Artifactual Increased Uptake of F18-Fluordeoxyglucose due to Metallic objects using Camera-based PET Imaging with X-Ray Attenuation Corrections

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Abstract

Camera-based PET/CT imaging allows for simultaneous functional and morphologic evaluation of lesions. Transmission data, obtained from the X-ray component of the hybrid device, are also used for attenuation correction of the F-18 Fluorodeoxyglucose (FDG) PET images. The aim of the present study is to describe an artifactual increase in FDG uptake on X-ray attenuation corrected camera-based PET studies. Eight patients who underwent FDG studies with a combined camera-based PET/CT scanner for evaluation of malignancies were found to have either internal or superficial metallic objects. All studies were processed using iterative reconstruction with and without attenuation correction. Artifactual foci of increased FDG uptake in regions of the body containing metallic objects were seen in X-ray attenuation corrected camera-based images. These same areas of increased FDG uptake were not seen on processing without attenuation correction. These findings arise from the impact of high-density elements on the CT based attenuation corrected images as an expression of the over-estimated attenuation coefficient of metals.

Key words: Artifact, camera based PET/CT, X-ray attenuation correction.

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Introduction

New technologies and new clinical applications using F-18 Fluorodeoxyglucose (FDG) have been recently developed. One of these novel approaches is the camera-based hybrid PET/CT scanner (1-3). The device consists of a variable angle dual head gamma camera with coincidence imaging capabilities and a low dose CT scanner mounted on the same gantry. Hybrid imaging allows for sequential acquisition of nuclear medicine and CT data. Precise image registration thus obtained provides integrated functional and anatomic lesion characterization (1,2,4-6). The transmission data, obtained from the X-ray component of the device, are also used to generate attenuation maps and attenuation corrected emission images are subsequently formed during the reconstruction process.

Since the introduction of this device into routine clinical use, increased FDG uptake has been seen on attenuation corrected images in a number of patients. These findings were not seen when the same studies were processed without attenuation correction. Present report describes this artifact and the potential pitfalls it may lead to in various clinical settings.

Materials and Methods

In the years 1999-2000 eight patients undergoing camera-based PET/CT imaging using FDG for the evaluation of malignant disease were found to have metallic objects in different regions of their bodies. Camera based PET/CT studies were performed in patients fasting for at least 4 hours prior to the study. A mean dose of 370 MBq F-18 FDG was injected 60 minutes before performing the scan. All scans were acquired using a combined variable angle dual head sodium iodide crystal gamma camera with coincidence acquisition capability and a low energy CT system supported by a common gantry (Millennium VG™ & HAWKEYE™, GE Medical Systems, Milwaukee, Wisconsin).

This device permits consecutive acquisition and inherent registration of coincidence emission and CT data. The longitudinal drive of the examination table is extended in order to move the patient to the X-ray image plane which is closer to the main rotating axis than the nuclear medicine detectors. Since the NM gantry is used to support the x-ray tube and detector, the rotation speed is limited, in practice, to below 2.8 rpm. A 'half scan' acquisition acquired over 220 degrees takes a minimum of 13 seconds to acquire data for one slice. The x-ray tube is a fixed anode, oil cooled tube operated at 140kVp, 2.5mA. The x-rays are generated on a Tungsten target and an added beam filter of 0.5mm copper

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is used to reduce the patient dose from soft x-rays. The attenuation map is reconstructed using filtered back-projection. The CT attenuation values are converted to 511 keV attenuation values using separate scaling factors for soft tissue and bone to account for the different ratio of attenuation at the x-ray energy and 511keV for bone and soft tissue.

Transaxial PET slices are derived using the Coincidence Ordered Subsets Expectation Maximization (COSEM) algorithm (the parameters were set to peak to peak, filter every 5 subsets, and 2 steps). In the present study all images were processed with and without attenuation correction. X-ray images were reconstructed and transmission data were integrated into the nuclear medicine database. Matching pairs of X-ray and nuclear medicine slices were fused, and images overlaying the transmission (CT) and emission (PET) data were generated. The images were processed and reviewed using the eNTGRA™ software package (GE Medical Systems, Milwaukee, Wisconsin).

Results

Attenuation corrected images of hybrid camera-based PET/CT studies were found to show an area of increased FDG uptake in regions of metallic objects in all 8 patients (Table 1). The findings were seen within the metal objects

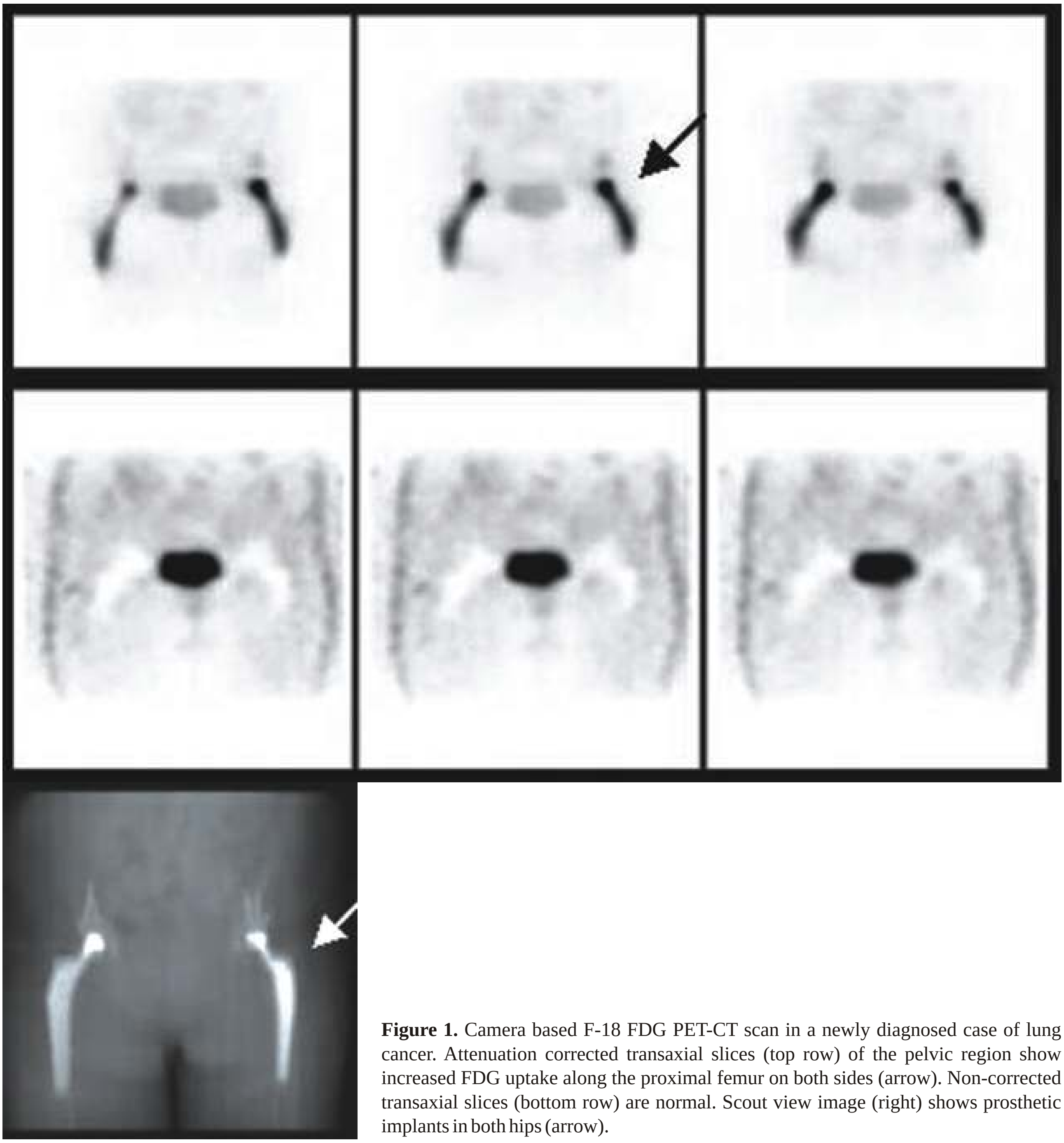

Figure 1. Camera based F-18 FDG PET-CT scan in a newly diagnosed case of lung cancer. Attenuation corrected transaxial slices (top row) of the pelvic region show increased FDG uptake along the proximal femur on both sides (arrow). Non-corrected transaxial slices (bottom row) are normal. Scout view image (right) shows prosthetic implants in both hips (arrow).

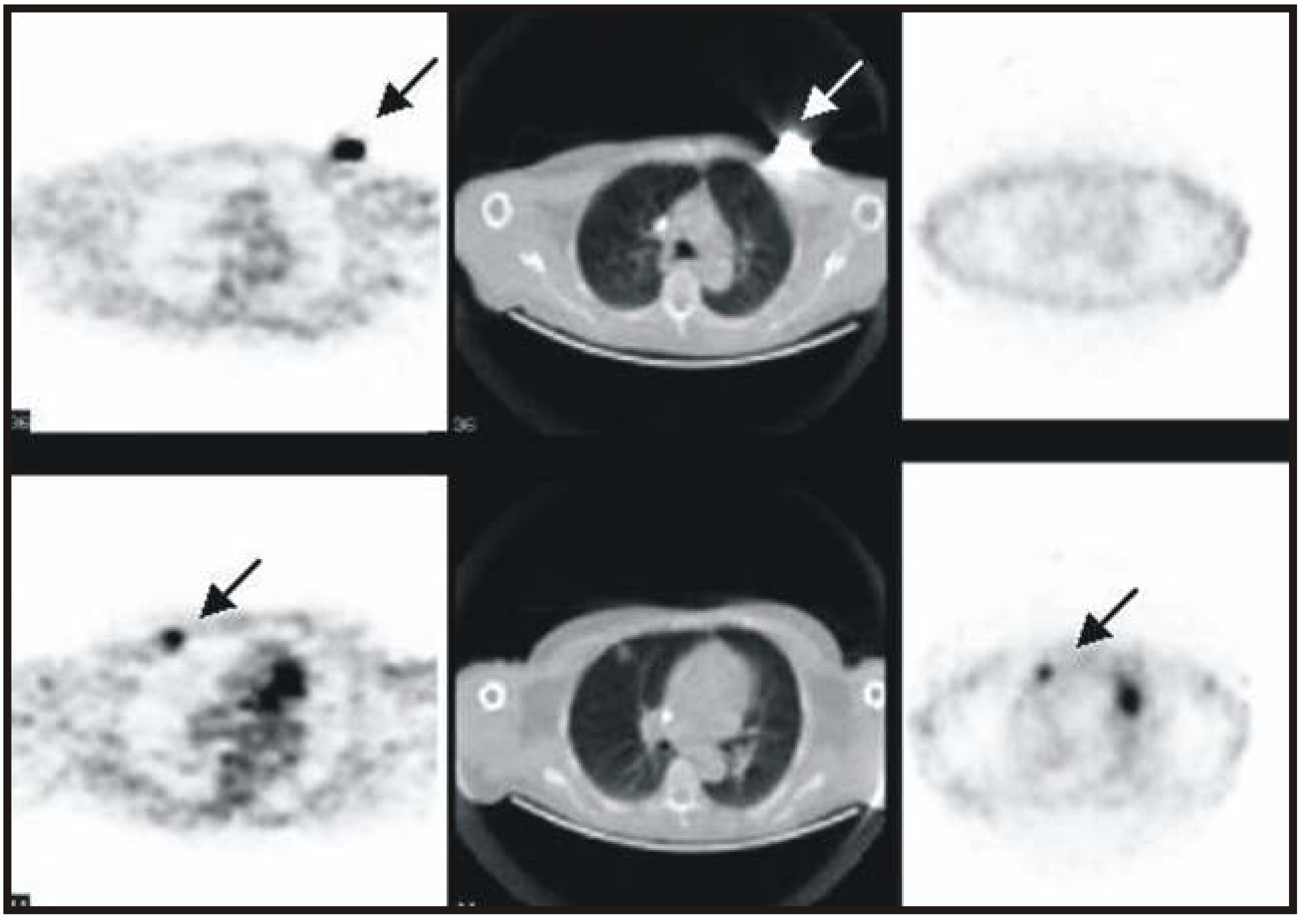

Figure 2. Camera based F-18 FDG PET-CT scan in the evaluation of a right pulmonary nodule in a patient with a history of colon cancer and lymphoma. Attenuation corrected transaxial slices (left column) show two foci of pathologic uptake in the anterior chest bilaterally (arrows). Non-corrected images (right column) show only a single area of increased FDG uptake in the right hemithorax (arrow). Corresponding CT (middle column), show the presence of a cardiac pacemaker in the left anterior chest wall (arrow). The right pulmonary nodule represents a metastasis from colon cancer.

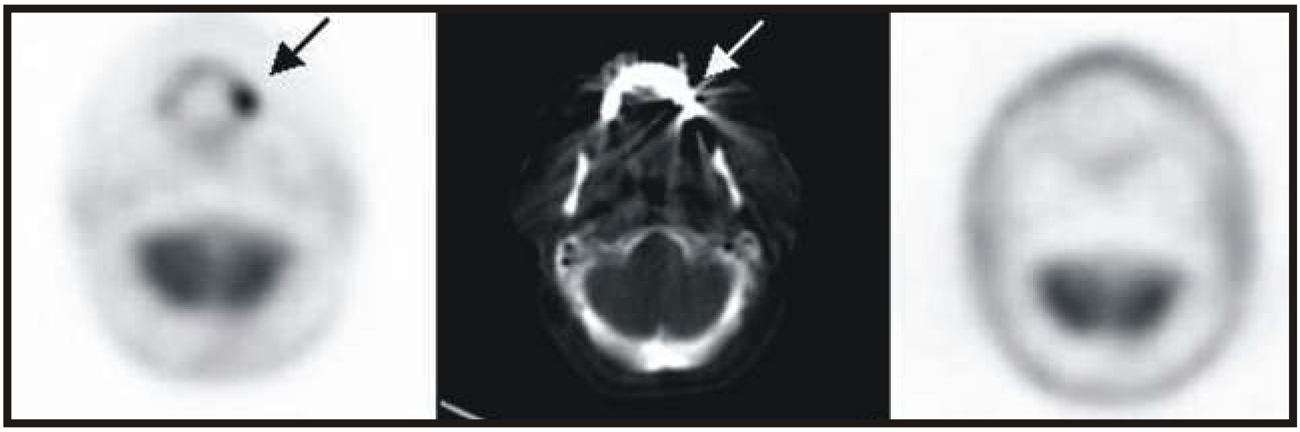

Figure 3: Camera based F-18 FDG PET-CT scan in a patient suspected of recurrent carcinoma of the tongue. Attenuation corrected transaxial slice (left) show focal increased activity in the left aspect of the floor of the mouth (arrow). Non-corrected transaxial slice (right) is normal. The area of increased FDG uptake in the left aspect of the floor of the mouth is not seen. Corresponding CT slice (center) demonstrates the presence of a dental bridge in the same region (arrow).

and not in the area adjacent to the devices. These foci of uptake were not present on the non-attenuation corrected images. The metallic objects included orthopedic prostheses in 3 patients, dental implants in 3 patients, a cardiac pacemaker in one patient and a superficial metal object (buckle) in one patient. The devices were composed of stainless steel, titanium and other metallic alloys. Presence of metallic devices was confirmed by correlation with findings on the low dose CT obtained during hybrid imaging and by patient history data. There were no patient

Patient	Age	Sex	Reason For Scan	Artifactual uptake	Metal Device
1	65	F	Soft tissue sarcoma of right thigh, staging	Increased FDG uptake in proximal right femur.	Plate for internal fixation of right femur
2	44	M	Osteogenic sarcoma of proximal humerus. Suspected local recurrence	Increased FDG uptake along proximal right humerus.	Prosthetic implant for reconstruction of right humerus
3	71	F	Ca. of lung. Staging	Bilateral increased FDG uptake in proximal femur.	Prosthetic implants for bilateral total hip replacement
4	56	M	Osteogenic sarcoma S/P hemipelvectomy Re-staging	Focus of increased FDG uptake in left aspect of the floor of the mouth.	Dental fillings
5	60	F	Ca. of breast Suspected local recurrence	Increased FDG uptake in right mandible.	Dental fillings
6	58	0	Ca. of tongue S/P tongue and neck dissection Suspected recurrence on CT	Increased FDG uptake in left maxilla.	Dental fillings
	79	M	Right lung nodule in a patient with a history of carcinoma of colon and lymphoma	Focus of increased FDG uptake in left chest wall.	Cardiac pacemaker
8	72	M	Malignant melanoma Restaging after excision of lesion in left calf	Superficial increased FDG uptake in the anterior abdominal wall.	Metal buckle

Table 1. Clinical data, PET findings and artifactual foci due to metallic devices in 8 patients

with prosthetic implant in whom this artifact was not present.

Figure 1 demonstrates an artifactual increased uptake in both hips caused by prosthetic metal implants, not seen on the non-corrected image of the same study. Figure 2 demonstrates an artifactual focus of increased FDG uptake in the left chest caused by a cardiac pacemaker. The area of increased uptake is not present on the non-corrected image. Figure 3 demonstrates an artifactual focus of increased uptake in the left aspect of the floor of the mouth caused by a dental bridge, not seen on the non-corrected image.

Discussion

The value of attenuation correction in PET studies using FDG has been previously described (7-9). While acquisition of transmission scans leads to additional imaging time and radiation exposure (10), attenuation correction has been shown to improve quantitation of radiotracers, decrease image distortion, enhance tumour localization and to make the intensity of lesions located deep in the body more comparable to those at superficial sites (11).

Several techniques for attenuation correction of emission data have been developed. Attenuation maps may be generated by transmission rod sources with either positron emitting isotopes such as Germanium-68 or single photon emmiting radiotracers such as Cesium-137. Images obtained from attenuation maps generated using radionuclide sources are relatively noisy even when the data is collected for a longer period. By comparison, the high flux of low energy photons obtained from CT studies provides attenuation maps characterized by low noise and good contrast (1,2). In addition, the fused images obtained from a PET/CT device allow for simultaneous evaluation of functional and anatomic lesion characteristics, thus facilitating the clinical interpretation of both CT and PET images. The impact of hybrid imaging on cancer patient management and on the accuracy of image interpretation has been assessed (4,5).

Present study describes 8 patients with foci of increased uptake of FDG within the regions of metallic objects, seen on attenuation corrected images utilizing CT derived attenuation maps. A previous case report described a metal related artifact in a rod-source attenuation corrected camera-based FDG image as an area of increased uptake in the intra-articular space of a prosthetic knee joint (12). A second study described artifactual increased FDG uptake from dental metallic implants in attenuation corrected images obtained with a dedicated PET/CT device (13). The artifactual uptake in these two studies was however demonstrated in areas adjacent to the metallic objects.

Present artifacts, observed with the use of camera-based PET/CT, are different and appears in the area superimposing the metallic device itself.

The artifact described in present study results from the method by which attenuation maps are derived from CT data. The effective energy of the low dose X-ray tube used in present device is 80 Kev while the energy of the annihilation photons is 511Kev. The attenuation measured at 80 keV must be corrected to the attenuation at 511 keV. However, the magnitude of this correction is dependent upon the effective attomic numer, Z, of the tissue. The current attenuation correction algorithm determines two correction factors, one for pixels with a CT number smaller then water (assuming the energy dependency of the tissue attenuation coefficient correction factor for these tissues is the same as that of water) and the second for pixels with a CT number greater then 0 (assuming the energy dependency of the tissue attenuation coefficient correction factor is that of a mixture of bone and water). However, the effective atomic numbers of metal objects may be much higher than that of bone and water, leading to a lower correction factor. The use of such correction factor results in an over-correction of attenuation and detection of artifactually increased uptake. Such artifacts are not created in coincidence FDG PET images which are corrected with a 511 keV transmission source.

Correct image interpretation is based on recognition of the normal and abnormal patterns of biodistribution of the tracer in diseased and healthy subjects (14). It is important to be aware of possible technical artifacts, which may be due to the patient status, the type of device or radiopharmaceutical used. FDG imaging, which plays a major role in the diagnosis and evaluation of cancer patients, has well known pitfalls and artifacts (14). Being familiar with the artifact described in present report is important for the routine clinical use of camera-based PET/CT. The promising role of FDG imaging in detecting infected prosthetic implants (15), which are basically metallic devices, make the knowledge of such potential artifacts clinically more significant. Reviewing the PET/CT study with knowledge of relevant anamnestic data and detecting a metal object on the CT, may avoid false positive reports. Parallel review of data processed with and without attenuation correction showing disappearence of areas of increased FDG uptake in the non-corrected study may determine the artifactual nature of these findings.

In conclusion, this report describes an artifact, seen on camera-based PET/CT images using FDG and X-ray attenuation correction. With more extensive use of this new modality in the future, physicians should be aware of this potential pitfall.

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