mean difference from baseline was –16.475 (95% confidence interval [CI], –15.264 to –17.686; $p < 0.001$). However, the pooled studies displayed statistical heterogeneity (Cochran's $Q = 24.11$, degree of freedom [df] = 6; $p < 0.001$), with an I^2 value of 75.1%, suggesting that a substantial proportion of the total variation was due to heterogeneity in the between-study variance (Fig. 2). From the available data, improvements in IPSS were sustained at 12 months (Table 2).

Similarly, the overall pooled effect size was +10.95 (95% CI, 10.015 to 11.878; $p < 0.001$) from preintervention to postintervention at 3 months. The pooled studies did not show any evidence of statistical heterogeneity (Cochran's $Q = 6.60$, $df = 6$, $p = 0.360$), with an I^2 value of 9.1%, suggesting that a minimal proportion of the total variation was due to heterogeneity in the between-study variance (Fig. 3). These changes were sustained for 12 months in this meta-analysis.

3.4. Sexual outcomes

Because of the limited number of series reporting outcomes using International Index of Erectile dysfunction and MSHQ-Bother scores, a meta-analysis using these measures was not included. Four series reported data on sexual outcomes using overall MSHQ scores.[9,21,25,26] The overall MSHQ change pooled effect size was –0.55 (95% CI, –1.621 to 0.531; $p = 0.321$) before and after intervention at 3 months. However, the pooled studies displayed statistical heterogeneity (Cochran's $Q = 11.79$, $df = 3$; $p = 0.008$), with an I^2 value of 74.5%, suggesting that a substantial proportion of the total variation was due to heterogeneity in the between-study variance (Fig. 4). For 12-month follow-ups, a pooled analysis was performed based on 3 studies (Table 2; Fig. 5).

3.5. Quality of life

Seven studies included data on QoL, measured using the IPSS-QoL score.[9,21–26] Only 3 studies were included in the 6-month analysis, and only 4 studies were included in the 12-month analysis. The preoperative QoL level was 4.63, which led to a significantly improved pooled estimate of 1.29 at 3 months. Moderate statistical heterogeneity existed for the pre-QoL score estimate ($I^2 = 51\%$, χ^2 p value for Cochran's Q, $p = 0.055$), but substantial heterogeneity existed for all other pooled estimates.

Table 1

Included studies—Patient demographics and study characteristics.

Series	Study type	Country	n	Inclusion criteria (abbrev.)	Exclusion criteria (abbrev.)	Follow-up, mo	Outcome measures	MINORS
Bach et al.[21] (2020)	Multicenter prospective control study	United Kingdom, Germany, Australia, New Zealand, Lebanon	144	– Subject has diagnosis of LUTS due to BPH – Prostate size ≥20 mL and ≤150 mL as measured by TRUS	– If unable to stop anticoagulation or antiplatelet perioperative – Bleeding disorder – History of gross hematuria – Systemic immune suppressants	3 mo for primary outcome	IPSS, IPSS-QoL, Qmax, MSHQ-EjD, ISI	13
Desai et al.[22] (2018)	Single center prospective cohort study	India	41	– Age 50–80 yr – Moderate to severe BPH (IPSS 5 > 12) – Qmax ≤15 mL/s – Failed standard medical therapy for BPH	– Prostate cancer or bladder cancer – Neurogenic bladder, urethral stricture, bladder neck contracture – Previous prostate surgery – Prostatitis, active infection – Anticoagulation or steroids – History of gross hematuria	6 mo	IPSS, IPSS-QoL, Qmax	13
Desai et al.[23] (2020)	Multicenter prospective cohort study	United States, Canada	86	– Age 45–80 yr – Baseline IPSS ≥12 – Qmax <15 mL/s – Inadequate failed response to medical treatment for LUTS due to BPH	– History of prostate cancer – Clinically significant bladder calculus – Previous urinary tract surgery, urethral stricture, bladder neck contracture – Chronic pelvic pain or use of anticholinergics	2 yr	IPSS, IPSS-QoL, Qmax, MSHQ-EjD, IIEF/SHIM	13
Gilling et al.[9] (2020)	Multicenter international randomized trial	United States, United Kingdom, Australia, New Zealand	116	– Age 45–80 yr – Prostate 30–80 mL TRUS – IPSS ≥12 – Qmax <15 mL/s	– Prostate cancer, prior prostate surgery or bladder cancer – Neurogenic bladder, bladder calculus, bladder diverticulum, bladder neck contracture – Chronic prostatitis, active infection – Urethral stricture, mental stenosis, damaged external sphincter, stress urinary incontinence, post void residual >300 mL, urinary retention or self-catheterization – Anticoagulation and anticholinergics or severe CVD	2 yr	IPSS, IPSS-QoL, Qmax, MSHQ-EjD, IIEF/SHIM, ISI	23
Kasraeian et al.[24] (2020)	Retrospective review of a single center prospectively collected data	United States	55	– Moderate to severe LUTS	– Anticoagulation	3 mo	IPSS, IPSS-QoL, Qmax, IIEF/SHIM	14
Misrai et al.[25] (2019)	Prospective multicenter single arm clinical trial	France	30	– Male 45–80 yr – IPSS ≥12 – Prostate volume 30–80 mL – Resistant to medical treatment	– Prostate cancer, prior prostate surgery or bladder cancer – Neurogenic bladder, bladder calculus, bladder diverticulum, urethral stricture, urinary retention, bladder neck contracture – Active infection, chronic prostatitis, stress incontinence, post void residual >300 mL – Anticoagulation, anticholinergics or severe CVD	12 mo	IPSS, IPSS-QoL, Qmax, MSHQ-EjD	14
Yafi et al.[26] (2020)	Prospective multicenter international clinical trial	United States	79	– Men 45–80 yr – Prostate 80–150 mL TRUS – IPSS ≥12 – Qmax <15 mL/s – Serum creatinine <2 mg/dL – Resistant to medical treatment – Mental capacity	– Prostate cancer – Clinically significant bladder calculus – Previous urinary tract surgery, urethral stricture, bladder neck contracture, urinary catheterization – Chronic pelvic pain, active infection, or use of anticholinergics	3 mo	IPSS, IPSS-QoL, MSHQ-EjD	12

BPH = benign prostatic hyperplasia; CVD = cardiovascular disease; IIEF/SHIM = International Index of Erectile Function/Sexual Health Inventory for Men; IPSS = International Prostate Symptom Score; IPSS-QoL = International Prostate Symptom Score Quality of Life; ISI = Incontinence Symptom Index; LUTS = lower urinary tract symptom; MSHQ-EjD = Male Sexual Health Questionnaire for Ejaculatory function; Qmax = urinary flow max; TRUS = transrectal ultrasound.

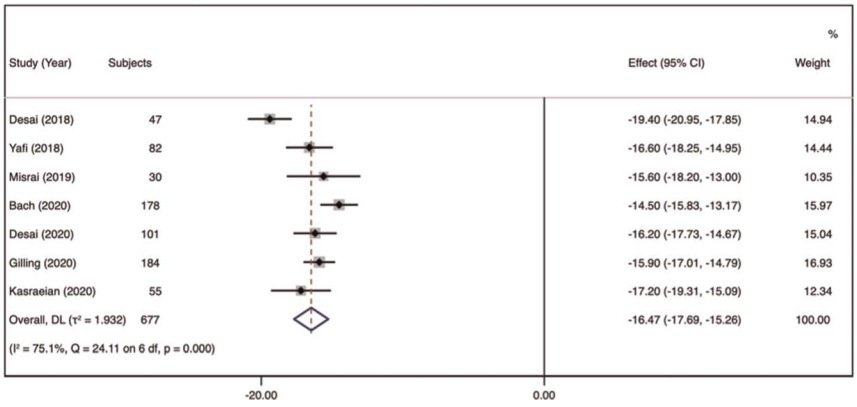

Figure 2. Pre- to post-intervention change in IPSS—summary effect size. CI = confidence interval; IPSS = International Prostate Symptom Score.

3.6. Perioperative outcomes

Seven articles[9,21–26] reported a mean procedural time ranging from 24 to 59 minutes. Six articles[9,21–26] also recorded mean Aquablation mean sequence times that ranged from 3.2 to 8 minutes. Reoperation rates for hematuria and other bleeding complications requiring return to theater were reported in 3 studies, ranging from 0%[25] to 7.9%.[21] Postoperative complications including hematuria and urinary retention were the most common. Of the 551 men included in the study, 2.9% returned to the theater for hemostasis. Notably, Bach et al.[21] (2020) described 14 patients who returned to the operation room for postoperative hemostasis, accounting for 7.9% of all enrolled patients. Significant adverse events that occurred postoperatively, if not defined, were classified as Clavien-Dindo grade 2 and greater.[29] Five studies[21,22,24–26] reported Clavien-Dindo grade 2 and grade 3 event occurrences ranging from 3.4% to 13.9%. No deaths were associated with Aquablation.

4. Discussion

Aquablation is a recent addition to the growing armamentarium for clinicians treating patients with LUTS secondary to BPH. Our systematic review and meta-analysis suggest that Aquablation provides reproducible and sustained improvement in urinary function, urinary bother, and relative preservation of sexual function. Among the analyzed studies, Aquablation demonstrated an acceptable morbidity profile.

A significant improvement in LUTS was observed in the pooled analysis of the IPSS reported by 7 included studies. There was an estimated improvement of −16.47 (95% CI, −17.69 to −15.26) on the IPSS scale at the 3-month follow-ups. At 12 months, the pooled summary of IPSS change reported by 4 of the 7 studies was similar to the 3-month follow-up outcomes. Although not directly comparable, these results seem superior compared with medical therapies and minimally invasive surgical interventions options, which both reported improved IPSS at 12 months by 3.5–7.5 and 7.2–8.7 points, respectively.[2,30,31] Indeed, the IPSS improvements are in line with other invasive enucleative approaches, such as TURP and photoselective vaporization of the prostate, which demonstrated significant improvements in IPSS of up to 15.5 points at 3 months.[7,9,32] However, substantial heterogeneity was observed in all of the pooled IPSS estimates. Although not examined further, the between-study variance could be clarified through subgroup meta-analyses or meta-regression if a larger sample of studies were present. Nevertheless, our findings suggest significant improvements in LUTS, despite not being directly comparable with alternative BPH therapies.

In addition to patient-reported outcomes, the objective functional benefits of Aquablation were also observed in the pooled estimate. Specifically, improvements in Qmax were observed in the pooled estimates by a magnitude of 10.95 mL/s at the 3-month follow-ups ($p < 0.001$). Similar to the IPSS, the changes demonstrated in Qmax were maintained at the 12-month follow-ups. It should be noted, however, that there was substantial heterogeneity in the preoperative Qmax score, but only some heterogeneity for

Table 2

Baseline functional scores prior to prostatic Aquablation.

Series	n	Age, mean (SD, range), yr	PV, mean (SD, range), mL	IPSS, mean (SD, range)	IPSS-QoL, mean (SD, range)	Qmax, mL/s	MSHQ-EjD, mean (SD, range)	IIEF/SHIM, mean (SD, range)	ISI
Bach et al.[21] (2020)	144	67.7 (8.5, 38–88)	59.3 (26.9, 20–148)	21.7 (7.2, 0–35)	4.7 (1.2, 1–6)	9	8 (3.9, 1–5)	NR	3.3
Desai et al.[22] (2018)	41	66 (6, 50–79)	48 (24, 20–118)	24.4 (4.4, 14–33)	4.5 (0.9, 2–6)	7.1	NR	NR	NR
Desai et al.[23] (2020)	86	67.5 (6.6, 52–70)	107.4 (22.1, 80–150)	23.2 (6.3, 12–35)	4.6 (1, 2–6)	8.7	8.1 (3.9, 1–15)	15.1 (7.4, 7.42–25)	NR
Gilling et al.[9] (2020)	116	66 (7.3, 45–80)	54.1 (16.2, NR)	22.9 (6.0, NR)	4.8 (1.1, NR)	9	8.1 (NR)	17.2 (NR)	4.8 (NR)
Kasraeian et al.[24] (2020)	55	67 (8.2, 50–84)	100 (44, 27–223)	21.6 (6.9, 6–35)	4.3 (1.1, 2–6)	7.4	NR	10.5 (8.7, 1–25)	NR
Misrai et al.[25] (2019)	30	68 (NR, 61–72)	60 (NR, 45–69)	18.5 (NR, 15–24)	5 (NR, 4–6)	8	8 (NR, 1–12)	NR	NR
Yafi et al.[26] (2020)	79	68 (6.46, 45–80)	107.8	23.7 (6.4, NR)	4.6 (1, NR)	NR	8 (4.1, NR)	14.6 (7.8, NR)	NR

IIEF/SHIM = International Index of Erectile Function/Sexual Health Inventory for Men; IPSS = International Prostate Symptom Score; IPSS-QoL = International Prostate Symptom Score Quality of Life; ISI = Incontinence Symptom Index; MSHQ-EjD = Male Sexual Health Questionnaire for Ejaculatory function; NR = not reported; PV = prostate volume; Qmax = urinary flow max; SD = standard deviation.

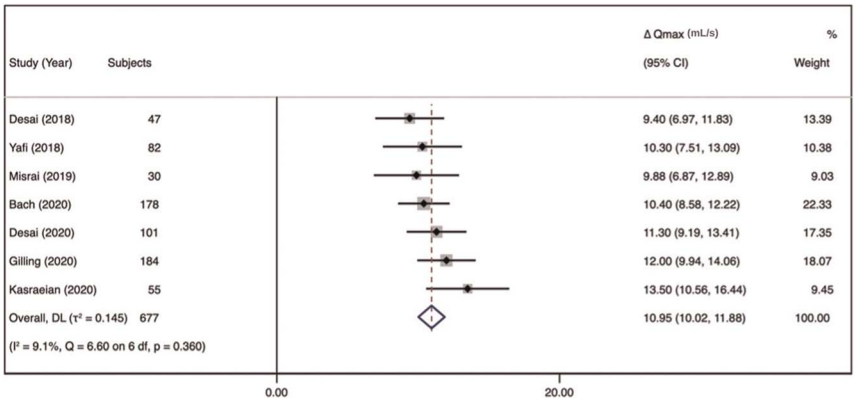

Figure 3. Pre- to post-intervention change in Qmax—summary effect size. CI = confidence interval; Qmax=urinary flow max.

all other pooled estimates. Maximal urinary flow rate improvements noted in the current meta-analysis, as demonstrated by Aquablation, seem superior to medical and minimally invasive therapies.[2,8] Aquablation functional improvements produced were comparable with those of TURP and photoselective vaporization of the prostate, which are associated with improved Qmax values of 10–13 mL/s at 12-month follow-ups.[33–36]

Regarding sexual function, the current meta-analysis included 4 cohorts that reported MSHQ in patients undergoing Aquablation. The association between sexual dysfunction and LUTS remains complex. A LUTS is an independent risk factor for sexual dysfunction[37,38] suggesting that medical or surgical interventions may impact sexual outcomes. Sexual function after medical treatment has inconsistent effects on libido, sometimes resulting in erectile and ejaculatory dysfunction.[30,38] It should be noted that heterogeneity in the sexual outcomes measured existed. As the included studies reported International Index of Erectile Function, MSHQ-Bother, and MSHQ (total) scores variably, meta-analysis was only performed on studies reporting MSHQ (total) because of data availability. The pooled estimates of the overall sexual function scores suggested nonsignificant declines at the 3-month follow-ups. It should be noted that the magnitude of the decline was quantified at −0.55 (95% CI, −1.621 to 0.531). This decline is of a lower magnitude than expected compared with TURP, which is estimated at −2.5 based on the placebo arm of the WATER trial.[9] Accordingly, it may be considered that there is currently no evidence that Aquablation drastically affecting sexual function postoperatively. While it should be noted that there was moderate statistical heterogeneity in the 3-month estimate, these results seem favorable. As Aquablation uses artificial intelligence incorporated with image processing to deliver precise treatments that adapt to individual anatomy without the use of diathermy, it is suggested that this contributes to the lower rate of postoperative retrograde ejaculation.[9] Vital structures, including the bladder neck or musculus ejaculatus, are often injured in diathermy-based resection techniques.[7,31,39,40] However, these key anatomical structures are spared in Aquablation as a result of preoperative planning along with semiautomated robotic surgery, which lowers the chances of iatrogenic error.

While still requiring the patient to undergo general anesthesia along with its associated risks, the mean procedural time and mean Aquablation sequence time ranged between 24 and 59 minutes and 3.2 and 8 minutes, respectively. Such a reduction in operative time is favorable when compared with TURP, which ranges from 35 to 81 minutes in operative time.[41] As the selected studies reported perioperative complications with different methods at various time points, it is difficult to ascertain a high level of confidence in the long-term outcomes of Aquablation.

The reoperation rates were reported in 4 studies in the meta-analysis. All articles reported hematuria postoperatively, with bleeding rates of 2.12%[22] and 19.8%.[23] Three articles[21,22,25] reported reoperation secondary to hematuria, with return-to-theater rates of bleeding between 2.12%[22] and 10%.[21] Desai et al.[22] (2018) described that despite concerns regarding the lack of cautery in

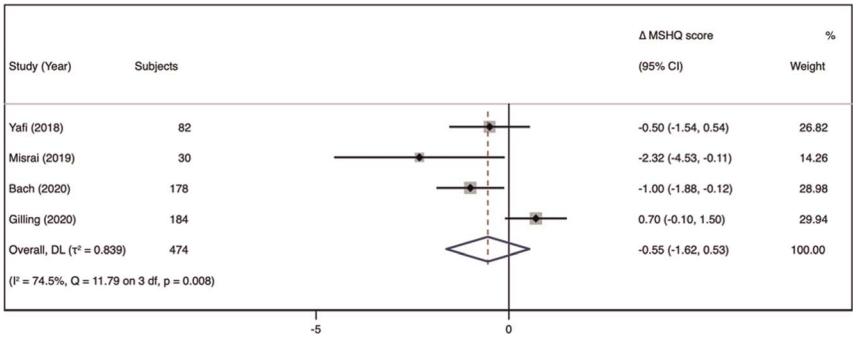

Figure 4. Pre- to post-intervention change in MSHQ—summary effect size. CI = confidence interval; MSHQ = Male Sexual Health Questionnaire.

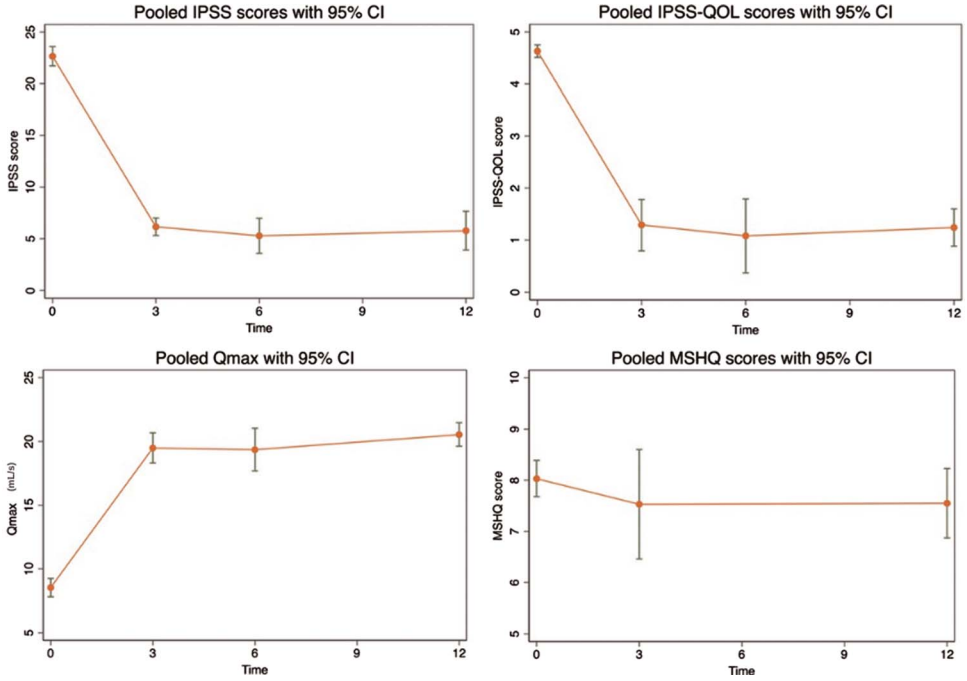

Figure 5. Pooled summary effect sizes with 95% CI for each score, over time in months (corresponds to Table 1). CI = confidence interval; IPSS = International Prostate Symptom Score; IPSS-QoL = International Prostate Symptom Score Quality of Life; Qmax = maximal urinary flow rate.

Aquablation, postoperative oozing was sufficiently controlled in most patients by the traction of the Foley catheter alone. Comparatively, the return to theater rate for hematuria in TURP is approximately 2.7%.[42] Furthermore, 6 articles demonstrated postoperative infection rates ranging from 2.12%[22] to 10%.[25] Incontinence was reported in only 2 studies and was of less concern, with a rate of occurrence of 0.6%[21] to 4.9%.[23] Collectively, the incidence of adverse events, including hematuria, infective complications, and incontinence, seems to represent an acceptable morbidity profile, particularly in the early experience of the novel technology and in the setting of a clinical trial.

Several key issues have been identified in literature. First, most studies were restricted to men with smaller prostate volumes. The WATER II study provides insight into the outcomes of Aquablation in men with larger prostates; however, further studies are necessary to examine the safety and efficacy of Aquablation in men with larger prostates, ranging from 80 to 150 mL. Second, there are limited studies evaluating the efficacy of Aquablation compared with TURP in randomized trials. Gilling et al.[9] performed a multicenter randomized study directly comparing outcomes for moderate to severe LUTS in patients with BPH across a 3-year follow-up period. Indeed, additional comparative data will allow for a robust appraisal of the clinical effects of Aquablation in clinical practice. A novel aspect of Aquablation pertains to the robotic technique with semiautomation that may allow surgeons to complement their expertise with standardization, in turn improving the outcomes for all urologists and their patients. The semiautomated aspect provides the potential for a low learning curve, allowing for effective, user-friendly adoption of the technique. Finally, limited cost data regarding the use of Aquablation have been made available and have not been previously published. A formal cost analysis is necessary, as the identified reduction in operating time and theater occupancy may offset the cost of equipment and disposables. Such data are critical for determining the role of Aquablation in contemporary practice.

The current study has several limitations. First, the available data represent a heterogeneous collection of patient cohorts, which may contribute to heterogeneity in the pooled estimates. Second, of the reported studies, variation in the outcome measures precluded a robust meta-analysis, which was most pertinent to sexual outcomes. In addition, studies reported outcomes at inconsistent time points postoperatively and thus were not immediately comparable. To date, limited robust comparative data with TURP or other well-defined controlled interventions are available. Finally, as discussed, the data from current studies largely represent those of well-defined patient series enrolled in clinical trials. Accordingly, the addition of further real-world data may improve the knowledge base of the data surrounding Aquablation.

5. Conclusions

A meta-analysis of the available data to date suggests that Aquablation seems to improve LUTS in men with BPH while providing relatively preserved sexual function. The morbidity and perioperative outcomes after Aquablation seem to be acceptable. More robust randomized trials comparing Aquablation with the existing treatment options are required to definitively determine the role of this intervention in contemporary clinical practice.

Acknowledgments

None.

Statement of ethics

Not applicable.

Conflict of interest statement

The article was created without consultation or input from PROCEPT BioRobotics, Inc. AA is an editorial board member of *Current Urology*.

Funding source

MP is sponsored by the Australian-America Fulbright Commission administered through a 2021–2022 Fulbright Future Scholarship funded by the Kinghorn Foundation.

Author contributions

All authors contributed equally in this study.

References

[1] Parsons JK, Mougey J, Lambert L, et al. Lower urinary tract symptoms increase the risk of falls in older men. *BJU Int* 2009;104(1):63–68.
[2] Roehrborn CG. Current medical therapies for men with lower urinary tract symptoms and benign prostatic hyperplasia: Achievements and limitations. *Rev Urol* 2008;10(1):14–25.
[3] Verhamme KM, Dieleman JP, Bleumink GS, Bosch JL, Stricker BH, Sturkenboom MC. Treatment strategies, patterns of drug use and treatment discontinuation in men with LUTS suggestive of benign prostatic hyperplasia: The Triumph Project. *Eur Urol* 2003;44(5):539–545.
[4] Lerner LB, McVary KT, Barry MJ, et al. Management of lower urinary tract symptoms attributed to benign prostatic hyperplasia: AUA GUIDELINE PART II—Surgical evaluation and treatment. *J Urol* 2021;206(4):818–826.
[5] Varkarakis J, Bartsch G, Horninger W. Long-term morbidity and mortality of transurethral prostatectomy: A 10-year follow-up. *Prostate* 2004;58(3):248–251.
[6] Christidis D, McGrath S, Perera M, Manning T, Bolton D, Lawrentschuk N. Minimally invasive surgical therapies for benign prostatic hypertrophy: The rise in minimally invasive surgical therapies. *Prostate Int* 2017;5(2):41–46.
[7] McVary KT, Roehrborn CG, Avins AL, et al. Update on AUA guideline on the management of benign prostatic hyperplasia. *J Urol* 2011;185(5):1793–1803.
[8] Bortnick E, Brown C, Simma-Chiang V, Kaplan SA. Modern best practice in the management of benign prostatic hyperplasia in the elderly. *Ther Adv Urol* 2020;12:1756287220929486.
[9] Gilling P, Barber N, Bidair M, et al. Three-year outcomes after Aquablation therapy compared to TURP: Results from a blinded randomized trial. *Can J Urol* 2020;27(1):10072–10079.
[10] Suarez-Ibarrola R, Bach T, Hein S, et al. Efficacy and safety of Aquablation of the prostate for patients with symptomatic benign prostatic enlargement: A systematic review. *World J Urol* 2020;38(5):1147–1163.
[11] Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71.
[12] Cumpston M, Li T, Page MJ, et al. Updated guidance for trusted systematic reviews: A new edition of the Cochrane Handbook for Systematic Reviews of Interventions. *Cochrane Database Syst Rev* 2019;10:ED000142.
[13] Higgins JP, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ* 2011;343:d5928.
[14] Higgins JP, Thomas J, Chandler J, et al. *Cochrane Handbook for Systematic Reviews of Interventions*. Oxford: John Wiley & Sons; 2019.
[15] Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: A tool for assessing risk of bias in non-randomised studies of interventions. *BMJ* 2016;355:i4919.
[16] Weir CJ, Butcher I, Assi V, et al. Dealing with missing standard deviation and mean values in meta-analysis of continuous outcomes: A systematic review. *BMC Med Res Methodol* 2018;18(1):25.
[17] Wan X, Wang W, Liu J, Tong T. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC Med Res Methodol* 2014;14:135.
[18] Ma J, Liu W, Hunter A, Zhang W. Performing meta-analysis with incomplete statistical information in clinical trials. *BMC Med Res Methodol* 2008;8:56.
[19] Borenstein M, Hedges LV, Higgins JP, Rothstein HR. *Introduction to Meta-analysis*. 2nd ed. Oxford: John Wiley & Sons; 2021.
[20] Harris RJ, Deeks JJ, Altman DG, Bradburn MJ, Harbord RM, Sterne JAC. Metan: Fixed- and random-effects meta-analysis. *Stata J* 2008;8(1):3–28.
[21] Bach T, Gilling P, El Hajj A, Anderson P, Barber N. First multi-center all-comers study for the Aquablation procedure. *J Clin Med* 2020;9(2):603.
[22] Desai MM, Singh A, Abhishek S, et al. Aquablation therapy for symptomatic benign prostatic hyperplasia: A single-centre experience in 47 patients. *BJU Int* 2018;121(6):945–951.
[23] Desai M, Bidair M, Bhojani N, et al. Aquablation for benign prostatic hyperplasia in large prostates (80–150 cc): 2-year results. *Can J Urol* 2020;27(2):10147–10153.
[24] Kasraeian A, Alcantara M, Alcantara KM, Altamirando JA, Kasraeian A. Aquablation for BPH. *Can J Urol* 2020;27(5):10378–10381.
[25] Misrai V, Rijo E, Zorn KC, Barry-Delongchamps N, Descazeaud A. Waterjet ablation therapy for treating benign prostatic obstruction in patients with small- to medium-size glands: 12-Month results of the first French aquablation clinical registry. *Eur Urol* 2019;76(5):667–675.
[26] Yafi FA, Tallman CT, Seard ML, Jordan ML. Aquablation outcomes for the U.S. cohort of men with LUTS due to BPH in large prostates (80–150 cc). *Int J Impot Res* 2018;30(5):209–214.
[27] Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (minors): Development and validation of a new instrument. *ANZ J Surg* 2003;73(9):712–716.
[28] Shea BJ, Reeves BC, Wells G, et al. AMSTAR 2: A critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ* 2017;358:j4008.
[29] Dindo D, Demartines N, Clavien PA. Classification of surgical complications: A new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 2004;240(2):205–213.
[30] Roehrborn CG, Casabé A, Glina S, Sorsaburu S, Henneges C, Viktrup L. Treatment satisfaction and clinically meaningful symptom improvement in men with lower urinary tract symptoms and prostatic enlargement secondary to benign prostatic hyperplasia: Secondary results from a 6-month, randomized, double-blind study comparing finasteride plus tadalafil with finasteride plus placebo. *Int J Urol* 2015;22(6):582–587.
[31] Perera M, Roberts MJ, Doi SA, Bolton D. Prostatic urethral lift improves urinary symptoms and flow while preserving sexual function for men with benign prostatic hyperplasia: A systematic review and meta-analysis. *Eur Urol* 2015;67(4):704–713.
[32] Kang DH, Cho KS, Ham WS, Choi YD, Lee JY. A systematic review and meta-analysis of functional outcomes and complications following the photoselective vaporization of the prostate and monopolar transurethral resection of the prostate. *World J Mens Health* 2016;34(2):110–122.
[33] Teng J, Zhang D, Li Y, et al. Photoselective vaporization with the green light laser vs transurethral resection of the prostate for treating benign prostate hyperplasia: A systematic review and meta-analysis. *BJU Int* 2013;111(2):312–323.
[34] Thangasamy IA, Chalasani V, Bachmann A, Woo HH. Photoselective vaporisation of the prostate using 80-W and 120-W laser versus transurethral resection of the prostate for benign prostatic hyperplasia: A systematic review with meta-analysis from 2002 to 2012. *Eur Urol* 2012;62(2):315–323.
[35] Bouchier-Hayes DM, Van Appledorn S, Bugeja P, Crowe H, Challacombe B, Costello AJ. A randomized trial of photoselective vaporization of the prostate using the 80-W potassium-titanyl-phosphate laser vs transurethral prostatectomy, with a 1-year follow-up. *BJU Int* 2010;105(7):964–969.
[36] Lukacs B, Loeffler J, Bruyère F, et al. Photoselective vaporization of the prostate with GreenLight 120-W laser compared with monopolar transurethral resection of the prostate: A multicenter randomized controlled trial. *Eur Urol* 2012;61(6):1165–1173.
[37] McVary K. Lower urinary tract symptoms and sexual dysfunction: Epidemiology and pathophysiology. *BJU Int* 2006;97(suppl 2):23–28.
[38] McVary KT, Gange SN, Shore ND, et al. Treatment of LUTS secondary to BPH while preserving sexual function: Randomized controlled study of prostatic urethral lift. *J Sex Med* 2014;11(1):279–287.
[39] Cornu JN, Ahyai S, Bachmann A, et al. 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. *Eur Urol* 2015;67(6): 1066–1096.
[40] Ahyai SA, Gilling P, Kaplan SA, et al. Meta-analysis of functional outcomes and complications following transurethral procedures for lower urinary tract symptoms resulting from benign prostatic enlargement. *Eur Urol* 2010; 58(3):384–397.
[41] Mamoulakis C, Ubbink DT, de la Rosette JJ. Bipolar versus monopolar transurethral resection of the prostate: A systematic review and meta-analysis of randomized controlled trials. *Eur Urol* 2009;56(5):798–809.
[42] Guo R, Yu W, Zhang K, Xu B. Impact of changing trends in medical therapy on transurethral resection of the prostate: Two decades of change in China. *Urology* 2016;92:80–86.

How to cite this article: Chen DC, Qu L, Webb H, Qin K, Chislett B, Xue A, Khaleel S, De Jesus Escano M, Chung E, Adam A, Bolton D, Perera M. Aquablation in men with benign prostate hyperplasia: A systematic review and meta-analysis. *Curr Urol* 2023;17(1):68–76. doi: 10.1097/CU9.0000000000000122