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PET/CT image artifacts caused by the arms

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Running title: PET/CT arm artifacts

Abstract

Positron Emission Tomography/Computed Tomography (PET/CT) images are usually obtained in arms-up position in cases with no head and neck pathology and in arms-down position to image head and neck area. Arms usually cause artifacts regardless of up or down positioning. Arms can cause various artifacts such as beam hardening and scatter, truncation and cold areas (cold artifacts) in obese or large sized patients, motion artifacts, implanted metal object artifacts, and artifacts related to radiotracer extravasation at the injection site. In this review article we will review the mechanisms of these artifacts and suggest solutions to reduce or eliminate them such as such as reviewing non-attenuation corrected PET image, performing extended field of view reconstruction, not applying scatter correction, using software to correct beam hardening, scatter and truncation artifacts. We will present various PET/CT images before and after corrections as related to such artifacts.

Key words: PET/CT, artifacts, arms, truncation, cold artifacts

Introduction

Positron Emission Tomography/Computed Tomography (PET/CT) images are usually obtained in arms-up position if there is no head and neck pathology and in arms-down position to image brain or head and neck area. In certain situations, patients cannot raise their arms up which causes artifacts in the body area, particularly in obese or large sized patients. Arms either in down or up position can cause various artifacts (*1*). As the area of interest in most of the cases is the body (chest, abdomen or pelvis), artifacts in arms-down imaging is more of a concern than the artifacts in arms-up imaging. Arms can cause various artifacts such as beam hardening and scatter artifacts in between right and left arm bones, truncation artifact, photopenic or cold areas (cold artifacts) in the soft tissues and bone in the region of abdomen and pelvis in obese or large sized patients, artifacts related to arm motion, metal objects in the arms, or extravasated activity at the injection site.

Beam Hardening and Scatter

Beam hardening is commonly seen on CT images. Beam hardening and scatter artifacts can occur between right and left arm bones on CT images and may result in inadequate correlation of CT data with PET images, mimic pathological conditions and inaccurate Hounsfield units if it is severe (*2-4*). Although beam hardening do not cause significant image artifacts on PET images, if it is severe it may cause suboptimal attenuation correction, reduction in the detectability of small lesions or inaccurate or suboptimal standardized uptake values (SUV) (Figure 1). The beam hardening and scatter artifacts are different mechanisms but appear as multiple linear bands/streaks between two high-attenuation objects (bone, metal, or barium) on CT images (Figure 1) (*3*). When the x-ray beam passes through the body, low-energy x-ray photons are attenuated more easily than the high-energy photons (*5*). These artifacts are a particular problem with high atomic number materials (bone, iodine or metal). The effects of beam-hardening in the image can be reduced using iterative reconstruction, or with beam hardening and scatter correction software (*5,6*).

Truncation and Cold Artifacts

Obtaining images in arms-down position in obese, or large sized patients usually causes truncation artifact (*7*). CT field of view (FOV) is smaller than PET FOV in large patients (object extending beyond the scanning field of view on CT) which may cause inaccurate attenuation correction (*8, 9*). In the arms-down position, the body of the patient extends beyond the transverse CT FOV and creates truncation that is extensive in obese or large patients (*1*).

In truncation artifact, at the periphery of the images, there is non-attenuation corrected (non-AC) PET data without corresponding CT images (*2, 7*). To minimize truncation artifact in the body, patients can be imaged in arms-up position. Truncation correction algorithm, extended field of view reconstruction (extending the reconstruction field of view) can correct these artifacts (*2, 9-11*). New scanners with larger CT FOV can create less truncation artifacts.

The cold artifacts seen on AC PET images (in abdominal and pelvic region in obese or large patients imaged in arms-down position or in head and neck region in patients imaged in hyper flexed arms-up position) are due to extensive truncation causing attenuation correction artifact or result of scatter correction. These cold artifacts are not seen on non-AC PET image, after extended field of view reconstruction, after removing the arms from the imaging FOV or when not applying scatter correction (Figures 2-6) (*1,12*). The cold artifacts seen only on the one side of the body is likely due to non-central placement of the patient on the imaging table or one arm to be more flexed than the other which can cause one-sided/unilateral truncation (Figures 2-4). Keeping the arms straight during the image acquisition and placing the patient symmetrically on the table can also reduce these artifacts. Non-AC PET images can grossly assess the areas but usually provide inadequate information in obese or large patients, particularly in deep tissues. When available using extended field of view reconstruction successfully eliminates these cold areas. Scatter correction may induce cold artifacts when it is applied with an iterative reconstruction (scatter correction artifact), particularly when the patients are scanned with their arms-down and the hands/fingers are placed away from the body, resulting in photopenic or cold areas seen at the level of hands (*12*). Not using scatter correction or changing the type of scatter correction (from relative to absolute) can eliminate this artifact (*12-14*). Scatter correction artifact can also be seen around kidneys and bladder as photopenic areas (halo-). Inaccurate scatter correction methods currently used in clinical PET imaging tend to overestimate the scatter contribution (*14*).

Other artifacts related to arms

The other artifacts caused by arms are related to arm motion, metal objects in the arms and extravasated activity at the injection site.

Arm motion can also cause cold artifacts (areas of "washed out" activity) and distorted arm anatomy on PET images (Figure 7A) (*15,16*). This can effect visual and quantitative assessment of PET uptake. Review of the non-AC PET images can help if the motion happened after acquiring the CT image and was not continuous during PET acquisition. Scatter limitation (no scatter correction) can correct overestimation of scatter caused by arm motion (*15, 16*).

Metal objects in the arms can cause beam hardening and scatter artifacts. Metal artifact reduction and metal deletion techniques can reduce these artifacts (*3*).

Radiotracer extravasation at the injection site causes various artifacts, such as reconstruction and scatter correction artifacts which may obscure the adjacent tissues, a hot spot at the injection site which may mimic a lesion, lymph node uptake which may be mistaken for metastasis, and erroneously low SUV and low uptake in tissues and lesions if extravasation is high (Figure 5). Accidental intra-arterial injection of radiotracer can cause diffusely increased uptake in the tissues distal to the injection site (glove pattern) and may cause underestimation of SUV of the lesions and inadequate assessment of the arm (Figure 7B) (*17*). Proper injection technique, removing the arm from imaging field of view or iterative reconstruction can help to reduce or eliminate these artifacts.

Discussion

It is important to understand and detect certain artifacts on PET/CT images for accurate interpretation of the images. In this review article we summarized the PET/CT artifacts caused by arms-down and arms-up positions and suggested solutions to reduce or avoid these artifacts.

Disclosure

No potential conflict of interest relevant to this article was reported.

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Figure Legends

Figure 1

Selected transaxial CT image shows beam hardening artifact in between two arms (arrows) with no artifact seen on PET image.

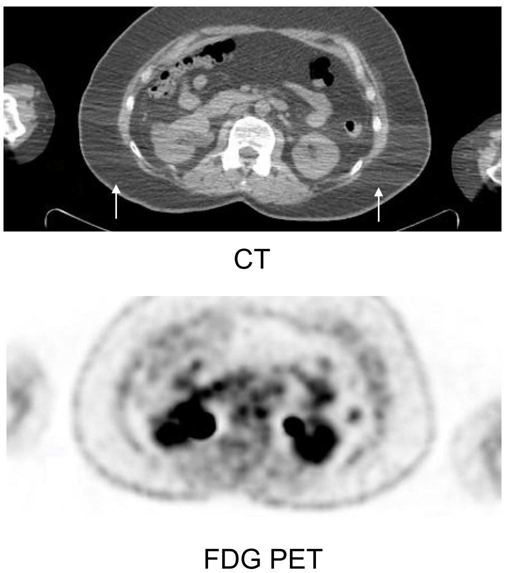


Figure 2

NaF PET/CT images of an adult, large sized patient who was imaged in arms-down position. Whole body coronal and maximum intensity projection (MIP) AC PET images demonstrate a large cold area (cold artifact) on left side of the abdomen and pelvis with reduced uptake in the bones (left lower ribs, hemi-pelvis, and hip) and soft tissues (left kidney) (A). Note that the left arm is further away from the body as compared to the right arm. This cold artifact is not seen on non-AC PET images (B).

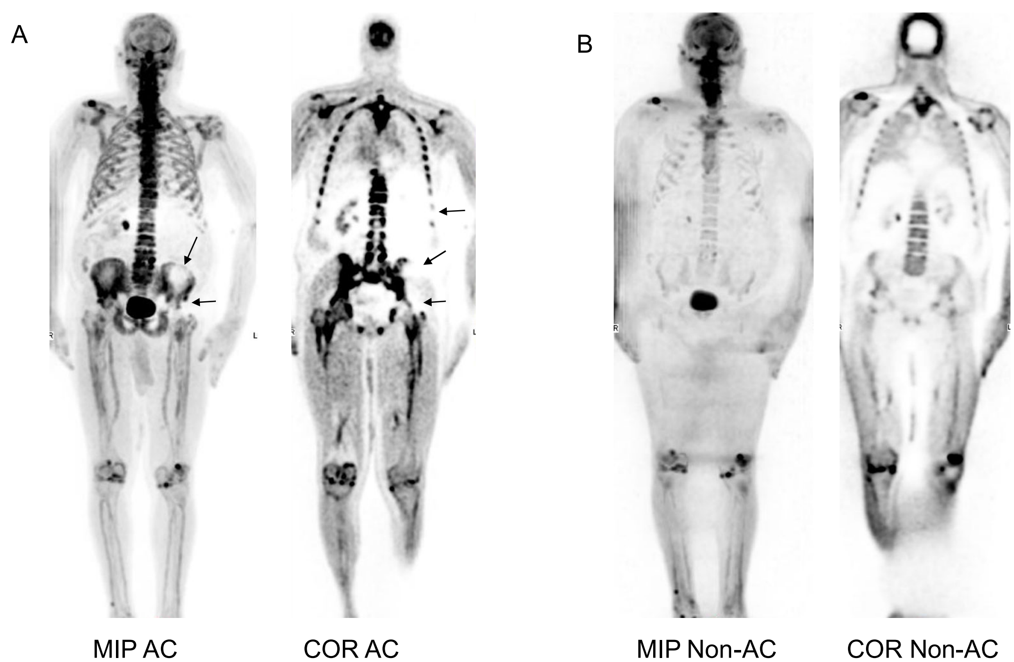


Figure 3

Whole body MIP (A) and transaxial pelvic (B) FDG PET AC images before and after extended field of view reconstruction (EFOV recon). Before EFOV reconstruction there is a cold artifact in the region of the right hip and pelvis which disappears after EFOV reconstruction (A and B, arrows). Cold artifact is also not present on non-AC PET image (C). Note that the right arm is further away from the body as compared to the left. Also note the right pelvic hypermetabolic mass seen on transaxial CT and non-AC PET images which was missed on AC PET image due to cold artifact (C, arrow head).

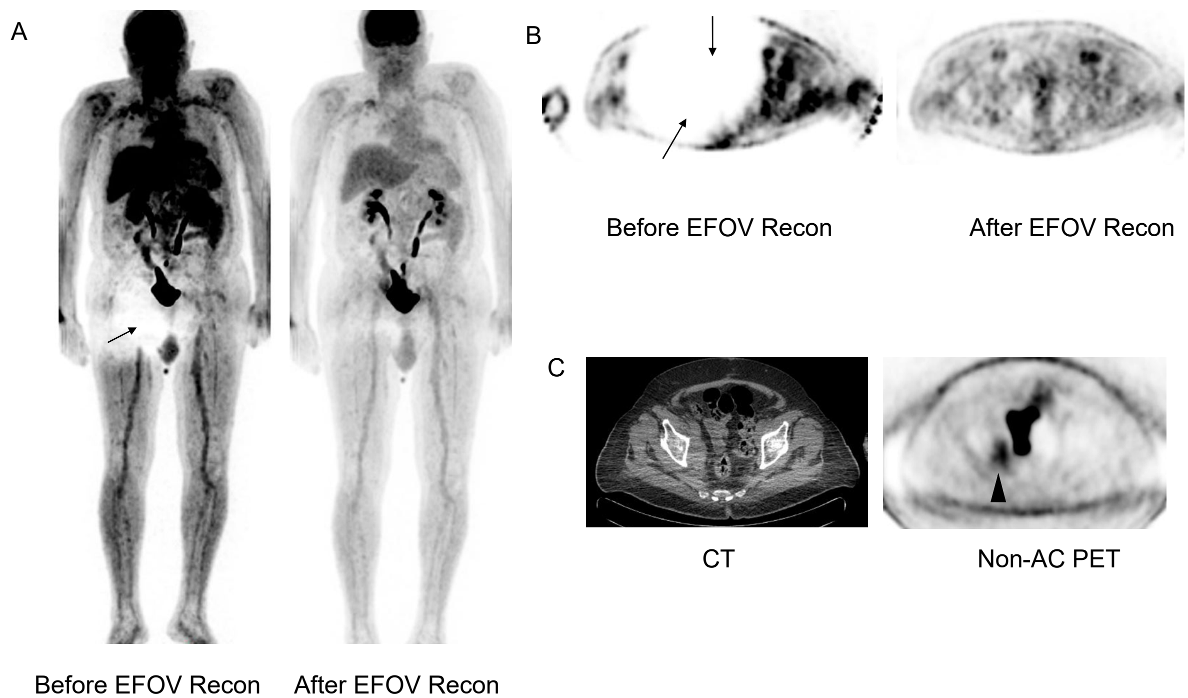


Figure 4

Whole body selected coronal CT, and AC NaF PET images (A) with a cold artifact seen in the region of the hips, more significant on the right side, on PET image in a large sized patient who was imaged in arms-down position (arrows). Note that the right arm is further away from the body as compared to the left. This cold defect is not seen after repeating the PET/CT image from the pelvis in the arms-up position (B). Note the enlarged prostate elevating the bladder on coronal pelvic PET image (arrow head, B).

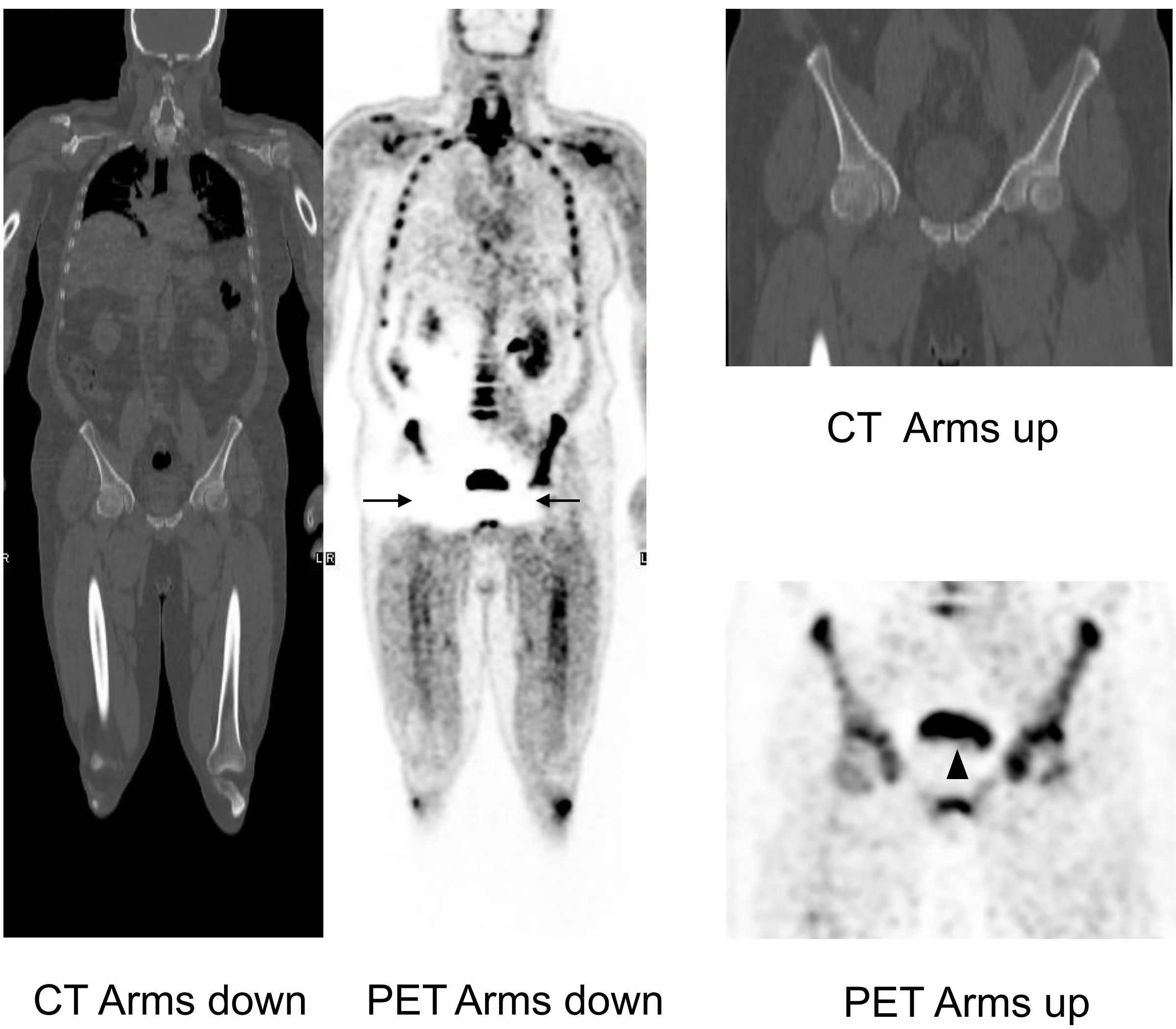
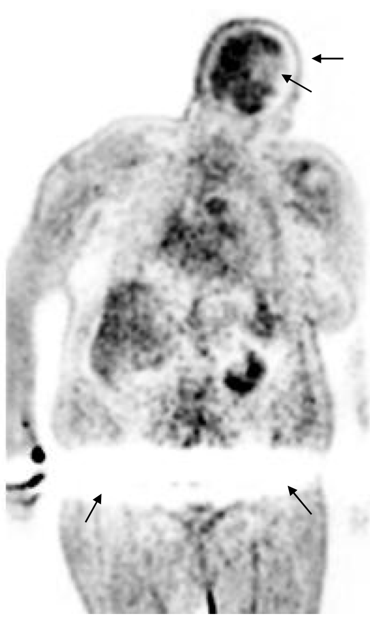


Figure 5

Whole body selected coronal AC FDG PET image demonstrates a linear area of cold artifact in the pelvis in a large sized patient who was imaged in arms-down position (arrows). This cold artifact is not present on non-AC PET image (selected coronal slice). A small cold artifact in the skin adjacent to right arm on non-AC PET image is result of scatter correction artifact due to activity extravasation at the injection site (arrow). Note the defect on the left side of the brain seen on both AC and non-AC images (caused by cerebral infarct seen on CT image which was not presented in the figure, arrows) and reduced uptake in the scalp on the left which is seen on AC image only (head motion after acquiring CT scan) (arrow).



AC PET

Non-AC PET

Figure 6

Whole body MIP, selected coronal and transaxial NaF PET images demonstrate a linear cold artifact in the skull, more prominent on the left side (A, arrow) which is not present on non-AC PET images (B).

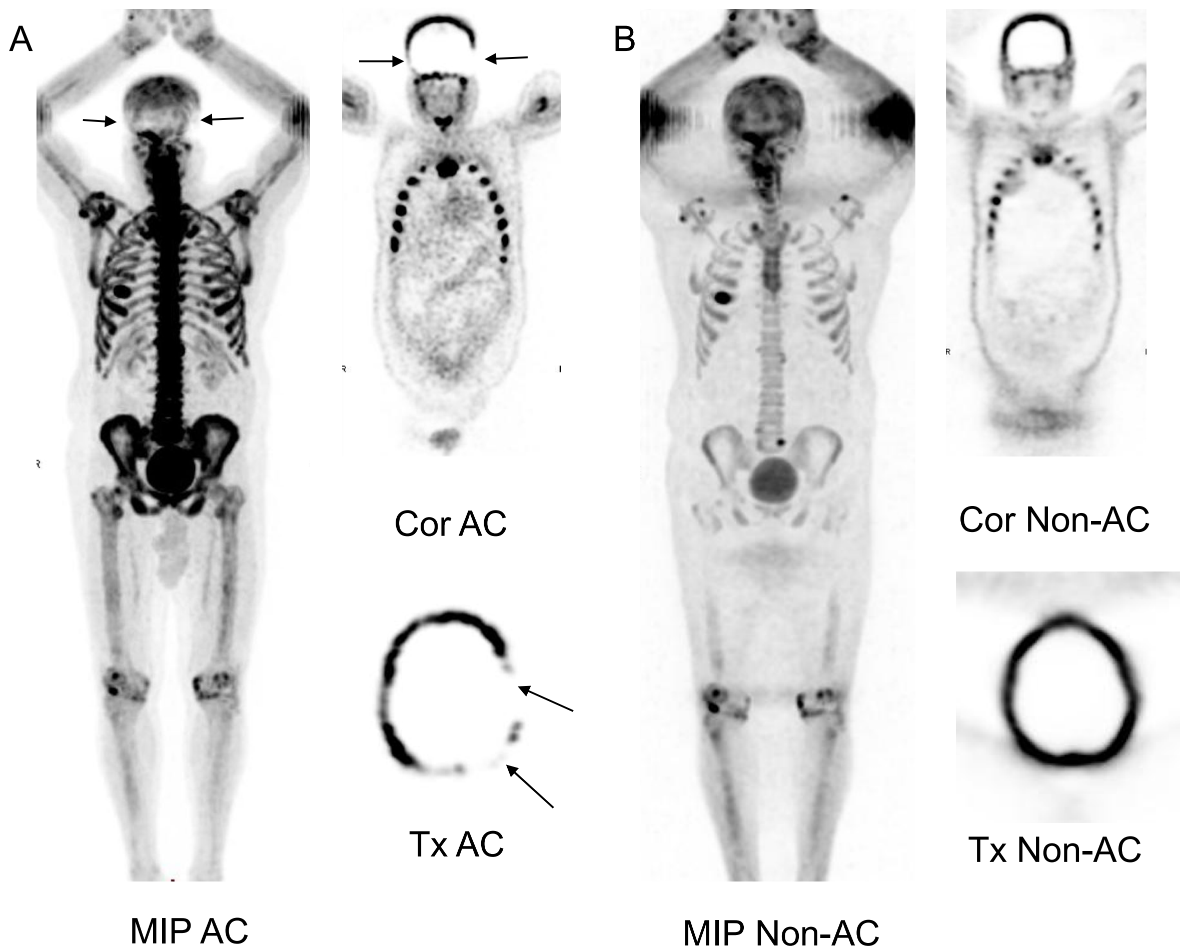


Figure 7

A-NaF PET MIP image demonstrates arm motion artifacts bilaterally (arrows). B- Accidental intra-arterial injection of radiotracer causing diffusely increased uptake in the tissues of left forearm and hand seen on FDG PET MIP image.