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Original Article

Perioperative anesthetic management characteristics associated with early postoperative voiding recovery and short-term urinary outcomes after HoLEP in elderly frail patients: a retrospective study

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Abstract: Objective: To identify anesthetic factors associated with early voiding recovery after holmium laser enucleation of the prostate (HoLEP) in elderly frail patients, and to compare short-term urinary outcomes by recovery status. Methods: This single-center retrospective study included frail patients (aged ≥75 years, Clinical Frailty Scale score ≥5) who underwent HoLEP between January 2021 and December 2024. Patients were classified into good recovery, defined as spontaneous voiding after first catheter removal, and poor recovery defined as the inability to void or the need for re-catheterization. Baseline characteristics, perioperative variables, short-term outcomes were compared. Stepwise logistic regression was used to identify factors associated with early voiding recovery. Multivariable logistic regression was used to assess the association between recovery status and a composite adverse outcome including postoperative incontinence, urinary tract infection, hematuria or clot retention, and 30-day readmission. Results: Among 194 frail patients, 136 (70.1%) had poor early voiding recovery. In multivariable analysis, poor recovery was independently associated with higher postvoid residual volume (PVR, $P<0.001$), intraoperative hypotension (OR 27.483, $P<0.001$), greater intraoperative fluid administration (per 100-mL increase: OR 1.627, $P<0.001$), and general anesthesia (OR 3.231, $P=0.023$). Patients with poor recovery had longer catheterization duration, longer hospital stay, and higher rates of incontinence, urinary tract infection, and readmission (all $P<0.05$). Poor recovery was independently associated with the composite adverse outcome (adjusted OR 4.301, $P<0.001$). Conclusion: Early voiding status after catheter removal serves as a simple and practical clinical indicator to identify elderly frail HoLEP patients at risk of adverse short-term urinary outcomes.

Keywords: Holmium laser enucleation of the prostate, elderly frail patients, anesthetic management, postoperative voiding recovery, short-term urinary outcomes

Introduction

Benign prostatic hyperplasia (BPH) is one of the most common benign conditions affecting older men, with its prevalence increasing steadily after age 50 and being most common in those aged 65 years and older [1, 2]. As the prostate enlarges, many patients develop lower urinary tract symptoms (LUTS), including urinary frequency, nocturia, weak stream, and a sensation of incomplete emptying, which can substantially disrupt daily life [3-5]. For patients with severe symptoms, poor response to medical therapy, or complications such as recurrent urinary retention or infection, surgical intervention is frequently indicated [2, 6]. Among available transurethral procedures, holmium laser enucleation of the prostate (HoLEP) has gained increasing acceptance. Current guidelines indicate that HoLEP provides reliable symptom improvement irrespective of prostate size. It is associated with lower perioperative bleeding

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risk, shorter catheterization time, and reduced hospital stay compared to some conventional techniques [7-9].

Given these advantages, HoLEP has become a major surgical option for elderly patients with BPH. However, in frail older individuals, the clinical focus extends beyond successful completion of the procedure to the course of early postoperative recovery. Frail patients often have multiple comorbidities, limited physiological reserve, and poor tolerance to perioperative stress [10-12]. In this vulnerable population, voiding recovery after catheter removal, the need for re-catheterization, and short-term urinary outcomes warrant particular attention. Existing studies on perioperative management for HoLEP have largely concentrated on anesthetic safety or general perioperative outcomes. Relatively few reports have specifically examined elderly frail patients. Furthermore, few studies have linked perioperative anesthetic management characteristics to early postoperative voiding recovery, which is an earlier and clinically practical milestone, while simultaneously evaluating short-term urinary outcomes across different recovery states.

Thus, current evidence does not fully describe the clinical trajectory of elderly frail patients undergoing HoLEP. This trajectory spans preoperative baseline status, perioperative features, early recovery, and short-term outcomes. Against this background, the present single-center retrospective study systematically reviewed preoperative baseline characteristics, perioperative anesthetic management features, early postoperative voiding recovery status, and short-term urinary outcomes in elderly frail patients undergoing HoLEP. The aim was not to isolate the effect of any single perioperative factor, but to characterize the relationship between perioperative management and postoperative recovery. This approach further highlights the value of early voiding recovery as a meaningful clinical endpoint and provides a reference for risk identification and perioperative care.

Methods

Study design and data sources

This study retrospectively reviewed the medical records of elderly male patients who underwent HoLEP at Hulunbuir Fourth People's Hospital between January 2021 and December 2024. After screening according to the inclusion and exclusion criteria, a total of 194 frail patients with complete perioperative data were ultimately included. The study data were primarily obtained from the electronic medical record system, anesthesia information system, operative and nursing records, discharge records, and outpatient, emergency department, and readmission records within 30 days after surgery. According to voiding status after the first catheter removal, patients were classified into a recovery group and a poor recovery group. On this basis, preoperative baseline characteristics, perioperative anesthetic management features, surgery-related variables, and short-term urinary outcomes were compared between the two groups. From the perspective of continuous observation spanning preoperative baseline status, perioperative characteristics, early postoperative recovery, and short-term outcomes, the study analyzed the perioperative recovery profile of elderly frail patients undergoing HoLEP.

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki [13]. The study protocol was approved by the Medical Ethics Committee of Hulunbuir Fourth People's Hospital. All study data were derived from records generated during routine clinical care, including electronic medical records, anesthesia records, surgical records, nursing records, and outpatient, emergency, and readmission records within 30 days after surgery. The study did not involve any additional intervention beyond the original clinical treatment and anesthesia management. All data were de-identified before analysis. Because this was a retrospective observational study and did not impose any additional burden related to examinations, treatment, or follow-up, the requirement for informed consent was waived with approval from the Ethics Committee of Hulunbuir Fourth People's Hospital.

Inclusion and exclusion criteria

The inclusion criteria were as follows: (1) undergoing HoLEP at Hulunbuir Fourth People's Hospital between January 2021 and December 2024; (2) a confirmed preoperative diagnosis of benign prostatic hyperplasia or benign prostatic obstruction, with corresponding surgical indications [2]; (3) age ≥75 years; (4) preoperative frailty assessed using the Clinical Frailty Scale (CFS); (5) complete perioperative anesthesia records, surgical records, nursing records, and follow-up data within 30 days after surgery, including outpatient visits, emergency visits, and readmissions; and (6) availability of sufficient data to assess early postoperative urinary recovery and short-term urological outcomes.

The CFS is a 9-point judgment-based scale ranging from 1 to 9, with higher scores indicating greater frailty. In this study, frailty was evaluated preoperatively based on the patient's medical history, comorbidities, functional status, ability to perform activities of daily living, and cognitive status. According to the standard CFS classification, a score of ≥5 was defined as frailty [14].

Exclusion criteria were as follows: (1) concomitant prostate malignancy; (2) neurogenic bladder or other neurological disorders that could substantially interfere with the assessment of urinary function; (3) a history of major prostate or urethral surgery, or concurrent urological procedures that might affect the evaluation of postoperative urinary recovery; and (4) incomplete or missing clinical data that precluded outcome assessment.

Data collection and clinical relevance

Baseline patient characteristics: The baseline data collected in this study included four parts: general demographic characteristics, preoperative health status and baseline risk factors, preoperative laboratory findings, and baseline urological variables. General demographic characteristics included age and body mass index (BMI). These variables described the basic patient profile. Preoperative overall condition and baseline perioperative risk factors included the CFS score, hypertension, type 2 diabetes mellitus, coronary artery disease, a history of cerebrovascular disease, the American Society of Anesthesiologists physical status classification (ASA class), and anticoagulant/antiplatelet use. These variables reflected overall preoperative health status, physiological reserve, and baseline perioperative risk. Preoperative laboratory findings included hemoglobin, serum albumin, and serum creatinine. These indicators were used to assess anemia status, nutritional status, and baseline renal function. Baseline urological variables included preoperative catheterization status, a history of urinary retention, prostate volume, total prostate-specific antigen (PSA), post-void residual volume (PVR), maximum urinary flow rate (Qmax), and the International Prostate Symptom Score (IPSS). These variables were mainly used to characterize preoperative voiding function and the degree of urinary obstruction, and to provide a basis for subsequent comparisons of perioperative characteristics and short-term urinary outcomes across different states of early postoperative voiding recovery.

Perioperative anesthetic management variables: Data on perioperative anesthetic management were collected from the following domains: anesthesia type, intraoperative hemodynamic status, anesthetic support, and analgesic medication use. Anesthesia type was categorized as general anesthesia or neuraxial anesthesia [15]. Intraoperative hypotension was defined as a sustained decrease in mean arterial pressure (MAP) >20% from baseline or MAP <65 mmHg for ≥5 minutes, consistent with perioperative hypotension guidelines [16]. Intraoperative fluid administration (crystalloids and colloids) was recorded as a continuous variable (mL). Rather than using a predefined 'excessive' threshold, we examined the association with early voiding recovery per 100-mL increase. Anesthetic support variables included anesthesia duration, intraoperative fluid administration, and blood transfusion, which may, to some extent, reflect the complexity of intraoperative management [17]. With respect to analgesic medication, opioid use was recorded. All of the above data were obtained from the anesthesia information system, anesthesia records, and intraoperative monitoring records. These variables were mainly used to characterize the perioperative anesthetic management features of elderly frail patients undergoing HoLEP and to compare the relevant patterns across different states of early postoperative voiding recovery.

Surgery-related variables: The surgery-related variables collected in this study included surgeon experience, operative time, enucleated tissue weight, estimated intraoperative blood loss, and intraoperative complications [18]. Surgeon experience was assessed by the number of years performing HoLEP or cumulative surgical case volume, reflecting operator proficiency [19]. Operative time, enucleated tissue weight, and estimated intraoperative blood loss reflected the surgical burden [20]. Intraoperative complications included bladder perforation, urethral injury, and prostatic capsular perforation [21], as recorded in operative records, anesthesia records, and inpatient progress notes.

Postoperative variables: Postoperative variables mainly included catheterization duration, voiding status after the first catheter removal, need for re-catheterization, postoperative urinary incontinence, urinary tract infection, hematuria or clot retention, length of hospital stay, and readmission within 30 days after surgery. In this study, early postoperative voiding recovery was used as the primary observational indicator. Patients were classified according to voiding performance after the first catheter removal. Good early postoperative voiding recovery was defined as the ability to void spontaneously after the first catheter removal without the need for re-catheterization. Poor early postoperative voiding recovery was defined as failure to void spontaneously, need for re-catheterization, or documented evidence of unsatisfactory voiding. Voiding status after the first catheter removal and the need for re-catheterization were mainly used to determine whether early postoperative voiding recovery was satisfactory [22].

Catheterization duration and length of hospital stay were mainly used to reflect the postoperative recovery process [23]. Postoperative urinary incontinence, urinary tract infection, hematuria or clot retention, and readmission within 30 days after surgery were mainly used to assess short-term urinary outcomes [24-26]. In this study, the occurrence of any one of the following events - postoperative urinary incontinence, urinary tract infection, hematuria or clot retention, or readmission within 30 days after surgery - was defined as a short-term composite adverse urinary outcome. Because catheterization duration and length of hospital stay mainly reflect the postoperative recovery process, they were compared separately and were not included in the composite endpoint. The relevant data were primarily obtained from nursing records, inpatient progress notes, discharge records, and outpatient, emergency department, and readmission records within 30 days after surgery, and were used for subsequent comparisons of short-term outcomes across different states of early postoperative voiding recovery.

Statistical analysis

All statistical analyses were performed using SPSS version 27.0. Continuous variables were first tested for normality and homogeneity of variance. Variables with a normal distribution and homogeneous variance are presented as the mean ± standard deviation ($\bar{x} \pm s$), and between-group comparisons were performed using the independent-samples t test. Variables that did not follow a normal distribution are presented as the median (P25, P75), and between-group comparisons were conducted using the Mann-Whitney U test. Categorical variables are expressed as n (%), and between-group comparisons were performed using the chi-square test; when the expected cell count was small or the assumptions for the chi-square test were not met, Fisher's exact test was used. A two-sided *P* value <0.05 was considered statistically significant.

Early postoperative voiding recovery status was used as the primary observational indicator, with the recovery group coded as 0 and the poor recovery group coded as 1. Stepwise logistic regression was performed using forward selection with entry criterion of $P<0.05$ and removal criterion of $P>0.10$. Variables entered into the stepwise procedure were those that showed unadjusted differences with $P<0.10$ in the between-group comparisons or were considered clinically relevant based on prior literature. The final models (Model 1, Model 2, and Model 3) were constructed as prespecified hierarchical models to evaluate the incremental contribution of surgical burden and anesthetic factors beyond baseline characteristics. For multiple comparisons in baseline characteristics (**Tables 1** and **2**), no adjustment for multiplicity was applied due to the exploratory nature of the study; therefore, the reported *P* values should be interpreted with caution, and findings are considered hypothesis-generating. The sample sizes of the two recovery groups were unbalanced (58 vs. 136), which is inherent to the retrospective cohort and reflects the actual clinical distribution. Multivariable regression was used to adjust for baseline differences rather than to balance group sizes; no

Table 1. Comparison of baseline characteristics between patients with different early postoperative voiding recovery status

Variable	Good recovery group (n=58)	Poor recovery group (n=136)	Statistic	*P* value
General demographic characteristics				
Age (years)	78.0 (76.0, 80.0)	80.0 (77.0, 82.0)	Z=2.273	0.023
BMI (kg/m^2)	23.6±2.6	23.0±2.6	t=1.302	0.195
Overall health status and baseline perioperative risk factors				
CFS score (5, 6, and 7), n (%)	36 (62.1%)/13 (22.4%)/9 (15.5%)	74 (54.4%)/55 (40.4%)/7 (5.2%)	χ^2=9.492	0.009
Hypertension [n (%)]	40 (69.0%)	84 (61.8%)	χ^2=0.914	0.339
Type 2 diabetes mellitus [n (%)]	14 (24.1%)	26 (19.1%)	χ^2=0.626	0.429
Coronary artery disease [n (%)]	8 (13.8%)	34 (25.0%)	χ^2=3.011	0.083
History of cerebrovascular disease [n (%)]	8 (13.8%)	30 (22.1%)	χ^2=1.764	0.184
ASA class (II/III/IV) [n (%)]	34 (56.9%)/24 (41.4%)/1 (1.7%)	55 (40.4%)/75 (55.1%)/6 (4.4%)	χ^2=4.751	0.093
Use of anticoagulant/antiplatelet agents [n (%)]	13 (22.4%)	38 (27.9%)	χ^2=0.641	0.430
Preoperative laboratory findings				
Hemoglobin (g/L)	129.9±11.6	129.6±11.3	t=0.201	0.841
Serum albumin (g/L)	40.2±3.4	38.9±3.0	t=2.821	0.005
Serum creatinine (μmol/L)	83.0 (72.1, 93.2)	85.2 (75.0, 97.3)	Z=1.209	0.226
Baseline urological variables				
Preoperative catheterization, n (%)	14 (24.1%)	40 (29.4%)	χ^2=0.563	0.453
History of urinary retention, n (%)	15 (25.9%)	50 (36.8%)	χ^2=2.169	0.141
Prostate volume (mL)	62.0 (54.0, 80.2)	72.5 (62.0, 84.8)	Z=2.316	0.021
PSA (ng/mL)	6.4 (5.1, 8.2)	7.2 (5.3, 8.9)	Z=1.053	0.292
PVR (mL)	107.9±37.5	148.5±43.3	t=6.213	<0.001
Qmax (mL/s)	8.5 (7.0, 10.0)	7.0 (6.0, 9.0)	Z=2.992	0.003
IPSS score (points)	22.3±3.9	23.4±4.4	t=1.759	0.080

Note: Data are presented as mean ± SD, median (IQR), or n (%). *P* values are unadjusted for multiple comparisons (exploratory analysis). BMI, Body Mass Index; CFS, Clinical Frailty Scale; ASA, American Society of Anesthesiologists; PSA, Prostate-Specific Antigen; PVR, Post-Void Residual urine volume; Qmax, maximum urinary flow rate; IPSS, International Prostate Symptom Score.

Table 2. Comparison of perioperative anesthetic management characteristics and surgery-related variables between patients with different early postoperative voiding recovery status

Variable	Good recovery group (n=58)	Poor recovery group (n=136)	Statistic	*P* value
Perioperative anesthesia management variables				
General anesthesia, n (%)	15 (25.9%)	74 (54.4%)	χ^2=5.392	<0.001
Intraoperative hypotension, n (%)	15 (25.9%)	62 (45.6%)	χ^2=6.610	0.010
Use of vasoactive drugs, n (%)	12 (20.7%)	34 (25.0%)	χ^2=0.418	0.518
Anesthesia duration (min)	78.4±13.0	83.5±15.4	t=-2.431	0.016
Intraoperative fluid administration (mL)	618.5 (528.5, 759.7)	853.5 (726.9, 1016.5)	Z=-6.057	<0.001
Blood transfusion, n (%)	2 (3.4%)	7 (5.1%)	Fisher	0.607
Opioid use, n (%)	112 (73.7%)	40 (83.3%)	χ^2=1.862	0.172
Surgery-related variables				
Primary surgeon HoLEP experience (≥100 cases/<100 cases)	42 (72.4%)/16 (27.6%)	96 (70.6%)/40 (29.4%)	χ^2=0.066	0.797
Operative time (min)	50.0 (41.0, 55.0)	52.0 (45.0, 59.0)	Z=-2.491	0.013
Enucleated tissue weight (g)	30.4±9.7	34.3±9.2	t=-2.633	0.009
Estimated intraoperative blood loss (mL)	54.0 (33.0, 77.3)	64.0 (45.3, 83.5)	Z=-2.376	0.017
Overall intraoperative complication rate, n (%)	4 (6.8%)	13 (9.6%)	χ^2=0.360	0.548

Note: Data are presented as mean ± SD, median (IQR), or n (%). *P* values are unadjusted for multiple comparisons (exploratory analysis). HoLEP, Holmium Laser Enucleation of the Prostate.

propensity score matching was performed because the primary aim was to identify associated characteristics rather than to estimate a causal treatment effect. We also verified that the number of events per variable (EPV) in the logistic regression models exceeded the recommended minimum of 10 (primary model: 136 events/9 variables = 15.1; secondary composite outcome model: 63 events/4 variables = 15.8), indicating that overfitting is unlikely to be a major concern in the present analyses.

The occurrence of any of the following events - postoperative urinary incontinence, urinary tract infection, hematuria or clot retention, or readmission within 30 days after surgery - was defined as a short-term composite adverse urinary outcome. Because catheterization duration and length of hospital stay mainly reflect the postoperative recovery process, they were analyzed separately and were not included in the composite endpoint. To further evaluate the association between early postoperative voiding recovery status and short-term outcomes, logistic regression analysis was performed using the short-term composite adverse urinary outcome as the dependent variable, with adjustment for recovery status, CFS score, PVR, and intraoperative hypotension.

Results

Comparison of baseline characteristics between the two groups

As shown in **Table 1**, the two groups were not entirely comparable with respect to preoperative baseline status. Compared with the good recovery group, the poor recovery group was older, showed a different distribution of CFS scores, had lower albumin levels, larger prostate volume, higher PVR, and lower Qmax, suggesting worse frailty status, nutritional reserve, and preoperative voiding function in the poor recovery group. In contrast, no statistically significant differences were observed in BMI, hypertension, diabetes, history of cerebrovascular disease, ASA classification, preoperative catheterization, history of urinary retention, PSA, or IPSS. These findings suggest that differences in early postoperative voiding recovery are associated with patients' baseline condition, and they also provide the clinical context for subsequent analyses of perioperative anesthetic management characteristics and short-term urinary outcomes.

Comparison of perioperative anesthetic management characteristics and surgery-related variables according to early postoperative voiding recovery status

Table 2 shows that the poor recovery group experienced a greater anesthetic and surgical burden during the perioperative period. Regarding anesthetic management, this group had significantly higher proportions of general anesthesia and intraoperative hypotension, longer anesthesia duration, and greater intraoperative fluid administration (all $P<0.05$). In contrast, no significant between-group differences were observed in the use of vasoactive drugs, blood transfusion, or opioid use (all $P>0.05$). Surgery-related variables also showed that the poor recovery group had longer operative time, greater enucleated tissue weight, and higher estimated intraoperative blood loss, and these differences were also statistically significant (all $P<0.05$). By contrast, surgeon experience category and the overall incidence of intraoperative complications did not differ significantly between the two groups (all $P>0.05$). Overall, the poor recovery group had a worse preoperative baseline and required more complex perioperative management and support.

Stepwise logistic regression analysis of characteristics associated with early postoperative voiding recovery

As shown in **Table 3**, in Model 1, after adjustment for age, CFS score, albumin, and PVR, PVR remained significantly associated with poor early postoperative voiding recovery ($P<0.001$), indicating that higher preoperative residual urine volume predicts poor recovery. Age and albumin were not statistically significant in Model 1. The overall test for CFS score was statistically significant, indicating that frailty stratification as a whole was associated with early postoperative voiding recovery status. However, the results of the subgroup comparisons did not show a fully consistent pattern, suggesting that this association may not be strictly linear. It may also have been influenced by the relatively small sample size in some strata and by confounding after multivariable adjustment. In Model 2, operative time was added to the variables included in Model 1. PVR remained significantly associated with poor early postoperative voiding recovery ($P<0.001$), whereas operative time itself did not reach statistical significance ($P>0.05$). This suggests that although surgical burden differed between the two groups in the univariate comparison, its independent contribution appeared relatively limited after accounting for preoperative baseline status. Model 3 further incorporated general anesthesia, intraoperative hypotension, and intraoperative fluid administration. After this additional adjustment, PVR, intraoperative

Table 3. Stepwise logistic regression analysis of characteristics associated with early postoperative voiding recovery

Variable	Model 1, OR (95% CI)	*P* value	Model 2, OR (95% CI)	*P* value	Model 3, OR (95% CI)	*P* value
Age (years)	1.054 (0.935-1.188)	0.392	1.043 (0.925-1.177)	0.491	1.046 (0.903-1.211)	0.551
CFS score (overall)	-	0.003	-	0.005	-	<0.001
CFS score (1)*	1.380 (0.615-3.098)	0.434	1.174 (0.512-2.691)	0.705	0.792 (0.284-2.209)	0.656
CFS score (2)*	0.128 (0.034-0.486)	0.003	0.115 (0.029-0.461)	0.002	0.009 (0.001-0.094)	<0.001
Serum albumin (g/L)	0.919 (0.817-1.035)	0.163	0.918 (0.814-1.035)	0.161	0.980 (0.846-1.134)	0.785
Per 10-mL increase in postvoid residual urine volume	1.298 (1.167-1.443)	<0.001	1.276 (1.146-1.421)	<0.001	1.252 (1.094-1.434)	0.001
Operative time (min)	-	-	1.038 (0.996-1.081)	0.074	1.037 (0.985-1.092)	0.170
General anesthesia	-	-	-	-	3.231 (1.176-8.878)	0.023
Intraoperative hypotension	-	-	-	-	27.483 (4.970-151.973)	<0.001
Per 100-mL increase in intraoperative fluid administration	-	-	-	-	1.627 (1.222-2.165)	<0.001

Note: *Reference categories for CFS score: CFS score 5 as reference. CFS score (1): CFS=6 vs. CFS=5; CFS score (2): CFS=7 vs. CFS=5. CFS, Clinical Frailty Scale; OR, Odds Ratio; CI, Confidence Interval; PVR, Post-Void Residual urine volume.

Table 4. Comparison of short-term urinary outcomes between patients with different early postoperative voiding recovery status

Variable	Good recovery group (n=58)	Poor recovery group (n=136)	Statistic	*P* value
Catheterization duration (days)	2.0 (2.0,3.0)	4.0 (3.0, 4.0)	Z=-9.221	<0.001
Postoperative urinary incontinence, n (%)	5 (8.6%)	33 (24.3%)	χ^2=6.318	0.012
Urinary tract infection, n (%)	3 (5.2%)	31 (22.8%)	χ^2=8.735	0.003
Hematuria or clot retention, n (%)	4 (6.9%)	22 (16.2%)	χ^2=3.017	0.082
Length of hospital stay (days)	4.0 (4.0, 5.0)	6.0 (5.0, 6.0)	Z=-7.572	<0.001
Readmission within 30 days after surgery, n (%)	0 (0.0%)	15 (11.0%)	Fisher	0.008

hypotension, and increased fluid administration remained significantly associated with poor early postoperative voiding recovery (all *P*<0.05), whereas age, albumin, operative time, and general anesthesia were not statistically significant. Overall, after accounting for preoperative baseline status and surgical burden, some perioperative anesthetic management characteristics still showed significant associations with early postoperative voiding recovery, among which the associations of intraoperative hypotension and greater fluid administration appeared to be relatively more consistent.

Comparison of short-term urinary outcomes between patients with different early postoperative voiding recovery status

Table 4 shows that short-term urinary outcomes differed to some extent between patients with different early postoperative voiding recovery status. Compared with the recovery group, the poor recovery group had a longer catheterization duration, higher rates of postoperative urinary incontinence and urinary tract infection, a longer hospital stay, and a higher rate of readmission within 30 days, with all differences reaching statistical significance (all *P*<0.05). In addition, the incidence of hematuria or clot retention was also higher in the poor recovery group, although the difference did not reach statistical significance (*P*=0.082). These findings suggest that early postoperative voiding recovery correlates not only with immediate voiding status but also with subsequent short-term urinary outcomes.

Logistic regression analysis of the association between early postoperative voiding recovery status and adverse short-term urinary outcomes

Because our primary interest was the association between early postoperative voiding recovery status and adverse short-term urinary outcomes, recovery status was retained in the model as the key variable. In addition, CFS score, preoperative PVR, and intraoperative hypotension were included for adjustment in consideration of patients' baseline condition and perioperative characteristics, so that the analysis would better reflect the clinical context.

As shown in **Table 5** and **Figure 1**, in the unadjusted logistic regression analysis, poor recovery, increased PVR, and intraoperative hypotension were all statistically associated with adverse short-term urinary outcomes (all *P*<0.05), whereas CFS score was not statistically significant (*P*>0.05). After further adjustment for CFS score, PVR, and intraoperative hypotension, the association between poor recovery status and adverse short-term urinary outcomes remained significant (OR=4.301, 95% CI: 1.910-9.684, *P*<0.001), while none of the other variables reached statistical significance. These findings suggest that early postoperative voiding recovery status may have clinical value in identifying patients at increased risk of unfavorable short-term urinary recovery. In addition to the composite endpoint, separate exploratory analyses were performed for each individual urinary complication. As shown in Supplementary Table 1, poor early postoperative voiding recovery was significantly associated with postoperative urinary incontinence, urinary tract infection, and 30-day readmission, but not with hematuria or clot retention, after adjustment for covariates.

Discussion

In this retrospective study of elderly frail patients undergoing HoLEP, early postoperative voiding recovery was associated with preoperative baseline characteristics, intraoperative

Table 5. Logistic regression analysis of the association between early postoperative voiding recovery status and adverse short-term urinary outcomes

Variable	Unadjusted OR (95% CI)	*P* value	Adjusted OR (95% CI)	*P* value
Poor recovery (vs recovery group)	4.951 (2.367-10.355)	<0.001	4.301 (1.910-9.684)	<0.001
CFS score (per 1-point increase)	1.403 (0.901-2.184)	0.134	1.387 (0.843-2.283)	0.198
PVR (per 10-mL increase)	1.100 (1.030-1.175)	0.005	1.027 (0.953-1.108)	0.483
Intraoperative hypotension (vs no)	1.960 (1.092-3.516)	0.024	1.483 (0.791-2.781)	0.219

Note: Adjusted ORs derived from a multivariable logistic regression model including recovery status, CFS score, PVR (per 10-mL increase), and intraoperative hypotension. OR, Odds Ratio; CI, Confidence Interval; CFS, Clinical Frailty Scale; PVR, Post-Void Residual urine volume.

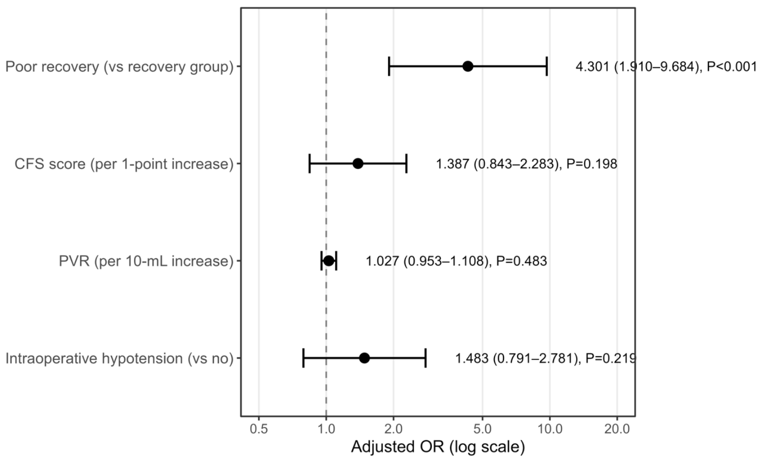

Figure 1. Forest plot of factors associated with short-term adverse urological outcomes. Note: OR, Odds Ratio; CFS, Clinical Frailty Scale; PVR, Post-Void Residual urine volume.

anesthetic management factors, and surgical burden. Patients who experienced poor voiding recovery after the first catheter removal presented with a less favorable preoperative profile, received different intraoperative care, and went on to have worse short term urinary outcomes. These findings suggest that the simple observation of voiding status after catheter removal may serve as an early clinical indicator for identifying patients at heightened risk of a poor postoperative course.

The comparison of baseline characteristics between the two recovery groups showed that patients with poor early voiding recovery were older and had a different distribution of CFS scores, with a higher proportion classified as CFS 6 and fewer as CFS 7. This finding may reflect more conservative management or different selection patterns for the most frail patients in this cohort. In addition, the poor recovery group had lower serum albumin levels, larger prostate volume, higher postvoid residual volume, and lower maximum urinary flow rate. The association between higher preoperative PVR and poor recovery remained robust in multivariable analyses, indicating that baseline bladder dysfunction is an important predictor of postoperative void. Similar observations have been reported by Di Maida et al. [22], who found that higher preoperative PVR independently predicted early re-catheterization after HoLEP. The presence of larger prostate volume and lower Qmax in the poor recovery group further supports the notion that these patients had more severe bladder outlet obstruction, which may have contributed to delayed detrusor recovery following surgical decompression.

When perioperative anesthetic management was compared, the poor recovery group had a higher proportion of general anesthesia, more frequent intraoperative hypotension, longer anesthesia duration, and greater intraoperative fluid administration. In the stepwise logistic regression model that adjusted for baseline status and surgical time, general anesthesia, intraoperative hypotension, and higher fluid volumes were each independently associated with poor voiding recovery. The association with general anesthesia may reflect the differential effects of anesthetic agents on bladder function. General anesthesia typically involves the use of intravenous and inhalational agents that can impair detrusor contractility and alter the sensory feedback pathways involved in micturition. By contrast, neuraxial anesthesia may allow earlier recognition of bladder filling and more coordinated voiding once the block resolves. Westhofen et al. [15] compared spinal versus general anesthesia for HoLEP in high-risk patients and found that the choice of anesthesia influenced perioperative outcomes, although its specific effect on early voiding recovery was not always distinguished. The present study adds to this literature by showing that even after accounting for differences in surgical complexity and patient frailty, the use of general anesthesia was associated with a greater likelihood of poor voiding recovery [27, 28].

Intraoperative hypotension was another factor strongly associated with poor early voiding recovery. Elderly frail patients have limited physiological reserve and are particularly vulnerable to fluctuations in blood pressure during anesthesia. Hypotension may reduce perfusion to the bladder and the pelvic floor musculature, potentially leading to ischemic stress that impairs detrusor function in the immediate postoperative period. Although the bladder has a rich collateral blood supply, prolonged or repeated episodes of hypotension could compromise microvascular flow, especially in patients with preexisting vascular comorbidities [29-31]. Greater intraoperative fluid administration was also independently correlated with poor voiding recovery. Excessive fluid infusion may lead to bladder overdistension, edema of the bladder wall, or altered detrusor compliance, all of which can interfere with the restoration of normal voiding mechanics. Alternatively, higher fluid volumes may simply reflect a more complicated intraoperative course or a compensatory response to hypotension, rather than a direct causal facto [32, 33]. Nevertheless, the persistence of this association after adjustment for other variables suggests that fluid management deserves attention as a modifiable element of perioperative care.

Surgery related variables such as longer operative time, greater enucleated tissue weight, and higher estimated blood loss were all associated with poor voiding recovery in the unadjusted comparisons. However, when these variables were entered into the multivariable model along with anesthetic factors, operative time did not retain statistical significance. This pattern indicates that the effect of surgical burden on early voiding recovery is largely mediated by anesthetic support intensity and baseline patient condition. In other words, patients who require longer operations and have larger prostheses also tend to receive more fluids, experience more hypotension, and have a higher likelihood of receiving general anesthesia, making it difficult to isolate the independent contribution of surgical duration alone [9, 34].

The comparison of short-term urinary outcomes revealed that patients with poor early voiding recovery had longer catheterization duration, longer hospital stay, higher rates of postoperative urinary incontinence and urinary tract infection, and a higher readmission rate within 30 days. The incidence of hematuria or clot retention was also numerically higher in the poor recovery group, although the difference did not reach statistical significance. These findings demonstrate that the first voiding trial after catheter removal is not merely an isolated endpoint but rather a marker that reflects a broader pattern of recovery. Poor voiding recovery often necessitates re-catheterization, which extends indwelling catheter use and increases the risk of catheter-associated urinary tract infection (CAUTI). Prolonged catheterization may also delay hospital discharge and contribute to patient discomfort and immobility, further compounding the risk of adverse events. The higher rate of urinary incontinence in the poor recovery group is consistent with the hypothesis that these patients had more profound detrusor dysfunction or impaired sphincter coordination, which may take longer to recover after prostatic surgery [32, 35, 36].

When the composite adverse short term urinary outcome was used as the dependent variable, poor early voiding recovery remained strongly associated with an increased risk of this composite endpoint, even after adjustment for CFS score, preoperative PVR, and intraoperative hypotension. The fact that other variables lost statistical significance after adjustment for recovery status suggests that early voiding recovery may integrate information from multiple domains, including preoperative bladder function, intraoperative events, and the patient's overall resilience. From a clinical perspective, this observation supports the use of voiding status after the first catheter removal as a simple and practical screening tool. In routine clinical practice, where detailed frailty assessments or urodynamic studies may not be readily available, observing whether a patient can void successfully after catheter removal provides immediate and actionable information. Those who fail this trial should be considered for closer monitoring, targeted interventions such as bladder retraining or pharmacologic support, and earlier follow up after discharge.

Several limitations in this study should be acknowledged. As a single-center retrospective study, its findings may not be generalizable to other populations or settings. Furthermore, the two recovery groups were imbalanced in size (58 vs. 136), which reflects the natural distribution of early voiding recovery in this frail cohort but may have introduced bias in the estimation of some subgroup effects. We also did not use a predefined cutoff to define 'excessive' fluid administration; instead, fluid volume was analyzed as a continuous variable, which limits direct comparison with studies that use dichotomous thresholds. Frailty assessment using the CFS, though practical, involves clinical judgment and may be subjective; more objective measures such as the Fried phenotype were not available. The classification of early voiding recovery relied on medical record documentation, which may not capture subtle voiding dysfunction or patient reported symptoms. Long-term urinary outcomes beyond 30 days were not collected, including lower urinary tract function assessed by urodynamic studies or validated symptom scores, as well as quality-of-life measures. Consequently, the persistence of voiding difficulties, late recovery of continence, and overall patient-reported outcomes could not be evaluated. Future prospective studies with follow-up periods of at least 6-12 months are warranted to address these gaps and to determine whether early voiding recovery status predicts long-term functional outcomes. Although the sample size was adequate for the primary analyses, it may have limited the detection of smaller associations within subgroups such as specific frailty levels or anesthetic techniques. Finally, the observational design precludes causal inference, and the findings should be interpreted as hypothesis generating. Future research should prospectively validate these results in a multicenter cohort with standardized protocols for anesthesia and postoperative voiding assessment. Incorporating urodynamic studies before and after surgery may help clarify the mechanisms linking intraoperative hypotension, fluid administration, and detrusor dysfunction. Randomized controlled trials comparing different anesthetic techniques or fluid management strategies specifically in frail elderly patients undergoing HoLEP would provide higher-level evidence. Additionally, exploring whether early interventions such as pelvic floor physiotherapy or pharmacologic bladder support could improve voiding recovery in high-risk patients is warranted.

Conclusion

This study demonstrated that, in elderly frail patients, early postoperative voiding recovery after HoLEP was associated with preoperative baseline status, surgical burden, and perioperative anesthetic management characteristics, and that short-term urinary outcomes also differed according to recovery status. After adjustment for selected baseline and perioperative factors, poor early postoperative voiding recovery remained associated with adverse short-term urinary outcomes. The present study particularly underscores the clinical significance of early postoperative voiding recovery as an observation outcome. In practice, voiding status after catheter removal may serve as an early and practical indicator of recovery for identifying patients at increased risk of unfavorable short-term recovery.

Disclosure of conflict of interest

None.

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Supplementary Table 1. Multivariable logistic regression analysis of the association between early postoperative voiding recovery status and individual short-term urinary complications

Outcome	Adjusted OR (95% CI)*	*P* value
Postoperative urinary incontinence	3.204 (1.146-9.001)	0.026
Urinary tract infection	3.875 (1.120-13.306)	0.032
Hematuria or clot retention	2.109 (0.652-6.824)	0.214
Readmission within 30 days	6.420 (1.732-21.889)	0.005

Note: *Adjusted for CFS score, PVR (per 10-mL increase), and intraoperative hypotension. Reference group: good recovery.