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ORIGINAL RESEARCH

The relationship between psoas muscle index and surgical/oncological outcomes in prostate cancer patients undergoing radical prostatectomy: a retrospective single-center study

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Abstract

Background: This study aimed to investigate the association between preoperative psoas muscle index (PMI), surgical and oncological outcomes, and the requirement for adjuvant radiotherapy (ART) in patients with prostate cancer (PCa) undergoing radical prostatectomy (RP). **Methods**: Fifty-eight patients who underwent RP for localized PCa between January 2021 and August 2024 were retrospectively evaluated. Demographic, clinical, and pathological characteristics, as well as preoperative PMI values, were recorded. The relationships between PMI, ART requirement, and pathological findings were analyzed. Additionally, the predictive performance of PMI for ART was assessed using Receiver Operating Characteristic (ROC) curve analysis. **Results**: The mean age of patients was 65.34 ± 6.63 years, and the mean PMI was 6.12 ± 1.44 cm^2/m^2. ART was required in 31% of patients. The ART group had significantly lower PMI values (5.32 ± 1.57 *vs.* 6.48 ± 1.24 cm^2/m^2; $p = 0.01$). Total Prostate Spesific Antigen (PSA) and PSA density were also significantly higher in the ART group ($p = 0.002$ and $p = 0.001$, respectively). Patients with pathological stage ≥T3 and those with extraprostatic extension had significantly lower PMI values ($p = 0.01$ and $p = 0.04$, respectively). ROC analysis identified a cut-off value of 5.91 cm^2/m^2 for PMI, with 68% sensitivity and 72% specificity (Area Under the Curve (AUC): 0.712; 95% Confidence Interval (CI): 0.560–0.865; $p = 0.01$). In multivariate analysis, lower PMI (Odds Ratio (OR) = 0.48, $p = 0.027$) and pathological T stage ≥T3 (OR = 12.85, $p = 0.014$) independently predicted the need for ART. **Conclusions**: In patients undergoing RP, lower PMI was associated with adverse pathological features and ART requirement. Preoperative PMI assessment, when combined with PSA and PSA density, may provide additional value in predicting aggressive tumor behavior. Validation through larger, multicenter, prospective studies is warranted.

Keywords

Adjuvant radiotherapy; Prostate cancer; Psoas muscle index

1. Introduction

Prostate cancer (PCa) is one of the most common malignancies of the male reproductive system, ranking as the second most frequently diagnosed cancer and the fifth leading cause of cancer-related mortality among men worldwide [1]. In patients with localized and locally advanced PCa, radical prostatectomy is widely performed as a curative treatment option, particularly in those with long life expectancy [2]. Postoperative adjuvant radiotherapy (ART) aims to target presumed microscopic disease before PSA failure and is especially considered in high-risk groups [3]. Predictive factors for recurrence include elevated preoperative PSA, persistent PSA (PSA >0.1 ng/mL at 4–8 weeks postoperatively), positive surgical margins, pathological stage ≥T3a, lymph node metastasis, and International Society of Urological Pathology (ISUP) grade >3 [3–7]. However, not all patients with these adverse features experience biochemical recurrence; indeed, approximately 52% of cases present with at least one such risk factor without necessarily progressing to recurrence [8]. For this reason, various nomograms incorporating clinicopathological parameters and imaging findings have been developed to more accurately predict the need for adjuvant therapy after RP [8–10].

Sarcopenia, particularly prevalent in older adults, is characterized by loss of skeletal muscle mass and function, and is associated with adverse outcomes such as falls, functional decline, and increased mortality [11]. The psoas muscle index (PMI), calculated using computed tomography (CT), is considered a reliable parameter for assessing total skeletal muscle mass and has been validated as a surrogate marker of sarcopenia [12–14]. Meta-analyses have reported sarcopenia prevalence rates of 10–27% in individuals aged ≥60 years [15], while in patients with solid tumors, sarcopenia prevalence has been reported as 51.9% in early-stage and 76.1% in advanced PCa [16]. Furthermore, reduced skeletal muscle mass has been shown to be associated with worse overall and progression-free survival in PCa patients [17, 18].

In this context, investigating whether PMI reflects not only sarcopenia but also adverse pathological features and potential ART requirement in PCa may provide valuable insights. Therefore, in this study, we aimed to evaluate the relationship between preoperative PMI, surgical and oncological outcomes, and the need for adjuvant radiotherapy in patients with localized PCa undergoing radical prostatectomy.

2. Materials and methods

This study was conducted retrospectively in accordance with the principles of the Declaration of Helsinki after obtaining ethical approval from the Ethics Committee of Bursa Yuksek Ihtisas Training and Research Hospital, Health Sciences University (date: 25 September 2024, no: 2024-TBEK-2024/09-02). Patients who were diagnosed with localised PCa in the urology clinic between January 2021 and August 2024 and underwent laparoscopic radical prostatectomy were included in the study. Patient data were obtained from hospital records, and patients with incomplete data were excluded from the study.

The patients' age, comorbidities, body mass index, total PSA measured at diagnosis, prostate volume measured by ultrasound, ISUP grade in biopsy pathology, preoperative PMI, and postoperative pathology data (ISUP grade, extraprostatic extension, seminal vesicle involvement, surgical margin status, lymph node involvement, presence of lymphovascular invasion) were recorded. Pelvic lymph node dissection was performed selectively according to preoperative risk stratification, including PSA level, biopsy ISUP grade, clinical stage, and guideline-based risk assessment, rather than routinely in all patients. Preoperative multiparametric prostate magnetic resonance (MRI) was available in a subset of patients; however, as it was not performed systematically across the entire cohort, MRI findings were not included in the analysis. In addition, PSA levels of patients undergoing follow-up in the postoperative period were recorded. The decision for adjuvant radiotherapy was based on postoperative pathological risk factors, including pathological stage ≥T3, positive surgical margins, extraprostatic extension, and/or persistent PSA levels during early postoperative follow-up, in accordance with contemporary guideline recommendations. Adjuvant radiotherapy was initiated within the early postoperative period before documented biochemical recurrence; patients treated with radiotherapy following a delayed PSA rise were not classified as receiving adjuvant treatment.

Muscle mass measurement for patients was assessed by measuring PMI in cm^2/m^2 in computed tomography images taken in the preoperative period. Abdominopelvic computed tomography was routinely obtained as part of the standard preoperative evaluation or staging workup at our institution. PMI measurements were performed using the most recent preoperative CT scan available for each patient. The time interval between CT imaging and radical prostatectomy was within a clinically acceptable preoperative window, and no patient received systemic therapy or experienced significant clinical change that would be expected to substantially alter muscle mass during this period. PMI was defined as the total cross-sectional area of the bilateral psoas muscle at the third lumbar vertebra in cm^2 divided by the patient's height in m^2 [19, 20].

Statistical analyses were performed using IBM SPSS Statistics (version 26.0, IBM Corp., Armonk, NY, USA). The distribution of continuous variables was evaluated using the Shapiro-Wilk test. Continuous data showing a normal distribution were presented as mean ± standard deviation, while data not showing a normal distribution were presented as median (interquartile range). Categorical variables were expressed as numbers and percentages (%). For intergroup comparisons, Student's *t*-test was used for data showing a normal distribution, and the Mann-Whitney U test was used for data not showing a normal distribution. The chi-square test or Fisher's exact test was preferred for comparing categorical variables. To account for potential confounding variables that may influence ART decisions, a multivariate logistic regression analysis was performed. ROC (Receiver Operating Characteristic) curve analysis was applied to evaluate the performance of the PMI in predicting the need for adjuvant radiotherapy; the cut-off value, sensitivity, and specificity values were calculated. In all statistical tests, the significance level was accepted as $p < 0.05$.

3. Results

In the study, which included fifty-eight patients, the average age of the patients was recorded as 65.34 ± 6.63 years. The participants' total PSA value was calculated as 12.04 ± 7.61 ng/mL on average, and their PMI was calculated as 6.12 ± 1.44 cm^2/m^2 on average. At least one additional disease was present in 62.1% of the patients. The descriptive data and comorbid conditions of the patients are presented in Tables 1 and 2.

TABLE 1. Descriptive data of patients.

Data	Mean ± SD	Minimum	Maximum
Age (yr)	65.34 ± 6.63	50	78
BMI (kg/m^2)	27.68 ± 3.56	21.22	37.65
Total PSA (ng/mL)	12.04 ± 7.61	2.27	44.04
PSA density (ng/mL/cc)	0.22 ± 0.17	0.03	1.02
Prostate volume (cc)	57.22 ± 23.77	23	130
PMI (cm^2/m^2)	6.12 ± 1.44	2.62	9.38

SD: Standard deviation; BMI: Body mass index; PSA: Prostate Specific Antigen; PMI: Psoas muscle index.

TABLE 2. Patients' comorbid conditions.

Data	n (58)	%
Comorbidities		
Yes	36	62.1
No	22	37.9
Diabetes mellitus		
Yes	11	19.0
No	47	81.0
Hypertension		
Yes	24	41.4
No	34	58.6
Coronary artery disease		
Yes	11	19.0
No	47	81.0
Neurological disease		
Yes	3	5.2
No	55	94.8
Chronic obstructive pulmonary disease		
Yes	5	8.6
No	53	91.4

According to the D'Amico risk classification, 25.9% of patients were in the low-risk group, 50% were in the intermediate-risk group, and 24.1% were in the high-risk group. According to biopsy pathology, 29.3% of patients were found to have postoperative upgrade/stage increase. Adjuvant RT was required in 31% of patients postoperatively. Table 3 presents the preoperative D'Amico risk classification and biopsy pathologies, as well as postoperative pathology characteristics and adjuvant treatment application data.

TABLE 3. Pre- and post-operative data.

Data	n (58)	%
D'Amico risk group		
Low	15	25.9
Intermediate	29	50.0
High	14	24.1
Biopsy pathology ISUP grade		
1	25	43.1
2	22	38.0
3	6	10.3
4	5	8.6
5	0	0.0
Radical prostatectomy pathology ISUP grade		
1	16	27.6
2	30	51.7
3	8	13.8
4	1	1.7
5	3	5.2

TABLE 3. Continued.

Data	n (58)	%
Up grade		
Yes	17	29.3
No	41	70.7
Need for adjuvant therapy		
Yes	18	31.0
No	40	69.0
T stage		
<3	36	62.1
≥3	22	37.9
Extraprostatic extension		
Yes	16	27.6
No	42	72.4
Seminal vesicle invasion		
Yes	3	5.2
No	55	94.8
Lymphovascular invasion		
Yes	3	5.2
No	55	94.8
Perineural invasion		
Yes	29	50.0
No	29	50.0
Lymph node dissection		
Not performed	37	63.8
Negative result	20	34.5
Positive result	1	1.7
Surgical margin positivity		
Yes	22	37.9
No	36	62.1
Persistent PSA		
Yes	14	24.1
No	44	75.9

ISUP: International Society of Urological Pathology; PSA: Prostate Specific Antigen.

The included cases were categorised as patients requiring adjuvant RT (Group 1) and patients not requiring adjuvant RT (Group 2). Accordingly, the mean PMI was 5.32 ± 1.57 cm^2/m^2 in Group 1 and 6.48 ± 1.24 cm^2/m^2 in Group 2, with a significantly lower value observed in Group 1 ($p = 0.01$). Total PSA and PSA density were significantly higher in Group 1 ($p = 0.002$ and $p = 0.001$, respectively). No significant differences were observed between the two groups in the other compared data (Table 4).

Pathological T stage, PMI was found to be significantly higher in patients with <T3 compared to those with ≥T3 ($p = 0.01$). PMI was found to be significantly lower in patients with extraprostatic extension compared to those without ($p = 0.04$). No significant differences were observed in other comparative analyses involving PMI (Table 5).

TABLE 4. Comparison of data between Groups 1 and 2.

Data	Group 1 (those requiring adjuvant therapy) (n: 18)	Group 2 (those not requiring adjuvant therapy) (n: 40)	p value
PMI (cm^2/m^2) (mean ± SD)	5.32 ± 1.57	6.48 ± 1.24	0.010
Age (yr) (mean ± SD)	65.94 ± 7.15	65.08 ± 6.46	0.660
BMI (kg/m^2) (mean ± SD)	28.53 ± 3.19	27.30 ± 3.69	0.200
Total PSA (ng/mL) (median IQR)	16.51 (10.20–19.44)	8.04 (6.55–12.32)	0.002
PSA density (ng/mL/cc) (median IQR)	0.27 (0.22–0.43)	0.15 (0.10–0.21)	0.001
Prostate volume (cc) (median IQR)	50.5 (35.75–63.75)	54.00 (40.25–72.25)	0.380

PMI: Psoas muscle index; SD: Standard deviation; BMI: Body mass index; PSA: Prostate Specific Antigen; IQR: Inter quartile range.

TABLE 5. Comparison of postoperative pathology data in terms of PMI according to the presence of additional diseases.

Data	PMI (cm^2/m^2) (mean ± SD)	p value
Comorbidities		
Yes	6.02 ± 1.66	0.46
No	6.28 ± 0.98	
T stage		
<3	6.51 ± 1.28	0.01
≥3	5.48 ± 1.49	
Extraprostatic extension		
Yes	5.42 ± 1.59	0.04
No	6.38 ± 1.30	
Seminal vesicle invasion		
Yes	5.46 ± 0.94	0.33
No	6.15 ± 1.46	
Lymphovascular invasion		
Yes	5.75 ± 0.98	0.57
No	6.14 ± 1.46	
Perineural invasion		
Yes	6.26 ± 1.55	0.46
No	5.98 ± 1.33	
Surgical margin positivity		
Yes	5.78 ± 1.43	0.17
No	6.32 ± 1.43	
Persistent PSA		
Yes	5.74 ± 1.51	0.28
No	6.24 ± 1.41	

PMI: Psoas muscle index; SD: Standard deviation; PSA: Prostate Specific Antigen.

In the multivariate logistic regression analysis, after adjusting for potential confounding factors, lower PMI remained an independent predictor of the need for adjuvant radiotherapy (OR = 0.482, 95% CI: 0.253–0.919, p = 0.027), indicating that decreased muscle mass was significantly associated with a higher likelihood of ART. Additionally, pathological T stage (≥T3) was identified as another independent factor associated with ART requirement (OR = 12.845, 95% CI: 1.691–97.576, p = 0.014).

When ROC analysis was performed for PMI in patients undergoing radical prostatectomy, the AUC was 0.712; 95% confidence interval (CI) 0.560–0.865, with p = 0.01. A cut-off value of 5.91 cm^2/m^2 was determined for PMI, with 68% sensitivity and 72% specificity (Fig. 1). This value suggests that low PMI may be associated with adverse pathological features in prostate cancer and, consequently, with the need for adjuvant therapy.

4. Discussion

In this study, we evaluated the association between preoperative psoas muscle index (PMI) and postoperative surgical and oncological outcomes in patients with localized prostate cancer (PCa) undergoing radical prostatectomy. Our findings demonstrated that PMI was significantly lower in patients requiring adjuvant radiotherapy (ART). This suggests that sarcopenia may be more pronounced in this subgroup. Moreover, the observation of lower PMI values in patients with extraprostatic extension indicates a potential link between sarcopenia and aggressive tumor characteristics. These results imply that low PMI may reflect not only sarcopenia itself but also the subgroup of patients with more adverse pathological features. In the literature, sarcopenia has also been reported to correlate with poorer overall survival and progression-free survival in PCa patients [17, 18]. Furthermore, the reported prevalence of sarcopenia ranging from 51.9% in early-stage to 76.1% in advanced PCa [16] supports our findings. In this context, ROC analysis in our study identified a cut-off value of 5.91 cm^2/m^2 for PMI (AUC: 0.712; 95% CI: 0.560–0.865; p = 0.01). This suggests that low PMI may be associated with adverse disease course and the potential need for adjuvant therapy in PCa. However, given the moderate sensitivity and specificity values, this cut-off should be interpreted as exploratory rather than definitive, and PMI should currently be considered an adjunctive parameter rather than a standalone predictive tool.

We also observed that patients with pathological stage ≥T3 had significantly lower PMI values. Pathological stage ≥T3 typically reflects extracapsular extension, seminal vesicle in-

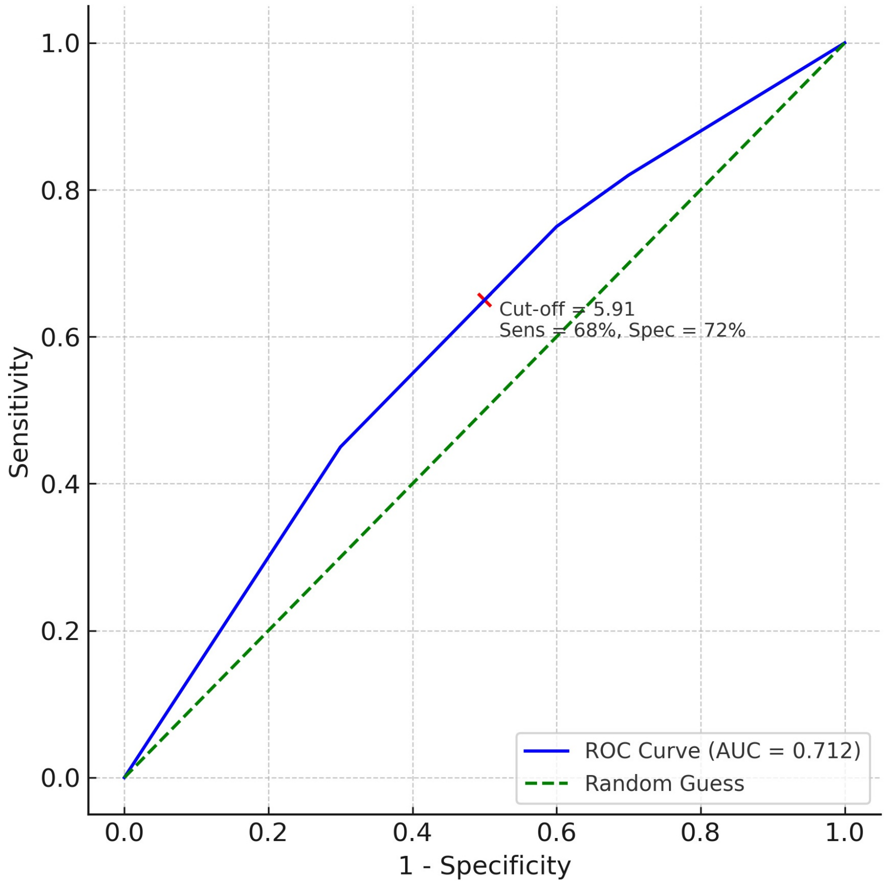

FIGURE 1. ROC curve of psoas muscle index in relation to adverse clinical and pathological outcomes. ROC: Receiver Operating Characteristic; AUC: Area Under the Curve; Sens: Sensitivity; Spec: Specificity.

vasion, or invasion of adjacent structures, and is indicative of more aggressive tumor biology [21]. Low PMI in this group may not only reflect increased tumor burden and adverse prognostic factors but also systemic frailty and metabolic stress associated with sarcopenia. Thus, reduced PMI may point to impaired physical status, weakened immune-metabolic responses, and accelerated tumor progression. Since pathological stage ≥T3 is regarded as a high-risk feature for recurrence and ART requirement following RP [5, 22], preoperative PMI measurements may provide additional information in identifying such patients and may serve as a useful adjunct for treatment planning. Furthermore, after adjusting for potential confounding factors in the multivariate logistic regression model, we observed that PMI remained an independent predictor of adjuvant radiotherapy requirement. This finding suggests that the association between lower PMI and increased ART necessity is not solely driven by tumor-related variables but also reflects an independent contribution of reduced muscle mass. In addition, pathological T stage (≥T3) also remained independently associated with ART need, reinforcing the established role of locally advanced disease as a key determinant of postoperative treatment decisions. Incorporating PMI into preoperative evaluation could contribute to more personalized management strategies.

In the literature, factors such as seminal vesicle invasion, lymph node metastasis, persistent PSA, and positive surgical margins have frequently been emphasized as predictors of ART requirement [3, 5–7]. These factors are considered key prognostic indicators of progression and biochemical recurrence in PCa. However, in our study, no significant associations were observed between these features and ART requirement, which may be attributed to the relatively small sample size and consequently reduced statistical power. In our cohort, persistent PSA may reflect residual local disease in some patients, while in others it may indicate occult micrometastatic disease that was not detectable at the time of surgery, particularly given the selective use of lymph node dissection based on preoperative risk assessment.

PSA density, a PSA value adjusted for prostate volume, is recognized as a stronger prognostic marker than PSA alone [23]. Elevated PSA density has been linked to higher tumor burden and adverse pathological features such as positive surgical margins, extraprostatic extension, and seminal vesicle invasion [24]. Prior studies have demonstrated that high PSA and PSA density are strongly associated with biochemical recurrence and are frequently included in clinicopathological nomograms predicting adjuvant therapy requirement [24, 25]. In line with these findings, our study revealed that patients requiring ART had significantly higher total PSA and PSA density values. This suggests that elevated PSA and PSA density may be markers of aggressive tumor biology and an increased risk of micrometastatic disease. Consequently, alongside PSA and PSA density, PMI may serve as an additional parameter in tailoring postoperative treatment strategies.

Our study has several limitations. First, it was a retrospective, single-center study, which may introduce selection and data collection bias. Second, the relatively small sample size limited statistical power and may have prevented certain clinicopathological features from reaching statistical significance in relation to ART requirement. Third, PMI was measured only from CT images, without incorporating functional muscle assessment or nutritional status, which are also relevant to sarcopenia. Additionally, the relatively short follow-up period restricted our ability to evaluate long-term oncological outcomes and survival. Given that the study period spans from January 2021 to August 2024, the resulting follow-up duration remains insufficient for assessing long-term oncological endpoints such as biochemical recurrence, metastasis-free survival, and cancer-specific mortality. Therefore, the prognostic value of PMI should be interpreted with caution, and longer-term prospective studies are needed to validate these findings. Furthermore, the lack of longitudinal assessment, including nutritional parameters and repeated PMI measurements during follow-up or at the time of biochemical recurrence, limits our ability to evaluate dynamic changes in sarcopenia and their relationship with disease progression. Additionally, the absence of systematically available preoperative prostate MRI data limited the evaluation of MRI-based local staging parameters in relation to PMI and ART requirement.

5. Conclusions

In conclusion, the findings of our study demonstrate that PMI can be used in addition to traditional clinical-pathological factors to predict the need for ART. In particular, our findings that patients with low PMI have a more aggressive disease course and a higher need for ART offer a new perspective on current follow-up strategies. The use of PMI as a routine assessment tool in the preoperative period may contribute to the more accurate identification of high-risk patients and the more effective guidance of treatment plans. Therefore, our study highlights the need for further studies with larger sample groups.

AVAILABILITY OF DATA AND MATERIALS

The datasets generated and/or analyzed during the current study are not publicly available due to patient privacy restrictions but are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

SZ and AG—designed the research study. SZ, DB, MK and CB—performed the research. OE—analyzed the data. All authors wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Bursa Yuksek Ihtisas Training and Research Hospital, Health Sciences University (Date: 25 September 2024, Approval No: 2024-TBEK-2024/09-02). Informed consent forms were obtained from all patients included in the study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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