Physiological distribution and range of normal SUVmax values of ^{18}F-Choline PET/CT

Short Communication

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ABSTRACT

Introduction: ^{18}F-Choline PET-CT is an increasingly used technique in patients with prostate cancer. The main indication is to localise the disease in patients with biochemical recurrence. To accurately interpret ^{18}F-Choline PET, knowledge of normal tracer distribution is paramount. The aim of this study was to describe the normal distribution pattern of ^{18}F-Choline by measuring the maximum standardized uptake values (SUVs) of various organs.

Methods: ^{18}F-Choline PET was performed in ten consecutive patients. Approximately 370 MBq of tracer was injected intravenously and a low amperage CT scan was performed for attenuation correction of PET images.Maximum SUVs were calculated on the reconstructed images for various organs. These SUVmax values depend on multiple factors and could be variable depending on the reconstruction CT methods, acquisition time and region of interest (ROI) parameters.

Results: Physiologic symmetric increased tracer uptake was noted in the salivary glands and parotid glands. Intense physiological uptake was present in the liver, pancreas, duodenum, stomach, kidneys and urinary bladder and moderate to intense uptake in the sublingual glands, lacrimal glands, nasal mucosa, thyroid gland, tonsils, adrenal glands, large bowel, bone marrow and spleen. Low-grade-to-moderate uptake was present in the choroid plexus, pituitary gland, soft palate, pharynx, left myocardium, lungs, mediastinal blood pool, testicles and muscles. Prostate and prostatic beds were excluded from the volumes of interest.

Conclusion: This study is the first one to describe a normal range of SUVmax values for ^{18}F-Choline PET in various organs.

Key words: ^{18}F-choline; Normal distribution; PET; Prostate cancer

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INTRODUCTION

Prostate cancer (PC) is one of the main causes of death in men in Western World [1]. Positron Emission Tomography has a significant role in staging and restaging prostate cancer, especially in patients who have undergone radical treatment and are presenting with rising prostate-specific antigen levels (PSA) [2]. Whole body study ^{18}F-Choline PET-CT is a non-invasive test that allows accurate assessment of the extent of disease and the detection of sites of recurrence. The sensitivity of choline PET is positively correlated with serum PSA, PSA velocity and Gleason score [3]. ^{18}F-Choline can detect the presence of disease not identified on other modalities such as Bone Scintigraphy (BS) and pelvis Magnetic Resonance Imaging (MRI). MRI is an accurate noninvasive technique for nodal staging in patients with PC, but accuracy rates vary widely. The sensitivity varies from 0% to 100% and the specificity varies from 94% to 100% [4]. MRI has been shown to have a low sensitivity in determination of tumor involvement of pelvic lymph nodes, because nodal involvement is not always correlated with enlargement, hence failed to depict metastases in patients with unenlanged nodes [5]. On the contrary, ^{18}F-Choline PET shows high sensitivity not only for the detection of primary prostate cancer but also for nodal staging. The sensitivity and specificity for patient based lymph node staging of prostate cancer is 100% and 95%. Nevertheless, sensitivity of choline PET/CT seems to be low for the detection of small lymph node metastases and micrometastases [6]. ^{18}F-Choline PET-CT is indicated in patients with equivocal findings on conventional imaging where confirmation or exclusion of disease will influence patient management and in patients with suspected recurrence with rising PSA [7]. The aim of this study was to describe the whole-body physiological distribution of ^{18}F-Choline and to describe the average and range of SUVs values that are paramount to correct interpretation of findings and to appropriate patient management.

METHODS

Ten consecutive patients with histopathologically proven PC who underwent ^{18}F-Choline PET-CT imaging for primary staging or restaging for biochemical recurrence were included. Measurements were made in organs showing choline uptake. A region of interest (ROI) was drawn manually and the maximum standardized uptake value [SUVmax] average and range were calculated for the following organs: brain, pituitary gland, choroid plexus, lacrimal glands, salivary glands, parotid glands, sublingual glands, nasal mucosa, thyroid, soft palate, tonsils, pharynx (nasopharynx, oropharynx, hypopharynx), mediastinum blood pool (ROI drawn over the aortic arch), lungs, bone marrow (ROI drawn over L1 vertebral body), left myocardium, liver, spleen, kidneys, adrenal glands, pancreas, bladder, testicles, muscles (ROI drawn over muscles of the posterior thigh), duodenum , large bowel and stomach. The size of each ROI used for SUV measurements was variable.

Patient preparation

There was no special preparation and no fasting.

Scanning

Whole-body PET/CT was performed approximately 60 min after ^{18}F-Choline injection. A low amperage CT scan was performed for attenuation correction of PET images (65mA, 220kV, field of view about 500 mm, CT slice thickness 3mm). Just after the nonenhanced CT, whole-body PET images were acquired for 6-7 bed positions, 3 min per bed, from upper thighs to vertex; images were reconstructed using a time of flight and point spread function algorithm (TOF +PSF).

CT Parameters

CT parameters Slice Thickness: 3.0 mm, 65 mAs, 120 kV.

RESULTS

Table 1 summarizes the range and the average of the Standardized Uptake Value Max (SUVmax) in various organs.

For the evaluation of the uptake we used a 4-point scale visual method method (no or faint uptake, low, moderate and intense) modified as follows: no or faint uptake, SUVmax almost zero; low, SUVmax< 2,5; moderate, $6 \geq$ SUVmax $\geq 2,5$; and intense, SUVmax> 6.

In the head and neck region, low-grade-to-moderate physiological cerebral uptake was present in the choroid plexus and in pituitary gland. Prominent intense uptake was present in the salivary and parotid glands. Moderate-to-intense uptake was present in the sublingual glands. Moderate uptake was present in the lacrimal glands, nasal mucosa, thyroid gland and tonsils. The uptake in the soft palate was low-grade-to-moderate and in the pharynx (nasopharynx, oropharynx, hypopharynx) was low-grade.

In the chest and abdomen, significant intense uptake was present in the liver, pancreas, duodenum and stomach.Intense uptake in the stomach was seen in all the patients. Moderate-to-intense uptake was present in adrenal glands and large bowel. Moderate uptake was present in bone marrow and spleen.

Table 1: Maximum SUVs recorded in the different organs.

Region	SUVmax Range	SUVmax Average
Brain	0.19 - 0.28	0.23
Pituitary gland	2.61 – 6.35	3.90
Choroid plexus	1.32 – 2.96	2.08
Lacrimal glands	2.72 – 4.56	3.51
Salivary glands	7.21 – 11.60	9.45
Parotid glands	6.01 – 11.53	8.59
Sublingual glands	3.9 – 8.40	5.58
Nasal mucosa	3.2 – 4.91	3.79
Thyroid	2.89 – 4.00	3.26
Soft palate	1.80 – 3.06	2.27
Tonsils	2.89 – 8.08	5.25
Pharynx	1.51 – 3.25	2.01
Mediastinum blood pool	0.42 – 1.26	0.77
Lungs	0.30 – 1.29	0.71
Bone marrow	3.29 – 6.16	4.09
Left myocardium	1.85 – 3.29	2.62
Liver	11.93 – 15.57	14.01
Spleen	3.28 – 5.90	5.06
Kidneys	11.29 - 21.90	17.52
Adrenal glands	3.42 – 7.42	4.97
Pancreas	8.85 – 15.31	12.35
Bladder	3.25 – 57.13	17.06
Testicles	0.64 – 2.48	1.68
Muscles	1.00 – 3.65	1.76
Duodenum	2.09 – 15.33	9.74
Large bowel	3.90– 9.44	6.80
Stomach	6.59 – 11.27	9.08

SUV: Standardized uptake value

Low-grade-to-moderate was present in left myocardium and low-grade uptake was present in the lungs, the mediastinal blood pool, the testicles and the muscles. The uptake in the kidneys and the bladder was variable but mainly intense and depended on the amount of ^{18}F-Choline excreted in the ureters and on the patient's preparation to empty their bladder. Prostate and prostatic beds were excluded from the volumes of interest.

DISCUSSION

The role of ^{18}F-CholinePET has been increasing in the last few years and it has proven to be a valuable test with a significant impact on patient management [8]. We expect that the knowledge of normal range of uptake will inform reporters and allow for more accurate differentiation between normal and abnormal findings, therefore leading to fewer false-positive and false-negative findings, improving the accuracy of reports and increasing reporters' confidence. A recent article described physiological tracer distribution as well as variants and pitfalls. We believe that our study is a useful adjunct to the existing literature by providing normal ranges of uptake for areas of physiological distribution [9].

Malignant lesions can be identified and characterised based on the level of uptake, which is usually quantified using SUV values For example in a recent study, lytic metastases (mean SUV 11±3.2) and sclerotic metastases (mean SUV 7.6±3.0) showed high uptake [10]. In our study, bone marrow's normal SUVmax range was 3.29 – 6.16 (ROI drawn over L1 vertebral body), therefore confirming the findings from this study and providing a useful range of values that will help the reporter to differentiate benign from malignant findings.

^{18}F-Choline PET can also detect other malignancies such as hepatocellular carcinoma. The range of normal uptake values provided by our study can inform judgement on the presence of non-prostate cancer malignancies.

Caution is however needed as non-malignant inflammatory findings can show increased choline uptake [9, 11] and that may lead to false interpretations. For example ^{18}F-Choline PET can be positive in conditions like sinusitis, thyroiditis and otomastoiditis [9]. Low to moderate uptake in mediastinal and hilar lymph nodes is a common finding in ^{18}F-Choline PET-CT studies in patients with prostate cancer and is usually unrelated to prostate cancer. The uptake in these lymph nodes is mostly due to reactivity /inflammatory [9, 12].

The information provided also by the diagnostic CT component of PET-CT imaging may be valuable in the differentiation of physiological bowel activity and ^{18}F-Choline excretion in the ureters.

Limitations

Given the retrospective nature of our study data like the age, previous or ongoing androgen deprivation therapy (ADT), PSA range, Gleason score are not accessible. Given the purpose of the article the normal biodistribution of choline in various organs is unlikely to be affected by these factors [6].

Differences such as between staging and restaging patients who has already received additional treatments and the patients without any additional treatment to surgery are not the goal of this paper and we do not expect a difference in tracer distribution between such groups of patients.

Data like the difference between SUVmax in patients with ongoing ADT and without ADT especially on the skeleton and the number of pre-operative and post-operative patients are not accessible but it is unlikely to affect the normal biodistribution of choline in various organs. Furthermore there is no major difference between SUVmax in patients with ongoing ADT and without ADT especially on the skeleton, because ADT doesn't significantly impair ^{18}F-Choline uptake in malignant lesions [13].

The limitations of this study also include limited number of patients, reconstruction algorithms and variable regions of interest (ROIs).

CONCLUSION

Knowledge of the normal range of SUV values in areas of physiological tracer distribution will inform judgement and provide increased diagnostic accuracy in ^{18}F-Choline PET reports, therefore leading to improved patient management.

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