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Analysis of risk factors for persistent PSA after radical prostatectomy: results from a high-volume center in Southeast China

Sida Hao[1†], Hao Wang[1†], Shen Lin[1], Hong Chen[1], Liping Xie[1] and Xiangyi Zheng[1*]

Abstract

Background For localized prostate cancer, a comprehensive treatment approach centered around radical prostatectomy (RP) is often their optimal choice. Successful RP can typically reduce prostate-specific antigen (PSA) levels to below 0.1 ng/mL within 6 to 8 weeks postoperatively. However, in clinical practice, 5 to 24% of patients may have a PSA ≥ 0.1 ng/mL at 6 to 8 weeks after surgery, a phenomenon known as PSA persistence. Many studies based on data from Europe and United States have shown an association between PSA persistence and poor postoperative outcomes, further analyzing the risk factors for PSA persistence. However, relevant research based on data from China remains scarce.

Methods Retrospective study of 1,347 prostate cancer patients who underwent RP at the First Affiliated Hospital of Zhejiang University School of Medicine from July 15, 2016, to August 31, 2022. Based on inclusion criteria, univariate and multivariate logistic regression analyses were conducted to explore the independent risk factors for persistent PSA.

Results Among the 826 prostate cancer patients after RP, 124 patients experienced persistent PSA. In univariate logistic regression analysis, robot-assisted laparoscopic radical prostatectomy (RARP), preoperative PSA, high-risk group, preoperative International Society of Urological Pathology (ISUP) grades 2–5, postoperative ISUP grades 3–5, percentage of positive cores, cT3, ≥pT3b, extracapsular extension (EPE), seminal vesicle invasion (SVI), positive surgical margins (PSM) and Prostate Specific Antigen Density (PSAD) were all significantly associated with PSA persistence after RP ($P < 0.05$). In terms of surgical approach, RARP was considered a protective factor against postoperative PSA persistence (OR:0.53, $p < 0.05$). In multivariate logistic regression analysis, preoperative ISUP grade 4, percentage of positive cores and PSM were independent risk factors of PSA persistence after RP ($P < 0.05$).

Conclusion Preoperative PSA, high-risk group, preoperative ISUP grades 2–5, postoperative ISUP grades 3–5, percentage of positive cores, cT3, ≥pT3b, EPE, SVI, PSM and PSAD were independent risk factors for PSA persistence in

[†]Sida Hao and Hao Wang contributed equally to this work and should be regarded as co-first authors.

*Correspondence:
Xiangyi Zheng
zheng_xy@zju.edu.cn

Full list of author information is available at the end of the article

prostate cancer patients after RP. This provides assistance for early monitoring and treatment of patients at high risk of persistent PSA in clinical practice.

Keywords Prostate cancer, PSA persistence, Radical prostatectomy, Risk factors

Introduction

Prostate cancer (PCa) is the most common malignant tumor of the urinary system worldwide. According to the Global Cancer Statistics 2020, there were 1,414,259 new cases of prostate cancer globally in 2020, with 375,304 deaths due to prostate cancer. Its incidence and mortality rates ranked third and eighth respectively globally [1]. The 2023 U.S. Cancer Statistics revealed that prostate cancer, lung cancer, and colorectal cancer were the most prevalent cancers among males, with prostate cancer accounting for the highest proportion at 29% [2]. The National Cancer of China updated its statistical report on cancer in February 2024, showing a continuous increase in the incidence of prostate cancer among the Chinese population. In 2022, there were 134,200 new cases of prostate cancer nationwide, with 47,500 deaths attributed to prostate cancer. The age-standardized mortality rate was 3.26 per 100,000 people [3]. The high incidence rate of prostate cancer makes it an important public health issue in China. In Europe and United States, 80% of newly diagnosed prostate cancer patients have localized prostate cancer. For this group of patients, a comprehensive treatment plan centered around radical prostatectomy (RP) is often their optimal choice [4]. Although RP aims to completely remove prostate tumor tissue, in clinical practice, due to factors such as residual foci, tumor microinvasion, and micro-metastasis, some prostate cancer patients still face the risk of cancer recurrence after undergoing radical surgery. Currently, the early detection of recurrence after radical prostatectomy still relies on postoperative prostate-specific antigen (PSA) monitoring. Successful RP often results in a postoperative PSA level dropping to below 0.1 ng/mL within 6 to 8 weeks [5–7].

Currently, major guidelines worldwide recommend using a threshold of 0.1–0.2 ng/mL to define PSA Persistence after radical prostatectomy [5–7]. If PSA fails to decrease below 0.1–0.2 ng/mL, possible reasons such as local tumor residue, pre-existing tumor metastasis, and residual benign prostate tissue should be considered. Patients need to be reassessed, and appropriate treatment options should be selected, following the same principles as PSA recurrence. In clinical practice, approximately 9% of patients have a PSA value persistently above 0.1 ng/mL at 6–8 weeks after undergoing radical prostatectomy [8]. Many researchers have investigated the relationship between PSA persistence and the prognosis after radical prostatectomy. Kimura et al [9] conducted a meta-analysis of these results and found that PSA persistence is significantly associated with biochemical recurrence (BCR), tumor recurrence, and tumor-specific death. For patients with PSA persistence after radical prostatectomy, early salvage radical radiotherapy can provide survival benefits. Therefore, predicting PSA persistence after RP is of crucial importance for assessing patient life expectancy and selecting postoperative treatment options. Several studies have reported on the risk factors for postoperative PSA persistence and its relationship with prognosis after RP in European and American populations. However, similar studies based on Chinese population have not been reported [9–11].

Our study conducted a retrospective analysis of 1347 prostate cancer patients who underwent radical prostatectomy at the First Affiliated Hospital of Zhejiang University School of Medicine between July 15, 2016, and August 31, 2022. A multifactor logistic regression model was used to analyze clinical indicators such as age, Body Mass Index (BMI), surgical approach, preoperative PSA, prostate volume, Prostate Specific Antigen Density (PSAD), clinical stage, postoperative pathological stage, extracapsular extension (EPE), seminal vesicle invasion (SVI), Lymph node involvement (LNI), and positive surgical margins (PSM) to identify independent predictive factors for postoperative PSA persistence after RP. The aim of this study is to provide clinical data based on the population in southeast China to assist urologists in formulating comprehensive treatment plans and clinical decisions for prostate cancer.

Methods

Study population and inclusion criteria

This study is a retrospective study that included a total of 1347 prostate cancer patients who underwent radical prostatectomy at the First Affiliated Hospital of Zhejiang University School of Medicine between July 15, 2016, and August 31, 2022. Based on the inclusion criteria, a total of 826 patients were included in this study finally. This research has been approved by the Ethics Committee of the First Affiliated Hospital, Zhejiang University School of Medicine.

Inclusion criteria:

1. Postoperative PSA Follow-up: Patients had to have available postoperative PSA follow-up data within 4–8 weeks after prostatectomy;
2. Clinical Data Availability: Complete clinical data were necessary for inclusion, allowing for comprehensive analysis;

3. Treatment History: Patients who had not received hormone therapy, neoadjuvant chemotherapy, radiotherapy, or immunotherapy before surgery were included to avoid confounding treatment effects;
4. Surgical History: Only patients without a history of previous prostate surgery were considered to maintain the consistency of surgical outcomes;
5. Metastasis Status: Patients without definite prostate cancer metastasis before surgery were included.

Data collection

The collected clinical information of the patients includes age, height, weight, BMI, prostate volume, PSAD, preoperative tPSA, total number of prostate puncture needles, number of positive needles, puncture positivity rate, preoperative and postoperative prostate biopsy pathology Gleason Score (GS) and International Society of Urological Pathology (ISUP) grouping, clinical and pathological T stage, surgical methods for RP, EPE, SVI, PSM, LNI, postoperative tPSA values at 4–8 weeks.

Variable definition

PSA persistence: PSA > 0.1 ng/ml at 6 wk after RP.

Age: Based on the patient information entered into the system of the First Affiliated Hospital of Zhejiang University School of Medicine, record the age of the patient on the day of radical prostatectomy.

Preoperative tPSA: The last time the tPSA value is tested before surgery, and no rectal digital examination, prostate massage, or prostate puncture operation has been performed within the previous month.

Prostate volume: Based on the last preoperative transrectal ultrasound measurement, prostate volume (cm3) = left and right diameter of the prostate (cm) x upper and lower diameter (cm) x anterior posterior diameter (cm) x 0.52. PSA: tPSA (ng/mL)/Prostate volume (cm3).

Total number of prostate puncture needles, number of positive needles, and puncture positivity rate: All prostate puncture operations are completed by experienced physicians from the First Affiliated Hospital of Zhejiang University School of Medicine. The puncture method is transrectal ultrasound-guided perineal puncture biopsy. The standard puncture method is to use an 18GTRU-CUT needle sequentially located on the outer front of the right peripheral area; Outer side of the right peripheral area; Middle part of the right peripheral area; Right peripheral area adjacent to the center; Left peripheral area adjacent to the center; Middle of the left peripheral area; Outside the left peripheral area; The outer edge of the left peripheral area is slightly anterior; Left migration zone; Complete 10 needle puncture biopsies in the right migration area. If suspicious areas are found during the puncture process, 1–2 additional needles can be inserted. The percentage of positive needles = (number of positive needles/total number of punctures) x 100%.

Preoperative prostate puncture pathology GS and ISUP grouping: The pathological grading of prostate cancer is based on the Gleason scoring system, which divides prostate cancer tissue into primary and secondary grading areas. Each area is scored 1–5 points based on its tissue morphology, and finally added up to obtain GS. The ISUP grading is based on the 2014 ISUP histological subtype Gleason grading consensus, and prostate cancer is classified into ISUP1-5 groups based on the Gleason score. Experienced pathologists from the First Affiliated Hospital of Zhejiang University School of Medicine rated and grouped the preoperative prostate puncture pathological tissue.

Postoperative GS grading and ISUP grouping: Experienced pathologists from the First Affiliated Hospital of Zhejiang University School of Medicine rated and grouped the pathology of postoperative radical prostatectomy specimens. The standard is the same as preoperative.

Clinical and pathological TMN staging: based on the TNM staging system developed by the American Joint Committee on Cancer Staging (AJCC) in 2017, 8th edition.

Statistical analyses

Frequency and percentage were used to report the categorical data. Pearson's chi-square test was employed to assess differences between categorical variables. The mean and standard deviation, or the median and interquartile range, describe continuous variables. The normality of continuous variables was evaluated using the Kolmogorov-Smirnov test. Students' t-test or Mann-Whitney U test were used to compare continuous variables. Logistic regression is used to assess whether variables are independent predictors. A p-value less than 0.05 was considered statistically significant.

The sustained independent risk factors for PSA were obtained through binary logistic regression analysis. In univariate analysis, variables with statistical significance are analyzed using multivariate logistic regression, and variables without statistical significance are eliminated one by one in multivariate logistic regression analysis. Statistical analysis was performed using R 4.2.3 software.

Results

According to inclusion criteria, the study ultimately included 826 patients who underwent radical prostatectomy (Fig. 1). Due to the limited number of positive findings in lymph nodes and the high number of missing values, they were excluded from further analysis.

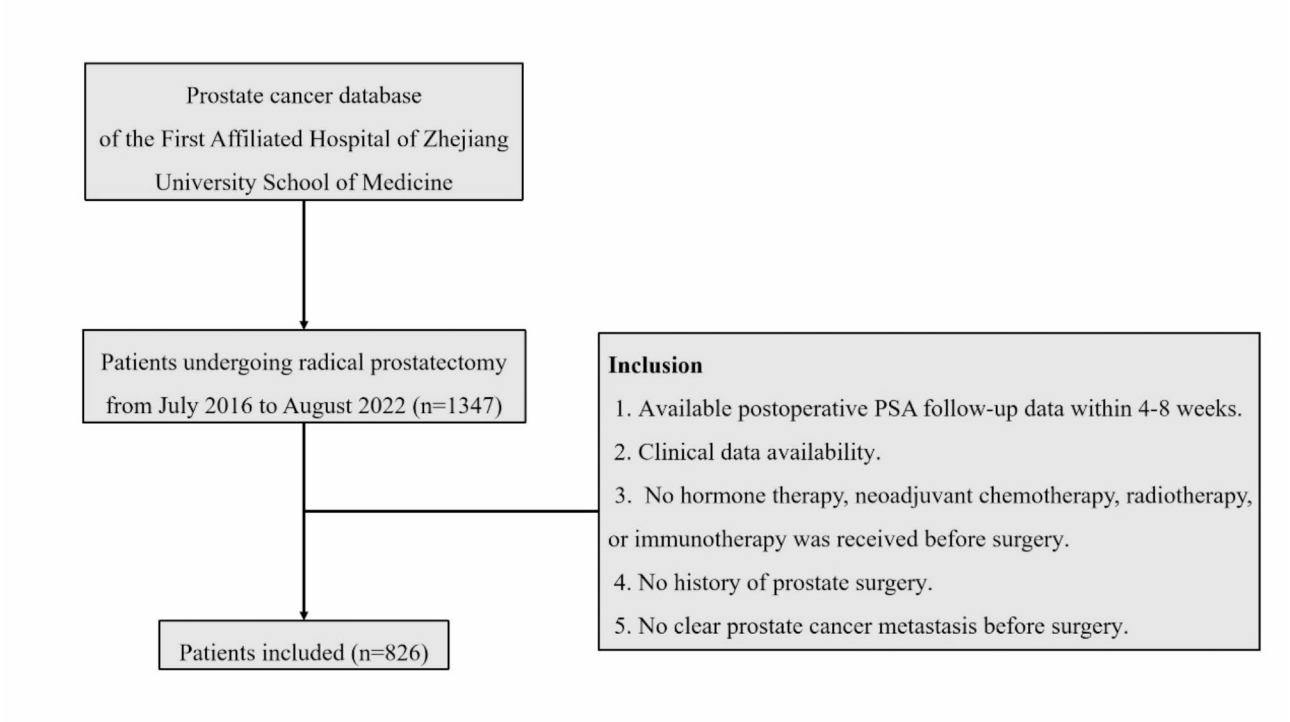

Fig. 1 Patients selection flow chart

The baseline characteristics of patients between PSA persistence and no PSA persistence was provided (Table 1). The incidence of persistent PSA after RP was approximately 15%. From the preoperative clinical characteristics, there was no statistically significant difference in age, BMI, clinical T stage, prostate volume and risk groups between patients with persistent PSA and those with PSA < 0.1 ng/ml. However, compared to patients with PSA < 0.1ng/mL, patients with persistent PSA have higher pre-operative PSA (median PSA 17.3ng/mL vs. 10.3ng/mL), higher percentage of positive cores (median percentage of positive needles 50% vs. 38%), higher ISUP grades (ISUP 4 group accounting for 25.8% vs. 13.1%; ISUP 5 group accounting for 8.1% vs. 5.3%). From a pathological perspective, patients with persistent PSA were more likely to have PSM (52.4% vs. 33.5%), EPE (38.7% vs. 23.9%), SVI (32.3% vs. 11.1%), and PSAD (0.58 vs. 0.35) compared to patients with PSA < 0.1ng/ml. Postoperative pathology showed more advanced T staging (≥pT3b accounting for 32.3% vs. 10.8%) and higher IUSP grading groups (ISUP group 4 17.7% vs. 8.8%; ISUP group 5 17.7% vs. 8.0%).

Univariate logistic regression analysis indicated that RARP, preoperative PSA, high-risk group, preoperative ISUP grades 2–5, postoperative ISUP grades 3–5, percentage of positive cores, cT3, ≥pT3b, PSM, EPE, SVI and PSAD were all significantly associated with PSA persistence after RP (Fig. 2). These findings suggest that these characteristics may serve as potential predictive factors for PSA persistence among patients after RP. Then we further perform multivariate logic on variables with statistical significance in univariate logic. The result showed that preoperative ISUP grading group 4, percentage of positive cores and PSM had statistical significance (Fig. 3A).

From the perspective of surgical techniques, there were statistically significant differences in the distribution of open RP, laparoscopic RP, and RARP between the two groups. Therefore, subgroup analysis will be conducted to investigate the relationship between different surgical approaches and PSA persistence. Then, prognosis.

we conducted univariate and multivariate logistic regression analyses for each group. However, we found that there were too many missing values in the RARP group, so we removed them and then analyzed. In the open RP group, the univariate logistic regression showed that weight, preoperative ISUP grade 4, percentage of positive cores, postoperative ISUP grade 2, ≥pT3b and SVI were associated with PSA persistence (Fig. 4). Then, we conducted multivariate analysis on these significant variables, the result indicated that only percentage of positive cores exhibited statistical significance (Fig. 3B). In the laparoscopic RP group, the univariate logistic regression indicated that preoperative PSA, preoperative ISUP grades 2–5, postoperative ISUP grades 3–5, percentage of positive cores, ≥pT3b, PSM, EPE, SVI and PSAD were all associated with PSA persistence (Fig. 5). The multivariate analysis showed that PSM, EPE and SVI

Table 1 Baseline characteristics of patients between PSA persistence and no PSA persistence

	PSA persistence (*n* = 124)	No PSA persistence (*n* = 702)	*P* value
Age (year)	68.0 [63.0;71.0]	69.0 [64.0;73.0]	0.128
Height (m)	1.69 [1.64;1.73]	1.70 [1.65;1.73]	0.787
Weight (kg)	67.5 [62.0;75.0]	68.0 [61.0;72.0]	0.157
BMI	23.8 [22.3;25.9]	23.5 [22.0;25.1]	0.136
Surgical technique			0.034
Open	41 (33.1%)	161 (22.9%)	
Laparoscopic	45 (36.3%)	261 (37.2%)	
Robot-assisted	38 (30.6%)	280 (39.9%)	
Pre-operative PSA (ng/ml)	17.3 [10.9;25.8]	10.3 [7.11;16.3]	< 0.001
Risk Group			< 0.001
Low-risk	3 (2.42%)	74 (10.5%)	
Intermediate-risk	20 (16.1%)	189 (26.9%)	
High-risk	101 (81.5%)	439 (62.5%)	
Pre-operative ISUP Grade			< 0.001
1	18 (14.5%)	222 (31.6%)	
2	34 (27.4%)	210 (29.9%)	
3	30 (24.2%)	141 (20.1%)	
4	32 (25.8%)	92 (13.1%)	
5	10 (8.06%)	37 (5.27%)	
% Positive Cores	0.50 [0.30;0.76]	0.38 [0.20;0.50]	< 0.001
Post-operative ISUP Grade			< 0.001
1	10 (8.06%)	99 (14.1%)	
2	24 (19.4%)	304 (43.3%)	
3	46 (37.1%)	181 (25.8%)	
4	22 (17.7%)	62 (8.83%)	
5	22 (17.7%)	56 (7.98%)	
Clinical T Stage			0.066
1	1 (0.81%)	29 (4.13%)	
2	119 (96.0%)	662 (94.3%)	
3	4 (3.23%)	11 (1.57%)	
Pathological T stage			< 0.001
≤ pT2	61 (49.2%)	506 (72.1%)	
pT3a	23 (18.5%)	120 (17.1%)	
≥pT3b	40 (32.3%)	76 (10.8%)	
PSM	65 (52.4%)	235 (33.5%)	< 0.001
EPE	48 (38.7%)	168 (23.9%)	0.001
SVI	40 (32.3%)	78 (11.1%)	< 0.001
PSAD (ng/ml/ml)	0.58 [0.37;0.89]	0.35 [0.22;0.54]	< 0.001
Prostate Volume (ml)	33.0 [26.1;44.3]	30.7 [24.3;39.9]	0.129

PSM:positive surgical margins , EPE:extracapsular extension

were all statistically significant (Fig. 3C). In the RARP group, the univariate logistic regression showed that age, preoperative PSA, preoperative ISUP grades 3, percentage of positive cores, ≥pT3b, EPE, SVI and PSAD were associated with PSA persistence (Fig. 6). The multivariate analysis indicated that preoperative PSA and percentage of positive cores were statistically significant (Fig. 3D). The research results indicate that, regardless of the surgical approach, percentage of positive cores, SVI and ≥pT3b were independent risk factors for PSA persistence.

Discussion

RP is the standard treatment for patients with clinically localized prostate cancer and the PSA test is the cornerstone of postoperative follow-up for them. The European Association of Urology (EAU) guidelines for the diagnosis and treatment of prostate cancer recommend PSA testing for asymptomatic patients after radical prostatectomy at 3, 6, 9, and 12 months post-surgery, followed by semiannual testing for the next two years, and then annual testing thereafter [6]. However, the half-life of PSA is 3.15 days, the residual PSA in the preoperative body should be completely metabolized within 4 weeks after RP theoretically. The guidelines also indicated that PSA levels within 6 weeks post-successful radical prostatectomy should be below detection (PSA < 0.1 ng/mL). Generally, residual PSA post-surgery can originate from three pathways: systemic tumor micro-metastasis not detected before surgery, residual localized prostate cancer tissue, and residual benign prostate tissue. For the first two scenarios, postoperative PSA persistence holds certain value in early assessment of surgical quality and risk of recurrence.

A retrospective study based on a single-center database in Europe indicated that patients with persistent PSA had lower 15-year rates of metastasis-free survival, tumor-specific survival, and overall survival compared to patients with PSA < 0.1ng/mL (53% vs. 93.2%; 75.5% vs. 96.2%; 64.7% vs. 81.2%, $P < 0.01$) [8]. Skove et al. [12] found that among patients with PSA ≥ 0.01 ng/mL within 1–3 months postoperatively, 54% progressed to biochemical recurrence within 3–6 months postoperatively. Ploussard et al.'s [11]multicenter retrospective study indicated that 74.4% of patients with persistent PSA elevation experienced further PSA increase during long-term follow-up, ultimately progressing to biochemical recurrence. Bianchi et al. [13]conducted a study on 319 patients who underwent RP combined with extended pelvic lymph node dissection. They found that approximately one-quarter of patients with postoperative pathology indicating lymph node positivity experienced postoperative PSA persistence. Compared to patients with postoperative PSA levels less than 0.1 ng/mL, this group faced a higher risk of postoperative recurrence and cancer-specific mortality. These studies highlight the importance of PSA persistence for postoperative follow-up and prognosis evaluation in prostate cancer. However, existing studies on the risk factors for PSA persistence and its impact on prostate cancer prognosis are mostly based on data from Western populations, and there is currently a lack of studies based on Chinese data.

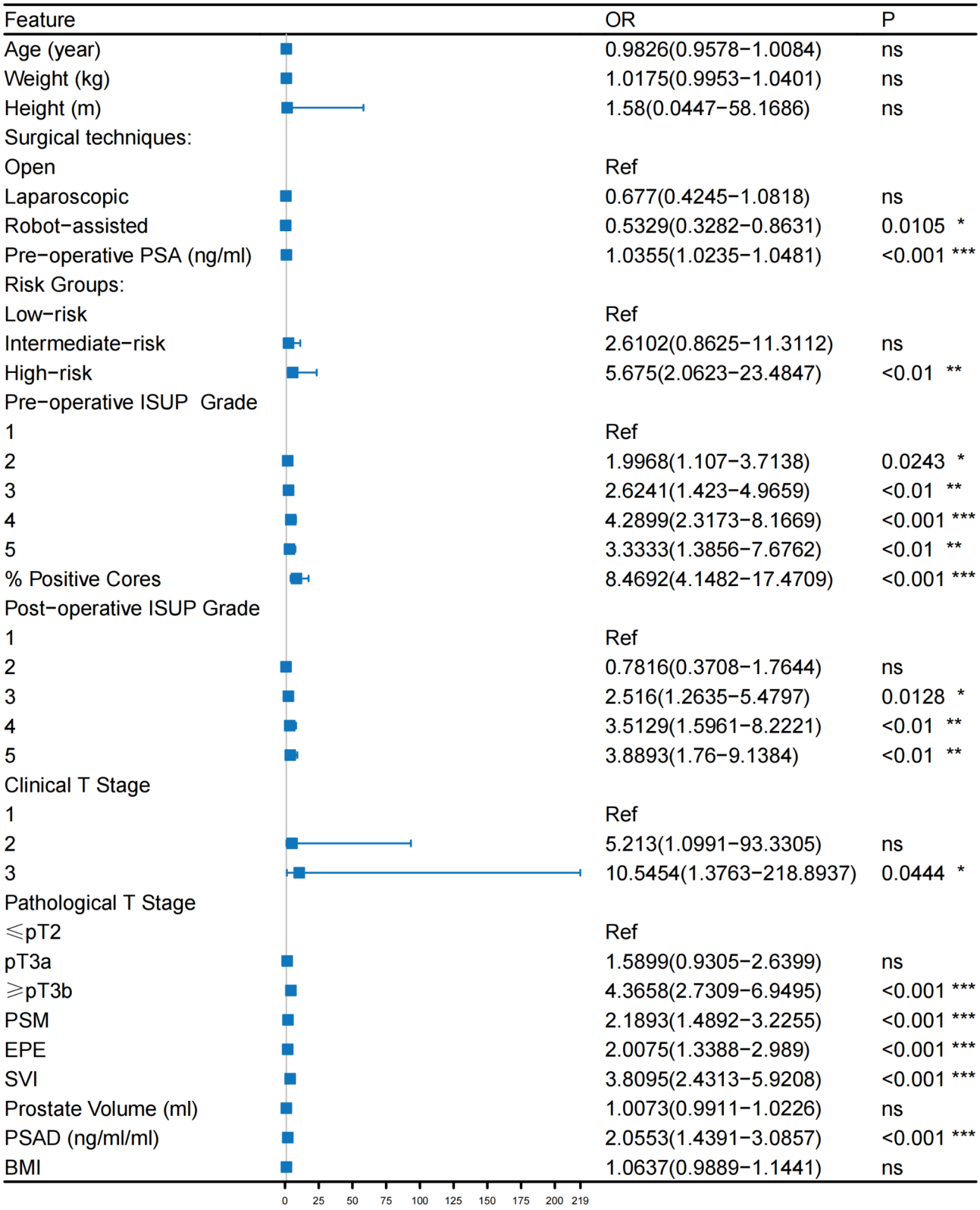

Fig. 2 Univariate logistics regression analysis of potential predictors for PSA persistence in prostate cancer patients after RP. * $p<0.05$, ** $p<0.01$, *** $p<0.001$

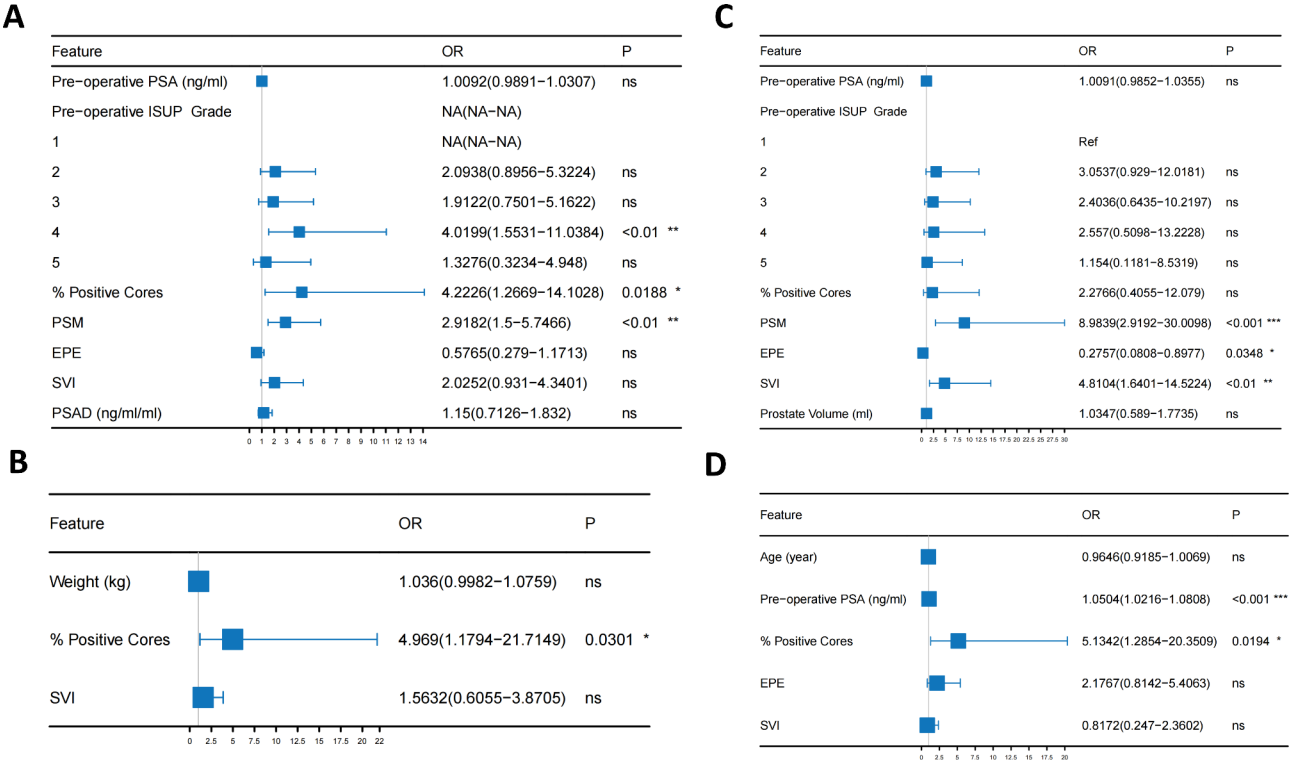

Fig. 3 Multivariate logistics regression analysis for PSA persistence in prostate cancer patients after RP. **A**: Forest plot displaying the OR values of PSA persistence in prostate cancer patients after RP. **B**: Forest plot displaying the OR values of PSA persistence in open RP subgroup patients. **C**: Forest plot displaying the OR values of PSA persistence in laparoscopic RP subgroup patients. **D**: Forest plot displaying the OR values of PSA persistence in RARP subgroup patients

Our study conducted a retrospective analysis of clinical data from 826 prostate cancer patients at the First Affiliated Hospital of Zhejiang University School of Medicine. It identified risk factors associated with persistent PSA elevation after RP. Among the 826 patients included in this study, 15% (124 cases) experienced postoperative PSA persistence, indicating that PSA persistence is a common phenomenon after radical prostatectomy. This proportion is similar to the reported percentages of patients experiencing PSA persistence in foreign literature, which range from 5 to 24% among surgical patients, consistent with our findings [8, 10, 14]. In analyzing the clinical and pathological characteristics of the patients, we found that those with persistent PSA elevation had higher preoperative PSA, higher percentage of positive cores and higher ISUP grades. Regarding pathological characteristics, they exhibited more advanced pathological T stage, higher ISUP grade, and were more prone to PSM, EPE, and SVI. Our univariate logistic regression analysis yielded similar conclusions, with the factors mentioned above being identified as independent risk factors for PSA persistence. Interestingly, in univariate analysis, we found that RARP was a protective factor for persistent PSA status (OR:0.53, $p<0.05$). Sengupta et al. [15]collected clinical information of patients with PSA>0.1ng/mL 60–120 days after RP. Similarly, they found in multivariate analysis that high preoperative PSA, pathological ISUP grade group≥2, PSM, and SVI were associated with persistent PSA. A Meta-analysis revealed patients with persistent PSA consistently showed unfavorable clinicopathological features and a more than 3.5-fold risk of poorer biochemical recurrence, metastasis, and prostate cancer-specific mortality prognosis independently, when compared to patients with undetectable PSA [16]. Meanwhile, Kim confirmed that postoperative PSA persistence was a risk factor for radiographic progression in prostate cancer patients with positive lymph nodes ($p<0.05$). Patients with PSA persistence had a shorter 5-year progression-free survival rate compared to those with undetectable PSA (64.2% vs. 93.2%, $p<0.05$) [17]. Gandaglia et al. [18] also found that the impact of PSA persistence on prognosis may be influenced by PSM, with PSA being associated with tumor-specific survival only in patients with a margin-positive risk>10%. While previous studies have indicated that PSA persistence is related to poor prognosis in prostate cancer patients, our study did not directly evaluate prognosis. Instead, we focused on identifying the prevalence of PSA persistence and its association with specific clinical and pathological variables. Further

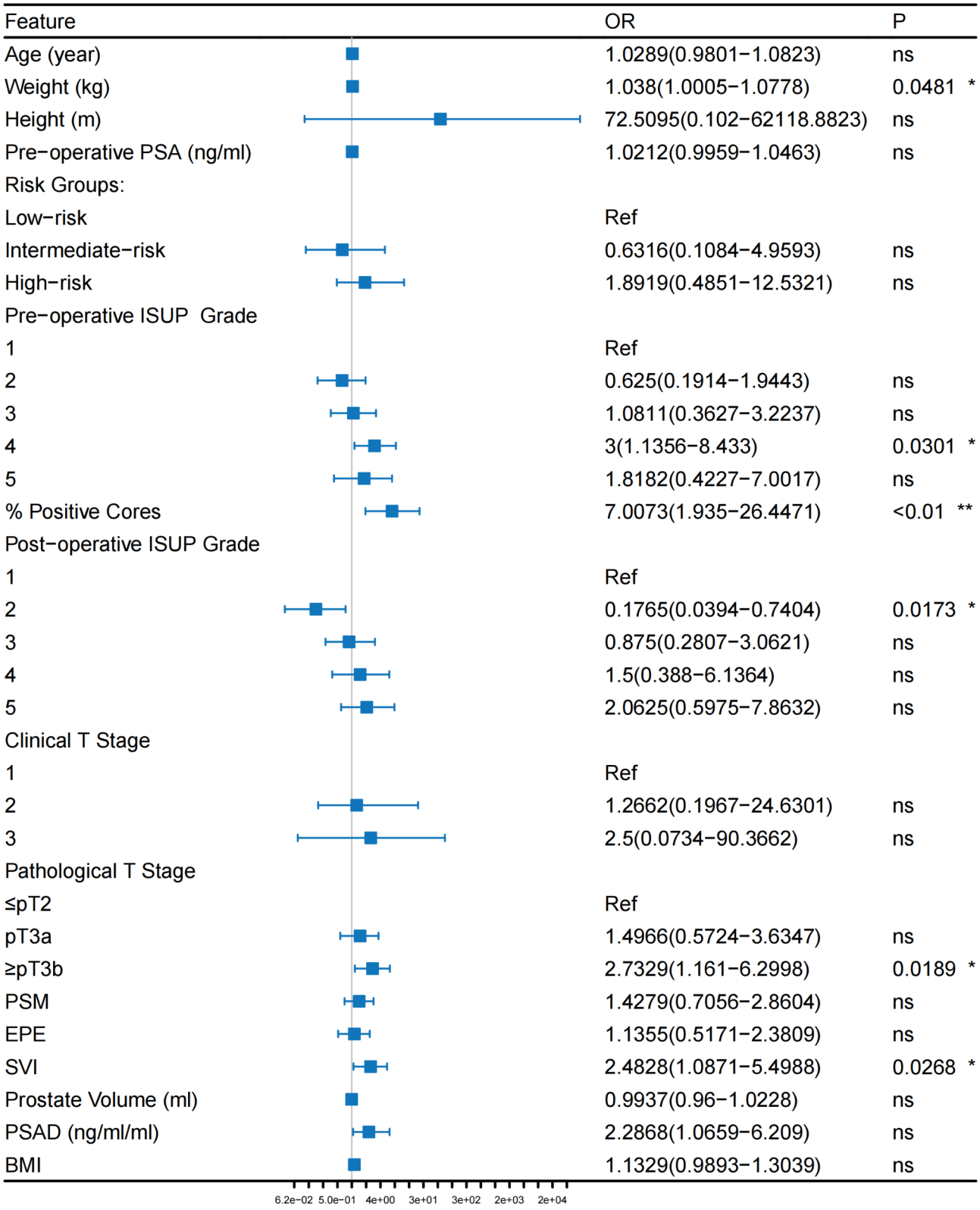

Fig. 4 Univariate logistics regression analysis of potential predictors for PSA persistence in open RP subgroup patients

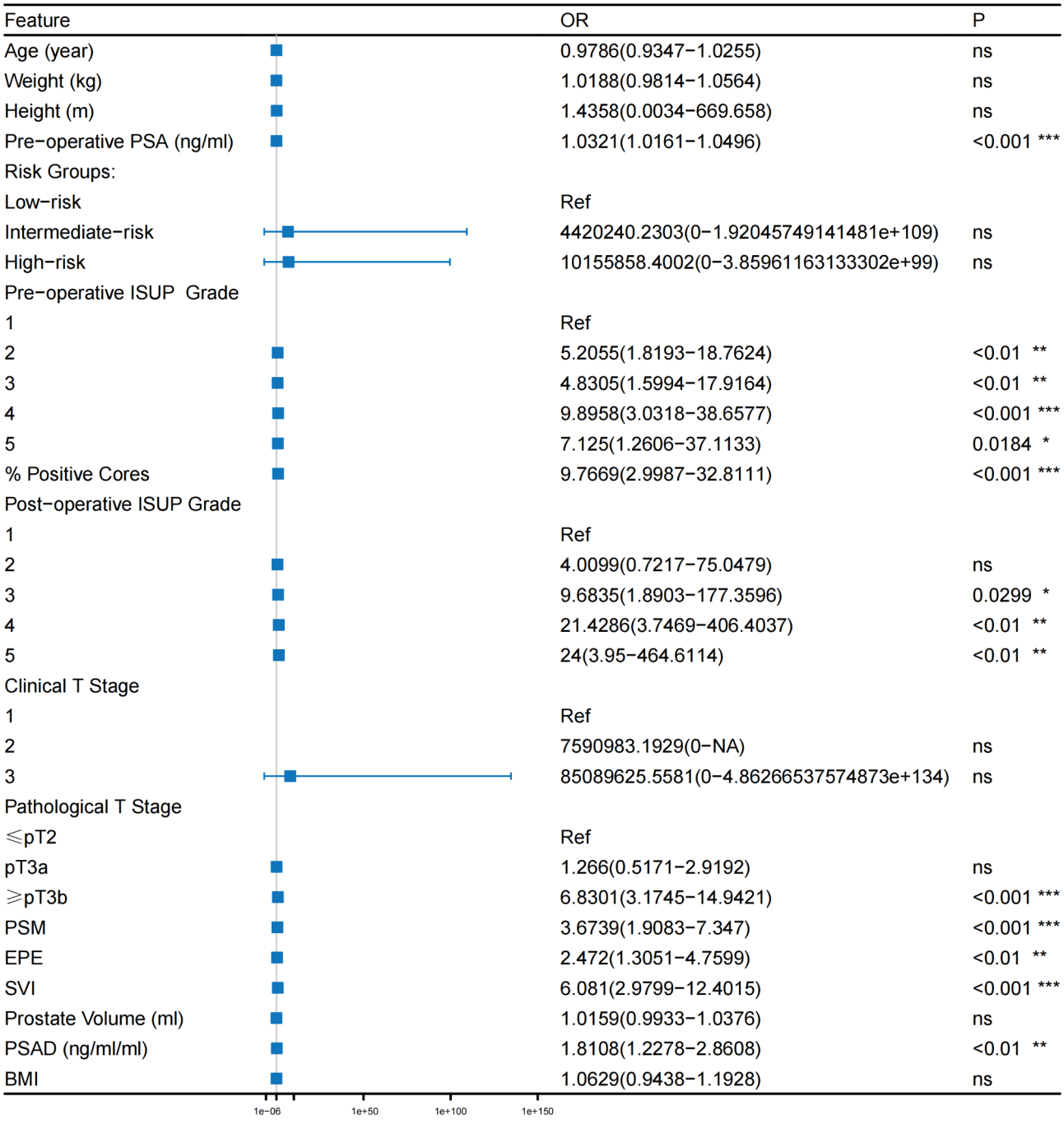

Fig. 5 Univariate logistics regression analysis of potential predictors for PSA persistence in laparoscopic RP subgroup patients

studies are necessary to explore the prognostic implications of PSA persistence in this patient population.

In our study, we compared the learning curves of robotic-assisted, laparoscopic, and open RP. We found that RARP has a shorter learning curve, with proficiency reached after 45–100 cases, compared to 80–150 cases for laparoscopic RP and at least 100 cases for open RP. A systematic review demonstrated that the learning curve for operative time was identified as 10–250 cases for RARP and 40–250 cases for laparoscopic RP [19]. Although there are significant differences in the definition of outcome metrics and performance thresholds across these studies, the overall results suggest that the learning curve for robot-assisted laparoscopic prostatectomy is shorter. This shorter learning curve for robotic-assisted surgery leads to more consistent and effective outcomes, making it the preferred method.

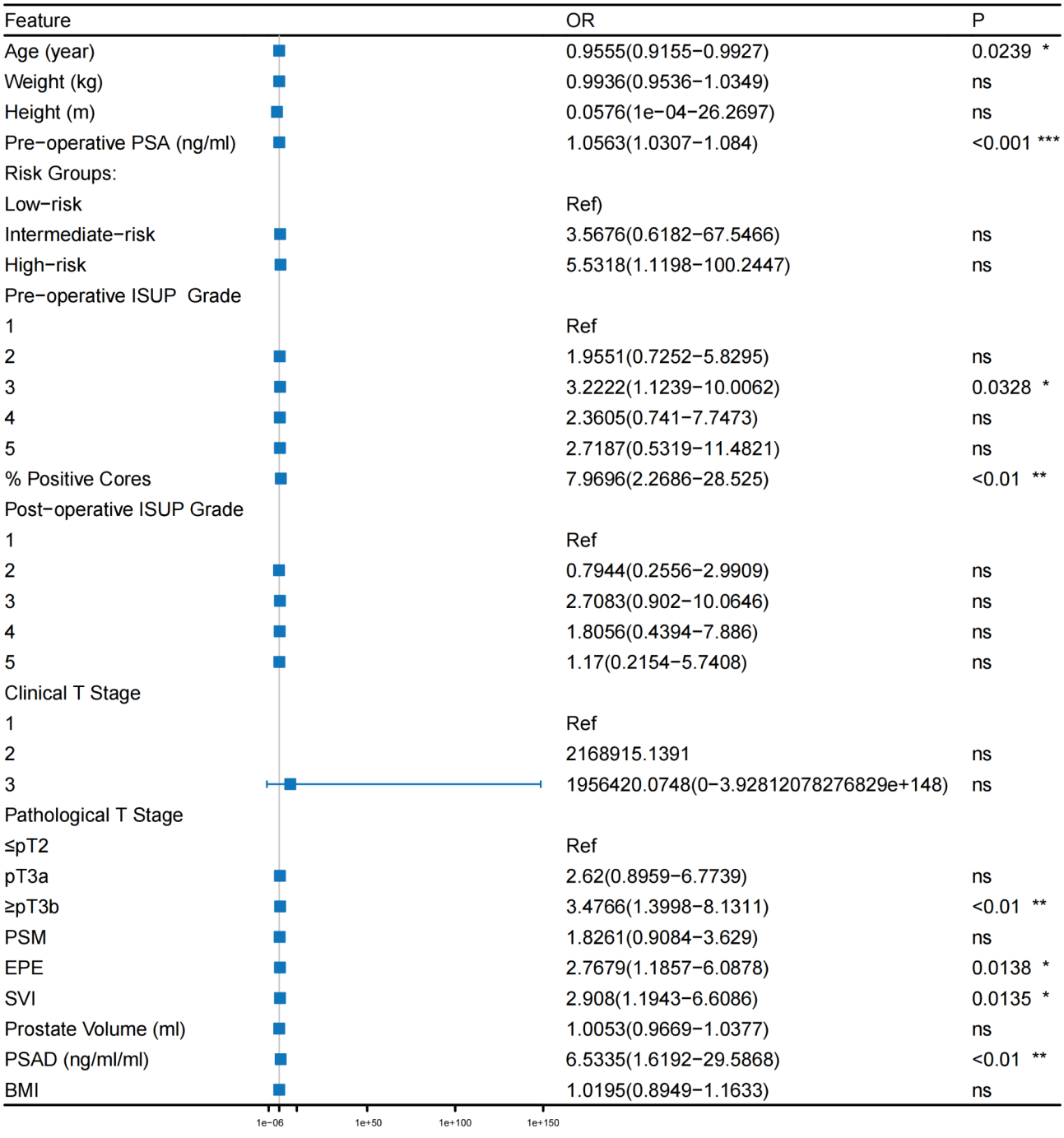

Fig. 6 Univariate logistics regression analysis of potential predictors for PSA persistence in RARP subgroup patients

Zapatero et al. [20]. provided evidence that high-dose radiotherapy combined with risk-adapted ADT can improve biochemical outcomes and overall survival rates in localized prostate cancer, including high-risk categories. In high-risk patients, neoadjuvant therapy before RP may have a positive impact on recurrence rates, with a 3-year BCR-free rate was 70% (95% CI 57%, 90%) [21]. These findings suggest that integrating neoadjuvant ADT into treatment protocols could be a beneficial strategy for managing PSA persistence and improving patient prognosis in high-risk prostate cancer cases. Based on existing data, salvage radiotherapy and androgen deprivation therapy have been shown to benefit postoperative patients with persistent PSA in terms of metastasis-free survival, cancer-specific survival, and overall survival. Studies have reported that compared to salvage ADT after RP, salvage radiotherapy combined with ADT treatment can benefit patients with persistent PSA elevation

in terms of 10-year cancer-specific survival rate and overall survival rate (81.7% vs. 51.9%; 73% vs. 30.5%, $P<0.01$) [22]. Barreras et al. [23]found that postoperative patients receiving salvage radiotherapy combined with androgen deprivation therapy (ADT) had a higher cancer-specific survival rate within 5 years compared to those receiving ADT alone (81.2% vs. 34.2%). Some domestic researchers have also found that patients with PSA≥0.1ng/mL but <0.2ng/mL at 6 weeks after radical prostatectomy can benefit from salvage radiotherapy in terms of 5-year BCR free survival rate for patients with persistent PSA after surgery [24].

Our study has some limitations. First, this is a single center retrospective study, which may lead to inevitable selection bias and recall bias during the research process. The results can be validated and improved through higher quality prospective studies. Secondly, due to the limited number of positive findings and high missing values in lymph nodes, further analysis was not conducted in this study. Third, this study focused on the risk factors leading to persistent PSA and did not analyze the prognosis of patients with persistent PSA. However, this is a rare study in China to analyze the risk factors for PSA persistence in prostate cancer patients after RP.

Conclusion

In patients after RP, factors associated with preoperative PSA, high-risk group, preoperative ISUP grades 2–5, postoperative ISUP grades 3–5, percentage of positive cores, cT3, ≥pT3b, PSM, EPE, SVI and PSAD predict PSA persistence. From a pathological perspective, patients with persistent PSA were more likely to have PSM, EPE, SVI, and PSAD compared to patients with PSA<0.1ng/ml. This study analyzed the risk factors for PSA persistence in prostate cancer patients after radical prostatectomy, showing broad applicability and good discriminative ability in different populations, providing assistance for the early monitoring and treatment of high-risk patients with persistent PSA in clinical practice.

Author contributions

Conceptualization, Sida Hao and Hao Wang; Funding acquisition, Xiangyi Zheng and Liping Xie; Methodology, Hong Chen; Software, Shen Lin; Supervision, Xiangyi Zheng and Liping Xie; Validation, Sida Hao; Writing – original draft, Sida Hao and Hao Wang; Writing – review & editing, Xiangyi Zheng and Liping Xie.

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Data availability

The data in this study are available from the author for correspondence upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the ethics committee of The First Affiliated Hospital of Zhejiang University School of Medicine. The ethics committee of The First Affiliated Hospital of Zhejiang University School of Medicine waived the need for Informed Consent due to the retrospective nature of the study. The study was performed in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Urology, the First Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou 310003, Zhejiang, China

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