



Predictors of active surveillance discontinuation in prostate cancer: Large Korean multicenter cohort study

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Purpose: Active surveillance (AS) is an established management strategy for favorable-risk prostate cancer (PCa). In real-world practice, decisions to continue AS or active treatment (AT) are influenced by both disease-related and patient-related factors. This study aimed to identify factors associated with the transition from AS to AT in a large multicenter cohort.

Materials and Methods: We analyzed 716 patients with PCa managed with AS across 12 institutions. Baseline clinical characteristics, comorbidity burden assessed via the Charlson comorbidity index (CCI), performance status evaluated using the Eastern Cooperative Oncology Group (ECOG) score, and disease-related factors, including prostate-specific antigen (PSA), PSA density (PSAD), and magnetic resonance imaging findings, were collected. Cox proportional hazards regression was used to identify factors associated with conversion to AT.

Results: During a mean follow-up of 28.4 months, 224 patients (31.3%) transitioned from AS to AT, most frequently because of pathologic reclassification (60.3%). In multivariate analysis, maximum core involvement (hazard ratio [HR] 1.015, $p=0.003$) and $PSAD \geq 0.10$ ng/mL/cm³ (HR 1.478, $p=0.044$) were independently associated with conversion to AT. Although ECOG performance status and CCI were not statistically significant in multivariate models, patients with poorer functional status or greater comorbidity burden remained on AS rather than proceeding to AT.

Conclusions: In this large multicenter study, PSAD was the strongest predictor of transition to AT during AS for PCa. Beyond disease-related factors, patient condition also appeared to influence real-world decisions about continuing AS.

Keywords: Active surveillance; Prostate cancer; Risk factors; Treatment outcome

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INTRODUCTION

Active surveillance (AS) is now a cornerstone of contemporary management for localized prostate cancer (PCa), reflecting recognition that many tumors are indolent and do not require immediate definitive treatment. Large prospective cohorts show that AS achieves excellent cancer-specific outcomes while minimizing treatment-related morbidity, supporting its widespread use in patients with low-risk and selected favorable intermediate-risk disease [1-3].

Despite rising guideline endorsement, substantial variation remains in patient selection for AS, surveillance intensity, and criteria for transition to active treatment (AT). Real-world evidence indicates that clinical practice often deviates from standardized protocols, underscoring persistent uncertainty regarding optimal risk stratification and surveillance strategies [4,5]. This heterogeneity highlights the need for robust, large-scale evidence that better reflects contemporary practice patterns [6].

Improvements in diagnostic technology, particularly multiparametric magnetic resonance imaging (mpMRI), enhance risk assessment at diagnosis and reduce the risk of understaging significant disease [7-9]. The integration of mpMRI into AS protocols has enabled expansion beyond traditional low-risk populations to include selected patients with favorable intermediate-risk disease [10,11]. However, uncertainty persists regarding which patients can safely remain on long-term AS, especially as eligibility broadens to older individuals and those with more heterogeneous clinical profiles [12,13].

Notably, treatment decisions during AS are not only influenced by cancer-related factors. Life expectancy, functional status, comorbidity burden, and patient preferences are central to real-world decision-making, particularly when the oncologic benefit of definitive treatment is uncertain [14]. Prior studies indicate that patients with limited functional reserve or substantial competing risks may be managed less aggressively without compromising cancer-specific outcomes, underscoring the need for individualized care [15].

Owing to the increasing application of AS and variability in clinical practice, additional real-world evidence is needed to identify factors associated with transition to AT. Therefore, this multicenter study evaluated factors influencing conversion from AS to AT in a large cohort of patients with PCa.

MATERIALS AND METHODS

1. Ethics statement

This study was approved by the Institutional Review

Board (IRB) of Chung-Ang University Gwangmyeong Hospital (approval number: 2312-126-142) and the participating institutions. All procedures were conducted in accordance with the Declaration of Helsinki. The written informed consent was waived by the IRB due to the retrospective nature of the study.

2. Study population and design

We conducted a multicenter retrospective study of Korean patients with PCa who would now be considered candidates for AS between 2019 and 2025. Twelve institutions participated: Seoul National University Bundang Hospital, Seoul National University Hospital, Asan Medical Center, Samsung Medical Center, National Cancer Center, Pusan National University Yangsan Hospital, Chonnam National University Hwasun Hospital, Kyungpook National University Chilgok Hospital, Hanyang University Hospital, Hallym University Sacred Heart Hospital, Seoul St. Mary's Hospital, and Korea University Ansan Hospital. Overall, 716 patients were included. Patients were stratified by age at diagnosis (≤ 70 years vs. > 70 years). This threshold was selected to ensure a balanced distribution for comparative analysis ($n=324$ for ≤ 70 years and $n=392$ for > 70 years) and reflects the overall mean age of 70.8 years in our multicenter cohort. All patients had favorable-risk PCa, defined as very low-, low-, or favorable intermediate-risk disease according to the National Comprehensive Cancer Network guidelines, and were managed with AS per institutional protocols. Clinical, pathological, and imaging data were extracted from medical records.

3. Data collection and covariates

Baseline demographic variables included age, body mass index, smoking status, and comorbidities. Comorbidity burden was assessed using the Charlson comorbidity index (CCI), and functional status was evaluated using the Eastern Cooperative Oncology Group (ECOG) performance status.

Serum prostate-specific antigen (PSA), PSA density (PSAD), testosterone, renal function variables, and estimated glomerular filtration rate (eGFR) were recorded at baseline. Biopsy data included Gleason grade group (GG), biopsy technique, total number of biopsy cores, number and percentage of positive cores, and maximum core involvement.

4. Radiological assessment

All available transrectal ultrasonography and mpMRI scans were reviewed. Experienced genitourinary radiologists interpreted images following the Prostate Imaging Reporting and Data System (PI-RADS) v2.0 or v2.1 guidelines.

mpMRI data included suspicious lesions, lesion size, and PI-RADS score when available.

5. AS protocol and study endpoints

AS involved regular PSA testing (typically every 3–6 months), clinical assessments, and repeat biopsy or imaging per institutional protocols. The primary outcome was the transition from AS to AT. Reasons for discontinuing AS, including pathologic reclassification, clinical progression, patient preference, or overall condition, were recorded. Both AS duration and total follow-up time were calculated. Pathologic reclassification was defined as an upgrade in GG (e.g., GG 1 to GG ≥ 2), an increase in the number of positive cores beyond the initial AS eligibility criteria, or a maximum core involvement exceeding 50%.

6. Statistical analysis

Continuous variables are presented as mean $\pm$ standard deviation and compared using Student's t-test, while categorical variables are compared using the chi-square test. Kaplan–Meier analysis was used to evaluate time to AS discontinuation, with differences assessed using the log-rank test.

Univariate and multivariate Cox proportional hazards regression identified factors associated with conversion to AT, including age, CCI, PSA level, and PSAD. Variables including positive core counts, maximum core involvement, and MRI findings were incorporated into the multivariate Cox proportional hazards model. To account for institutional variability and potential clustering effects among the 12 centers, we utilized a center-adjusted Cox proportional hazards model.

Analyses were conducted using IBM SPSS version 27.0 (IBM Corp.), and p-values <0.05 were considered statistically significant.

RESULTS

1. Baseline demographic and clinical characteristics

Among the 716 patients, 324 were ≤ 70 years and 392 were >70 years. Older patients had higher rates of hypertension and diabetes, higher CCI scores, and poorer ECOG performance status (all $p<0.05$). Renal function, assessed via eGFR, was lower in men >70 years ($p<0.001$), while baseline PSA and testosterone levels did not differ between groups

Table 1. Baseline clinical characteristics of patients stratified by age

Variable	Men ≤ 70 y (n=324)	Men >70 y (n=392)	p-value
Age (y)	64.1 $\pm$ 5.4	76.3 $\pm$ 3.7	<0.001
BMI (kg/m ²)	23.7 $\pm$ 5.0	23.3 $\pm$ 4.5	0.303
Hypertension	135 (41.7)	197 (50.3)	0.024
Diabetes mellitus	50 (15.4)	91 (23.2)	0.011
CCI			<0.001
0–1	303 (93.5)	333 (84.9)	
2–3	20 (6.2)	51 (13.0)	
≥ 4	1 (0.3)	8 (2.0)	
ECOG performance status			<0.001
0	317 (97.8)	351 (89.5)	
1	6 (1.9)	38 (9.7)	
2	1 (0.3)	3 (0.8)	
Smoking			0.046
Never smoker	62 (19.1)	102 (26.0)	
Ex-smoker	128 (39.5)	157 (40.1)	
Current smoker	83 (25.6)	72 (18.4)	
Unknown	51 (15.7)	60 (15.3)	
PSA (ng/mL)	5.9 $\pm$ 3.4	6.3 $\pm$ 5.3	0.171
Testosterone (pg/mL)	42.9 $\pm$ 130.7	24.3 $\pm$ 102.5	0.280
Creatinine (mg/dL)	0.9 $\pm$ 0.2	1.2 $\pm$ 2.2	0.070
eGFR (mL/min)	85.0 $\pm$ 13.6	76.2 $\pm$ 15.5	<0.001

Values are presented as mean $\pm$ standard deviation or number (%).

BMI, body mass index; CCI, Charlson comorbidity index; ECOG, Eastern Cooperative Oncology Group; PSA, prostate-specific antigen; eGFR, estimated glomerular filtration rate.

Table 2. Biopsy and imaging characteristics according to age group

Variable	Men ≤70 y (n=324)	Men >70 y (n=392)	p-value
TRUS abnormality	65 (20.1)	84 (21.4)	0.015
DRE abnormality	29 (9.0)	62 (15.8)	<0.001
Total volume (cc)	47.7±77.8	47.7±52.5	0.995
Transition zone volume (cc)	20.3±14.7	22.2±12.9	0.280
Gleason score			0.172
6 (3+3)	302 (93.2)	351 (89.5)	
7 (3+4)	20 (6.2)	38 (9.7)	
7 (4+3)	2 (0.6)	1 (0.3)	
Type of biopsy			0.087
Systematic (transrectal)	167 (53.7)	226 (63.3)	
MRI fusion (transrectal)	139 (44.7)	124 (34.7)	
Perineal Bx	2 (0.6)	3 (0.8)	
MRI target only	1 (0.3)	3 (0.8)	
Incidental detected	2 (0.6)	1 (0.3)	
Total biopsy cores (n)	12.9±3.6	12.5±2.6	0.066
Positive cores (n)	1.6±1.5	1.7±2.5	0.496
% of positive cores	17.1±74.7	17.5±66.7	0.946
Maximum % of positive core	14.7±12.7	16.1±14.9	0.206
MRI-positive lesion	109 (34.4)	170 (45.0)	0.006
Largest index lesion			0.390
<1 cm or invisible	133 (76.4)	163 (72.1)	
≥1 cm	41 (23.6)	63 (27.9)	
PI-RADS			0.011
No lesion	105 (33.5)	96 (25.5)	
1	5 (1.6)	5 (1.3)	
2	49 (15.7)	41 (10.9)	
3	69 (22.0)	81 (21.5)	
4	62 (19.8)	104 (27.7)	
Unknown	15 (4.8)	28 (7.5)	

Values are presented as number (%) or mean±standard deviation.

Percentages are calculated based on valid cases, excluding missing values.

TRUS, transrectal ultrasonography; DRE, digital rectal examination; MRI, magnetic resonance imaging; Bx, biopsy; PI-RADS, Prostate Imaging Reporting and Data System.

(Table 1).

2. Pathological and radiological characteristics

Most patients (91.2%) in both age groups had GG 1 disease at diagnosis. Biopsy techniques were comparable between the two age groups. Notably, MRI fusion transrectal biopsy was performed in 44.7% of the younger group and 34.7% of the older group, while MRI target-only biopsies were utilized in 0.3% and 0.8% of patients, respectively (Table 2). MRI-positive lesions were more common in men >70 years (45.0% vs. 34.4%, $p=0.006$), and higher PI-RADS scores were also more common in the older group ($p=0.011$). Other biopsy parameters, including the number and percentage of positive cores, did not differ between age groups.

3. Follow-up and surveillance outcomes

The mean follow-up duration was 28.4 months (interquartile range [IQR] 9.0–46.4 months), slightly longer in men >70 years (30.2 months vs. 26.1 months, $p=0.021$). In our cohort, 49.0% of patients ($n=351$) underwent at least one repeat biopsy. Notably, these biopsies were performed at an early stage, with a median duration of 10.9 months (IQR 6.2–12.1 months) from enrollment. Overall, 224 patients (31.3%) discontinued AS and transitioned to AT. The proportion of patients discontinuing AS did not differ significantly between age groups (31.8% in ≤70 years vs. 36.6% in >70 years, $p=0.237$). Pathologic reclassification was the leading cause of discontinuation in both groups, followed by clinical reclassification and patient preference (63.4% in ≤70 years vs. 58.0%

Table 3. Outcomes and discontinuation details of active surveillance (AS)

Variable	Men ≤70 y (n=324)	Men >70 y (n=392)	p-value
Total follow-up period (mo)	26.1±21.7	30.2±21.1	0.021
Discontinuation of AS			0.237
No	199 (68.2)	227 (63.4)	
Yes	93 (31.8)	131 (36.6)	
Reason of discontinuation			0.208
Pathologic reclassification	59/93 (63.4)	76/131 (58.0)	
Clinical reclassification	6/93 (6.5)	18/131 (13.7)	
Patient preference	18/93 (19.4)	16/131 (12.2)	
Patient age or general condition	2/93 (2.2)	4/131 (3.1)	
Others	8/93 (8.6)	17/131 (13.0)	
Duration of AS (mo)	17.0±17.7	18.8±18.1	0.207

Values are presented as mean±standard deviation or number (%).

Percentages are calculated based on valid cases, excluding missing values.

Table 4. Cox proportional hazards regression analysis of factors associated with transition to active treatment

	Univariate HR (95% CI)	p-value	Multivariate HR (95% CI)	p-value
Age (y)				
≤70	Reference	-	Reference	-
>70	0.946 (0.719–1.244)	0.690	0.951 (0.710–1.274)	0.735
CCI score				
0–2	Reference	-	Reference	-
≥3	0.467 (0.192–1.135)	0.093	0.522 (0.214–1.274)	0.153
PSA (ng/mL)				
<3	Reference	-	Reference	-
≥3	1.305 (0.831–2.048)	0.247	0.942 (0.542–1.637)	0.831
Positive cores	0.964 (0.895–1.038)	0.332	0.946 (0.870–1.029)	0.198
Maximum % of positive core	1.016 (1.007–1.026)	<0.001	1.015 (1.005–1.025)	0.003
MRI-positive lesion	1.156 (0.883–1.514)	0.292	1.116 (0.839–1.484)	0.452
PSA density (ng/mL/cm ³)				
<0.10	Reference	-	Reference	-
≥0.10	1.483 (1.084–2.028)	0.014	1.478 (1.011–2.162)	0.044

CCI, Charlson comorbidity index; PSA, prostate-specific antigen; Max., maximum; MRI, magnetic resonance imaging; HR, hazard ratio; CI, confidence interval.

in >70 years). The mean duration of AS before transition to AT was similar between both groups (Table 3).

4. Predictors of transition to AT

In univariate Cox regression analysis, maximum core involvement (hazard ratio [HR] 1.016, $p<0.001$) and PSAD ≥ 0.10 ng/mL/cm³ (HR 1.483, $p=0.014$) were significantly associated with transition to AT (Table 4). Age, PSA level, and CCI score showed no significant association with AS discontinuation. In multivariate analysis adjusted for institutional variability, both maximum core involvement (HR 1.015, $p=0.003$) and PSAD ≥ 0.10 ng/mL/cm³ (HR 1.478, $p=0.044$) remained independent predictors of conversion to AT. Notably, MRI-

positive lesions were not a significant predictor of treatment conversion in either univariate (HR 1.156, $p=0.292$) or multivariate analysis (HR 1.116, $p=0.452$). Similarly, positive core counts were not significantly associated in the multivariate model.

Age showed no association with treatment conversion. While higher CCI scores demonstrated a trend toward continued AS, the association was not statistically significant (HR 0.522, $p=0.153$).

5. Time to discontinuation analysis

Kaplan–Meier analysis demonstrated significantly higher rates of AS discontinuation in patients with PSAD

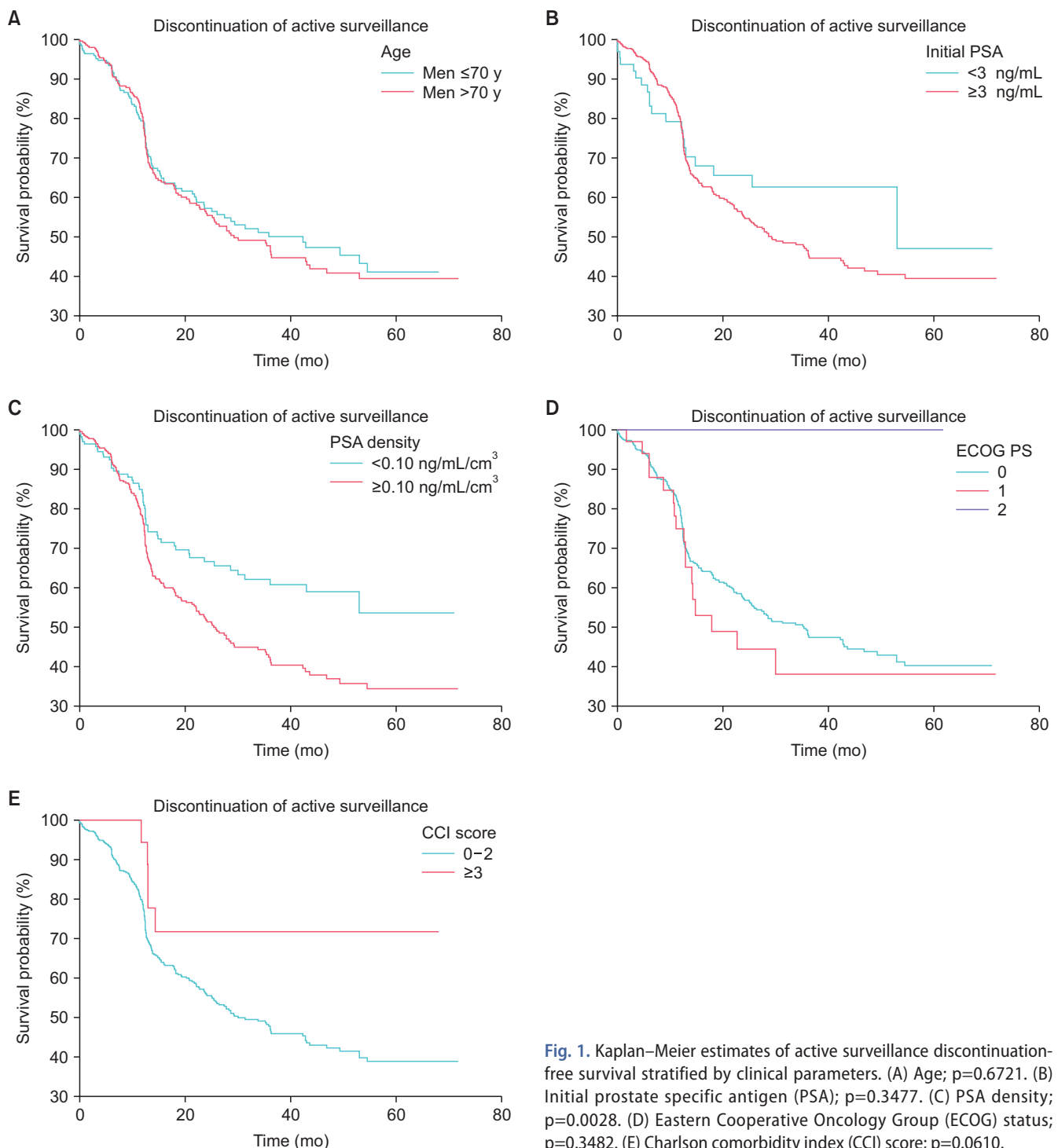


Fig. 1. Kaplan–Meier estimates of active surveillance discontinuation-free survival stratified by clinical parameters. (A) Age; $p=0.6721$. (B) Initial prostate specific antigen (PSA); $p=0.3477$. (C) PSA density; $p=0.0028$. (D) Eastern Cooperative Oncology Group (ECOG) status; $p=0.3482$. (E) Charlson comorbidity index (CCI) score; $p=0.0610$.

≥ 0.10 ng/mL/cm³ ($p=0.0028$). No significant differences were observed in AS discontinuation based on age, baseline PSA level, ECOG performance status, or CCI score; however, patients with higher CCI scores remained on AS longer (Fig. 1).

DISCUSSION

In this large, multicenter real-world cohort, factors asso-

ciated with transition from AS to AT in patients with PCa were evaluated. PSAD was the sole independent predictor of treatment conversion, while age showed no association with AS discontinuation. Specifically, performance status and comorbidity burden were not statistically significant predictors; however, patients with poorer functional status or higher CCI scores tended to remain on AS, suggesting that patient condition may influence clinical decision-making be-

yond tumor-related factors.

The PSAD cutoff ≥ 0.10 ng/mL/cm³ was utilized based on its established clinical significance and validated performance in Asian cohorts for identifying patients at higher risk of upgrading during AS [16]. PSAD is consistently reported as a robust predictor of disease upgrading during AS, and the study findings align with previous studies demonstrating its prognostic value for reclassification and transition to AT. Furthermore, recent evidence suggests that the clinical utility of PSAD extends beyond a single cutoff value, with longitudinal changes and integration with PSA kinetics providing additional prognostic information. While this analysis focused on baseline PSAD, the observed association supports its continued role as a key parameter in contemporary AS risk stratification [17-20].

The expanding role of mpMRI has also redefined AS practice by improving initial patient selection and reducing the risk of underestimating clinically significant diseases. Prior studies demonstrate that MRI-guided strategies potentially enhance risk adaptation and influence follow-up frequency. Interestingly, our multivariate analysis showed that visible lesions on mpMRI were not independent predictors of AS discontinuation. This finding suggests that radiological changes alone may not fully reflect the biological progression of the disease. Recent studies have emphasized the importance of density-based markers in patients with less-conspicuous imaging findings; for instance, prostate health index density has shown superior utility in detecting clinically significant cancer even in patients with negative MRI findings [21].

Our findings underscore that AS management in real-world settings is not determined solely by oncologic factors. While performance status and comorbidity burden were not statistically significant predictors in multivariate models, patients with higher ECOG scores or CCI values remained on AS. This trend aligns with prior reports suggesting that clinicians may be less inclined to recommend definitive treatment for patients with limited functional reserve. Moreover, it is consistent with contemporary perspectives emphasizing the importance of life expectancy and overall health status when the oncologic benefit of treatment is uncertain [12,14,15].

Furthermore, emerging qualitative and survivorship research demonstrates that a substantial proportion of patients discontinue AS in the absence of objective disease progression. This discontinuation is often driven by psychosocial factors, including anxiety, uncertainty, and loss of perceived control. Collectively, these findings suggest that treatment decisions during AS reflect a complex interplay of biological risk, patient condition, and non-oncologic factors. Further-

more, the observations of this study provide quantitative real-world evidence supporting this perspective by demonstrating that patient-related factors may subtly influence the duration of AS even when tumor characteristics are considered [22,23].

Despite growing interest in molecular and genomic risk stratification, including polygenic risk scores, their added value over established clinical factors remains modest, and routine integration into AS decision-making continues to evolve. Consequently, readily available clinical parameters—including PSAD, performance status, and comorbidity burden—continue to play a central role in routine practice. These findings support a pragmatic, individualized approach to AS that integrates tumor biology with patient condition while acknowledging the limitations of single-factor risk assessment [24-26].

This study has some limitations. The retrospective design introduces potential selection bias, and AS protocols varied across participating institutions, reflecting real-world heterogeneity [27]. Our study did not capture qualitative differences in the specific decision-making processes across the 12 participating institutions or among individual clinicians. Such heterogeneity in clinical practice, including differing thresholds for intervention or variations in patient counseling, is a common challenge in multicenter real-world studies and may have influenced the criteria for AS discontinuation. Second, follow-up duration was relatively short, precluding assessment of long-term oncologic outcomes, including metastasis or cancer-specific mortality. Third, longitudinal changes in PSAD and patient-reported outcomes were unavailable for analysis.

Nevertheless, the multicenter design and large sample size enhance the generalizability of these findings and provide valuable insight into contemporary AS practice.

CONCLUSIONS

PSAD was the strongest determinant of transition to AT during AS in this multicenter cohort. Beyond tumor-related factors, patient condition—including functional status and comorbidity burden—appeared to influence AS continuation in real-world practice. These findings highlight the importance of integrating both tumor characteristics and patient health status when managing patients on AS and support a more individualized approach to clinical decision-making.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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REFERENCES

1. Newcomb LF, Schenk JM, Zheng Y, Liu M, Zhu K, Brooks JD, et al. Long-term outcomes in patients using protocol-directed active surveillance for prostate cancer. *JAMA* 2024;331:2084-93.
2. Hamdy FC, Donovan JL, Lane JA, Metcalfe C, Davis M, Turner EL, et al. Fifteen-Year outcomes after monitoring, surgery, or radiotherapy for prostate cancer. *N Engl J Med* 2023;388:1547-58.
3. de Vos II, Luiting HB, Roobol MJ. Active surveillance for prostate cancer: past, current, and future trends. *J Pers Med* 2023;13:629.
4. Cooperberg MR, Meeks W, Fang R, Gaylis FD, Catalona WJ, Makarov DV. Time trends and variation in the use of active surveillance for management of low-risk prostate cancer in the US. *JAMA Netw Open* 2023;6:e231439.
5. Chiarelli G, Stephens A, Finati M, Cirulli GO, Tinsley S, Wang Y, et al. Active surveillance follow-up for prostate cancer: from guidelines to real-world clinical practice. *World J Urol* 2024;42:646.
6. Walker CH, Marchetti KA, Singhal U, Morgan TM. Active surveillance for prostate cancer: selection criteria, guidelines, and outcomes. *World J Urol* 2022;40:35-42.
7. Schoots IG, Petrides N, Giganti F, Bokhorst LP, Rannikko A, Klotz L, et al. Magnetic resonance imaging in active surveillance of prostate cancer: a systematic review. *Eur Urol* 2015;67:627-36.
8. Li T, Nalavenkata S, Fainberg J. Imaging in diagnosis and active surveillance for prostate cancer: a review. *JAMA Surg* 2025;160:93-9.
9. Engelman C, Adebuseye B, Maffei D, Stavrinides V, Bridge J, Kirkham A, et al. Magnetic resonance imaging-led risk-adapted active surveillance for prostate cancer: updated results from a large cohort study. *Eur Urol* 2025;88:167-75.
10. Lakes J, Al-Monajjed R, Busshoff I, Hübner A, Boschheidgen M, Valentin B, et al. Modern active surveillance in low- and intermediate-risk prostate cancer without re-biopsy. *Prostate Cancer Prostatic Dis* 2025 Sep 14 [Epub]. <https://doi.org/10.1038/s41391-025-01010-6>
11. Nayan M, Carvalho FLF, Feldman AS. Active surveillance for intermediate-risk prostate cancer. *World J Urol* 2022;40:79-86.
12. McLeay MT, Parker WP. Active surveillance for prostate cancer in older men. *Clin Geriatr Med* 2025;41:187-96.
13. Salari K, Kuppermann D, Preston MA, Dahl DM, Barrisford GW, Efstathiou JA, et al. Active surveillance of prostate cancer is a viable option for men younger than 60 years. *J Urol* 2019;201:721-7.
14. Daskivich TJ, Fan KH, Koyama T, Albertsen PC, Goodman M, Hamilton AS, et al. Effect of age, tumor risk, and comorbidity on competing risks for survival in a U.S. population-based cohort of men with prostate cancer. *Ann Intern Med* 2013;158:709-17.
15. Loeb S, Zhou Q, Siebert U, Rochau U, Jahn B, Mühlberger N, et al. Active surveillance versus watchful waiting for localized prostate cancer: a model to inform decisions. *Eur Urol* 2017;72:899-907.
16. Song ZJ, Qian JK, Yang Y, Wu HX, Wang MY, Jiang SY, et al. PSA density in the diagnosis of prostate cancer in the Chinese population: results from the Chinese Prostate Cancer Consortium. *Asian J Androl* 2021;23:300-5.
17. Press BH, Khajir G, Ghabili K, Leung C, Fan RE, Wang NN, et al. Utility of PSA density in predicting upgraded Gleason score in men on active surveillance with negative MRI. *Urology* 2021;155:96-100.
18. Gusev A, Rumpf F, Zlatev D, Twum-Ampofo JK, Gore JL, Dahl DM, et al. PSA density as a dynamic prognostic marker of bi-

- opsy grade progression during active surveillance. *Urol Oncol* 2025;43:709.e9-17.
19. Chou YJ, Jong BE, Tsai YC. Integrating PSA change with PSA density enhances diagnostic accuracy and helps avoid unnecessary prostate biopsies. *Diagnostics (Basel)* 2025;15:2027.
20. Benheddi T, Seguiet D, Puech P, Leroy X, Cailliau E, Behal H, et al. Long-term oncological outcomes of active surveillance for low-risk prostate cancer diagnosed during the MRI era. *Fr J Urol* 2025;35:102850.
21. Oshinomi K, Kikuchi S, Kishi H, Hayashi A, Okada S, Kurokawa M, et al. Utility of the prostate health index density for detecting clinically significant prostate cancer in patients with negative magnetic resonance imaging findings. *Prostate Int* 2025;13:271-5.
22. Briggs RJ, Dunn J, Chambers SK, Jakimowicz S, Green A, Heneka N. The lived experience of active surveillance for prostate cancer: a systematic review and meta-synthesis. *J Cancer Surviv* 2025 Feb 12 [Epub]. <https://doi.org/10.1007/s11764-025-01748-x>
23. Pastor-Navarro B, Rubio-Briones J, Borque-Fernando Á, Es-teban LM, Dominguez-Escrig JL, López-Guerrero JA. Active surveillance in prostate cancer: role of available biomarkers in daily practice. *Int J Mol Sci* 2021;22:6266.
24. Goss LB, Liu M, Zheng Y, Guo B, Conti DV, Haiman CA, et al. Polygenic risk score and upgrading in patients with prostate cancer receiving active surveillance. *JAMA Oncol* 2025;11:168-71.
25. Cooperberg MR, Zheng Y, Faino AV, Newcomb LF, Zhu K, Cowan JE, et al. Tailoring intensity of active surveillance for low-risk prostate cancer based on individualized prediction of risk stability. *JAMA Oncol* 2020;6:e203187.
26. Petrelli F, Dottorini L, Parsani G, Ceresoli F, Tagliatela D, Pampado M, et al. Active surveillance in intermediate-risk prostate cancer: a contemporary synthesis of evidence. *Clin Genitourin Cancer* 2025;23:102407.
27. Ko YH, Ryu JH, Kim YB, Shin TJ, Kim BH. Does protocol heterogeneity in active surveillance influence clinical outcomes? Insights from a multicenter prostate cancer cohort. *Investig Clin Urol* 2026;67:170-7.