Nuclear Medicine Imaging of Prostate Cancer Nuklearmedizinische Diagnostik des Prostatakarzinoms

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The new tracer Gallium-68 prostate-specific membrane antigen (Ga-68 PSMA) yields new promising options for the PET/CT diagnosis of prostate cancer (PCa) and its metastases. To overcome limitations of hybrid imaging, known from the use of choline derivatives, seems to be possible with the use of Ga-68 PSMA for PCa. The benefits of hybrid imaging with Ga-68 PSMA for PCa compared to choline derivatives shall be discussed in this article based on an overview of the current literature. **Key Points:**

- Ga-68 PSMA PET/CT can achieve higher detection rates of PCa lesions than PET/CT performed with choline derivatives
- The new tracer Ga-68 PSMA has the advantage of high specificity, independence of PSA-level and low nonspecific tracer uptake in surrounding tissue
- The new tracer Ga-68 PSMA seems very suitable for MR-PET diagnostic

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Zusammenfassung

Der neue Tracer Gallium-68 prostataspezifisches Membranantigen (Ga-68 PSMA) eröffnet für die PET/CT Diagnostik des Prostatakarzinoms (PCa) und seiner Metastasen neue vielversprechende Optionen. Bekannte Limitationen der Fusionsbildgebung unter Anwendung der, vor Einführung dieses Tracers verwendeten Cholin-Derivate, scheinen überwindbar. Welche Vorteile die Fusionsbildgebung unter Verwendung von Ga-68 PSMA für die PCa-Diagnostik bringt und welchen Stellenwert sie gegenüber den Cholin-Derivaten einnimmt, soll anhand eines aktuellen Literaturüberblicks in dieser Arbeit dargelegt werden.

Introduction

The use of gallium-68 (Ga-68)-labeled prostate-specific membrane antigen (PSMA) ligands for the diagnosis of prostate cancer is a promising innovation for the metabolic imaging of prostate cancer according to initial study results and empirical data from the clinical routine [1-10]. The purpose of the present study is to evaluate the current diagnostic value of positron emission tomography/computed tomography (PET/CT) using the new Ga-68-labeled PSMA tracer compared to previously used choline tracers. The comparison focuses on the most common tracer in German-speaking regions, i.e., Ga-68-labeled PSMA tracer with the chelator N,N'-bis[2-hydroxy-5-(carboxyethyl)benzyl] ethylenediamine-N,N'-diacetic acid (HBED-CC), referred to in the following as Ga-68-PSMA. Its diagnostic accuracy for detecting PCa is compared to that of labeled choline derivatives F-18 choline (F-18 fluoroethylcholine, F-18 fluoromethylcholine) and C-11 choline]. Tracers used less frequently for the diagnosis of prostate cancer, such as F-18 or C-11-labeled acetate derivatives (F-18 fluoroacetate and C-11 acetate), receptor ligands, or the standard tracer in diagnostic tumor imaging F-18 fluorodeoxyglucose are not discussed in this comparison because of their lack of relevance for the diagnosis of PCa.

Prostate cancer (PCa)

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Prostate cancer (PCa) is one of the most common tumor entities in men in the Western world with an increasing incidence and an annual global mortality rate of 300 000 [11–13]. Early detection of PCa recurrence and the diagnosis of spreading represent a challenge for diagnostic imaging. In this context metastasis detection is of high clinical relevance for the prognosis and treatment management of PCa [14, 15]. The diagnosis of PCa and its metastases is still a major challenge for imaging modalities [16]. PET/CT using tracers that bind specifically to the PSMA on the prostate cancer cell surface is a new and very promising diagnostic method.

Prostate-specific membrane antigen ▼

The prostate-specific membrane antigen (PSMA), also known as folate hydrolase I (FOLH1) or glutamate carboxypeptidase II (GCPII), is a type II transmembrane glycoprotein consisting of 750 amino acids primarily expressed by human prostate epithelial cells [17-19]. While initial observations assumed that the expression was limited to prostate cells, it is now known that it is also expressed to a limited degree in other tissues. For example, PSMA expression is seen in the brush border of the small intestine and in the proximal renal tubules, the spleen, the liver, the salivary glands, and the brain [18]. To date, PSMA expression in other types of human tissue has not be proven [20-22]. Primary PCa cells and their metastases show high PSMA expression [18, 23]. This elevated level of PSMA expression by prostate cancer cells compared to benign prostate epithelial cells is helpful for the diagnosis of specific tumors [24, 25]. The increased PSMA expression can also be used for imaging via a PSMA-labeled tracer after androgen deprivation therapy and in lymph node metastases in the case of lymphogenous spread [26, 27]. PSMA tracers are able to visualize prostate cancer cells regardless of the proliferation status of the tumor [28] However, there is a correlation between an elevated PSMA expression level and the aggressiveness of a tumor [31]. Moreover, PSMA can be viewed as a diagnostic as well as therapeutic target structure [32, 33]. It has been shown in multiple studies that PSMA with a prevalence of over 90% in PCa can be used as a diagnostic and therapeutic target structure [18, 34].

PSMA-labeled tracers

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PSMA can be labeled by antibodies, aptamers, and inhibitors. The first category includes, for example, antibody 591 and the first monoclonal antibody In-111 capromab pendetide (trade name: ProstaScint®; CytogenCorporation, Princeton, NJ) used for the specific diagnosis of prostate cancer. In 1996, In-111 capromab pendetide received FDA approval in the USA and is currently the only approved PSMA-labeled tracer for the diagnosis of PCa. However, its specificity is low. Therefore, use of In-111 capromab pendetide for the diagnosis of prostate cancer has been largely abandoned in Germany [35]. A reason for the low diagnostic value is its intracellular binding site. Aptamers are still in the developmental phase. In-vivo images and biodistribution data are not yet available. PSMA inhibitors can be subclassified into three groups: phosphonates, phosphates, phosphoramidites; thiols; and ureas. Phosphramidites which include, for example, the tracer (2RS,4S)-2-[18F]Fluoro-4-phosphonomethyl-pentanedioic acid (BAY1075 553) were of particular interest for the further development but were shown to be inferior to F-18 fluorocholine in a phase I study published in 2015 [36]. Urea-based inhibitors which include F-18 N-[N-[(S)-1,3-dicarboxypropyl]carbamoyl]-4-[18F]fluorobenzyl-L-cysteine (DCFBC) and Ga-68 (HBED-CC) conjugates also support development. The latter conjugate was developed in the work group of Professor Eisenhut at the German Cancer Research Center Heidelberg using the PSMA-specific pharmacophore Glu-NH-CO-NH-Lys(Ahx)-HBED-CC for radioactive labeling with Ga-68 for the specific diagnosis of PCa.

Ga-68-labeled PSMA tracer

As a urea-based inhibitor, Ga-68-PSMA is capable of binding to the PSMA target structure with very high affinity [18, 37]. Ga-68 labeling of the PSMA profits from the amphiphilic conjugate HBED-CC, which ensures cell uptake specificity, and from its internalization [32]. The first clinical results with this tracer show high potential for detecting small recurrent PCa lesions in patients with low PSA values. The results from the study group of Eder et al. revealed this and also showed the advantage of high tracer accumulation in small metastases and fast clearance from background tissue [38]. Radioactive labeling with Ga-68 in a radionuclide generator is a cost-effective "in-house" production method [6]. Moreover, this generator-based production makes the tracer readily available which is considered a further advantage.

Ga-68-PSMA versus choline derivatives PET /CT for the diagnosis of PCa

The relevance for the diagnosis of PCa to be expected as a result of the advantages of Ga-68-PSMA compared to the choline derivatives used prior to the introduction of Ga-68-PSMA is discussed in greater detail in the following section.

Various choline derivatives have been developed in the past for the metabolic imaging of PCa and its metastases [39, 40]. Although there are numerous studies reporting low sensitivity and specificity of the different choline derivatives for the detection of PCa lesions particularly in the case of low PSA values and high Gleason scores, PET/CT imaging was mainly performed using these tracers in cases of laboratory evidence of PCa recurrence prior to the introduction of Ga-68-PSMA [41 – 45]. Choline derivatives have limited diagnostic value in primary diagnosis particularly in the case of small tumors due to the invalid differentiation of PCa from prostate hyperplasia and prostatitis, in the case of lymphogenous metastasis due to the low sensitivity of choline derivatives and in the case of laboratory evidence due to the dependence of the diag-

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nostic sensitivity on the PSA level [46]. A general disadvantage of choline derivatives is that they are not tumorspecific tracers.

C-11 choline PET/CT

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Representative clinical values with the tracer C-11 choline are provided in the following original studies. Based on the status of 358 patients after radical prostatectomy in the case of PCa and biochemical recurrence (two PSA values > 0.2 ng/ml) in reference to histopathology (in 13% of cases) or imaging follow-up (in 87% of cases) Giovacchini et al. show: A PSA level between 0.2 - 1 ng/ml results in a 19% probability of true-positive lesion detection using tracer C-11 choline for PET/CT imaging [47]. Rinnab et al. provide a more positive evaluation of the detectability of PCa lesions via C-11 choline in the case of laboratory evidence of recurrence with a sensitivity of 93% and a positive predictive value (PPV) of 78% and with an 89% sensitivity and a PPV of 72% for PSA values < 2.5 ng/ml [48].

A PSA value < 2.5 ng/ml was present in 28/41 patients [48]. In the case of PSA values < 1.5 ng/ml, C-11 choline showed true-positive lesion detection of only 50% in the same study [48]. The detection rates for low PSA levels as in the case of Giovacchini et al. were not evaluated in this study [47, 48].

F-18 choline PET/CT

There are numerous studies in the literature describing low sensitivity and specificity of PET/CT with F-18 choline for the diagnosis of prostate cancer, in particular in the case of a low PSA level [41 - 45, 49 - 53].

Therefore, a study by Pelosi et al. showed a sensitivity of 20% for F-18 choline in 56 patients with biochemical recurrence after radical therapy of PCa at a PSA level </ = 1.1 ng/ml [50]. This was similar to the result for C-11 choline at a PSA level < 1 ng/ml in the study by Giovacchini et al. [47]. In 2015, a direct comparison of different F-18 choline tracers such as F-18 fluoromethylcholine and F-18 fluoroethylcholine, regarding the detectability of PCa was performed by Evangelista et al. in 2147 patients with PCa [55]. Improved PCa diagnosis via F-18 fluoromethylcholine with sensitivities of 42.9-96% compared to 62-85.7% with F-18 fluoroethylcholine was seen here [55]. Despite the superiority of F-18 fluoromethylcholine for diagnosing PCa shown here, this tracer also has the shortcomings typical of choline derivatives with respect to the visualization of PCa lesions at a low PSA level. In 2012, Poulson et al. published a prospective study in 210 patients with PCa (average Gleason score in 75% of patients > 7) and an average PSA level of 20.3 ng/ml (56). They showed a sensitivity of 73.2% for lymph node staging in PCa via F-18 fluoromethylcholine so that this tracer cannot be considered primarily indicated for lymphogenous metastasis in PCa according to the authors [56]. Insufficient detection of lymph node metastases by PET/CT with F-18 fluoroethylcholine in PCa is also described in the literature [57].

A direct comparison between F-18 choline and C-11 choline regarding the diagnosis of prostate cancer in a meta-analysis by Umbehr et al. shows diagnostic limitations for both

tracers [54]. The advantages attributed by the authors to F-18 choline and C-11 choline PET/CT for restaging in the case of laboratory evidence of recurrence during local treatment of PCa cannot be confirmed for histopathologically verified high-risk PCa prior to treatment [54].

In accordance with the currently available studies, the use of PET/CT with choline derivatives at PSA values of less than 1 ng/ml has not been recommended in the S3 guidelines for prostate cancer due to a lack of evidence of a benefit for consecutive therapeutic measures [58, 59].

Ga-68-PSMA PET/CT

Study results regarding the detection rate of PCa lesions via Ga-68-PSMA PET/CT are promising. In their review article of current innovations in urogenital diagnostic imaging, Maurer et al. present Ga-68-PSMA PET/CT in connection with a paradigm change in PCa imaging [10]. Mottagy and his workgroup use a similarly positive tone regarding the new diagnostic value of nuclear medicine based on the successful diagnosis of PCa with Ga-68-PSMA [60]. In 2013, Afshar-Oromieh et al. conducted a study regarding the evaluation of the diagnostic accuracy of Ga-68-PSMA PET/ CT in 37 patients with PCa and laboratory evidence of recurrence [1]. The quantitative evaluation of lesions yielded excellent contrast between tumorous and non-tumorous tissue [1]. Of 37 patients, 31 (83.8%) had at least one suspicious lesion in Ga-68-PSMA PET/CT with a detection rate of 60% at a PSA level < 2.2 ng/ml and a detection rate of 100% at a PSA level > 2.2 ng/ml [1]. A further study by Afshar-Oromieh et al. from 2014 shows that the uptake of Ga-68 is high both in the case of local recurrence and in metastasis of PCa with a sensitivity of 86.5 % [2]. This had already been shown by the same author in a case report in 2012 [61]. In a publication from the year 2015, Afshar-Oromieh et al. also showed a high specificity of Ga-68-PSMA PET/CT imaging for PCa [4]: The study results are based on 319 patients analyzed between May 2011 and January 2014 in a retrospective evaluation. At least one PCa lesion was detected in 82.8% of cases. The tracer uptake was measured here in 901 representative tumor lesions using maximum standard uptake values (SUVmax). The lesions were then examined histopathologically. 30 false-negative lesions were detected in 4 different patients, while all other lesions (n=416) were rated as true-positive or true-negative. The lesions were stratified according to the type of tumor invasion: 13 cases with local recurrence after prostatectomy, 328 lymph node metastases, 129 soft tissue metastases, 359 bone metastases, and 72 vital tumor lesions [3]. The clinical experiences of this workgroup resulted in the conclusion that Ga-68-PSMA PET/CT can be considered an important tool for diagnosing PCa recurrence. Demirkol et al. used Ga-68-PSMA PET/CT to examine a total of 22 PCa patients [3]. All but two patients had positive intra- and extraprostatic lesions in Ga-68-PSMA PET/CT [3]. The median serum PSA level at the time of imaging was 4.15 ± 40 ng/ml (range: 0.2 – 191.5 ng/ml). The detectability of tiny metastases via Ga-68-PSMA is again described as an advantage of this tracer in this study [3].

Comparison studies with Ga-68-PSMA PET/CT

In their retrospective analysis, Eiber et al. showed that Ga-68-PSMA PET/CT achieves significantly higher detection rates for PCa and its metastases in cases of laboratory evidence of recurrence after radical prostatectomy compared to study results of other hybrid imaging techniques using C-11 choline, F-18 choline, and C-11 acetate in studies from the literature [5]. 222 of 248 patients (89.5%) showed pathological tracer uptake rates in Ga-68-PSMA PET/CT. The detection rates were 96.8%, 93.0%, 72.7% and 57.9% for PSA levels of ≥ 2 , 1 to <2, 0.5 to <1 and 0.2 to <0.5 ng/ ml, respectively [5]. The author correlates these results to the detection rates from the literature of 34-88% for C-11 choline PET/CT, 43-79% for F-18 choline PET/CT, and 59-80% for C-11 acetate PET/CT and concludes that Ga-68-PSMA has a higher detection rate particularly in the clinically relevant area of low increases in PSA level (<0.5 ng/ml) [5]. In the study by Dietlein et al., 10 patients of a cohort including 14 patients (71%) were evaluated as positive with at least one lesion in Ga-68-PSMA PET/CT [6]. Every case relates to laboratory evidence of recurrence in previously treated PCa. To optimize the examination protocol of Ga-68-PSMA PET/CT, Afshar-Oromieh et al. published data regarding the biodistribution of this tracer and determined optimum contrast between the tumor and surrounding tissue 2-3 hours post-injection (p.i.). In the case of lesions that are difficult to detect, these authors therefore recommend performing imaging at a later time p.i. [7].

Additional comparison studies regarding the diagnostic accuracy of PET/CT with Ga-68-PSMA and choline derivatives also conclude that there are advantages from using the new tracer: The study by Afshar-Oromieh et al. from 2014 mentioned above compares the scientific data of two imaging modalities [2]. 37 patients with biochemical recurrence of PCa (PSA level: 0.01 - 116 ng/ml) were analyzed retrospectively. Both Ga-68-PSMA PET/CT and F-18 choline PET/CT did not detect any lesions in 5 patients. In total 78 lesions in 32 patients (86.5%) were evaluated as characteristic for PCa lesions with Ga-68-PSMA PET/CT and 56 lesions in 26 patients (70.3%) were evaluated as PCa lesions with F-18 choline PET/CT [2]. All lesions detected via F-18 choline PET/CT could also be detected via Ga-68-PSMA PET/CT [2]. In 7 patients with pathological radiotracer uptake in Ga-68-PSMA PET/CT, PCa was confirmed by histopathology after biopsy or open extirpation [2]. The presence of PCa lesions could be confirmed in all patients [2]. Neither false-positive nor false-negative lesions were determined [2]. In an earlier case report from 2012, the same author published the first intraindividual comparison between Ga-68-PSMA and F-18 fluoroethylcholine with the result of significantly better visualization of PCa lesions via Ga-68-PSMA in the case of laboratory evidence of recurrence after/during radiotherapy and hormone therapy [61].

In their study Morigi et al. compare F-18 fluoromethylcholine with Ga-68-PSMA for PET/CT imaging of PCa in 38 patients with an increasing PSA level post curative therapy and conclude that Ga-68-PSMA has a significantly higher detection rate than F-18 fluoromethylcholine in the case of biochemical recurrence with a low PSA level [62]. • Table 1 provides an overview of studies published to date regarding the detection rate of Ga-68-PSMA PET/CT for the diagnosis of PCa. • Table 2 compares these results to the detection rates of different choline derivatives. • Fig. 1, 2 show sample

Table 1 Overview of original	al articles evaluating	the detectability of PCa	by Ga-68 PSMA PET/CT.		
author(-s) (publication year)	n =	PSA value ¹ (ng/ml)	PSA value ¹ (median) (ng/ml)	N with Ga-68 PSMA HBED-CC PET/CT examination =	. sensitivity
Afshar-Oromieh et al. (2013) [1]	37	0.01 - 148	3.3	31	83.8%
Afshar-Oromieh et al. (2014), [2]	37	0.01 - 116	4.0	32	86.5%
Afshar-Oromieh et al. (2015) [4]	319	0.01 - 41.395	6.02	264	82.8%
Demirkol et al. (2015) [3]	22	0.2 - 191.5	4.15	20	90.9%
Eiber et al. (2015) [5]	248	0.2 - 59.4	1.99	222	89.5%
Dietlein et al. (2015), [6]	14	0.17 – 50 ²	6.33 ²	10	71%
Budäus et al. (2015) [68]	12	1.4 - 376	8.8	4	33.3%
Giesel et al. (2015), [9]	21	0.6 – 45 ²	6.84 ²	21	100%
Afshar-Oromieh (2015), [7]	19	-	-	14	73.7%
Morigi et al. (2015) [62]	38	0.04 - 12	1.74	25	65.8%
Sterzing et al. (2015) [8]	57	0.16-113	3.0	34	59.7%

¹ at time of PET/CT examination.

² no specific data at time of PET/CT examination.

author (s) (publication year)	tracer	n =	sensitivity in %	specificity in %	PPV in %	NPV in %	Acc in %
Budäus et al. (2015) [68] ^c	Ga68 HBED-CC PSMA	12	33	100	100	69	73
Afshar-Oromieh et al. (2015) [4] ^c	Ga68 HBED-CC PSMA	319	88	-	-	-	-
Lesion-based evaluation (2015) [4] ^c	Ga68 HBED-CC PSMA	901	77	100	100	91	-
Giovacchini et al. (2010) [47] ^d	C-11 choline	358	85	93	91	87	89
Rinnab et al. (2009) [48] ^d	C-11 choline	41	93	36	80	67	78
Husarik et al. (2007) [45] ^b	F-18 choline	22	50	100	100	92	92
Häcker et al. (2006) [44] ^b	F-18 choline	20	10	80	33	47	45
lgerc et al. (2007) [42]ª	F-18 choline	20	100	47	38	100	60
Pelosi et al. (2008) [50] ^d	F-18 choline	56	83	96	96	83	89
Cimitan et al. (2006) [49] ^c	F-18 choline	100	98	100	-	-	-
Poulsen et al. (2012) [56] ^b	F-18 choline	210	73	88	59	93	85
Tilki et al.	F-18 choline	56	40	96	76	83	70

Table 2 Comparative overview of the detectability of PCa using different tracers.

Patient collective stratified by a = patient with imaging suspicious for PCa, b = patient with histopathologically proven untreated PCa at time of imaging, c = patient with histopathologically proven treated PCa at time of imaging, d = patient with biochemical relapse.

images to visualize the advantages of Ga-68-PSMA PET/CT for diagnosing lymph node metastases in PCa compared to F-18 choline.

Despite the above advantages of Ga-68-PSMA PET/CT for PCa diagnosis, such as high sensitivity for PCa lesions regardless of PSA level and lesion size, high contrast of lesion compared to surrounding tissue, low

production costs, etc., there are two studies that provide a more critical view of Ga-68-PSMA PET/CT for the diagnosis of PCa. One of these studies is a retrospective analysis of 30 patients by the workgroup of Budäus et al. [68]. The goal of this study was to evaluate the promising ability to detect PCa lesions with Ga-68-PSMA PET/CT as seen in cases of laboratory evidence of recurrence for use in cases of biochemical recurrence after primary treatment and for lymph node stating [68]. To date, the diagnostic accuracy of Ga-68-PSMA PET/CT for the preoperative diagnosis of lymph node metastases in reference to histopathology has not yet been examined. Among the 30 patients in the cohort, 12 (40%) had lymph node metastases [68]. Ga-68-PSMA PET/CT identified 4 of 12 patients (33.3%) with truepositive lymph node metastases and 8 patients (66.7%) with false-negative lesions compared to the histopathological reference [68]. The authors recorded a dependence of lymph node metastasis detection in Ga-68-PSMA PET/CT on size and are the only workgroup to date to subsequently classify the diagnostic accuracy of Ga-68-PSMA PET/CT in the case of lymphogenous metastasis as reduced [68]. In a case report, Chakraborthy et al. published a Ga-68-PSMA PET/CT examination with false-negative results in poorly differentiated PCa with neuroendocrine differentiation

[69]: A clinical situation in which the diagnostic value of Ga-68-PSMA PET/CT may be low [69].

Using semiautomatic 3 D software for diameter and volume determination of lymph node metastases in CT compared to SUVmax of lymph node metastases in Ga-68-PSMA PET/CT, Giesel et al. showed superiority of the metabolic information of PET/CT with 50% PET-positive lymph node metastases compared to only 22% lymph nodes suspicious for metastasis by morphological criteria on CT and conclude that this diagnostic method can be used for PCa recurrence [9].

Possible future developments for Ga-68-PSMA PET/CT ▼

Reference is made to the publications of Afshar-Oromieh et al. from the year 2013 and Roethke et al. from the year 2013 in which the authors were able to show that Ga-68-labeled PSMA can also be used for MR-PET diagnostic imaging as an interesting tracer with the possibility for simple and accurate detection [64, 65]. In a case report regarding Ga-68-PSMA MR-PET, Eiber et al. show the advantages of the additional information provided by multiparametric MRI based on the example of diffusion restriction for the differentiation of postinterventional changes and tumor manifestations in the primary diagnosis of PCa after biopsy [66]. A comparison study between MR-PET and PET/CT using the new tracer Ga-68-PSMA including 20 PCa patients showed easier and better lesion detection with MR-PET 3 h p.i. than with PET/CT 1 h p.i. [66].

In addition to the diagnostic advantage of Ga-68-PSMA PET/ CT with the possibility of high contrast, Weineisen et al. em-



Fig. 1 PCa patient with mediastinal lymph node metastases. Top: CT scan; middle: Ga-68PSMA PET/CT scan; bottom: F-18 choline PET/CT scan. The intraindividual comparison visualizes a distinctly more non-specific tracer uptake in F-18 choline PET/CT compared to Ga-68PSMA PET/CT.

phasized the theranostic component of the binding structure PSMA that can be used as part of internal radiotherapy [67]. This is a further promising area that can be used in lutetium-177 (Lu-117) therapy of PCa.

The expanded use of Ga-68-PSMA PET/CT for PCa treatment planning is also very promising: In 2015, Sterzing et al. published a study including 57 patients with PCa who underwent Ga-68-PSMA PET/CT for planning purposes prior to radiotherapy and concluded that this imaging method holds a key position for individualized radiotherapy in PCa [8].

Summary

Since the introduction of the new tracer Ga-68-PSMA in PET/CT imaging of prostate cancer, a higher detection rate of PCa lesions than was possible with choline derivatives has been able to be achieved. The tracer Ga-68-PSMA has the advantages of a higher specificity for PCa cells and their



Fig. 2 PCa patient with lymph node metastases. Right) extent of lymph node metastases shown in the maximum intensity projection (MIP) with Ga-68PSMA PET/CT; left) extent of lymph node metastases shown in the maximum intensity projection (MIP) with F-18 choline PET/CT.

metastases, lower nonspecific tracer uptake in surrounding tissue, increased uptake in correlation with the dedifferentiation of the tumor, and independence from the PSA level. In addition to fusion imaging in PET/CT, the new tracer also seems very suitable for simultaneous MR-PET diagnostic imaging and its theranostic target structure PSMA is a promising binding site for internal radiotherapies.

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