

Original Article

Molecular tumor volume on PSMA PET/CT is an independent imaging biomarker associated with progression-free survival in patients with oligorecurrent prostate cancer

Monica Cheng¹, Umar Mahmood¹, Nathaniel D Mercaldo¹, Shadi A Esfahani¹, Thomas Ng¹, Xin Gao², Jason A Efstathiou³, Pedram Heidari¹

¹Department of Radiology, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA; ²Department of Medicine, Division of Hematology and Oncology, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA; ³Department of Radiation Oncology, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA

Received June 28, 2025; Accepted September 2, 2025; Epub October 25, 2025; Published October 30, 2025

Abstract: The purpose of this study is to evaluate the PSMA PET imaging parameters in association with outcomes among patients with oligorecurrent prostate cancer. This retrospective single-center study included 101 patients (median age 71; interquartile range 65-75) with biochemically recurrent prostate cancer who underwent PSMA PET between May 2021 and May 2022, revealing 5 or fewer sites of metastases (oligometastatic disease). Multiple variables including maximum standardized uptake value (SUV_{max}), mean standardized uptake value (SUV_{mean}), and molecular tumor volume (MTV) were measured and analyzed on a per-patient basis, along with total MTV and molecular tumor burden (MTB). Multivariable Cox proportional-hazards regression models were used to identify factors associated with progression-free survival (PFS). PSMA PET revealed a total of 216 lesions across all patients, of which 134 (62.0%) involved the lymph nodes and 56 (25.9%) involved the bone. A total of 61 (60.4%) patients received combined metastasis-directed and hormone therapy, and 40 (39.6%) received hormone therapy only. The median subsequent follow-up from PSMA PET detection of oligorecurrent disease was 18.2 months (IQR 10.3-25.0). MTV on PSMA PET was associated with worse PFS (hazard ratio: 1.05, 95% CI 1.00-1.11; $P = 0.04$). Molecular tumor volume on PSMA PET is associated with worse clinical outcomes in patients with oligorecurrent prostate cancer.

Keywords: Prostate, prostate adenocarcinoma, PET imaging, PSMA, molecular imaging, radiotheranostics, survival

Introduction

Prostate cancer is the second-leading cause of cancer-related death in men, with a rising incidence of the disease by 3% each year and approximately 30,000 new cases diagnosed in the United States in 2024 [1]. Prostate-specific membrane antigen (PSMA) positron emission tomography/computed tomography (PET/CT) has become an indispensable tool for early and accurate detection of prostate cancer both in the primary and recurrent setting. In patients who experience biochemical recurrence with low prostate-specific antigen (PSA), PSMA PET has demonstrated superior disease detection of lesions that are occult on conventional CT or MR imaging, with sensitivity rates of 58% for PSA below 1.0 ng/mL and greater than 76% for PSA above 1.0 ng/mL [2]. Earlier disease detection and the ability for quantitation using PSMA PET present opportunities to deliver targeted therapies and identify prognostic biomarkers, to improve disease control and survival outcomes [3].

Oligometastatic disease in prostate cancer is postulated as a distinctive intermediate state between localized and widespread disease, conferring the unique opportunity to deliver localized metastasis-directed therapy (MDT) to improve patient outcomes with the benefit of lower mor-

bidity compared to systemic therapy [4, 5]. MDT is delivered in the form of radiation therapy and surgical resection and has shown promise in preclinical and clinical trials for decreasing disease progression [6, 7]. Advancements in radiation therapy aided by improved imaging technologies, treatment planning and delivery, and targeting technologies have ushered the development of MDT techniques, including IMRT and SBRT. These techniques have dose-escalation capabilities that can conform to the prostate and oligometastatic sites with minimal additional toxicity and reduced risk of biochemical recurrence [8]. In clinical practice, MDT is often added to hormone therapy to synergistically improve progression-free survival (PFS) in patients with oligometastatic disease [9-12]. Factors that influence why some patients with oligometastatic prostate cancer fare better than others is an evolving area of investigation.

The ability to prognosticate using imaging and clinicopathologic markers is essential for guiding the clinical management of patients with oligorecurrent disease while minimizing morbidity. The purpose of this study is to determine the PSMA PET imaging markers associated with progression-free survival in patients with oligorecurrent prostate cancer.

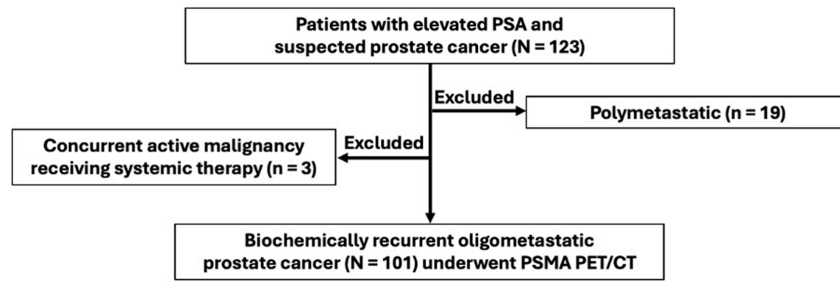


Figure 1. Flowchart of patient inclusion. PSA: prostate-specific antigen; PSMA: prostate-specific membrane antigen.

PET/CT acquisition protocol

PSMA PET/CT examinations were performed on the GE Medical Systems Discovery MI Gen 2 (n = 64) and Siemens Biograph CT 64 (n = 37) PET/CT scanners. Whole body PET/CT images were obtained from scalp to mid-thigh approximately 60 minutes after radiopharmaceutical injection. Noncontrast low-dose CT was used for attenuation correction and anatomic localization.

Method

Patient cohort

This retrospective single-center study included 123 patients with biochemically recurrent prostate cancer who underwent PSMA-targeted ^{68}Ga -gozetotide PET/CT scans between May 2021 and May 2022. The study protocol was approved by the local IRB. All patients had confirmed oligometastatic biochemical recurrence of prostate cancer after primary local therapies, including radical prostatectomy or radiation therapy with adjuvant therapy. Oligometastatic disease was identified on PSMA PET/CT performed at the time of biochemical recurrence. Exclusion criteria included polymetastatic disease (n = 19) or concurrent second active malignancy receiving systemic therapy (n = 3). The final study cohort was 101 patients, of whom 61 underwent MDT combined with hormone therapy and 40 received standard hormone therapy only (**Figure 1**).

Oligometastatic prostate cancer was defined as five or fewer sites of uptake suspicious for metastasis. To those oligometastatic sites, MDT was delivered as radiation therapy (e.g., SBRT or IMRT) or surgical resection. The primary endpoint was progression-free survival, defined as the interval until the occurrence of one of the following events: progression based on clinical or biochemical parameters, radiological evidence of disease progression, or death. Clinical and biochemical parameters followed PSA trends for biochemical recurrence as well as symptomatic changes or decline in functional status which may result in change of therapy. Biochemical recurrence was defined as PSA level of ≥ 0.2 ng/mL on two consecutive tests after radical prostatectomy, or PSA rise of ≥ 2 ng/mL above the nadir after radiation therapy according to the Phoenix definition [13-15]. Imaging evidence of disease progression followed RECIST 1.1 and PERCIST criteria. If no progression or death was observed, PFS was censored at the time of the last documented clinical follow-up. Demographic data and clinicopathological factors, including age, ethnicity, Gleason category, treatment modality, and follow-up, were extracted from the electronic health record.

Image analysis

The number, size, and location of PSMA-avid metastases were recorded. Standardized uptake values (SUVs) for each lesion, including SUV_{max} and SUV_{mean} were measured using the attenuation-corrected PET images by Siemens Healthineers syngo.via software. SUV_{mean} and molecular tumor volume (MTV) were measured using 40% isocontour, in keeping with previous literature [16]. The analysis utilized the maximum lesion values on a per-patient basis for MTV, SUV_{mean} , and SUV_{max} . The total MTV represents the sum of MTV values across lesions identified in each patient. Molecular tumor burden (MTB) for each patient was calculated by multiplying MTV with SUV_{mean} for each lesion and summing up the total number of lesions in the whole body.

Statistical analysis

Demographic summaries were computed for the entire cohort; continuous variables were summarized using the median (interquartile range, IQR), while categorical variables were summarized using the frequency (proportion). Kaplan-Meier curve was constructed to visualize the relationship between clinical and imaging variables and progression-free survival; the log-rank test was applied to evaluate survival differences between dichotomization of each variable (at the mean). Univariate and multivariable Cox proportional-hazards regression models were used to identify clinical and imaging variables independently associated with progression-free survival. The primary analysis modeled each continuous/ordinal variable as linear, but a secondary model was constructed in which the two ordinal variables, Gleason grade and number of metastases, were dichotomized. Gleason grade was dichotomized into low to intermediate-risk Gleason grades 1-3 and high-risk Gleason grades 4-5. The number of metastases was dichotomized into groups containing 1-2 and 3-5. These groups are depicted in **Table 1**. Variables included in the multivariable model were selected based on the univariable analysis using an inclusion threshold of $P < 0.2$. Variance inflation factors (VIF) were calculated to assess multicollinearity among predictors; $\text{VIF} > 5$ was considered indicative of potential collinearity based on

Table 1. Baseline patient and tumor characteristics

Characteristics	Unit	
Age*	71 (65-75)	Years (IQR)
Race & Ethnicity		
Black	2 (2.0)	No. of patients (%)
Hispanic	3 (3.0)	
White	92 (91.1)	
Other [†]	4 (3.9)	
PSA Level at Recurrence*	1.0 (0.36-2.70)	ng/mL (IQR)
≤ 0.2	10 (9.9)	No. of patients (%)
> 0.2 to < 2.0	60 (59.4)	
≥ 2.0	31 (30.7)	
Gleason Grade		
1	10 (9.9)	No. of patients (%)
2	13 (12.9)	
3	23 (22.8)	
4	24 (23.7)	
5	31 (30.7)	
Metastatic Lesions, No.*	2 (1-3)	Mean (IQR)
1	36 (35.6)	No. of patients (%)
2	29 (28.7)	
3	25 (24.8)	
4-5	11 (10.9)	
Lesion Location (n = 216)		
Lymph Node	134 (62.0)	No. of patients (%)
Bone	56 (25.9)	
Prostate Bed	18 (8.3)	
Lung	5 (2.4)	
Other [‡]	3 (1.4)	
Lesion Size*	7 (5-12)	mm (IQR)
≤ 4	13 (12.9)	No. of patients (%)
5-7	32 (31.7)	
8-9	8 (7.9)	
≥ 10	34 (33.7)	
Not measurable	14 (13.8)	
Treatment		
Metastasis-directed therapy with hormone therapy	61 (60.4)	No. of patients (%)
Hormone therapy alone	40 (39.6)	

*Presented as median and interquartile range; others are presented as number of patients and percentages. [†]Includes Asian and not otherwise specified. PSA: prostate-specific antigen. [‡]Other lesion locations include the liver, bladder, and adrenal gland.

previous literature [17]. For variables identified as collinear, sensitivity analyses were performed by running separate multivariable analyses in which the collinear variable was excluded while retaining other selected covariates. Each coefficient was exponentiated to reflect fold changes in the hazard ratio (HR) associated with a 1-unit increase in the covariate of interest; 95% confidence intervals and *p*-values were also calculated. A *p*-value less than 0.05 was regarded as statistically significant. Statistical analysis was performed using R software (version 4.3.1, R Foundation for Statistical Computing).

Results

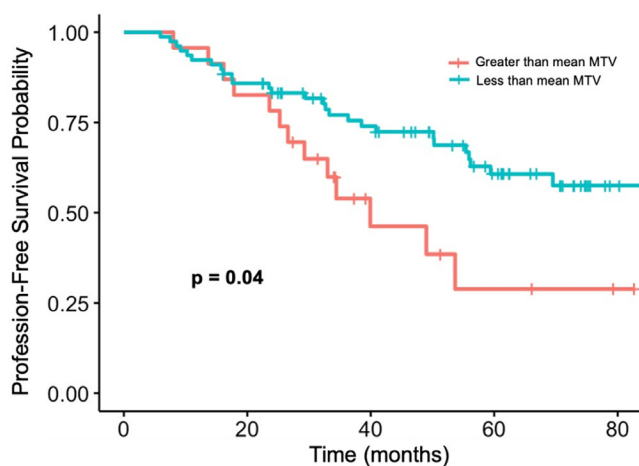
Patient characteristics

Table 1 describes the patient and tumor characteristics. There were 101 patients with a median age of 71 years (IQR 65-75) at the time of biochemical recurrence. The median PSA level was 1.01 ng/mL (IQR 0.36-2.7) at the time PSMA PET was performed for suspected biochemically recurrent disease. Just over half of patients (54.5%, 55/101) presented with high-grade Gleason group 4-5 disease at the time of initial diagnosis. The majority

Table 2. Cox proportional hazards analyses assessing the association between PSMA PET parameters and progression free survival

Measured Parameter	Univariable HR 95% (CI)	<i>p</i>	Multivariable HR (95% CI)	<i>p</i>	Multivariable HR (95% CI)	<i>p</i>
SUV _{max}	1.01 (0.99-1.02)	0.52				
SUV _{mean}	1.01 (0.98-1.03)	0.64				
MTV	1.06 (1.01-1.11)	0.02	1.05 (1.00-1.11)	0.04		
Total MTV	1.05 (1.00-1.10)	0.04			1.04 (0.99-1.10)	0.10
MTB	1.00 (0.99-1.00)	0.11				
PSA	1.01 (0.99-1.02)	0.09	1.01 (0.99-1.02)	0.36	1.01 (0.99-1.02)	0.38
Gleason Grade	1.20 (0.94-1.54)	0.15	1.30 (0.79-2.13)	0.31	1.29 (0.78-2.12)	0.33
Number of Metastases	1.11 (0.84-1.46)	0.46				
Treatment	1.03 (0.55-1.94)	0.93				

Data in parentheses are 95% confidence intervals. SUV_{max}: maximum standardized uptake value; SUV_{mean}: mean standardized uptake value; MTV: metabolic tumor volume; MTB: molecular tumor burden; HR: hazard ratio.

**Figure 2.** Kaplan-Meier survival curve stratified to MTV values above and below the mean, 2.3 mL. Greater MTV values were associated with worse progression-free survival ($P = 0.04$, using the log-rank test).

(64.3%, 65/101) had one or two sites of metastases on PSMA PET. There were 216 metastases across all patients, of which 134 (62.0%) involved the lymph nodes and 56 (25.9%) involved the bones.

PSMA PET parameters and progression-free survival

The median follow-up from PSMA PET detection of oligorecurrent disease was 18.2 months (IQR 10.3-25.0). A total of 61 patients received combined therapy with MDT and hormone therapy, and 40 received standard hormone therapy only. Forty patients experienced progressive disease. No treatment-related difference in PFS was detected in an exploratory unadjusted analysis using the log-rank test. Among all the variables considered, molecular tumor volume - measured as the maximal MTV on a per-patient basis - was the sole parameter that was significantly associated with worse progression-free survival on both univariate (HR: 1.06, 95% CI: 1.01-1.11; $P = 0.02$) and multivariable analysis (HR = 1.05, 95% CI: 1.00-

1.11; $P = 0.04$) (Table 2). This outcome is depicted on the Kaplan-Meier curve presented in Figure 2 and representative patient case in Figure 3. Total MTV demonstrated significance on univariate analysis (HR = 1.05, 95% CI: 1.00-1.10, $P = 0.04$) but not multivariable analysis. VIF were 10.48 for MTV, 10.83 for total MTV, 1.00 for Gleason grade, and 1.14 for PSA. Due to collinearity between the variables MTV and total MTV, each was assessed independently in the multivariable analyses in which one of the collinear variables was excluded while retaining the other selected covariates. The results of these analyses are summarized in Table 2. The other variables, PSA and Gleason grade, showed no evidence of collinearity. There was insufficient evidence to conclude that other PET-derived markers were associated with PFS.

Discussion

Identifying prognostic biomarkers is essential for guiding clinical management throughout the course of disease for patients with prostate cancer. In the present study, we evaluated the imaging biomarkers on PSMA PET and their associations with progression-free survival in patients with oligorecurrent prostate cancer. MTV was found to be a prognostic factor, with higher MTV associated with worse outcomes.

Previous studies have corroborated the potential value of MTV, a semi-quantitative PET parameter, in tumors such as lymphoma, lung cancer, and endometrial cancer [18-21]. Kubilay et al. (2022) suggested that ^{68}Ga -PSMA PET volumetric parameters like MTV have predictive value in the primary staging of prostate cancer, in which an increase in total lesion uptake values was associated with higher pathologic T stage and surgical margin positivity [22]. PSMA PET-derived volumetric measurements for the detection of progressive disease provide further insights into tumor biology and have garnered increasing support for consideration in the PSMA PET progression criteria [23, 24]. Seifert et al. found that total molecular

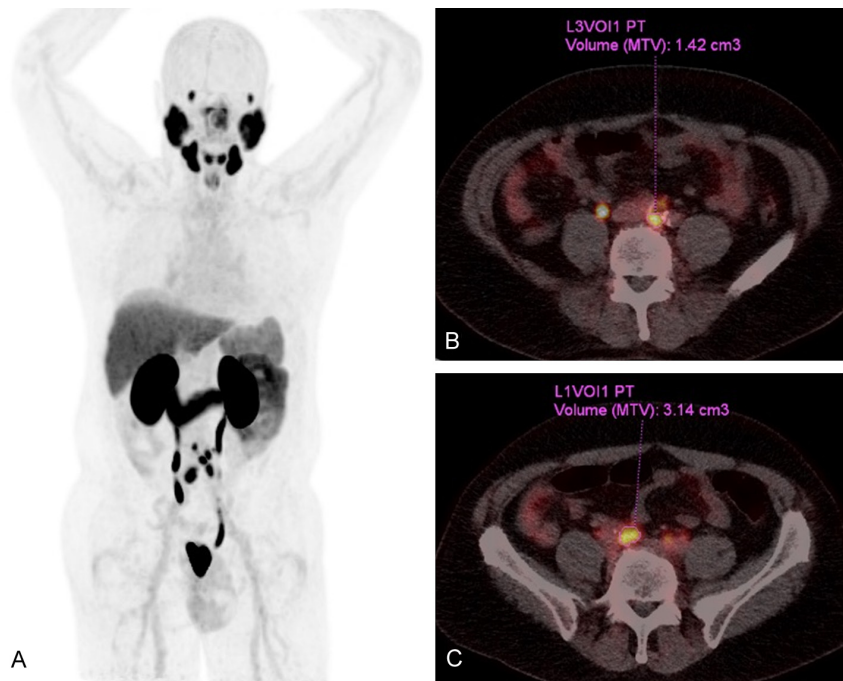


Figure 3. 61-year-old male with rising PSA of 1.67 ng/mL at the time of PSMA PET/CT on March 2022 demonstrating intense uptake to subcentimeter retroperitoneal lymph nodes and right common iliac lymphadenopathy. Maximum intensity projection image (A) shows extent of disease, with representative left para-aortic lymph node MTV of 1.42 cm³ (B) and greatest MTV measuring 3.14 cm³ in the right common iliac lymph node (C). Patient had been previously treated with radical prostatectomy and adjuvant radiation therapy to the prostatic fossa and pelvic lymph nodes in 2019. After oligorecurrence, patient was treated with bicalutamide and radiation therapy to the retroperitoneal and common iliac nodes, with progression of disease detected by rising PSA 21.5 months later.

tumor volume derived semi-automatically from ⁶⁸Ga-PSMA PET was a repeatable, reader-independent metric that may be used to assess therapeutic response in the context of metastatic disease [25].

Of note, neither SUV_{mean} nor SUV_{max} were associated with progression-free survival in this study, within the constraints of this limited-size study cohort. An earlier study by Murad et al. suggested that adjusted SUV measures - SUV_{max} and segmented SUV_{mean} - were associated with a lower risk of biochemical progression in patients with oligometastatic prostate cancer who underwent MDT [26]. However, their study sample was smaller, and recurrent disease consisted predominantly of 86% nodal metastases. Our current study included a broader spread of disease sites, including 62% nodal metastases and 38% skeletal or visceral metastases, as well as different therapeutic regimens, which may confer different results. Furthermore, the reliability of SUV measurements is affected by external factors such as patient body composition, radiotracer choice, and scan acquisition parameters.

Our study is a retrospective single-institution study with limitations inherent to such a study design and with a relatively small study sample. At the time of this study,

metastasis-directed therapy was delivered in combination with standard hormone therapy for patients with oligometastatic prostate cancer, or standard hormone therapy was given alone. This approach has been supported in previous studies; for example, the OLIGOPELVIS (NCT02274779) is an open-label phase II trial in 2021 that demonstrated better disease control in patients who received combined hormone therapy and pelvic radiation therapy in oligorecurrent pelvic nodal disease while reducing toxicity [27]. The oligometastatic disease state also offers potential therapeutic opportunities to delay not only further metastatic spread but also the initiation of systemic therapies. Although treatment modality was not associated with differences in PFS in this study, these findings should be interpreted cautiously given the size of the study cohort and limitations of a retrospective study. Future prospective studies may be valuable to further investigate the treatment-related associations which are outside the scope of the current study. Molecular profiling and identification of high-risk mutational signatures may also provide another avenue of future study in the ability to complement imaging biomarkers, facilitating risk stratification and improv-

ing patient selection for those most likely to respond to localized curative intent therapies and attain sustained disease control [10, 28, 29].

In conclusion, molecular tumor volume on PSMA PET/CT may serve as an imaging biomarker associated with progression-free survival in patients with oligorecurrent prostate cancer. This finding presents an opportunity to utilize this imaging parameter to facilitate patient selection and therapeutic optimization to improve patient outcomes.

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Monica Cheng, Department of Radiology, Massachusetts General Hospital, Harvard Medical School, No. 55 Fruit Street, Boston, MA 02114, USA. Tel: 1-617-724-9729; E-mail: mcheng0@mgh.harvard.edu

References

- [1] Siegel RL, Giaquinto AN and Jemal A. Cancer statistics, 2024. *CA Cancer J Clin* 2024; 74: 12-49.
- [2] Perera M, Papa N, Christidis D, Wetherell D, Hofman MS, Murphy DG, Bolton D and Lawrentschuk N. Sensitivity,

- specificity, and predictors of positive (68)Ga-prostate-specific membrane antigen positron emission tomography in advanced prostate cancer: a systematic review and meta-analysis. *Eur Urol* 2016; 70: 926-937.
- [3] Artigas C, Diamand R, Shagera QA, Plouznikoff N, Fokoue F, Otte FX, Gil T, Peltier A, Van Gestel D and Flamen P. Oligometastatic disease detection with (68)Ga-PSMA-11 PET/CT in hormone-sensitive prostate cancer patients (HSPC) with biochemical recurrence after radical prostatectomy: predictive factors and clinical impact. *Cancers (Basel)* 2021; 13: 4982.
 - [4] Jadvar H. Radiotheranostics in prostate cancer: introduction and overview. *J Nucl Med* 2016; 57 Suppl 3: 1S-2S.
 - [5] Ballas LK, de Castro Abreu AL and Quinn DI. What medical, urologic, and radiation oncologists want from molecular imaging of prostate cancer. *J Nucl Med* 2016; 57 Suppl 3: 6S-12S.
 - [6] D'Amico AV, Chen MH, Renshaw A, Loffredo M and Kantoff PW. Long-term follow-up of a randomized trial of radiation with or without androgen deprivation therapy for localized prostate cancer. *JAMA* 2015; 314: 1291-1293.
 - [7] Locke JA, Dal Pra A, Supiot S, Warde P and Bristow RG. Synergistic action of image-guided radiotherapy and androgen deprivation therapy. *Nat Rev Urol* 2015; 12: 193-204.
 - [8] Zaorsky NG, Harrison AS, Trabulsi EJ, Gomella LG, Showalter TN, Hurwitz MD, Dicker AP and Den RB. Evolution of advanced technologies in prostate cancer radiotherapy. *Nat Rev Urol* 2013; 10: 565-579.
 - [9] Gillissen S, Armstrong A, Attard G, Beer TM, Beltran H, Bjartell A, Bossi A, Briganti A, Bristow RG, Bulbul M, Caffo O, Chi KN, Clarke CS, Clarke N, Davis ID, de Bono JS, Duran I, Eeles R, Efstathiou E, Efstathiou J, Ekeke ON, Evans CP, Fanti S, Feng FY, Fizazi K, Frydenberg M, George D, Gleave M, Halabi S, Heinrich D, Higano C, Hofman MS, Hussain M, James N, Jones R, Kanesvaran R, Khamli RB, Klotz L, Leibowitz R, Logothetis C, Maluf F, Millman R, Morgans AK, Morris MJ, Mottet N, Mrabti H, Murphy DG, Murthy V, Oh WK, Ost P, O'Sullivan JM, Padhani AR, Parker C, Poon DMC, Pritchard CC, Rabah DM, Rathkopf D, Reiter RE, Rubin M, Ryan CJ, Saad F, Sade JP, Sartor O, Scher HI, Shore N, Skoneczna I, Small E, Smith M, Soule H, Spratt DE, Sternberg CN, Suzuki H, Sweeney C, Sydes MR, Taplin ME, Tilki D, Tombal B, Turkeri L, Uemura H, Uemura H, van Oort I, Yamoah K, Ye D, Zapatero A and Omlin A. Management of patients with advanced prostate cancer: report from the advanced prostate cancer consensus conference 2021. *Eur Urol* 2022; 82: 115-141.
 - [10] Deek MP, Yu C, Phillips R, Song DY, Deville C, Greco S, DeWeese TL, Antonarakis ES, Markowski M, Paller C, Denmeade S, Carducci M, Walsh PC, Pienta KJ, Eisenberger M and Tran PT. Radiation therapy in the definitive management of oligometastatic prostate cancer: the Johns Hopkins experience. *Int J Radiat Oncol Biol Phys* 2019; 105: 948-956.
 - [11] Rogowski P, Trapp C, von Bestenbostel R, Konnerth D, Marschner S, Schmidt Hegemann NS, Belka C and Li M. Radiotherapy in oligometastatic prostate cancer-a pattern of care survey among members of the German Society for Radiation Oncology (DEGRO). *Strahlenther Onkol* 2022; 198: 727-734.
 - [12] Tang C, Sherry AD, Haymaker C, Bathala T, Liu S, Fellman B, Cohen L, Aparicio A, Zurita AJ, Reuben A, Marmonti E, Chun SG, Reddy JP, Ghia A, McGuire S, Efstathiou E, Wang J, Wang J, Pilie P, Kovitz C, Du W, Simiele SJ, Kumar R, Borghero Y, Shi Z, Chapin B, Gomez D, Wistuba I and Corn PG. Addition of metastasis-directed therapy to intermittent hormone therapy for oligometastatic prostate cancer: the EXTEND phase 2 randomized clinical trial. *JAMA Oncol* 2023; 9: 825-834.
 - [13] Cookson MS, Aus G, Burnett AL, Canby-Hagino ED, D'Amico AV, Dmochowski RR, Eton DT, Forman JD, Goldenberg SL, Hernandez J, Higano CS, Kraus SR, Moul JW, Tangen C, Thrasher JB and Thompson I. Variation in the definition of biochemical recurrence in patients treated for localized prostate cancer: the American Urological Association Prostate Guidelines for Localized Prostate Cancer Update Panel report and recommendations for a standard in the reporting of surgical outcomes. *J Urol* 2007; 177: 540-545.
 - [14] Pound CR, Partin AW, Eisenberger MA, Chan DW, Pearson JD and Walsh PC. Natural history of progression after PSA elevation following radical prostatectomy. *JAMA* 1999; 281: 1591-1597.
 - [15] Roach M 3rd, Hanks G, Thames H Jr, Schellhammer P, Shipley WU, Sokol GH and Sandler H. Defining biochemical failure following radiotherapy with or without hormonal therapy in men with clinically localized prostate cancer: recommendations of the RTOG-ASTRO Phoenix Consensus Conference. *Int J Radiat Oncol Biol Phys* 2006; 65: 965-974.
 - [16] Capobianco N, Sibille L, Chantadisai M, Gafita A, Langbein T, Platsch G, Solari EL, Shah V, Spottiswoode B, Eiber M, Weber WA, Navab N and Nekolla SG. Whole-body uptake classification and prostate cancer staging in (68)Ga-PSMA-11 PET/CT using dual-tracer learning. *Eur J Nucl Med Mol Imaging* 2022; 49: 517-526.
 - [17] Marcoulides KM and Raykov T. Evaluation of variance inflation factors in regression models using latent variable modeling methods. *Educ Psychol Meas* 2019; 79: 874-882.
 - [18] Boellaard R, Buvat I, Nioche C, Ceriani L, Cottreau AS, Guerra L, Hicks RJ, Kanoun S, Kobe C, Loft A, Schoder H, Versari A, Voltin CA, Zwezerijnen GJC, Zijlstra JM, Mikhaeel NG, Gallamini A, El-Galaly TC, Hanoun C, Chauvie S, Ricci R, Zucca E, Meignan M and Barrington SF. International benchmark for total metabolic tumor volume measurement in baseline (18)F-FDG PET/CT of lymphoma patients: a milestone toward clinical implementation. *J Nucl Med* 2024; 65: 1343-1348.
 - [19] Barrington SF, Zwezerijnen BGJC, de Vet HCW, Heymans MW, Mikhaeel NG, Burggraaff CN, Eertink JJ, Pike LC, Hoekstra OS, Zijlstra JM and Boellaard R. Automated segmentation of baseline metabolic total tumor burden in diffuse large B-cell lymphoma: which method is most successful? A study on behalf of the PETRA consortium. *J Nucl Med* 2021; 62: 332-337.
 - [20] Shim SH, Kim DY, Lee DY, Lee SW, Park JY, Lee JJ, Kim JH, Kim YM, Kim YT and Nam JH. Metabolic tumour volume and total lesion glycolysis, measured using preoperative 18F-FDG PET/CT, predict the recurrence of endometrial cancer. *BJOG* 2014; 121: 1097-1106; discussion 1106.
 - [21] Wen W, Piao Y, Xu D and Li X. Prognostic value of MTV and TLG of (18)F-FDG PET in patients with stage I and II non-small-cell lung cancer: a meta-analysis. *Contrast Media Mol Imaging* 2021; 2021: 7528971.

- [22] Kubilay E, Akpınar C, Oğuz ES, Araz MS, Soydal C, Baltacı S, Urun Y and Suer E. Significance of metabolic tumor volume and total lesion uptake measured using Ga-68 labelled prostate-specific membrane antigen PET/CT in primary staging of prostate cancer. *Urol Oncol* 2022; 40: 408.e419-408.e425.
- [23] Fanti S, Goffin K, Hadaschik BA, Herrmann K, Maurer T, MacLennan S, Oprea-Lager DE, Oyen WJ, Rouviere O, Mottet N and Bjartell A. Consensus statements on PSMA PET/CT response assessment criteria in prostate cancer. *Eur J Nucl Med Mol Imaging* 2021; 48: 469-476.
- [24] Fanti S, Hadaschik B and Herrmann K. Proposal for systemic-therapy response-assessment criteria at the time of PSMA PET/CT imaging: the PSMA PET progression criteria. *J Nucl Med* 2020; 61: 678-682.
- [25] Seifert R, Rasul S, Seifert KE, Eveslage M, Rahbar Nikoukar L, Kessel K, Schafers M, Yu J, Haug AR, Hacker M, Bogemann M, Bodei L, Morris MJ, Hofman MS and Rahbar K. A prognostic risk score for prostate cancer based on PSMA PET-derived organ-specific tumor volumes. *Radiology* 2023; 307: e222010.
- [26] Murad V, Glicksman RM, Berlin A, Santiago A, Ramotar M and Metser U. Association of PSMA PET-derived parameters and outcomes of patients treated for oligorecurrent prostate cancer. *Radiology* 2023; 309: e231407.
- [27] Supiot S, Vaugier L, Pasquier D, Buthaud X, Magne N, Peiffert D, Sargos P, Crehange G, Pommier P, Loos G, Hasbini A, Latorzeff I, Silva M, Denis F, Lagrange JL, Morvan C, Campion L and Blanc-Lapierre A. OLIGOPELVIS GETUG P07, a multicenter phase II trial of combined high-dose salvage radiotherapy and hormone therapy in oligorecurrent pelvic node relapses in prostate cancer. *Eur Urol* 2021; 80: 405-414.
- [28] Oka R, Utsumi T, Noro T, Suzuki Y, Iijima S, Sugizaki Y, Somoto T, Kato S, Endo T, Kamiya N and Suzuki H. Progress in oligometastatic prostate cancer: emerging imaging innovations and therapeutic approaches. *Cancers (Basel)* 2024; 16: 507.
- [29] Colosini A, Bernardi S, Foroni C, Pasinetti N, Guerini AE, Russo D, Bresciani R, Tomasi C, Magrini SM, Bardoscia L and Triggiani L. Stratification of oligometastatic prostate cancer patients by liquid biopsy: clinical insights from a pilot study. *Biomedicines* 2022; 10: 1321.