

# Management of urological malignancies: Has positron emission tomography/computed tomography made a difference?

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## ABSTRACT

Positron emission tomography/computed tomography (PET/CT) technology has been a significant, but expensive addition to the oncologist's armamentarium. The aim of this review was to determine the clinical utility of PET/CT in urological oncology, its impact on disease outcome and cost-effectiveness. We searched MedLine and peer reviewed journals for all relevant literature available online from the year 2000 until January 2014 regarding the use of PET/CT in the management of urological malignancies.  $^{11}\text{C}$ -choline PET/CT has emerged as a powerful tool for assessment of biochemical relapse in prostate cancer. Use of novel radiotracers like  $^{124}\text{I}$ -girentuximab has shown promise in the diagnosis of clear cell renal carcinoma. Fluorodeoxyglucose PET has a proven role in seminoma for the evaluation of postchemotherapy residual masses and has shown encouraging results when used for detection of metastasis in renal, bladder, and penile cancer. Introduction of novel radiotracers and advanced technology has led to a wider application of PET/CT in urological oncology. However, testicular seminoma aside, its impact on disease outcome and cost-effectiveness still needs to be established.

**Key words:** Bladder cancer, penile cancer, positron emission tomography/computed tomography, prostate cancer, renal cell carcinoma, testicular germ cell tumor, urological

## INTRODUCTION

The hybrid positron emission tomography/computed tomography (PET/CT) technology was first introduced by Townsend, Nutt, and Beyer in 1998<sup>[1]</sup> and has since, become an important addition to the oncologist's armamentarium. The integration of anatomic imaging along with functional characterization allows for improved diagnosis, staging, assessment of treatment response, and early detection of disease relapse/recurrence. However, the full potential of PET/CT is yet to be realized in urology due to several limitations. We searched MedLine and peer reviewed journals

for all relevant literature available online from the year 2000 until Jan 2014 regarding the use of PET/CT in the management of urological malignancies. This review aims to critically appraise the clinical utility of PET/CT in the management of urological malignancies, its impact on disease outcome and also address its cost-effectiveness.

## RADIOTRACERS AND INSTRUMENTATION

Radionuclides used in PET scanning are generally isotopes with short half-lives such as carbon-11 (20 min), nitrogen-13 (10 min), oxygen-15 (2 min), and fluorine-18 (110 min). Radiotracers can be divided into two groups: Metabolic tracers (incorporated into compounds normally used by the body such as glucose) and receptor-specific radiopharmaceuticals.<sup>[2]</sup>

The most widely used radiotracer in oncology is fluorodeoxyglucose (2-fluoro-2-deoxy-d-glucose, FDG), a glucose analogue. Unfortunately,  $^{18}\text{F}$ -FDG is not an ideal radiotracer for use in urology due to its urinary elimination, which prevents the proper visualization of the bladder and its surroundings.<sup>[2]</sup>

Since 1998, significant advances have been made in both PET and CT technology. Availability of fast scintillators with high stopping power such as: Lutetium orthosilicate

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and gadolinium orthosilicate have made time-of-flight PET possible. This has led to improvement in not only lesion detection but also spatial resolution.<sup>[3]</sup> Moreover, incorporation of a 64-slice CT enables the acquisition of high quality whole body images in a matter of seconds.

## ROSTATE CANCER

Imaging in prostate cancer would have clinical utility only if it is able to (1) preoperatively identify extra-prostatic extension, seminal vesicle invasion and thereby impact the decision to do a nerve preserving radical surgery, (2) identify metastatic lymph nodes preoperatively and prevent a surgery, and (3) accurately detect relapse/recurrence following prior therapy.

Majority of the prostate cancers are not <sup>18</sup>F-FDG avid owing to their poor metabolic activity. Moreover, increased urinary elimination of FDG tends to obscure pelvic pathology. Hence, <sup>11</sup>C- or <sup>18</sup>F-choline have replaced FDG in the evaluation of prostate cancer and have shown promising results.<sup>[4]</sup>

### Local staging

<sup>11</sup>C-choline PET/CT had a sensitivity of 55–87%, specificity of 43–87%, and an accuracy of 60–84% when used for the detection of primary malignancy.<sup>[5-8]</sup>

Martorana *et al.* showed that the sensitivity improved to 83% when the lesions were > 5 mm compared with only 4% for smaller lesions.<sup>[7]</sup> The low specificity rates are attributed to confounding uptake of the tracer in the presence of benign prostatic hypertrophy, prostatitis, high-grade prostatic intraepithelial neoplasia, urinary activity in the base of the bladder or urethra, and by normal tissues surrounding the prostate gland, for example, pelvic musculature and rectum.<sup>[9]</sup> Moreover, clinically significant correlation could not be established between <sup>11</sup>C-choline uptake by localized prostate cancer and serum prostate specific antigen (PSA) levels, Gleason score, and tumor grade.<sup>[8,10]</sup>

On comparing <sup>11</sup>C-choline PET/CT with other imaging modalities for local staging, T2-weighted magnetic resonance imaging (MRI) imaging combined with a dynamic contrast enhanced imaging showed superior sensitivity and specificity.<sup>[11]</sup> Even for evaluation of suspected local recurrence following radical prostatectomy (RP), Panebianco *et al.* documented that endorectal coil dynamic contrast-enhanced MRI/MR spectroscopy was superior to <sup>18</sup>F-choline PET/CT.<sup>[12]</sup>

### Detection of lymph node metastasis

The sensitivity and specificity for detecting lymph nodes by <sup>11</sup>C-choline PET/CT in untreated cases later confirmed by histopathology were 60–78% and 82–98% respectively. As expected, the detection rates improved with increase in the size of the metastatic nodes with 0% detection rate for nodes <2 mm in size, 25–30% for 2–4.9 mm nodes, 33–43%

for 5–9.9 mm nodes, and 77–90% for nodes measuring 10 mm and larger.<sup>[13,14]</sup> Budiharto *et al.*<sup>[15]</sup> showed that in patients at high clinical risk for lymph node metastasis who were CT negative, the sensitivity of detecting lymph node metastasis was only 19% with specificity of 95%.

When used to detect recurrence of disease in pelvic and retroperitoneal lymph nodes following RP, Scattoni *et al.* could achieve a sensitivity, specificity, and accuracy of 66%, 100%, and 92%, respectively.<sup>[16]</sup> A meta-analysis looking at CT and MRI detection rates of lymph node metastasis revealed pooled sensitivity and specificity rates of 39% and 82%, respectively.<sup>[17]</sup>

Though <sup>18</sup>F-choline PET/CT seems to perform better than conventional imaging, its accuracy is not sufficient to replace pelvic lymph node dissection as the gold standard for initial staging.<sup>[18]</sup> Hence, PET/CT has no role in the initial staging of prostate cancer. However, in the select group of high risk prostate cancer (PSA > 20 ng/mL, Gleason 8-10, locally advanced tumor) <sup>18</sup>F-choline PET/CT could be used to detect metastasis and thereby change management as shown by Beheshti *et al.*<sup>[19]</sup> in approximately 20% of their high-risk study group. This would help prevent the cost and morbidity of RP/radiotherapy (RT) in this subgroup.

### Detection of skeletal metastasis

Picchio *et al.*<sup>[20]</sup> compared <sup>11</sup>C-choline PET/CT and bone scintigraphy for the detection bone metastasis in patients showing PSA progression following primary treatment and found that though the sensitivity (89% vs. 70–100%) of choline PET/CT was poorer, it exhibited a higher specificity (98–100% vs. 75–100%), and accuracy (95–96% vs. 85–93%). Osteoblastic bone lesions occasionally show no choline uptake and need to be picked up on CT.<sup>[20]</sup> Increased uptake of NaF reflects the rapid bone turnover associated with osteoblastic skeletal metastasis. <sup>18</sup>F-NaF (fluoride) PET/CT when used to detect bone metastasis in patients with high-risk prostate cancer showed sensitivity and specificity of 100%. Beheshti compared <sup>18</sup>F-choline PET and <sup>18</sup>F-fluoride PET and found that though choline PET helped in early detection of bone marrow involvement, fluoride PET was better for sclerotic lesions.<sup>[21]</sup> In another study, Beheshti *et al.*<sup>[22]</sup> showed that the degree of sclerosis had an inverse relation with choline activity. Sclerotic lesions on CT with a Hounsfield unit > 825 showed no choline activity and may represent healed bone lesions in patients who have received androgen deprivation. Despite its high sensitivity and specificity, <sup>18</sup>F-fluoro PET and <sup>18</sup>F-choline PET have not replaced bone scintigraphy and the European Association of Urology (EAU) guidelines recommend their use for staging in equivocal cases only.<sup>[23]</sup>

### Detection of prostate cancer recurrence

<sup>11</sup>C-choline PET/CT has been used to assess biochemical relapse after treatment. In a study by Giovacchini *et al.*,<sup>[24]</sup>

the sensitivity, specificity, and accuracy of choline PET for detection of prostate cancer in previously detected prostate cancer was 85%, 93%, and 89%, respectively. They also showed that sensitivity improved with increasing PSA levels and the PSA cutoff with the best sensitivity (73%) and specificity (72%) profile was 1.4 mg/mL. Advanced age, initial pathological stage, and prior biochemical failure were factors which predicted higher detection rates.

Schillaci *et al.*<sup>[25]</sup> used <sup>18</sup>F-fluorocholine PET/CT to restage patients post RP and found detection rates of 20% for a PSA < 1 ng/mL, 55% for a PSA of 1–2 ng/mL, 80% for a PSA of 2–4 ng/mL, and 87% for a PSA >4 ng/mL. Ceci *et al.*<sup>[26]</sup> has shown that <sup>11</sup>C-choline PET/CT can detect relapse in patients with hormone-resistant prostate cancer and advocated that withdrawal of hormone therapy may not be necessary prior to scanning. Finally, Soyka *et al.*<sup>[27]</sup> have shown that <sup>18</sup>F-fluorocholine PET/CT results could change the management of at least 48% of patients with disease recurrence following prior treatment (RP/RT or combination).

Hence, choline PET/CT has emerged as a powerful tool for evaluation of biochemical relapse in the setting where conventional imaging (CT/MRI or bone scan) has failed to pick up disease. Though the PSA level at the time of scanning is a strong predictor, Picchio *et al.*<sup>[28]</sup> advise against the use of choline PET/CT for restaging post RP for PSA levels <1 ng/mL and this has been reiterated by the latest EAU guidelines.<sup>[23]</sup> This would help cut costs and avoid unnecessary radiation exposure.

## RENAL CANCER

The detection of renal cell carcinoma (RCC) with PET is often hampered because most radiotracers, for example, FDG are excreted through the kidneys. Diuretics and bladder catheterization have been tried to minimize this limitation.

### *Diagnosis and staging of renal cell carcinoma*

When FDG PET was used for the diagnosis of RCC, the maximum standard uptake values (SUV<sub>max</sub>) within the region of interest varied between <1.5 and >24<sup>[29,30]</sup> and no cutoff value could be identified, which would be specific for RCC. No correlation was found between the SUV and the subtype of RCC.<sup>[31]</sup> Moreover, owing to the urinary activity of FDG, significant tumor size correlation was seen only if the lesion was >5 cm.

However, FDG PET is highly sensitive for metastatic RCC and showed activity in 95% of the metastatic lesions picked up by CT.<sup>[32]</sup> A meta-analysis investigated the role of <sup>18</sup>F-FDG PET in RCC<sup>[33]</sup> and concluded that <sup>18</sup>F-FDG PET is useful in the diagnosis and staging of metastatic lesions with a sensitivity of 87% and a specificity of 93%, but presents limitations when diagnosing primary tumors.

In recent times, novel receptor specific radiotracers have been used to overcome the limitations of FDG. The antibody cG250 (girentuximab) acts against carbonic anhydrase 9, which is over-expressed in clear cell carcinomas. In a phase III study, sensitivity and specificity of <sup>124</sup>I-cG250 PET/CT was 86.2% and 85.9% (vs. 75.5% and 46.8% for CT), respectively for identifying clear cell RCC.<sup>[34]</sup> Hence, girentuximab PET/CT allows for accurate and noninvasive diagnosis of clear cell RCC and thus may help in formulating the best management protocols for these patients.

### *Assessment of treatment response*

Higher SUV<sub>max</sub> indices on FDG PET correlated with poorer prognosis and overall survival in patients with RCC.<sup>[29,30]</sup> A decrease in SUV<sub>max</sub> of <20% following therapy also portends poor prognosis.<sup>[35]</sup> PET/CT has still not been incorporated into the commonly used criteria for evaluating disease response, for example, the response evaluation criteria in solid tumors (RECIST) and is currently used only as an adjunct.<sup>[36]</sup>

## TESTICULAR GERM CELL TUMORS

The prognosis of testicular cancer is excellent with 5 years survival rates >95%. PET-CT must be able to overcome the lacuna in current imaging tools in order to make any significant impact in current management protocols. However, this has been marred by the major limitations of FDG PET/CT, which include inability to detect lesions < 1 cm and also distinguish between mature teratoma from normal/necrotic tissue.<sup>[37]</sup>

### *Nonseminomatous germ cell tumor*

In the study by National Cancer Research Institute Testis Cancer Clinical Studies group,<sup>[38]</sup> <sup>18</sup>F-FDG PET/CT failed to detect micrometastasis resulting in unacceptable retroperitoneal relapse in a high risk study group on surveillance. Oechsle *et al.*<sup>[39]</sup> concluded that <sup>18</sup>F-FDG PET was unable to provide additional information to which CT scan and serum markers provided and was not sufficiently sensitive to identify patients at low-risk of relapse to guide management decisions.

### *Seminomatous germ cell tumor*

De Santis *et al.*<sup>[40]</sup> correlated size of the residual lesions on CT (>3 cm or ≤ 3 cm) with the presence or absence of a viable residual tumor. The diagnostic values of <sup>18</sup>F-FDG PET were as follows: Specificity 100%, sensitivity 80%, positive predictive value 100%, and negative predictive value 96%, respectively. These results were corroborated in another study by Becherer *et al.*<sup>[41]</sup> In seminomatous germ cell tumors (GCT), <sup>18</sup>F-FDG must be used for evaluating residual masses >3 cm after chemotherapy, obviating the need for a morbid surgery like retroperitoneal lymph node dissection.

## BLADDER CANCER

As already emphasized, the role of  $^{18}\text{F}$ -FDG PET for the detection of localized disease is limited due to the urinary excretion of  $^{18}\text{F}$ -FDG. Forced diuresis and dual phase protocols have been employed to improve the sensitivity and specificity of detecting residual/recurrent disease as well as nodal staging.

### Local staging or restaging

A recent study using an adaptation of the dual phase protocol enabled excellent urinary tracer washout and achieved a sensitivity, specificity, and accuracy of 92%, 87%, and 89%, respectively.<sup>[42]</sup> The systematic review by Lu *et al.*<sup>[43]</sup> reported pooled estimates of diagnostic accuracy of FDG PET/CT and FDG PET compared with pathological proof (biopsy or surgery) and/or follow-up for staging and/or restaging of patients with bladder carcinoma. Pooled sensitivity was 82% and specificity 89%.

### Detection of metastasis

$^{18}\text{F}$ -FDG PET had sensitivity and specificity of 81% and 94% for detecting metastasis and was able to affect a change in management of 68% of the patients.<sup>[44]</sup> FDG PET also showed better sensitivity and specificity for detecting bone metastasis than did bone scintigraphy.<sup>[45]</sup>

## PENILE CANCER

Due to the significant potential morbidity of inguinal and pelvic lymphadenectomy, the search for an imaging modality that can accurately identify lymphatic metastases continues. A systematic review by Sadeghi *et al.*<sup>[46]</sup> reports pooled estimates of diagnostic accuracy for FDG PET/CT compared with inguinal lymph node dissection and/or follow-up. Pooled sensitivity of PET/CT is 80.9%, pooled specificity 92.4%. In patients with clinically palpable nodes, the pooled sensitivity improved to 96.4% and hence, may justify the use of PET/CT in this subgroup. However, false negative rates are high and PET/CT is poor in detecting micrometastasis.

## COST EFFECTIVENESS OF PET/CT

PET/CT is a potentially important but very expensive investigation. High end PET/CT systems cost anywhere between 2.5 and 3 million dollars and operational costs including service costs are substantial. The only one systematic review looking at the economic evaluation on the use of PET/CT for cancer staging had disappointing results.<sup>[47]</sup> However, the review did not include any of the urological malignancies and the methodology used for analysis was also questionable.

## FUTURE PERSPECTIVES

Though more expensive than CT, the advantages of MRI include reduced radiation exposure and the ability to measure

tissue properties such as diffusion, enhancement and specific metabolites with high resolution. Hence, the hybrid imaging modality of PET/MRI combines the highest anatomical detail as well as biochemical and functional information provided by MRI with the metabolic, molecular, and physiologic information from PET. The first PET/MRI was initiated into clinical use in 2007 for imaging the brain and since then technical advancements have paved the way for its use for molecular imaging in oncology.<sup>[48]</sup> In a preliminary study,  $^{68}\text{Ga}$  Gallium-prostate specific membrane antigen tagged PET/MRI proved superior than PET/CT in detecting local recurrence including lymph node metastasis < 10 mm in cases of biochemical failure following primary treatment of prostate cancer.<sup>[49]</sup>

## CONCLUSION

PET/CT in urological oncology is challenging because of the urinary excretion of many tracers. The only accepted indication for  $^{18}\text{F}$ -FDG PET/CT is for the evaluation of postchemotherapy residual masses in seminomatous GCT. Novel radiotracers like  $^{124}\text{I}$  Girentuximab may be used for the diagnosis of clear cell RCC.  $^{11}\text{C}$ -choline PET/CT has emerged as a powerful tool for assessment of biochemical relapse in prostate cancer. FDG PET/CT has also shown improved sensitivity and specificity for detection of metastatic disease in renal, bladder and penile cancer. Development of new radiotracers together with technological advances and further studies including economic evaluation are needed to further establish the role of PET/CT in the management of urological malignancies.

## REFERENCES

1. Beyer T, Townsend DW, Brun T, Kinahan PE, Charron M, Roddy R, *et al.* A combined PET/CT scanner for clinical oncology. *J Nucl Med* 2000;41:1369-79.
2. Emonds KM, Swinnen JV, Mortelmans L, Mottaghy FM. Molecular imaging of prostate cancer. *Methods* 2009;48:193-9.
3. Kadmas DJ, Casey ME, Conti M, Jakoby BW, Lois C, Townsend DW. Impact of time-of-flight on PET tumor detection. *J Nucl Med* 2009;50:1315-23.
4. Powles T, Murray I, Brock C, Oliver T, Avril N. Molecular positron emission tomography and PET/CT imaging in urological malignancies. *Eur Urol* 2007;51:1511-20.
5. Testa C, Schiavina R, Lodi R, Salizzoni E, Corti B, Farsad M, *et al.* Prostate cancer: Sextant localization with MR imaging, MR spectroscopy, and  $^{11}\text{C}$ -choline PET/CT. *Radiology* 2007;244:797-806.
6. Scher B, Seitz M, Albinger W, Tiling R, Scherr M, Becker HC, *et al.* Value of  $^{11}\text{C}$ -choline PET and PET/CT in patients with suspected prostate cancer. *Eur J Nucl Med Mol Imaging* 2007;34:45-53.
7. Martorana G, Schiavina R, Corti B, Farsad M, Salizzoni E, Brunocilla E, *et al.*  $^{11}\text{C}$ -choline positron emission tomography/computerized tomography for tumor localization of primary prostate cancer in comparison with 12-core biopsy. *J Urol* 2006;176:954-60.
8. Van den Bergh L, Koole M, Isebaert S, Joniau S, Deroose CM, Oyen R, *et al.* Is there an additional value of  $^{11}\text{C}$ -choline PET-CT to T2-weighted MRI images in the localization of intraprostatic tumor nodules? *Int J Radiat Oncol Biol Phys* 2012;83:1486-92.
9. Murphy RC, Kawashima A, Peller PJ. The utility of  $^{11}\text{C}$ -choline PET/CT

- for imaging prostate cancer: A pictorial guide. *AJR Am J Roentgenol* 2011;196:1390-8.
10. Souvatzoglou M, Weirich G, Schwarzenboeck S, Maurer T, Schuster T, Bundschuh RA, *et al.* The sensitivity of [11C] choline PET/CT to localize prostate cancer depends on the tumor configuration. *Clin Cancer Res* 2011;17:3751-9.
  11. Watanabe H, Kanematsu M, Kondo H, Kako N, Yamamoto N, Yamada T, *et al.* Preoperative detection of prostate cancer: A comparison with 11C-choline PET, 18F-fluorodeoxyglucose PET and MR imaging. *J Magn Reson Imaging* 2010;31:1151-6.
  12. Panebianco V, Sciarra A, Lisi D, Galati F, Buonocore V, Catalano C, *et al.* Prostate cancer: 1HMRS-DCEMR at 3T versus [(18) F] choline PET/CT in the detection of local prostate cancer recurrence in men with biochemical progression after radical retropubic prostatectomy (RRP). *Eur J Radiol* 2012;81:700-8.
  13. Schiavina R, Scattoni V, Castellucci P, Picchio M, Corti B, Briganti A, *et al.* 11C-choline positron emission tomography/computerized tomography for preoperative lymph-node staging in intermediate-risk and high-risk prostate cancer: Comparison with clinical staging nomograms. *Eur Urol* 2008;54:392-401.
  14. Contractor K, Challapalli A, Barwick T, Winkler M, Hellawell G, Hazell S, *et al.* Use of [11C] choline PET-CT as a noninvasive method for detecting pelvic lymph node status from prostate cancer and relationship with choline kinase expression. *Clin Cancer Res* 2011;17:7673-83.
  15. Budiharto T, Joniau S, Lerut E, Van den Bergh L, Mottaghy F, Deroose CM, *et al.* Prospective evaluation of 11C-choline positron emission tomography/computed tomography and diffusion-weighted magnetic resonance imaging for the nodal staging of prostate cancer with a high risk of lymph node metastases. *Eur Urol* 2011;60:125-30.
  16. Scattoni V, Picchio M, Suardi N, Messa C, Freschi M, Roscigno M, *et al.* Detection of lymph-node metastases with integrated [11C] choline PET/CT in patients with PSA failure after radical retropubic prostatectomy; results confirmed by open pelvic-retroperitoneal lymphadenectomy. *Eur Urol* 2007;52:423-9.
  17. Hövels AM, Heesakkers RA, Adang EM, Jager GJ, Strum S, Hoogeveen YL, *et al.* The diagnostic accuracy of CT and MRI in the staging of pelvic lymph nodes in patients with prostate cancer: A meta-analysis. *Clin Radiol* 2008;63:387-95.
  18. Häcker A, Jeschke S, Leeb K, Prammer K, Ziegerhofer J, Segal W, *et al.* Detection of pelvic lymph node metastases in patients with clinically localized prostate cancer: Comparison of [18F] fluorocholine positron emission tomography-computerized tomography and laparoscopic radioisotope guided sentinel lymph node dissection. *J Urol* 2006;176:2014-8.
  19. Beheshti M, Imamovic L, Broinger G, Vali R, Waldenberger P, Stoiber F, *et al.* 18F choline PET/CT in the preoperative staging of prostate cancer in patients with intermediate or high risk of extracapsular disease: A prospective study of 130 patients. *Radiology* 2010;254:925-33.
  20. Picchio M, Spinapolice EG, Fallanca F, Crivellaro C, Giovacchini G, Gianolli L, *et al.* [11C] Choline PET/CT detection of bone metastases in patients with PSA progression after primary treatment for prostate cancer: Comparison with bone scintigraphy. *Eur J Nucl Med Mol Imaging* 2012;39:13-26.
  21. Beheshti M, Vali R, Waldenberger P, Fitz F, Nader M, Loidl W, *et al.* Detection of bone metastases in patients with prostate cancer by 18F fluorocholine and 18F fluoride PET-CT: A comparative study. *Eur J Nucl Med Mol Imaging* 2008;35:1766-74.
  22. Beheshti M, Vali R, Waldenberger P, Fitz F, Nader M, Hammer J, *et al.* The use of F-18 choline PET in the assessment of bone metastases in prostate cancer: Correlation with morphological changes on CT. *Mol Imaging Biol* 2009;11:446-54.
  23. Heidenreich A, Bastian PJ, Bellmunt J, Bolla M, Joniau S, van der Kwast T, *et al.* EAU guidelines on prostate cancer. Part II: Treatment of advanced, relapsing, and castration-resistant prostate cancer. *Eur Urol* 2014;65:467-79.
  24. Giovacchini G, Picchio M, Coradeschi E, Bettinardi V, Gianolli L, Scattoni V, *et al.* Predictive factors of [(11) C] choline PET/CT in patients with biochemical failure after radical prostatectomy. *Eur J Nucl Med Mol Imaging* 2010;37:301-9.
  25. Schillaci O, Calabria F, Tavolozza M, Caracciolo CR, Finazzi Agrò E, Miano R, *et al.* Influence of PSA, PSA velocity and PSA doubling time on contrast-enhanced 18F-choline PET/CT detection rate in patients with rising PSA after radical prostatectomy. *Eur J Nucl Med Mol Imaging* 2012;39:589-96.
  26. Ceci F, Castellucci P, Mamede M, Schiavina R, Rubello D, Fuccio C, *et al.* (11) C-Choline PET/CT in patients with hormone-resistant prostate cancer showing biochemical relapse after radical prostatectomy. *Eur J Nucl Med Mol Imaging* 2013;40:149-55.
  27. Soyka JD, Muster MA, Schmid DT, Seifert B, Schick U, Miralbell R, *et al.* Clinical impact of 18F-choline PET/CT in patients with recurrent prostate cancer. *Eur J Nucl Med Mol Imaging* 2012;39:936-43.
  28. Picchio M, Briganti A, Fanti S, Heidenreich A, Krause BJ, Messa C, *et al.* The role of choline positron emission tomography/computed tomography in the management of patients with prostate-specific antigen progression after radical treatment of prostate cancer. *Eur Urol* 2011;59:51-60.
  29. Namura K, Minamimoto R, Yao M, Makiyama K, Murakami T, Sano F, *et al.* Impact of maximum standardized uptake value (SUVmax) evaluated by 18-Fluoro-2-deoxy-D-glucose positron emission tomography/computed tomography (18F-FDG-PET/CT) on survival for patients with advanced renal cell carcinoma: A preliminary report. *BMC Cancer* 2010;10:667.
  30. Revheim ME, Winge-Main AK, Hagen G, Fjeld JG, Fosså SD, Lilleby W. Combined positron emission tomography/computed tomography in sunitinib therapy assessment of patients with metastatic renal cell carcinoma. *Clin Oncol (R Coll Radiol)* 2011;23:339-43.
  31. Ueno D, Yao M, Tateishi U, Minamimoto R, Makiyama K, Hayashi N, *et al.* Early assessment by FDG-PET/CT of patients with advanced renal cell carcinoma treated with tyrosine kinase inhibitors is predictive of disease course. *BMC Cancer* 2012;12:162.
  32. Park JW, Jo MK, Lee HM. Significance of 18F-fluorodeoxyglucose positron-emission tomography/computed tomography for the postoperative surveillance of advanced renal cell carcinoma. *BJU Int* 2009;103:615-9.
  33. Martínez de Llano SR, Delgado-Bolton RC, Jiménez-Vicioso A, Pérez-Castejón MJ, Carreras Delgado JL, Ramos E, *et al.* Meta-analysis of the diagnostic performance of 18F-FDG PET in renal cell carcinoma. *Rev Esp Med Nucl* 2007;26:19-29.
  34. Divgi CR, Uzzo RG, Gatsonis C, Bartz R, Treutner S, Yu JQ, *et al.* Positron emission tomography/computed tomography identification of clear cell renal cell carcinoma: Results from the REDECT trial. *J Clin Oncol* 2013;31:187-94.
  35. Vercellino L, Bousquet G, Baillet G, Barré E, Mathieu O, Just PA, *et al.* 18F-FDG PET/CT imaging for an early assessment of response to sunitinib in metastatic renal carcinoma: Preliminary study. *Cancer Biother Radiopharm* 2009;24:137-44.
  36. Eisenhauer EA, Therasse P, Bogaerts J, Schwartz LH, Sargent D, Ford R, *et al.* New response evaluation criteria in solid tumours: Revised RECIST guideline (version 1.1). *Eur J Cancer* 2009;45:228-47.
  37. De Santis M, Pont J. The role of positron emission tomography in germ cell cancer. *World J Urol* 2004;22:41-6.
  38. Huddart RA, O'Doherty MJ, Padhani A, Rustin GJ, Mead GM, Joffe JK, *et al.* 18fluorodeoxyglucose positron emission tomography in the prediction of relapse in patients with high-risk, clinical stage I nonseminomatous germ cell tumors: Preliminary report of MRC Trial TE22 – The NCRI Testis Tumour Clinical Study Group. *J Clin Oncol* 2007;25:3090-5.
  39. Oechsle K, Hartmann M, Brenner W, Venz S, Weissbach L, Franzius C, *et al.* [18F] Fluorodeoxyglucose positron emission tomography in

- nonseminomatous germ cell tumors after chemotherapy: The German multicenter positron emission tomography study group. *J Clin Oncol* 2008;26:5930-5.
40. De Santis M, Becherer A, Bokemeyer C, Stoiber F, Oechsle K, Sellner F, *et al.* 2-18fluoro-deoxy-D-glucose positron emission tomography is a reliable predictor for viable tumor in postchemotherapy seminoma: An update of the prospective multicentric SEMPET trial. *J Clin Oncol* 2004;22:1034-9.
  41. Becherer A, De Santis M, Karanikas G, Szabó M, Bokemeyer C, Dohmen BM, *et al.* FDG PET is superior to CT in the prediction of viable tumour in post-chemotherapy seminoma residuals. *Eur J Radiol* 2005;54:284-8.
  42. Yang Z, Cheng J, Pan L, Hu S, Xu J, Zhang Y, *et al.* Is whole-body fluorine-18 fluorodeoxyglucose PET/CT plus additional pelvic images (oral hydration-voiding-refilling) useful for detecting recurrent bladder cancer? *Ann Nucl Med* 2012;26:571-7.
  43. Lu YY, Chen JH, Liang JA, Wang HY, Lin CC, Lin WY, *et al.* Clinical value of FDG PET or PET/CT in urinary bladder cancer: A systemic review and meta-analysis. *Eur J Radiol* 2012;81:2411-6.
  44. Apolo AB, Riches J, Schöder H, Akin O, Trout A, Milowsky MI, *et al.* Clinical value of fluorine-18 2-fluoro-2-deoxy-D-glucose positron emission tomography/computed tomography in bladder cancer. *J Clin Oncol* 2010;28:3973-8.
  45. Lodde M, Lacombe L, Friede J, Morin F, Saourine A, Fradet Y. Evaluation of fluorodeoxyglucose positron-emission tomography with computed tomography for staging of urothelial carcinoma. *BJU Int* 2010;106:658-63.
  46. Sadeghi R, Gholami H, Zakavi SR, Kakhki VR, Horenblas S. Accuracy of 18F-FDG PET/CT for diagnosing inguinal lymph node involvement in penile squamous cell carcinoma: Systematic review and meta-analysis of the literature. *Clin Nucl Med* 2012;37:436-41.
  47. Paone S, Ferroni E, Di Tanna GL, Corio M, Chiarolla E, Jefferson TO, *et al.* Systematic review of economic evaluation on the use of PET-CT for cancer staging. Rome: Agenzia Nazionale per i Servizi Sanitari Regionali; 2011.
  48. Pichler BJ, Wehrli HF, Kolb A, Judenhofer MS. Positron emission tomography/magnetic resonance imaging: The next generation of multimodality imaging? *Semin Nucl Med* 2008;38:199-208.
  49. Roethke MC, Kuru TH, Afshar-Oromieh A, Schlemmer HP, Hadaschik BA, Fenchel M. Hybrid positron emission tomography-magnetic resonance imaging with gallium 68 prostate-specific membrane antigen tracer: A next step for imaging of recurrent prostate cancer-preliminary results. *Eur Urol* 2013;64:862-4.

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