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Does MOSES pulse modulation reduce short-term catheter reinsertion following holmium laser enucleation of the prostate?

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Purpose: Previously published studies have shown small prostate size, capsular perforation and intraoperative bladder distension are associated with failed trial without a catheter (TWOC) after HoLEP. The study objective was to determine the relationship between MOSES pulse modulation versus standard laser technology and short-term catheter reinsertion following failed TWOC.

Materials and Methods: The study included 487 patients who underwent HoLEP, using standard holmium laser settings (180 patients) or MOSES pulse modulation (255 patients), between August 2018 and February 2021. Catheter reinsertion defined as reinsertion following failed TWOC within 30 days of surgery. Association of pulse modulation with catheter reinsertion was examined using single and multivariable logistic regression models. Comparisons of pre and intraoperative characteristics between patients treated without and with pulse modulation were made using a Wilcoxon rank sum test for numeric characteristics or Fisher's exact test for categorical characteristics.

Results: Short-term catheter reinsertion occurred in 14% (26/180) of the standard laser setting group as compared with 10% (24/252) of the pulse modulation group. There was no statistically significant association with short-term catheter reinsertion in single (unadjusted OR [standard settings vs. pulse modulation], 1.60; 95% CI, 0.80–2.91; p=0.12) or multivariable analysis adjusting for specimen weight and operative time (adjusted OR [standard settings vs. pulse modulation], 1.44; 95% CI, 0.77–2.68; p=0.25).

Conclusions: In this study, we found no association between post-HoLEP short-term catheter reinsertion following failed TWOC and MOSES pulse modulation. Although MOSES pulse modulation offers several well-documented advantages, catheter reinsertion events appear to be attributable to other factors.

Keywords: Cystoscopy; Holmium; Lasers; Prostatic hyperplasia; Urinary catheterization

INTRODUCTION

Holmium laser enucleation of the prostate (HoLEP) was introduced in 1998. It is now considered a standard, prostate size independent surgical procedure for the management of benign prostatic hyperplasia (BPH). HoLEP, as compared with the gold standard transurethral resection of the prostate (TURP), has been shown to have lower reoperation rates, shorter catheterization times and shorter postoperative hospital stays [1,2]. The long-term catheter-free rate following

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HoLEP is 99.7% [3].

Short-term postoperative catheter reinsertion following HoLEP is uncommon, but our group previously reported a rate of 17% [4]. Several factors for post-HoLEP failed trial without a catheter (TWOC) leading to catheter reinsertion have been hypothesized: anesthetic/analgesia, underlying detrusor dysfunction, immobility/voiding in supine position, presence of clot within the prostatic fossa and capsular edema. Recent studies performing HoLEP as an outpatient procedure have reported very low catheter reinsertion rates in the 2% to 3% range suggesting ambulation and getting out of the hospital setting is an important variable. Observation in the hospital with post-void ultrasound bladder volume may lead to premature catheter reinsertion to alleviate patient, nurse, and physician anxiety. Catheter reinsertion is a frustrating event for both patient and surgeon. From the surgeon's perspective catheter reinsertion is a minor setback, but to the patient it is temporarily indicative of a failed intervention and creates anxiety and inconvenience.

Prior series have evaluated factors contributing to post-HoLEP failed TWOC identifying a relationship with intraoperative bladder distention and an inverse relationship with final specimen weight (as specimen weight increases catheter reinsertion rate decreases) [4,5]. Since these studies were published the MOSES holmium laser pulse modulation software was introduced by Lumenis Ltd. (Yokneam, Israel) and has become widely available. Pulse modulated laser technology is focused on more efficient delivery of laser energy to target tissue, and is associated with improved hemostasis and shorter operating times [6]. To date, studies on perioperative HoLEP outcomes utilizing this new laser technology, specifically post-HoLEP failed TWOC leading to catheter reinsertion, are limited.

The objective of this study was to determine the relationship between pulse modulation and post-HoLEP catheter reinsertion following failed TWOC. We hypothesized use of pulse modulation may lead to a reduction in post-HoLEP catheter reinsertion rates, possibly secondary to decreased operating time (less capsular edema/fluid absorption) and improved hemostasis (less clot within the prostatic fossa). This study was conducted to decrease patient morbidity and to aid surgeons in equipment selection which may improve postoperative patient outcomes. This study is a continuation of our prior reported series given rapidly changing laser technology [4].

MATERIALS AND METHODS

After receiving Institutional Review Board of the Mayo Clinic Florida approval (approval number: 19-004344), we retrospectively reviewed our database. No funding was utilized for this study. There were 487 patients treated with HoLEP for BPH by a single surgeon at Mayo Clinic in Jacksonville, FL between August 2018 and February 2021. This study was limited to patients treated with the Lumenis MOSES P120 holmium laser (Lumenis Ltd.) without or with MOSES pulse modulation activated. We excluded patients treated with the Olympus Empower H100 (n=49) or Olympus Soltive Thulium lasers (n=3) (Olympus Corporation of Americas, Center Valley, PA, USA). Catheter reinsertion was defined as any reinsertion following a failed TWOC within 30 days of the procedure. Written informed consent was waived by the IRB as the database is in the minimal risk/exempt category.

All patients underwent HoLEP utilizing a modified 26 french continuous flow resectoscope with laser bridge, offset nephroscope, Piranha morcellator (Richard Wolf Medical Instruments, Vernon Hills, IL, USA), and MOSES P120 holmium laser. In the pulsed energy group we used MOSES 550 fibers. In the non-pulsed energy group we used Flexiva 550 fibers. There was no difference in surgical technique or postoperative management between groups (the only difference between groups was use of the MOSES pulsed energy setting).

The following laser settings were used to perform HoLEP: treatment settings of 2 J/20 Hz at the apex (to decrease energy deposition at the external sphincter), 2 J/40 Hz everywhere else (note: in the first half of patients a treatment setting of 2 J/50 Hz was used; this was decreased due to the theoretical increased risk of urinary incontinence), and hemostasis/coagulation settings of 1 J/20 Hz (MOSES technology was disabled for both fibers during coagulation).

HoLEP was performed using the en-bloc single incision technique. A posterior incision from bladder neck to veru down to the level of the surgical capsule was made. The distal extent of the left apical adenoma was released, and this was carried counterclockwise from 6 o'clock to 12 o'clock, distal to proximal. The distal extent of the right apical adenoma was then released, and this was carried clockwise from 6 o'clock to 12 o'clock, distal to proximal. The mucosal bridge was then released, along with any remaining anterior attachments. The entire adenoma was pushed into the bladder and morcellated. Hemostasis was achieved utilizing the coagulation settings noted above. We did not perform additional prophylactic hemostasis/coagulation with mono/bipolar energy. Instruments were removed and a 22 French 3-way Foley catheter with 30 mL balloon was placed (balloon inflated between 45–75 mL). Continuous saline bladder irrigation was initiated. Patients were observed in the hospital overnight. Postoperative day one continuous bladder irrigation was discontinued, and the catheter was removed for attempted TWOC. If a patient failed TWOC and catheter reinsertion was required, a second TWOC was attempted 48 hours later in the ambulatory/outpatient setting. Strict post-void residual cutoffs were not utilized, but rather clinical judgment was used to guide decision making regarding catheter reinsertion (typically, if a patient was able to void with no hesitancy/bladder discomfort the catheter was not reinserted). Increased post-void residuals were permitted if markedly elevated residuals were noted preoperatively.

The following data were collected and entered into a database: preoperative information (age, body mass index [BMI], prior BPH procedure, prostate volume, catheter dependence), specimen weight, intraoperative information (operative time, energy utilized relative to specimen weight) and postoperative information (catheter reinsertion). Data regarding catheter reinsertion or catheter dependence following HoLEP was collected utilizing both electronic chart review as well as direct patient contact (to account for events captured outside of our electronic database).

Numeric variables were summarized with sample median and range. Categorical variables were summarized with frequency and percentage of patients. In evaluation of the primary study aim associations of pulse modulation with catheter reinsertion following HoLEP were examined with single and multivariable logistic regression models where odds ratio (OR) and 95% confidence interval (CI) were estimated. Some guidelines suggest including no more than one variable in a logistic regression model for every ten patients who experience the outcome [7]. In our cohort, 50 patients had catheter reinsertion, so we adjusted for no more than 4 factors in multivariable models.

In secondary analysis, comparisons of preoperative and intraoperative characteristics between patients who were treated without pulse modulation and those treated with MOSES pulse modulation were made using a Wilcoxon rank sum test for numeric characteristics or Fisher's exact test for categorical characteristics. All p-values less than 0.05 were considered statistically significant. All statistical tests were two-sided. R version 3.6.2 was used for analyses (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

There were 180 patients treated without pulse modulation (Flexiva 550 laser fiber) and 255 patients treated with MOSES pulse modulation (MOSES 550 laser fiber) between August 2018 and February 2021. The rate of return to the operating room for postoperative hemorrhage requiring cystoscopy/clot evacuation/fulguration was 2.5%. Table 1 shows a comparison of preoperative patient characteristics, specimen information, and intraoperative characteristics. When comparing the two cohorts, there were no differences in

Table 1. Comparison of preoperative patient characteristics, specimen information, and intraoperative characteristics for patients undergoing HoLEP for the treatment of BPH utilizing no pulse modulation or MOSES pulse modulation

Variable	No pulse modulation (n=180)	MOSES pulse modulation (n=255)	p-value
Preoperative patient characteristics			
Age, y	72 (67–76)	71 (66–75)	0.44
Body mass index, kg/m^2	27.8 (25.3–31.1)	28.2 (25.5–31.7)[9]	0.40
Catheter dependent	57 (32)[4]	75 (29)[2]	0.60
Foley, suprapubic	39 (22)	57 (22)	
Self-catheter	18 (10)	18 (7)	
Prior BPH procedure	17 (9)	38 (15)[3]	0.11
Prostate volume, mL	89 (65–120)[14]	98 (69–124)[8]	0.18
Specimen information			
Specimen weight, g	61 (35–83)[1]	67 (46–91)[2]	0.02
Intraoperative characteristics			
Energy utilized, J	86,070 (68,313–116,045)[12]	101,440 (81,630–129,840)[14]	<0.001
Energy utilized/specimen weight, J/g	1,565 (1,169–2,385)[13]	1,528 (1,151–2,046)[16]	0.26
Operative time, min	78 (64–95)	88 (73–106)	<0.001

The sample median (minimum–maximum) is shown for numeric variables. Number (percentage of patients) is shown for categorical variables. Superscript numbers represent the number of patients with missing data in each group.
HoLEP, holmium laser enucleation of the prostate; BPH, benign prostatic hyperplasia.
All p-values for comparison between the no pulse modulation and MOSES pulse modulation groups were from the Wilcoxon rank sum test for numeric variables and Fisher's exact test for categorical variables.

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patient age, BMI, or preoperative catheter dependence (Table 1, all p≥0.40). Specimen weight was higher for those treated with pulse modulation as compared without pulse modulation (median, 67 g vs. 61 g; p=0.02). The pulse modulation cohort had a higher amount of energy utilized compared to the non-pulse modulation cohort (median, 101,440 J vs. 86,070 J; p<0.001), but no statistically significant difference in the amount of energy utilized relative to specimen weight (median, 1,528 J/g vs. 1,565 J/g; p=0.26). Finally, the pulse modulation cohort had a longer operative time compared to those without pulse modulation (median, 88 min vs. 78 min; p<0.001). Long-term, all men within the study group achieved catheter independence.

Association of laser fiber type with failed trial without a catheter leading to catheter reinsertion

Catheter reinsertion occurred in 14% (26/180) of the non-pulse modulation cohort as compared with 10% (24/252) of the pulse modulation cohort. We did not find a statistically significant association of pulse modulation with catheter reinsertion in single variable analysis (unadjusted OR, 1.60; 95% CI, 0.80–2.91; p=0.12) or multivariable analysis adjusting for specimen weight and operative time (adjusted OR, 1.44; 95% CI, 0.77–2.68; p=0.25) (Table 2).

DISCUSSION

Very few studies have looked at factors associated with failed postoperative TWOC leading to catheter reinsertion. The significance of catheter reinsertion following a bladder outlet procedure is often overlooked, but it may have a significant impact on patients. A small study utilizing validated survey methods by Jakobsson highlighted catheter impact on men: half had discomfort, a third experienced practical/psychosocial difficulties in handling/wearing a catheter, and a third experienced discomfort with catheter placement [8]. This study underscores the importance of identifying factors associated with postoperative catheter reinsertion in order to avoid them and reduce patient morbidity.

Our current knowledge of factors related to post-bladder outlet procedure catheter reinsertion following failed TWOC comes from review of the current literature. Kim et al. [9] reported on catheter reinsertion following TURP. The study included 76 patients and 15 failed TWOC requiring reinsertion. Their group identified two factors associated with TWOC failure: capsular perforation and small specimen weight. Another study evaluated failed TWOC in patients who underwent HoLEP [5]. The study included 166 patients and 9 failed TWOC requiring reinsertion. Their group identified two factors associated with TWOC failure: intraoperative bladder distention volume and weight adjusted morcellation time. Finally, our group, in a prior series, evaluated failed TWOC in patients who underwent HoLEP [4]. The study included 143 patients and 23 failed TWOC requiring reinsertion. A single factor was significantly associated with TWOC failure: low specimen weight. None of the previously mentioned studies evaluated the impact of available equipment, specifically, the type of laser, or laser fiber utilized to perform the procedure. This is an important variable to consider given the significant advances in laser technology seen within the last decade.

HoLEP may be performed utilizing a range of laser powers (30 W–120 W), laser settings and fiber types. Originally, the procedure was described utilizing an 80 W holmium laser set to 2 J/40 Hz [10]. Minagawa et al. [11] evaluated 74 patients who underwent HoLEP utilizing a 30 W holmium laser set to 1.5 J/20 Hz in an effort to prove safety/efficacy of a low-power laser to decrease overall procedural cost and increase international adoption of HoLEP. Their results for prostates <200 g compared favorably to prior studies, and thus concluded HoLEP could be safely performed with acceptable results utilizing a low-power laser. The study made limited mention of perioperative outcomes, but did state, given the Japanese health system, mean catheter time was 2.7 days and mean hospital stay was 5.3 days, making their perioperative outcomes somewhat difficult to generalize to other healthcare settings. In 2017, Lumenis introduced the MOSES Pulse 120H laser platform with MOSES single use laser fibers. The laser is high-power and when paired with MOSES laser fibers allows unique pulsed laser patterns that displace fluid between the laser tip and target tissue allowing for more efficient energy delivery [3]. Krambeck et al. [3]

Table 2. Association of pulse modulation with catheter reinsertion after HoLEP

MOSES pulse modulation	% (fraction) with catheter reinsertion	Unadjusted OR (95% CI)	p-value	Adjusted OR (95% CI)[a]	p-value
No	14 (26/180)	1.60 (0.80–2.91)	0.12	1.44 (0.77–2.68)	0.25
Yes	10 (24/252)	1.00 (reference)		1.00 (reference)	

HoLEP, holmium laser enucleation of the prostate; OR, odds ratio; CI, confidence interval.
[a]:Adjusted for specimen weight on log scale and operative time.

compared Slimline 550 and 1,000 fibers to MOSES 550 fibers in 150 patients undergoing HoLEP. They reported a statistically significant difference in operating room time and hemostasis when performing HoLEP using the MOSES 550 fibers as compared with the Slimline fibers. Perioperative catheter reinsertion rate for the entire cohort was 2.6% and 100% were catheter-free 72 hours post-op.

In a continuing effort to reduce patient morbidity and guide surgeon equipment selection we evaluated the relationship between holmium laser MOSES pulse modulation software and short-term post-HoLEP catheter reinsertion rates following failed TWOC. Our data show patients who underwent HoLEP utilizing MOSES pulse modulation as compared with no pulse modulation had a lower rate of postoperative failed TWOC requiring reinsertion, but this difference was not statistically significant (10% vs. 14%; OR, 1.60; p=0.12). We recognize post-HoLEP catheter reinsertion following failed TWOC is a complex issue. Prior studies noted above identified several factors associated with catheter reinsertion including low specimen weight (a surrogate for smaller prostate size), capsular perforation and intraoperative bladder distention. We surmise patients with smaller prostates who undergo HoLEP may have increased voiding difficulty following catheter removal due to increased resistance within the prostatic fossa secondary to capsular edema/fluid absorption and blood clots. We hypothesized use of the MOSES pulse modulation, which has been associated with shorter operative times (potentially less capsular edema/fluid absorption) and improved hemostasis (less clot), may decrease the risk of post-HoLEP failed TOWC leading to catheter reinsertion. The findings of this study do not support that hypothesis.

Study limitations include: retrospective nature, unmatched cohort, potential for underreported catheter reinsertion events, lack of urodynamic data, single institution/surgeon, varying levels of trainee participation, and lack of randomization. Longer operation time in the pulsed energy group thought to be related to increased emphasis on hemostasis and surgical trainee involvement. Specimen weight, as opposed to prostate size, was included in the analysis as we feel specimen weight is a more accurate reflection of preoperative prostate volume than radiographic measurements, which are highly operator-dependent and are not obtained in every patient prior to undergoing HoLEP. In addition, multivariate analysis is dictated by the number of events (catheter reinsertions) that occurred, and no more than 4 variables were able to be included in the analysis.

Ultimately, optimal timing for a trial of void should balance the need for timely catheter removal with the need to minimize catheter reinsertion. Previously noted factors which may impact successful TWOC following HoLEP should lead surgeons to develop an evidence-based approach to select patients most likely to pass a hospital-based TWOC compared with patients most likely to pass an outpatient TWOC. Delaying catheter removal in the latter group allows for several days of postoperative recovery which may lead to systemic resorption of intraoperative fluid, decreased capsular edema and clot breakdown; thus, maximizing a patient's ability to undergo a single TWOC and avoid catheter reinsertion and the associated morbidity. Expansion of outpatient and ambulatory HoLEP may also minimize catheter reinsertion through the mechanism of improved patient mobility and the beneficial effects of ambulation on voiding. Size criteria for determining optimal TWOC timing remain to be determined and should be the subject of future studies.

CONCLUSIONS

In this study, we found no association between post-HoLEP short-term catheter reinsertion following failed TWOC and MOSES pulse modulation. Although MOSES pulse modulation offers several well-documented advantages, catheter reinsertion events appear to be attributable to other factors.

CONFLICTS OF INTEREST

Chandler D. Dora, MD has received payment from Lumenis, LTD for speaking engagements, panel participation and case observation. The other authors have no conflicts of interest to declare.

AUTHORS' CONTRIBUTIONS

Research conception and design: Chandler D. Dora and Dane E. Klett. Data acquisition: Chandler D. Dora, Dane E. Klett, and Bryce Baird. Statistical analysis: Colleen T. Ball. Data analysis and interpretation: Chandler D. Dora, Dane E. Klett, and Colleen T. Ball. Drafting of the manuscript: Dane E. Klett. Supervision: Chandler D. Dora. Approval of the final manuscript: Chandler D. Dora.

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