

Independent and time-dependent predictors of urinary continence recovery after single-port robot-assisted radical prostatectomy: a retrospective cohort study

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Abstract

Background

Postprostatectomy incontinence (PPI) following radical prostatectomy (RP) significantly affects patients' quality of life. Although predictors of urinary continence recovery after conventional robot-assisted radical prostatectomy have been widely investigated, evidence regarding predictive factors for PPI recovery in the context of single-port robot-assisted radical prostatectomy (sp-RARP) remains limited. This study aimed to identify predictors associated with urinary continence recovery after sp-RARP and evaluate their predictive performance over time.

Methods

This retrospective study included 98 patients who underwent sp-RARP performed by the same surgeon (C.W.) at the First Affiliated Hospital of Harbin Medical University between July 2023 and December 2024. The primary endpoint was urinary continence recovery after sp-RARP. Potential predictors were evaluated using univariate and multivariate Cox proportional hazards regression analyses. The performance of the significant predictors was further assessed using time-dependent receiver operating characteristic (tdROC) curve analysis at 2, 4, 12, 24, and 48 weeks after surgery.

Results

Four independent predictors associated with urinary continence recovery were identified including age ($p = 0.024$; HR = 0.964; 95% CI: 0.934–0.995), prostate volume ($p = 0.003$; HR = 0.982; 95% CI: 0.970–0.994), modified “Hood” technique ($p = 0.005$; HR = 3.091; 95% CI: 1.404–6.806), and bladder neck preservation (BNP) ($p = 0.029$; HR = 1.972; 95% CI: 1.070–3.633). tdROC analysis demonstrated that the predictive performance of these factors varied throughout follow-up. Prostate volume showed the most sustained improvement in predictive ability, reaching an AUC of 0.909 at 48 weeks. Age and BNP level peaked at 12 and 24 weeks, with AUC values of 0.804 and 0.899, respectively, followed by slight decreases. The modified “Hood” technique demonstrated the highest predictive value at 4 weeks post-operatively (AUC = 0.858), with gradual attenuation over long-term follow-up.

Conclusions

Age, prostate volume, the modified “Hood” technique, and bladder neck preservation were independent predictors of urinary continence recovery after sp-RARP. Their predictive performance varied across the postoperative recovery period. The modified “Hood” technique showed the strongest predictive value during early recovery, whereas age and bladder neck preservation demonstrated relatively greater predictive value during the intermediate recovery period. Prostate volume progressively improved and

sustained its predictive performance over long-term follow-up. These findings suggest that different clinical and surgical factors may contribute to urinary continence recovery at different stages after sp-RARP and may provide a basis for individualized prediction and postoperative management.

Introduction

Prostate cancer (PCa) is the second most common malignancy among men worldwide¹, and radical prostatectomy (RP) represents the primary treatment for localized disease in patients with a life expectancy exceeding 5–10 years². The main complication after RP is postprostatectomy incontinence (PPI). The incidence of PPI after RP ranges from 4% to 31%³. PPI is generally defined as the use of > 1 pad per day⁴.

The choice of technique during the operation is directly related to the function of the urethral sphincter, and the integrity of the neurovascular bundle and the preservation of the pelvic floor support structure have a decisive effect on the outcome of PPI⁵. At present, the main surgical methods for RP include open radical prostatectomy (ORP), laparoscopic radical prostatectomy (LRP), multiport RARP (mp-RARP) and single-port RARP (sp-RARP). The recovery rate of urinary incontinence after RARP is significantly greater than that after LRP⁶. Compared with mp-RARP, sp-RARP has no significant difference in urinary incontinence recovery at 3 months, 6 months or 12 months; however, it has clear advantages in terms of postoperative pain control and a shorter hospital stay, which is helpful for the early mobility and rehabilitation of patients⁷.

At present, the known predictors of urinary incontinence recovery after mp-RARP with high-quality evidence include preoperative factors such as membranous urethral length⁸, whole body skeletal muscle content⁹, prostate volume¹⁰, age, and body mass index (BMI)¹¹. The choice of surgical technique, including bladder neck preservation (BNP)¹⁰, neurovascular bundle (NVB) preservation¹¹, and the “Hood” technique¹² is also an independent factor.

However, few studies have investigated the predictors of urinary incontinence recovery after sp-RARP. Therefore, this study aimed to identify independent predictors of urinary continence recovery after sp-RARP and to characterize their time-dependent predictive performance during postoperative follow-up.

Materials and Methods

Data Source

We selected 98 patients who underwent sp-RARP at the First Affiliated Hospital of Harbin Medical University from July 2023 to December 2024 by the same surgeon (C.W.). All operations were performed with the DaVinci Xi platform and single-port device. All patients were informed in writing about the surgical methods and risks, and signed the surgical consent form. None of the 98 patients underwent conversion to open surgery. All patients underwent prostate specific antigen (PSA) testing, digital rectal

examination (DRE) and prostate magnetic resonance imaging (MRI) before surgery. Patients who met the following inclusion and exclusion criteria were selected: (1) underwent surgical treatment based on a preoperative examination and had a life expectancy of more than 10 years, (2) underwent lung CT, electrocardiogram, cardiac color Doppler ultrasound, and prostate magnetic resonance imaging before surgery, and underwent a transperineal prostate biopsy under ultrasound guidance, and the biopsy results revealed a diagnosis of prostate cancer. The exclusion criteria included the following: (1) magnetic resonance imaging and bone scan showed that the tumor had distant metastasis or severe invasion of periprosthetic tissues, which was expected to be difficult to remove by surgery; (2) inability to tolerate surgical treatment under general anesthesia by preoperative evaluation; (3) postoperative complications and Clavien-Dindo grade ≥ 2 ; (4) a preoperative diagnosis of urethral stricture or neurogenic bladder; (5) refusal to follow up and (6) recurrence during follow-up and the need for further surgery. In accordance with the inclusion and exclusion criteria, 98 eligible patients were ultimately included. This study was approved by the Ethics Committee of the First Affiliated Hospital of Harbin Medical University.

Surgical technique

The surgical steps have been previously reported¹³. This article focuses only on surgical techniques that may be associated with PPIs.

After the position of the prostatovesical junction was determined, the anterior lip of the prostate was separated from the bladder sphincter by sharp and blunt dissection. The neck of the bladder was found, and the urethra was transected near the prostate (Fig. 1A). Dissection continued posteriorly to fully mobilize the seminal vesicles and vas deferens, which were then divided. The seminal vesicles were elevated and dissected along their course using combined blunt and sharp dissection to identify the plane between the prostatic capsule and prostatic fascia. The neurovascular bundles (NVBs) were preserved by performing dissection within the fascial layer. The prostatic capsule and surrounding fascia were further separated on both the dorsal and the ventral aspects down to the prostatic apex (Fig. 1B). The distal urethra was fully mobilized, and a second urethral transection was performed close to the apex, preserving as much of the external urethral sphincter as possible (Fig. 1C). The remaining structure was defined as the “Hood” configuration (Fig. 1D). Using 2–0 V-Loc sutures, a parachute-style running suture (PSRS) was performed to approximate the bilateral lateral levator ani muscles to the outer layer of the posterior trigone of the bladder. As the pneumoperitoneum pressure gradually decreased, the suture was tightened incrementally, and the bladder neck was drawn toward the external urethral sphincter at the prostatic apex (Fig. 1E). A Foley catheter (18 Fr, three-way) was reinserted, and an additional 2–0 V-Loc suture was used to perform continuous anastomosis between the external urethral sphincter and the bladder neck. The bladder was filled with 100 mL of saline via the catheter to confirm watertight integrity at the anastomotic site. Finally, a third 2 – 0 V-Loc suture was used to perform a left-to-right continuous approximation of the superior aspect of the preserved “Hood” structure to the ventral surface of the bladder neck, providing anterior reinforcement of the reconstructed urethra (Fig. 1F).

Figure1. DA: detrusor apron, P: prostate, PF: prostate fascia, PC: prostate capsule, IUO: internal urethral orifice, US: urethral stump, B: bladder, BN: bladder neck, EPF: endopelvic fascia.

Statistical Analysis

According to the exclusion and inclusion criteria, a total of 98 patients were enrolled in this study with a 48-week follow-up period. The day of surgery was set as the starting point of follow-up, and the urinary continence recovery status of patients at different time points was recorded. PPI is defined as the use of > 1 pad per day. Urinary continence recovery was defined as the use of ≤ 1 urinary pad per day, which was considered the endpoint event in this study. All patients had their urinary catheters removed at 2 weeks post-operatively; thus, the first follow-up was conducted on the day of catheter removal. Subsequent follow-ups were performed at 4, 12, 24 and 48 weeks after surgery. Patients lost to follow-up were defined as censored data, and no deaths occurred during the follow-up period.

SPSS Statistics 27 was used for data analysis. Continuous variables were compared using Student's *t*-test or the Mann–Whitney *U* test, and categorical variables were compared using the χ^2 test or Fisher's exact test. *R* language was used to construct the tdROC curve. The PH assumption was verified by the Schoenfeld residual test for continuous variables and by plotting log survival curves for categorical factors. Survival analyses were performed using the Cox proportional hazards regression model, with urinary continence recovery defined as the event of interest. Variables with clinical relevance or potential associations in univariate analysis were included in multivariate Cox regression analysis. The multivariate Cox model was validated using the backward likelihood ratio selection method. The predictive performance of individual predictors over time was assessed using tdROC curve analysis, and the area under the curve (AUC) was calculated at predefined postoperative time points.

Results

The baseline characteristics are summarized in Table 1. Significant differences in DVC ligation, BNP, total urethral reconstruction, and operation time between the two groups ($p < 0.05$). During the 48-week follow-up, 87 patients achieved urinary continence recovery, while 11 were censored.

After univariate Cox regression analysis was performed to identify the various factors that might affect postoperative urinary continence recovery, the final selection was made on the basis of age, prostate volume, previous cerebral infarction, DVC ligation, BNP, total urethral reconstruction, and the modified “Hood” technique. It was included in the multivariate Cox regression model.

Multivariable Cox proportional hazards regression analysis, revealed that the modified “Hood” technique, BNP, age, and prostate volume were independently associated with urinary continence recovery after adjustment for potential confounders. Age ($p = 0.024$; [HR] = 0.964; 95% CI: 0.934–0.995), prostate volume ($p = 0.003$; [HR] = 0.982; 95% CI: 0.970–0.994), modified “Hood” technique ($p = 0.005$; [HR] = 3.091; 95% CI: 1.404–6.806), bladder neck preservation (BNP) ($p = 0.029$; [HR] = 1.972; 95% CI: 1.070–3.633) (Table 2).

As a sensitivity analysis, a backward likelihood ratio selection procedure was subsequently applied. The resulting reduced model retained the same four predictors—age, prostate volume, BNP, and modified “Hood” technique—with comparable effect estimates and statistical significance, supporting the robustness of the primary multivariable findings (Table 3).

To systematically evaluate the time-varying discriminatory capacity of four predictors (age, prostate volume, modified “Hood” technique, and BNP) for the 48-week clinical endpoint, tdROC curves were constructed (Fig. 2), and the corresponding area under the curve (AUC) values were calculated at five postoperative follow-up time points: 2, 4, 12, 24, and 48 weeks. All four predictors exhibited prominent time-dependent predictive patterns with distinctly different trends across follow-up durations. The predictive performance of log-transformed age increased gradually over time, with the AUC increasing from 0.677 at week 2 to a peak of 0.804 at week 24, followed by a mild decline to 0.798 at week 48. The AUC of prostate volume was 0.714 at 2 weeks after surgery. As the follow-up time increased, the AUC gradually increased, and reached 0.909 at 48 weeks. The modified “Hood” technique achieved a maximum AUC of 0.858 as early as post-operative week 4, followed by a continuous decrease from week 12 (AUC = 0.793) to the 48-week endpoint (AUC = 0.703). The AUC of BNP was 0.626 at week 2; its discriminatory power improved to a moderate level (AUC = 0.745) at week 4 and peaked at 0.899 at week 12. The excellent predictive performance was sustained between week 12 and week 24 (AUC = 0.896 at week 24), with a slight decrease to 0.860 at week 48.

Table 1

Baseline and perioperative characteristics of patients who underwent single-port robot-assisted radical prostatectomy

Variables	Overall (n = 98)	Non-Hood group (n = 63)	Modified Hood group (n = 35)	p value
Age(years)	69.07 ± 6.96	69.25 ± 7.35	68.74 ± 6.29	p = 0.729
BMI (kg/m²)	24.20 ± 3.06	24.29 ± 3.18	24.04 ± 2.86	p = 0.705
PSA (ng/ml)	17.60(6.87–44.90)	17.70(7.43–53.57)	14.40(3.03–37.95)	p = 0.350
Prostate volume(ml)	40.95(24.29–54.41)	41.40(24.96–60.02)	27.39(23.22–49.92)	p = 0.131
Gleason grade group				
Grade group 1–2	29	20	9	p = 0.531
Grade group 3–5	69	43	26	
Clinical stage				
cT1–T2	42	26	16	p = 0.670
cT3-T4	56	37	19	
DVC ligation				
Yes	53	53	0	p<0.001
No	45	10	35	
BNP				
Yes	62	35	27	p = 0.034
No	36	28	8	
Total urethral reconstruction				
Yes	54	19	35	p<0.001
No	44	44	0	
Operation time(min)	189.50(154.50-237.75)	210(170–270)	170(150–196)	p<0.001
Previous cerebral infarction				

Variables	Overall (n = 98)	Non-Hood group (n = 63)	Modified Hood group (n = 35)	p value
Yes	35	24	11	p = 0.509
No	63	39	24	

Table 1. BMI: body Mass Index; PSA: prostate-specific antigen; DVC: dorsal venous complex; BNP: bladder neck preservation.

Table 2

Multivariate Cox regression for predictors of urinary continence recovery after single-port robot-assisted radical prostatectomy

Variables	aHR	95% CI	p value
Age	0.964	0.934–0.995	0.024
Prostate volume	0.982	0.970–0.994	0.003
Previous cerebral infarction	0.877	0.533–1.444	0.607
DVC ligation	1.071	0.487–2.353	0.864
BNP	1.972	1.070–3.633	0.029
Total urethral reconstruction	1.191	0.603–2.354	0.615
Modified Hood Technique	3.091	1.404–6.806	0.005

Table 2.DVC: dorsal venous complex; BNP: bladder neck preservation.

Table 3

Final multivariate Cox regression model for predicting urinary continence recovery after single-port robot-assisted radical prostatectomy

Variables	aHR	95% CI	p value
Age	0.965	0.935–0.995	0.023
Prostate volume	0.982	0.970–0.994	0.002
BNP	2.072	1.145–3.748	0.016
Modified Hood Technique	3.263	1.946–5.473	<0.001

Table 3. BNP: bladder neck preservation.

Figure 2. A: Marker = $\log(0.965) \times \text{Age}$; 2 weeks calculated at 2.001 weeks; time = 48/event = 0 treated as no-event controls; B: Marker = $\log(0.982) \times \text{Prostate Volume}$; 2 weeks calculated at 2.001 weeks; time = 48/event = 0 treated as no-event controls; C: Marker = $\log(2.072) \times \text{BNP}$; 2 weeks calculated at

2.001 weeks; time = 48/event = 0 treated as no-event controls; D: Marker = $\log(3.263) \times$ Modified Hood Technique; 2 weeks calculated at 2.001 weeks; time = 48/event = 0 treated as no-event controls

Discussion

PCa is the second most common tumor in men, and RP is currently the mainstream treatment[1]. RARP is currently the mainstream treatment method for localized prostate cancer in developed countries such as those in Europe and America¹⁴. With the increasing number of RP performed and a growing proportion of younger patients undergoing surgery, postoperative urinary continence recovery has emerged as an increasingly significant clinical concern¹⁵. In this study, the predictors of urinary continence recovery after sp-RARP were explored, and tdROC was further used to evaluate the predictive ability of different predictors at different postoperative time points.

Modified “Hood” technique as an early predictor of urinary continence recovery with peak performance at 4 weeks

In contrast, the modified “Hood” technique ($p = 0.005$; [HR] = 3.091; 95% CI: 1.404–6.806) was an independent protective factor against urinary continence recovery. The core mechanism of this technique lies in the preservation of the detrusor muscle. One prospective study analyzed 311 patients who underwent robot-assisted radical prostatectomy with bladder neck reconstruction (RS-RARP). In that study, detrusor preservation was stratified into grades 0 to 3 (grade 0 = complete resection, grade 3 = complete preservation). The results demonstrated that the odds ratios (ORs) for grade 1, grade 2 and grade 3 preservation groups at 3 months post surgery were 3.84, 9.83 and 16.06, respectively, revealing a clear dose–effect relationship¹⁶. Consistent with previous findings, our study demonstrated similar results. In the multivariable Cox proportional hazards model adjusted for potential confounders, patients who received the modified “Hood” technique had a 3.091-fold greater likelihood of achieving urinary continence recovery. Therefore, although sp-RARP already offers inherent advantages such as reduced postoperative pain and shorter hospitalization¹⁷, incorporation of the modified “Hood” technique may provide an additional benefit for urinary continence recovery by preserving periurethral anatomical support structures.

According to the tdROC curve, the predictive value of the modified “Hood” technique for postoperative urinary continence peaked at 4 weeks, but decreased to 0.703 after 48 weeks. However, the AUC was greater than 0.5 throughout the entire period, indicating that the modified “Hood” technique had a positive protective effect on postoperative urinary continence recovery. The AUC at 4 weeks after the operation was as high as 0.858, which was the highest among all follow-up points in this study, reflecting the anatomical advantages of the modified “Hood” technique in preserving the fascia around the urethra¹⁸, protecting the blood supply of the urethral sphincter and neurovascular bundle¹⁹, and playing an important role in the early recovery of urinary continence at 1 month after the operation. The predictive performance of the modified “Hood” technique was relatively limited at 2 weeks after surgery (AUC = 0.765). This may be explained by the fact that urinary continence recovery remains in an early

transitional phase during this period. At 2 weeks after catheter removal, transient postoperative factors, including periurethral tissue edema, local inflammatory responses, and incomplete functional recovery of the urethral sphincter, may substantially influence urinary continence outcomes. Consequently, the anatomical benefits conferred by the modified “Hood” technique may not yet be fully reflected in continence status at this early time point. As functional recovery progresses, the contribution of anatomical preservation becomes increasingly apparent, which may explain the improved predictive performance observed at 4 weeks after surgery. A large prospective study of the Hood technique (300 patients) reported rates of recovery of urinary control of 21% at 1 week after catheter removal, 36% at 2 weeks, 83% at 4 weeks, and 88% at 6 weeks, with subsequent improvements to 91% at 12 weeks and 95% at 48 weeks¹². This findings suggest that 1 month after surgery is a critical period for recovery from urinary continence. As time progressed, the AUC of the modified “Hood” technique gradually decreased, mainly because of the increase in factors affecting urinary control outcomes in the medium and long term, and the relative decline in the explanatory power of a single surgical factor for urinary control outcomes.

BNP as a stable predictor of intermediate- and long-term continence outcomes

BNP ($p = 0.029$; [HR] = 1.972; 95% CI: 1.070–3.633) was also an independent protective factor against urinary continence recovery. A meta-analysis collated data from multiple studies and revealed that patients in the BNP group had a significantly higher urinary continence rate one month after surgery than those in the nonpreservation group did (OR = 2.88, 95% CI 1.80– 4.60; $P < 0.05$), and this difference persisted from 3 to 4 months after surgery (OR = 2.32, 1.42–3.80; $P < 0.05$)²⁰. In a randomized controlled trial, the degree of urinary incontinence in the bladder neck preservation group was significantly lower than that in the control group at all time points after surgery. The social urinary control rates at 3, 6, and 12 months after surgery were 84.2% vs 55.3% ($p < 0.001$), 89.5% vs 74.8% ($p = 0.05$), and 94.7% vs 81.4% ($p = 0.027$), respectively. Multivariate logistic regression analysis confirmed that BNP was an independent positive predictor of urinary continence²¹.

At 2 weeks after surgery, the AUC of BNP was 0.626, indicating limited discriminatory ability for urinary continence recovery during the very early postoperative phase. This may be attributed to the fact that early continence status is substantially influenced by transient postoperative factors, including tissue edema, inflammatory responses, and incomplete recovery of sphincter function, which may obscure the predictive value of anatomical or functional indicators. As follow-up extended to 4 weeks after surgery, the predictive performance of the BNP improved significantly (AUC = 0.745), suggesting that the BNP can be used to provide meaningful prognostic stratification for urinary continence recovery during the early recovery phase. The AUC reached 0.899 at 12 weeks and remained highly consistent at 24 weeks (AUC = 0.896), indicating excellent and stable discriminatory ability during the intermediate recovery period. At 48 weeks after surgery, although the AUC slightly decreased to 0.860, the predictive

performance of BNP remained strong, suggesting that it maintained a stable association with long-term urinary continence outcomes.

Age as a long-term predictor of urinary continence recovery

Age ($p = 0.024$; [HR] = 0.964; 95% CI: 0.934–0.995) was identified as an independent risk factor for urinary continence recovery after surgery, indicating that patients with advanced age had a lower probability of regaining urinary continence within 48 weeks after surgery. Age has been well-established as an independent risk factor for postoperative urinary incontinence. This phenomenon may be attributed to multiple age-related alterations, such as degenerative changes in the nerves and membranous urethra among elderly men^{22–23}, as well as sarcopenia-induced atrophy of pelvic floor supportive muscles secondary to systemic skeletal muscle loss, which impairs the urethral closure mechanism and ultimately leads to poor long-term continence recovery⁹. A multicenter cohort involving 14,920 patients demonstrated significant intergroup differences in the incidence and severity of urinary incontinence at 12 months after surgery across distinct age strata²⁴. Another registry-based study using the CaPSURE database ($n = 5,742$) further reported that each 10-year increase in age doubled the risk of secondary surgical intervention for refractory incontinence (HR = 2.0)⁴. Consistent with these previous findings, multivariate Cox regression in the present study revealed age as an independent adverse predictor of continence recovery following sp-RARP; specifically, each additional year of age corresponded to a 3.6% reduction in the instantaneous hazard of regaining urinary continence within 48 weeks post-operatively (HR = 0.964). The time-dependent discriminatory performance of age derived from tdROC curves further illustrated its dynamic predictive value across follow-up. At 2 weeks after surgery, the AUC of age was only 0.677, indicating a weak predictive power for the outcome of postoperative urinary incontinence. The predictive capacity improved moderately to an AUC of 0.739 at week 4 and 0.754 at week 12, before reaching its peak at week 24, followed by a mild decline at week 48. Collectively, these tdROC results suggested that age exhibited stable and robust long-term predictive efficacy for continence recovery at 24 and 48 weeks, whereas it could barely differentiate short-term urinary control outcomes immediately after catheter removal at postoperative week 2.

Prostate volume as a long-term predictor of urinary continence recovery

In the present study, prostate volume remained independently associated with urinary continence recovery after adjustment for potential confounding factors ($p = 0.003$; HR = 0.982, 95% CI: 0.970–0.994). According to the tdROC curve analysis, the AUC of prostate volume progressively increased from 0.714 at 2 weeks after surgery to 0.909 at 48 weeks. These findings suggest that the predictive value of prostate volume for urinary continence recovery becomes increasingly apparent as the postoperative recovery period progresses. A larger prostate volume may increase the technical difficulty of

intraoperative dissection and the preservation of critical anatomical structures. In particular, during RARP, a larger prostate may restrict the available working space within the pelvis, thereby increasing the difficulty of precise anatomical dissection and surgical manipulation²⁵. This may compromise the preservation of periurethral anatomical structures and neurovascular bundle (NVB), potentially contributing to delayed recovery of urinary continence. In addition, a larger prostate may make adequate preservation of the functional urethral length more challenging. In a retrospective study, patients with a preserved urethral length (PUL) ≥ 16 mm had a significantly greater likelihood of urinary continence recovery (HR = 1.87, $p = 0.022$)²⁶.

The progressive increase in the AUC of prostate volume, which ultimately reached 0.909 at 48 weeks, may indicate that its predictive value becomes more prominent during the intermediate and late stages of postoperative recovery. In contrast to surgical factors such as the modified “Hood” technique and BNP, which demonstrated relatively strong discriminatory performance during the early and intermediate stages of recovery, prostate volume represents a preoperative, patient-specific anatomical characteristic whose predictive value becomes increasingly evident over longer follow-up. This time-dependent pattern may suggest that, as transient postoperative factors gradually diminish, baseline anatomical characteristics may play an increasingly important role in determining long-term urinary continence recovery after sp-RARP.

Dynamic pattern of urinary continence recovery after sp-RARP

Taken together, the time-dependent patterns observed in the present study suggest that urinary continence recovery after sp-RARP may represent a dynamic process rather than an outcome determined by a single dominant factor. During the early postoperative phase, surgical anatomical preservation, particularly the modified “Hood” technique, showed the strongest discriminatory performance, with the AUC peaking at 0.858 at 4 weeks. During the intermediate phase, the predictive performance of BNP was sustained, reaching an AUC of 0.899 at 12 weeks. In contrast, the predictive performance of age and prostate volume became increasingly evident during later follow-up, with prostate volume achieving the highest AUC of 0.909 at 48 weeks. These findings may indicate a transition from surgery-related anatomical determinants in the early phase toward patient-specific and baseline anatomical characteristics during longer-term recovery.

Limitations

Several limitations should be acknowledged. First, this was a retrospective, single-center study with a relatively small sample size, which may have introduced selection bias and residual confounding and may limit the generalizability of the findings. In particular, the modified “Hood” technique was not randomly assigned, and differences in concomitant surgical procedures between groups may have contributed to residual confounding despite multivariable adjustment. Second, all procedures were performed by a single experienced surgeon using the same robotic platform. Although this improved

procedural consistency, it may limit the external applicability of our findings to centers with different surgical techniques, robotic platforms, or levels of surgical expertise. Third, several potentially relevant predictors of continence recovery, including membranous urethral length, baseline pelvic floor function, postoperative rehabilitation, and other functional parameters, were not available and therefore could not be incorporated into the analysis. Fourth, given the limited sample size, internal or external validation of the predictive performance was not performed, and the observed AUC values may therefore be subject to optimism. In addition, the tdROC analysis evaluated the discriminatory performance of individual predictors rather than that of a combined multivariable prediction model; the incremental predictive value of integrating these factors remains to be established. Finally, follow-up was limited to 48 weeks, precluding assessment of very long-term continence outcomes. Larger, prospective, multicenter studies with longer follow-up periods and appropriate internal and external validation are warranted to confirm these findings and to develop a comprehensive time-dependent prediction model for urinary continence recovery after sp-RARP.

Conclusion

In conclusion, age, prostate volume, BNP, and the modified “Hood” technique were independently associated with urinary continence recovery after sp-RARP. Their time-dependent discriminatory patterns differed substantially across postoperative follow-ups. The modified “Hood” technique demonstrated its strongest predictive performance during the early recovery phase, peaking at 4 weeks, whereas the discriminatory performance of BNP was sustained from the intermediate to later stages. In contrast, the predictive performance of age and prostate volume became increasingly evident with longer follow-up, with prostate volume achieving the highest AUC at 48 weeks. These findings suggest that urinary continence recovery after sp-RARP is a dynamic and multifactorial process, in which surgical anatomical preservation may be particularly relevant to early recovery, whereas patient-specific and baseline anatomical characteristics become increasingly important during later-stage recovery. Further prospective multicenter studies are warranted to validate these findings and determine whether integrating these time-dependent predictors can improve the individualized prediction of continence recovery.

Declarations

Human Ethics and Consent to Participate declarations The study was conducted in accordance with the Declaration of Helsinki and approved by the local ethics committee of the First Affiliated Hospital of Harbin Medical University (2025508, December 2, 2025).

The requirement for informed consent was waived by the ethics committee because of the retrospective nature of the study (2025508, December 2, 2025).

Author approval All co-authors have read the final manuscript, and have approved the submission to BMC Urology.

Competing interests

The authors declare that they have no competing interests.

Clinical trial number

not applicable.

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Author Contribution

JQ: Writing original draft, Formal analysis; GZ: Writing review & editing; XJ, XY: Data curation; JS, HL: Visualization; YY, GJ, CW: Resources (surgical procedures and intraoperative image collection). All authors have read and approved the final version of the manuscript.

Data Availability

The datasets analyzed during the current study are not publicly available because of ethical and institutional restrictions but are available from the corresponding author upon reasonable request.

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Figures

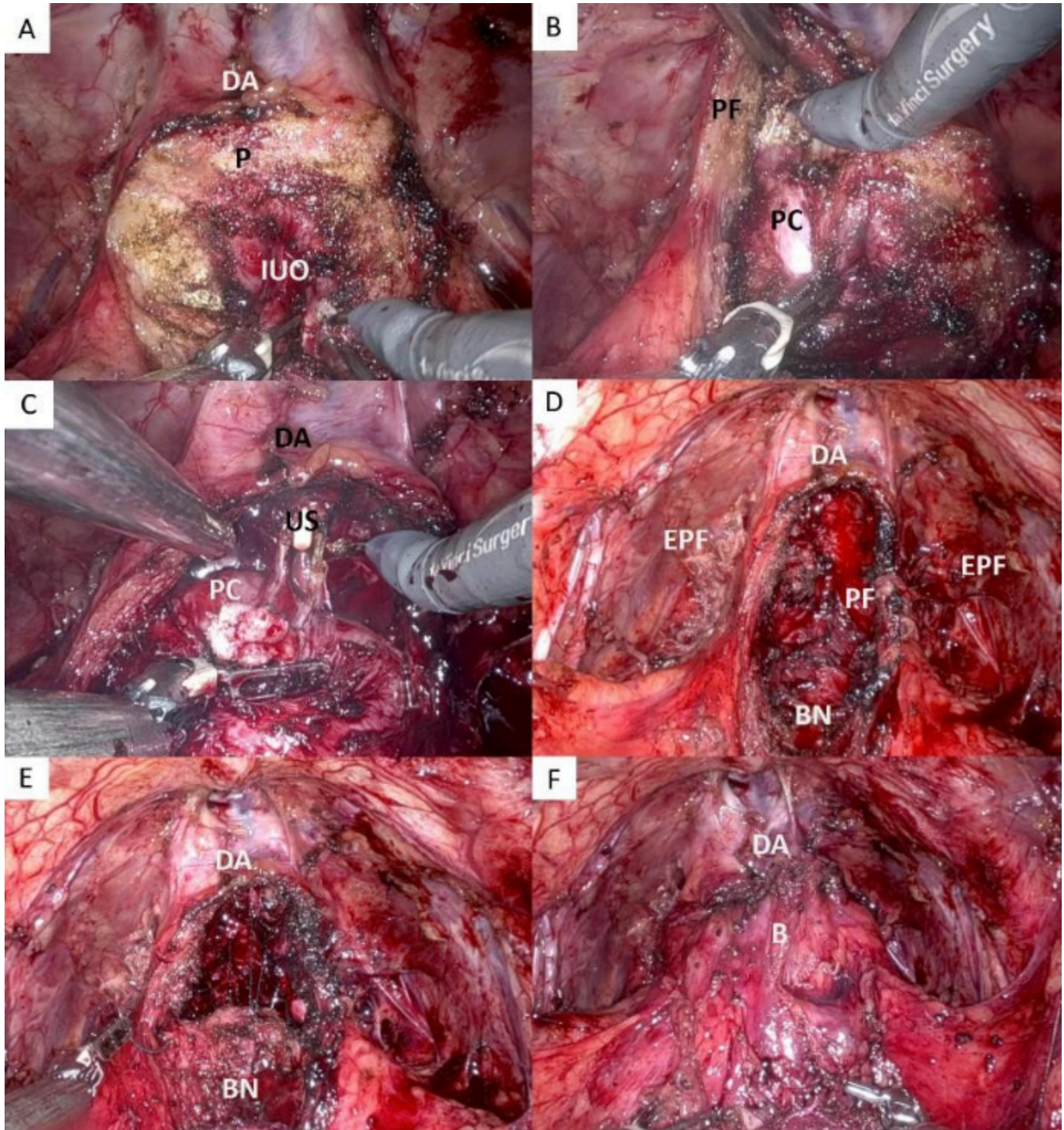


Figure 1

BNP, "Hood" structure and total urethral reconstruction

DA: detrusor apron, P: prostate, PF: prostate fascia, PC: prostate capsule, IUO: internal urethral orifice, US: urethral stump, B: bladder, BN: bladder neck, EPF: endopelvic fascia.

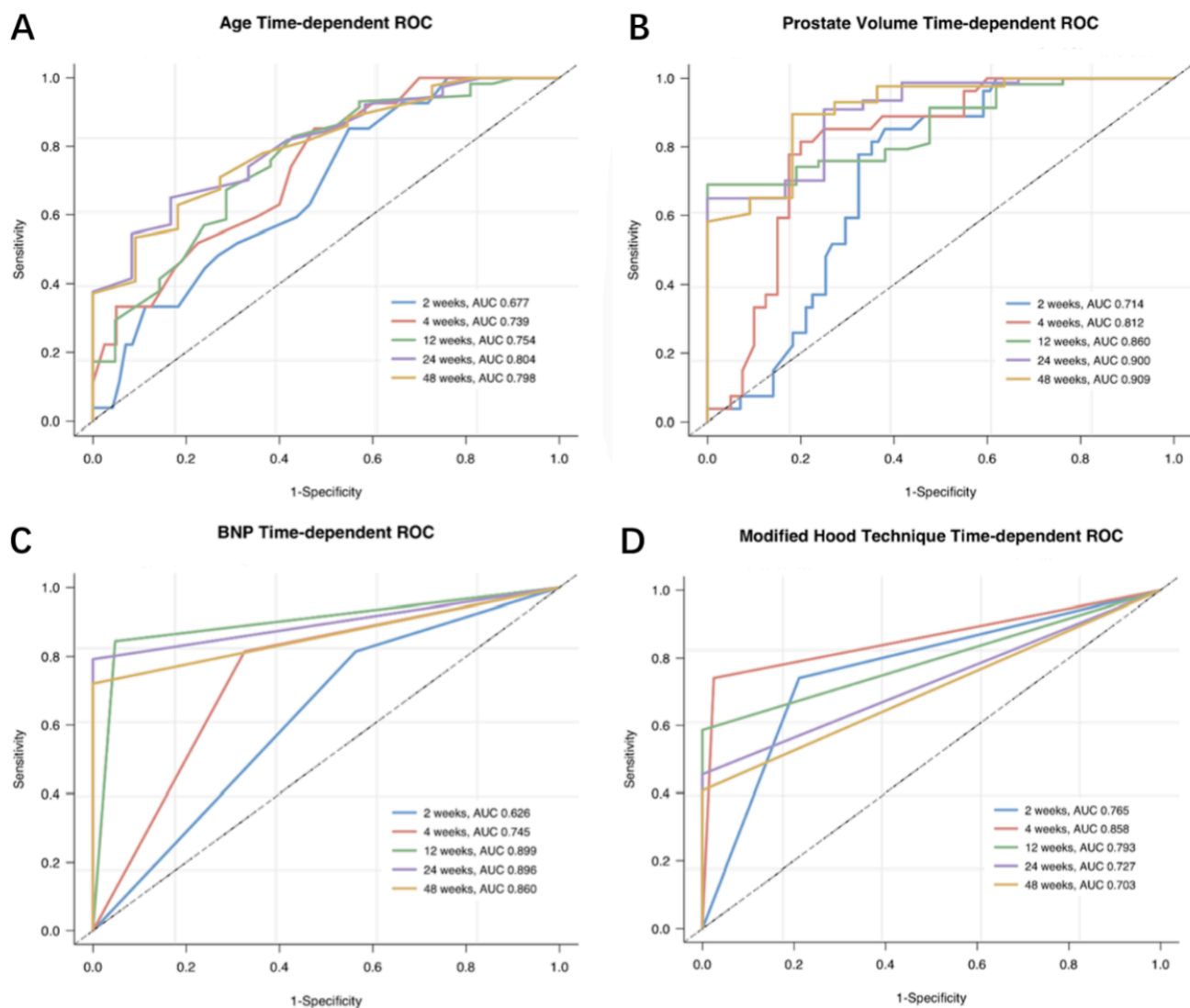


Figure 2

Time-dependent ROC curve

A: Marker = $\log(0.965) \times \text{Age}$; 2 weeks calculated at 2.001 weeks; time=48/event=0 treated as no-event controls; B: Marker = $\log(0.982) \times \text{Prostate Volume}$; 2 weeks calculated at 2.001 weeks; time=48/event=0 treated as no-event controls; C: Marker = $\log(2.072) \times \text{BNP}$; 2 weeks calculated at 2.001 weeks; time=48/event=0 treated as no-event controls; D: Marker = $\log(3.263) \times \text{Modified Hood Technique}$; 2 weeks calculated at 2.001 weeks; time=48/event=0 treated as no-event controls