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BRIEF COMMUNICATION

# Focal Tracer Uptake: A Potential Artifact in Contrast-Enhanced Dual-Modality PET/CT Scans

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This study was performed to evaluate a possible artifact related to the administration of intravascular contrast agent in dual-modality PET/CT imaging. **Methods:** Thirty oncology patients underwent whole-body PET/CT. CT images, which were collected in the presence of intravenous and oral iodinated contrast agent, were used for PET attenuation correction. PET images were assessed for the artifact, defined as a region of high count rate on attenuation-corrected images in accurate coregistration with a contrast-enhanced blood vessel. Intravascular enhancement of thoracic veins was quantified by application of regions of interest, and quantities in patients with the artifact (group 1) and without the artifact (group 2) were correlated. Body surface area was calculated for all patients. **Results:** The contrast-induced PET artifact was present in 4 (13%) of 30 patients. Mean density differences in intravascular enhancement were highly significant ($P < 0.001$) in a comparison of group 1 (2,262 ± 304 Hounsfield units [HU]) and group 2 (1,058 ± 209 HU). Body surface area was significantly lower ($P = 0.035$) in the patients of group 1 (1.67 ± 0.11 $m^2$) than in the patients of group 2 (2.01 ± 0.18 $m^2$). **Conclusion:** Contrast-enhanced dual-modality PET/CT examinations may result in a PET artifact that is due to the transient bolus passage of undiluted intravenous contrast agent.

**Key Words:** contrast enhancement; PET/CT; artifact; attenuation

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The availability of dual-modality PET/CT tomographs opens new diagnostic strategies, particularly in the field of oncologic imaging. Morphology can be fused with function quickly and accurately (*1*). Combined PET/CT examinations have the potential to overcome limitations of morphologic and functional imaging when acquired separately. The integration of CT provides accurate anatomic information for PET. Furthermore, PET acquisition time is reduced by approximately 30% when PET attenuation correction is based on CT and when no transmission scans are required. For CT imaging, the lack of functional information, which is considered a major limitation of morphologic cross-sectional datasets, can be overcome by integration of PET. PET and CT images therefore complement one another in the diagnosis of malignant diseases. Maximal diagnostic yield of PET/CT mandates high-quality PET and CT datasets. Image quality should meet the standards of separately acquired PET and CT scans.

Not all malignancies, however, show increased uptake of the radioactive tracer. Diagnostic CT requires the administration of intravenous and oral contrast agents for delineation of vessels and bowel, respectively. Because attenuation correction of the PET component in dual-modality tomographs is based on CT (*2*), the presence of contrast agents may lead to inaccuracies in the reconstruction of functional images. Retrospective analysis of the first 30 contrast-enhanced whole-body PET/CT examinations acquired at our PET/CT site revealed an artifact mimicking focal tracer uptake in regions of high contrast enhancement.

## MATERIALS AND METHODS

Thirty whole-body scans covering the head, neck, thorax, abdomen, and pelvis of oncology patients were obtained on a dual-modality PET/CT system (biograph; Siemens Medical Solutions, Hoffman Estates, IL). For optimal CT image quality (vascular and parenchymal delineation comparable with a separately acquired CT scan), 140 mL of an iodinated contrast agent containing 300 mg of iodine per milliliter (Xenetix 300; Guerbet GmbH, Sulzbach, Germany) were administered intravenously with an automated injector (XD 5500; Ulrich Medical Systems, Ulm, Germany). To ensure sufficient vascular and parenchymal contrast, the flow rate was set to 3 mL/s for the first 80 mL. The remaining 60 mL were administered at 2 mL/s for continuous vascular enhancement during the acquisition of the CT sections. CT parameters were set to 130 mA, 120 kV, a slice width of 5 mm, and a table feed of 8 mm per rotation with a rotation time of 800 ms. After acquisition of the CT data, the patient table was automatically moved farther into the imaging system and PET images were collected starting with the upper thigh and pelvis.

PET images were collected 1 h after injection of 350 MBq of $^{18}$F-FDG within a scan window of 5 min per bed position (6–8 bed positions per patient). In-plane spatial resolution amounted to 4.6 mm (for a point source in air), and the axial field of view for 1 bed position was 15.5 cm, with a bed overlap of 15 planes (plane spacing, 2.425 mm). PET images were corrected for attenuation on the basis of the CT data (*2*). Iterative algorithms (nonlinear Fourier

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**FIGURE 1.** Attenuation-corrected PET image (A), PET/CT fusion image (B), CT image (C), and PET image uncorrected for attenuation (D) of 43-y-old woman with centrally located non–small cell cancer of right lung and mediastinal lymph node metastasis. PET attenuation artifact is due to highly concentrated contrast agent in right subclavian vein (arrow in A), which is not detectable on PET image uncorrected for attenuation (D). On attenuation-corrected PET, hot spot in right axillary region could be misinterpreted as metastasis.

rebinning and nonlinear attenuation-weighted ordered-subsets expectation maximization) with 2 iterations and 8 subsets were used for image reconstruction. Data were filtered (3.0 mm in full width at half maximum) and corrected for scatter.

Imaging studies were evaluated qualitatively for the artifact, defined as a region of high count rate on attenuation-corrected images in accurate coregistration with a contrast-enhanced blood vessel. Each patient study was assessed by 2 radiologists and 2 nuclear medicine physicians, and evaluation was performed in consensus. In patients with the PET artifact (group 1), regions of interest were applied to the center of the underlying vessel (minimum size, 20 pixels) to quantify the degree of contrast enhancement. In patients without the PET artifact (group 2), density was measured in the subclavian vein of the arm into which the contrast agents had been administered. Mean density values and SDs were calculated for each group.

Each patient's body surface area was calculated as described by Mosteller (*3*). Mean values of the body surface areas were compared between the 2 groups.

Statistical analysis was through determination of mean values and SDs. Significance was checked by the $\chi^2$ test. $P < 0.05$ denoted statistical significance.

## RESULTS

The contrast-related artifact mimicking focal tracer uptake was identified in 4 (13%) of the 30 evaluated examinations. All artifacts projected onto a highly enhanced thoracic vein. Three of these 4 patients presented with the artifact in projection onto the right subclavian vein (Fig. 1). In all 3 patients, the contrast agent had been injected through the right antecubital vein. In the fourth patient, the artificial focal tracer accumulation projected over the superior vena cava just distal to the tip of a central venous catheter that had been used for administering the contrast agent (Fig. 2).

Quantitative region-of-interest analysis of the intravenous density in the artifact areas revealed a mean density (±SD) of 2,262 (±304) Hounsfield units (HU) (range, 1,878–2,603 HU) on CT images. Measurements of CT HU in the subclavian veins of patients exhibiting artifact-free PET images revealed a mean density of 1,058 ± 209 HU and a range of 634–1,368 HU. CT density differences between veins exhibiting the PET artifact and veins that did not were statistically highly significant ($P < 0.001$).

The mean body surface area of all examined patients amounted to 1.96 ± 0.21 $m^2$. The mean surface area in patients expressing the artifact (1.67 ± 0.11 $m^2$) was lower than that in patients without the artifact (2.01 ± 0.18 $m^2$). This difference was also statistically significant ($P = 0.035$).

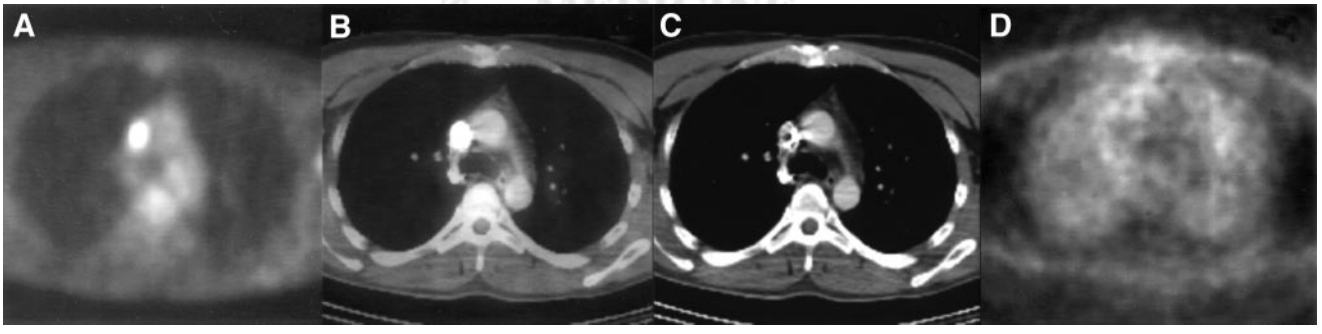



**FIGURE 2.** Attenuation-corrected PET image (A), PET/CT fusion image (B), CT image (C), and PET image uncorrected for attenuation (D) of 34-y-old man with hepatic metastases from colorectal cancer. Artifact caused by contrast agent leads to error in CT-based attenuation correction of PET images and simulates focal tracer uptake. Without knowledge of fusion images, interpreter is likely to misinterpret finding as mediastinal lymph node metastasis. When PET images are uncorrected for attenuation, artifact is not expressed (D).

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## DISCUSSION

To exploit the diagnostic power associated with dual-modality PET/CT, knowledge of associated artifacts is crucial. This study highlights such an artifact, which is related to the passage of iodinated contrast agents during the acquisition of CT images.

In dual-modality PET/CT tomographs, PET images are corrected for attenuation on the basis of CT data (*2*), which must be collected in the presence of intravenous and oral contrast agents to permit vascular and intestinal delineation, respectively. Furthermore, intravenous enhancement is crucial for the evaluation of parenchymal organs to maximize both sensitivity and specificity (*4*). Contrast bolus passage and vascular and parenchymal contrast enhancement are, however, temporary effects. Although present during the acquisition of CT images, most of the contrast agent will already be eliminated from the vascular system and the parenchymal organs when the PET data are collected. CT x-rays are therefore attenuated by the contrast agent, whereas PET annihilation quanta are not. The resulting overestimation of the PET attenuation can result in an artifact, as illustrated in this study.

Furthermore, attenuation of x-rays by iodinated contrast agents is significantly higher at CT energies (up to 140 keV) than at the 511-keV PET photon energy (Fig. 3) (*5*). An overestimation of PET attenuation in the presence of intravascular iodinated contrast agents is therefore to be expected in all currently available PET/CT tomographs.

The PET artifact was limited to the thoracic veins containing undiluted iodinated contrast agent. No artifacts were present in other body regions. This finding suggests that the contrast-related PET artifact is dependent on threshold and requires very high contrast agent concentrations, which are achieved during passage of only the undiluted contrast bolus. Hence, the presence of such an artifact outside the thoracic veins is highly unlikely.

The artifact was present in 4 of 30 evaluated whole-body examinations. In all 4 patients, the inflowing veins contained highly concentrated contrast agent with a mean density of 2,262 HU. The lowest density resulting in an artifact amounted to 1,878 HU. In contrast to these 4 patients, the density of the intravenous contrast agent in the inflowing subclavian veins of the 26 patients without the artifact amounted to a mean of 1,058 HU. The density values did not overlap, resulting in a highly significant statistical difference ($P < 0.001$) between these 2 groups.

Compared with the body surface areas of patients in whom the PET artifact was not present (mean, $2.0 \pm 0.18$ $m^2$), the body surface areas of all 4 patients expressing the artifact were low (mean, $1.67 \pm 0.11$ $m^2$). This difference proved statistically significant ($P = 0.035$). Adaptation of the amount of contrast agent in patients with a lower body surface area may therefore be necessary. There are, of course, other factors influencing contrast agent kinetics, such as cardiovascular function, blood volume, or venous anatomy, making it difficult to predefine the correct amount of required contrast agent. Increasing the delay between contrast injection and CT acquisition may reduce the risk of artifact development but goes along with decreased scan quality due to acquisition of the scans in a suboptimal enhancement phase. The acquisition of an unenhanced CT scan as part of the combined PET approach would, of course, avoid the artifact due to contrast agent administration but would reduce the CT to merely a means for anatomic correlation without its own diagnostic potential. An artifact induced by the temporary presence of highly concentrated iodinated contrast agents within thoracic veins will likely continue to be a problem in contrast-enhanced dual-modality PET/CT examinations.

By coregistration of CT and PET images, a hot spot in the PET image can be directly attributed to the highly contrast-

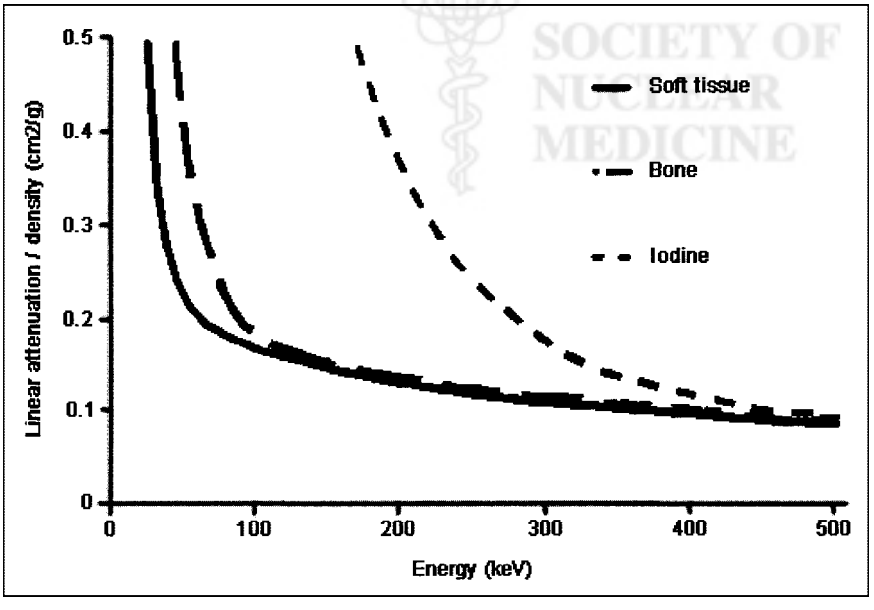



**FIGURE 3.** Attenuation per unit density at different energies for soft tissue, bone, and iodine. Iodine contrast agents cause higher attenuation at CT energies than at PET photon energy.

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enhanced blood vessel, thus identifying this region of focal tracer uptake as an artifact and preventing misinterpretation. Pathologic changes close to the blood vessel causing the artifact may, however, be missed on film evaluation, as focal tracer uptake within a small lesion may be attributed to the artifact. Evaluation of PET images uncorrected for attenuation may be necessary in these cases. Close evaluation of CT and PET images in the area of the artifact will nevertheless be crucial to prevent diagnostic errors.

## CONCLUSION

Contrast-enhanced dual-modality PET/CT examinations may result in a PET artifact of apparently increased tracer uptake due to the transient bolus passage of an undiluted intravenous contrast agent. The evaluating physician has to be aware of this artifact to prevent false-positive interpretations.

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