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Positron Emission Tomography/Computed Tomography: Protocol Issues and Options

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Combined positron emission tomography/computed tomography (PET/CT) became FDA-approved for clinical use in late 2001. There are several design advantages of combined PET/CT over PET and CT acquired on separate devices, including more accurate CT and PET data co-registration, improved lesion localization, consolidation of imaging studies, and reduced scan times compared to dedicated PET. There are several protocols that can used to scan patients on combined PET/CT devices. Although there is no single "correct" protocol for performing a PET/CT scan, the use of oral and intravenous contrast media may improve the diagnostic value of the CT component. Whether to utilize contrast media depends on important clinical variables, including the specific type of tumor and the likelihood of encountering viable abdominal and pelvic malignancy. This article discusses various protocols pertinent to PET/CT imaging, including how the CT portion of a PET/CT scan can be performed and optimized, as well as PET/CT interpretation and reporting issues.
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Combined positron emission tomography/computed tomography (PET/CT) has been in clinical use for nearly 5 years after its development and initial evaluation at the University of Pittsburgh from 1998 to 2001.[1-5] Advantages of combined PET/CT over PET and CT acquired on separate devices include more accurate CT and PET data coregistration (Fig. 1), improved lesion localization, consolidation of imaging studies, and reduced scan times compared with dedicated PET. In addition, the PET/CT gantry opening has a large enough design to accommodate a flat pallet for radiation therapy planning purposes, potentially offering more accurate assessment of tumor volume.

There have been many technological developments since the prototype PET/CT scanner, with newer-generation PET/CT scanners using 2- to 64-slice (detector-row) CT scanners and "high-resolution" PET scanners with 4-mm lesion detectability. On commercial PET/CT scanners, the CT can be performed as a stand-alone procedure, whereas typically the PET component cannot be used without first performing CT.

There are many CT and PET scan protocol decisions to consider with PET/CT, as well as logistical and personnel issues that can affect interpretation and reporting. This article will discuss various protocols pertinent to PET/CT imaging, including a discussion of how the CT portion of a PET/CT scan can be performed, as well as a discussion of PET/CT interpretation and reporting issues.

Standard PET/CT Protocol

One of the major benefits of combined PET/CT is the ability to acquire accurately coregistered PET and CT images in a single imaging session. However, the general protocols for CT are different with PET/CT because, unlike PET imaging, which typically is a neck-through-pelvis survey of the body, CT traditionally has been performed for regional evaluation (eg, head, neck, chest, abdomen, and pelvis). PET/CT imaging protocols therefore must be adjusted to adequately evaluate the primary area of malignant involvement, as well as the most likely areas of tumor spread.

For a typical "diagnostic" PET/CT scan using oral and intravenous (IV) contrast for the CT, patients generally are given oral contrast and injected with ^{18}F-fluorodeoxyglucose (FDG) approximately 1 hour before scanning. The patient subsequently is positioned in the PET/CT scanner and immobilized as indicated (for instance, soft collars may be used to reduce neck movement in patients with head and neck cancer or lymphoma with neck involvement). The first step in a standard PET/CT protocol generally involves the acquisition of a digital scout radiograph, in which the full patient is visualized and the area of interest is selected (Fig. 2 [#1]). Patients then undergo the CT portion of

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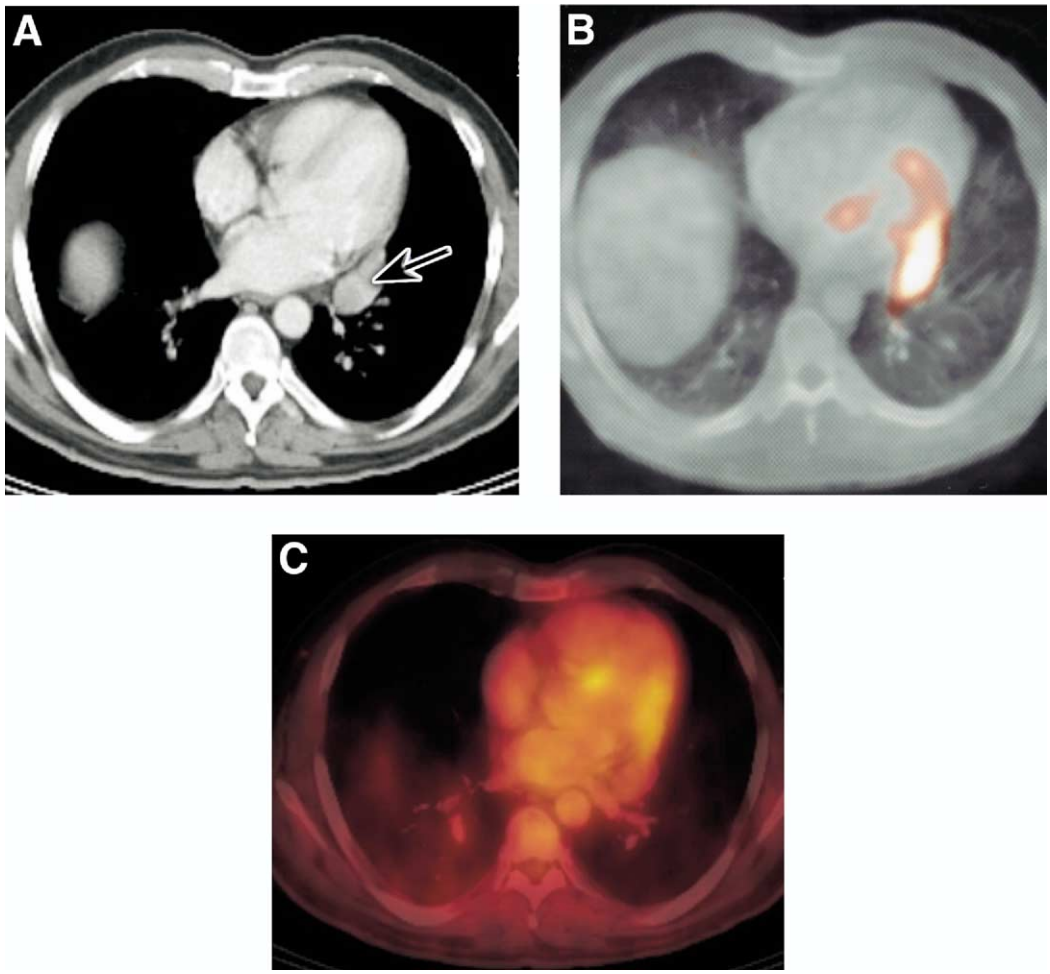

Figure 1 Inaccurate retrospective co-registration. This patient was referred from an outside institution for evaluation of a pericardiac mass identified on axial CT (arrow) (A). The CT was subsequently retrospectively coregistered to axial corresponding PET images acquired on a different device to give the axial fused PET and CT image (B). Initial interpretation of the fused image in (B) was that the mass was malignant. A repeat PET/CT was performed at UPMC on a hardware-based combined PET/CT device, and an axial PET/CT image (C) shows only minimal FDG activity in the pericardiac mass. The original coregistration misregistered cardiac FDG activity to the pericardiac mass. Subsequent biopsy showed a benign hamartoma, compatible with the findings on the repeat PET/CT.

the examination (Fig. 2 [#2]), followed by the PET portion of the examination (Fig. 2 [#3]). A common misconception is that the CT and PET data are acquired simultaneously; however, the data are acquired sequentially, with CT always performed first. Most scanners without a separate transmission rod source will not allow PET acquisition only but will allow dedicated CT acquisition. Because of the sequential data acquisition, there is still a high probability of CT and PET image misregistration if the patient moves between the CT and PET portions of the examination (Fig. 3). Once attenuation correction (AC) and scatter correction are performed using the attenuation coefficients from the corresponding CT portion of the scan (Fig. 2 [#4]), fused accurately coregistered images are available for interpretation (Fig. 2 [#5]).

Protocol Options

One important PET/CT protocol decision is whether IV contrast will be used and how and when it will be administered. There are different CT scan protocols for combined PET/CT that are performed in clinical practice today: (1) noncontrast with low current (~40 mAs used for AC and localization only) (Fig. 4A), (2) noncontrast with normal current (~140 mAs), (3) normal current with IV and/or oral contrast (Fig. 4B), or (4) both low-dose (for AC) and full-current (for diagnostic interpretation) CT (Fig. 4C).[6]

Low-Dose Noncontrast CT

Performing CT at a low-dose (~40-60 mAs) reduces the sensitivity and specificity of the modality for detecting malignant lesions but usually is adequate for general anatomical localization and is sufficient for performing PET AC. In this method, the CT replaces the typical transmission scan performed on dedicated PET scanners, significantly reducing scan times (as much as 40%) relative to dedicated PET. It also provides better anatomical localization compared with traditional point source–based transmission scans, particularly in

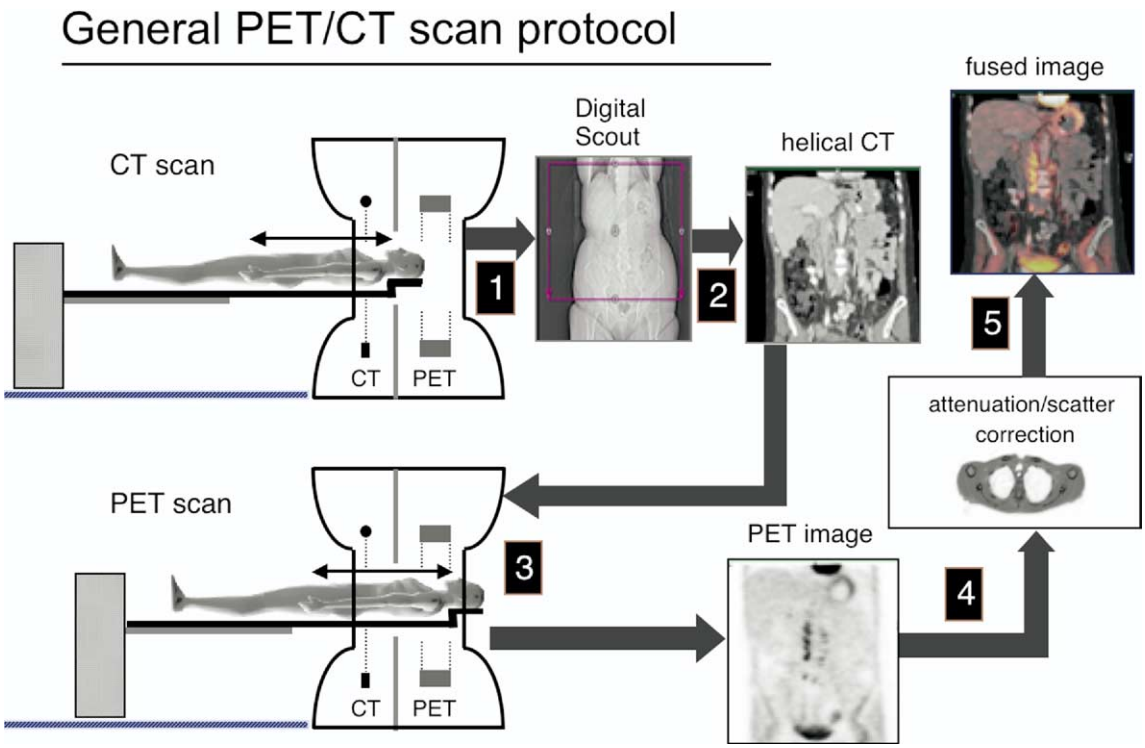

Figure 2 Standard PET/CT Protocol. A digital scout radiograph is first acquired, in which the full patient is visualized and the area of interest is selected (1). Patients then undergo the CT portion of the examination (2), followed by the PET portion of the examination (3), Once attenuation correction and scatter correction are performed using the attenuation coefficients from the corresponding CT portion of the scan (4), fused, accurately coregistered images are available for interpretation (5). (Figure courtesy of David W. Townsend, University of Tennessee, Knoxville, TN.)

the lung (Fig. 5). Outpatient imaging centers without medical personnel that are available immediately or centers in which the interpreting physician is trained in PET/nuclear medicine generally use this type of scanning algorithm. In addition to the decreased diagnostic sensitivity, additional disadvantages of this type of approach include the presence of CT images that need to be interpreted but generally cannot be billed for separately because of the poor quality of the images (Fig. 5). If clinically indicated, a separate diagnostic-quality CT may be performed as part of the PET/CT scanning session or as a separate CT performed on another CT scanner. However, in addition to decreasing the accuracy of the coregistration, using another device to acquire a diagnostic CT diminishes the advantage of imaging consolidation provided by PET/CT.

Noncontrast CT

This method uses a full-dose CT before performing the PET portion of the examination. This method might be performed in patients with a significant contrast allergy or, perhaps, in

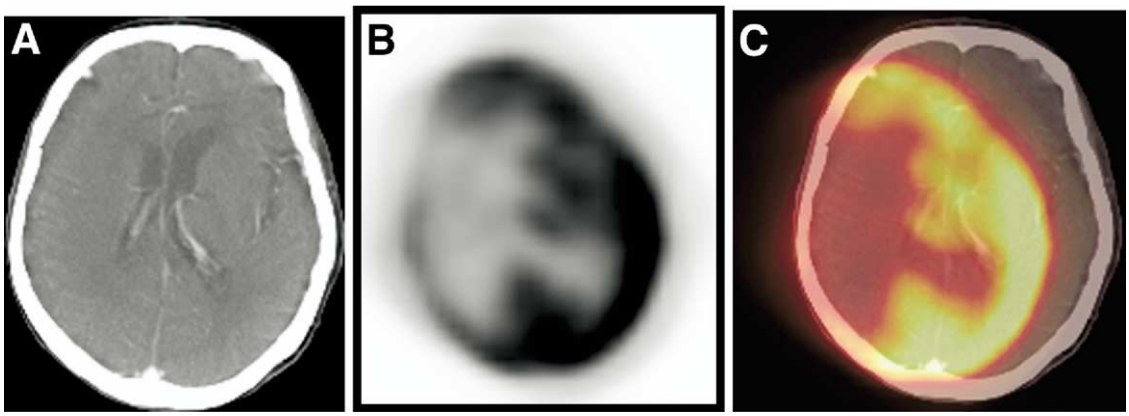

Figure 3 Misregistration caused by patient movement. Misregistration of axial CT (A) and PET (B) images are shown on an axial PET/CT image (C). This type of misregistration is due to movement of the patient's head to the right after the CT acquisition (during the PET acquisition).

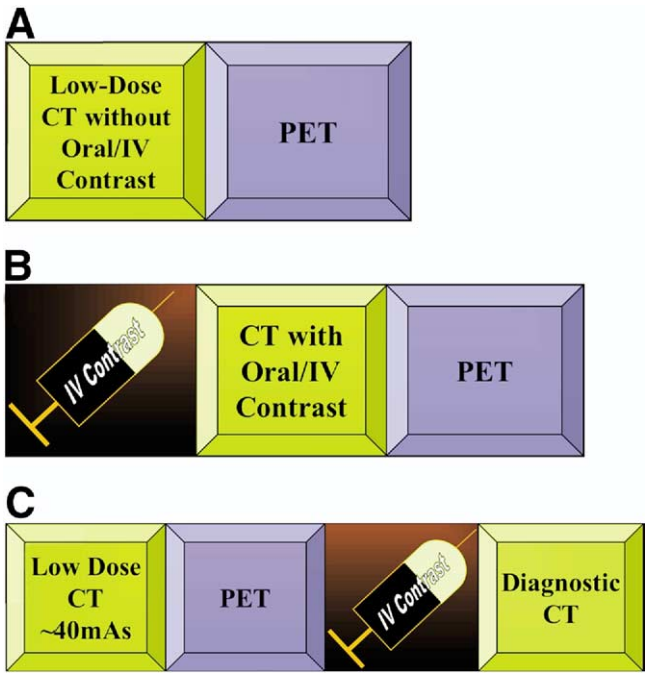

Figure 4 PET/CT protocols with and without IV contrast. Shown are 3 commonly used protocols in PET/CT imaging. (A) The first protocol uss the CT for attenuation correction and localization purposes; however, the CT is inferior quality to a CT scan performed at full dose with oral and IV contrast, as performed for the second protocol (B). The last protocol (C) uses the first low-dose CT for attenuation correction to avoid artifacts caused by contrast and uses the second full-dose contrast-enhanced CT for diagnostic purposes.

patients being evaluated for a single pulmonary nodule. The CT portion of the examination generally is interpreted and reported, particularly in cases in which this is the desired CT imaging protocol.

Contrast-Enhanced CT

The protocol that takes maximal advantage of the original design concepts of a state-of-the-art CT and PET in the same device is one that uses contrast-enhanced CT protocols for PET/CT imaging. This method attempts to maximize the diagnostic potential of the CT scan by using both oral and IV contrast before performing the PET portion of the examination. Depending on the quality of the CT component, the PET/CT scanner, these images may be comparable to the quality of a CT scan performed on a dedicated CT scanner.[6-9] However, factors including breathing artifacts and large scanning field of view can result in significant differences in the quality of the images.[10]

One important consideration for the use of IV contrast is whether there is appropriate medical coverage available to respond to possible untoward contrast reactions. Also debate still exists as to whether IV and/or oral contrast offer overlapping, purely complementary, or synergistic information, given the added information offered by FDG on the PET part of the examination. Several studies have been published confirming improved diagnostic accuracy of contrast-enhanced CT compared with that of noncontrast CT for differentiating between benign and malignant processes.[11-35] Although many of these studies demonstrate a diagnostic improvement of contrast over noncontrast CT, many also suggest that, for various tumor types, using a multiphasic enhancement technique may further improve the diagnostic capability of CT. Malignancies with characteristic enhancement patterns, such

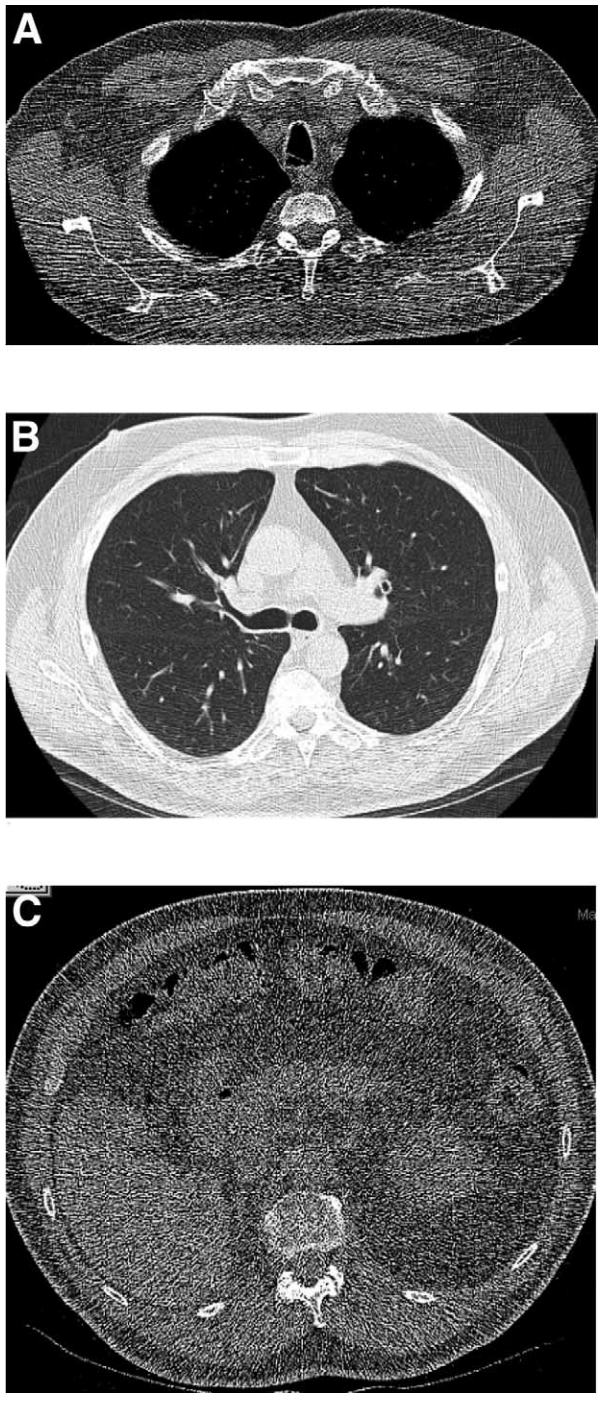

Figure 5 Low-dose CT performed at 40 mAs. Select images from a CT scan performed at 40 mAs show poor quality of the images obtained at this tube current with the exception of the lung. This method generally provides more information in the thorax (A and B) than in the neck and abdomen (C), where there is more tissue to attenuate the radiation beam from the CT.

as hepatocellular carcinoma, which generally enhance (and may only be detectable) during the arterial phase, may be less apparent on portal venous or delayed-phase images.[11,16,31] Conversely, cholangiocarcinomas may show delayed enhancement, and optimization of the CT protocol for this indication includes performing a delayed-phase scan at approximately 10 minutes. These types of protocols are possible with PET/CT, although they require more planning and, in some cases, more time.

Because most oral and IV contrast agents have the potential of generating artifacts on the AC PET images on most scanners, there are also protocol considerations when using contrast agents for the CT portion of a PET/CT examination. These artifacts, which are discussed in more depth in the subsequent sections, generally are easy to recognize and not usually clinically relevant. In addition, contrast agents render vessels and bowel distinct from other structures, helping to improve reader confidence and specificity in differentiating benign from malignant FDG uptake. Centers must, therefore, weigh the potential benefits of having a contrast-enhanced CT with the disadvantages of AC artifacts on PET from using contrast. At the University of Pittsburgh Medical Center, the overwhelming majority of CT scans performed as part of a PET/CT are performed with oral and IV contrast.

Low-Dose CT Followed by Contrast-Enhanced CT

One way to avoid CT AC artifacts caused by IV contrast is to perform a low-dose noncontrast CT that can be used for AC first. Then, after the PET portion of the examination, a contrast-enhanced CT can be performed for diagnostic purposes. However, the disadvantage of this protocol is an increase in the radiation exposure to the patient because they are undergoing 2 CT scans.[36]

Artifacts on PET/CT Related to CT Protocols

IV Contrast AC Artifacts

As mentioned previously, one of the stated reservations about the use of contrast media is that they may cause artifacts on the AC PET images when using CT for AC.[9,37-40] When dense contrast material is present in central venous structures during the CT acquisition, but not during the PET portion of the examination, there tends to be an overcorrection of the PET data. This mismatch causes an area of linear artifact (mimicking intense FDG accumulation) on the AC PET images (Fig. 6).[41] Atypically, this artifact can appear focal and mimic a malignant lymph node in the axilla or supraclavicular area.[40] Conversely, a focus of FDG-avid tumor also could be obscured by the artifact.[41] In addition, artifacts can have atypical appearances that can confound image interpretation as well. A relatively simple solution to diagnostic uncertainty regarding the presence of a CT-based AC artifact is to inspect the non-AC PET images, which should show no evidence of FDG activity. Unfortunately, it can be cumbersome to switch between the AC PET data and non-AC PET data using many PET/CT viewing systems, and some fusion viewing systems will not allow side-by-side comparison of AC and non-AC PET images. Alternatively, venous AC artifacts can be reduced by using dual-head CT contrast injectors that uses a saline flush after the contrast bolus to decrease the amount of contrast material in the central veins.

Oral Contrast AC Artifacts

Several oral contrast agents are available for clinical use in diagnostic imaging. In general, oral contrast agents should be given no longer than 1 hour before scanning to maximize the potential that all small bowel loops are ideally opacified but avoiding the dense concentration of contrast within the colon that occurs with longer delays. There are several different types of oral contrast media. Undiluted barium is not recommended for PET/CT because it will cause both streak artifacts on the CT portion of the examination, as well as severe AC artifacts on the PET portion of the examination. A standard dilution of water soluble oral contrast such as Gastroview (Mallinckrodt Inc, Hazelwood, MO), using a 2% solution of sodium and meglumine diatrizoate will tend to cause some degree of AC artifact (Fig. 7), whereas contrast agents that are lower in attenuation, such as Volumen (E-Z-EM Inc, Westbury, NY), generally do not.[42-48] Most of the time, there is overlap of physiologic and artifactual bowel activity, and as long as the appearance of bowel activity is linear, it usually is not a source of concern. However, when the oral contrast AC artifacts are more focal or irregular, they can be a diagnostic challenge. It is imperative to check the non-AC PET data in these instances to be sure that a suspected lesion is not an AC artifact.

Although some studies suggest that the use of oral contrast media does not typically cause clinically significant AC artifacts,[48] it has been reported by a different group that collections of barium-based oral contrast material within the bowel do cause artifacts and overestimates of FDG activity in the bowel by as much as 20%.[48,49] The same group has proposed a region-growing CT-based AC algorithm that appears to correct most, if not all CT-based AC artifacts. However, most PET/CT scanners to date do not use this alternative method of AC.

It is still unclear to some interpreting physicians what the added clinical value of oral contrast is with PET/CT scanning given the additional information that is obtained by having FDG from the PET portion of the examination. However, when there is focal FDG uptake representing a possible metastatic lesion, it is helpful to have improved contrast of structures offered by using IV and oral contrast, even if a lesion shows only subtle enhancement. Several benign processes also have characteristic enhancement patterns that would otherwise be difficult to diagnose confidently without contrast (Fig. 8).

It may be helpful to create contrast protocols based on indications, for instance, patients having tumors with a low prevalence of abdominal metastases (eg, primary head and neck carcinoma) might be scanned without the use of oral contrast medium, whereas those with a greater likelihood of abdomino-pelvic tumor would receive contrast.

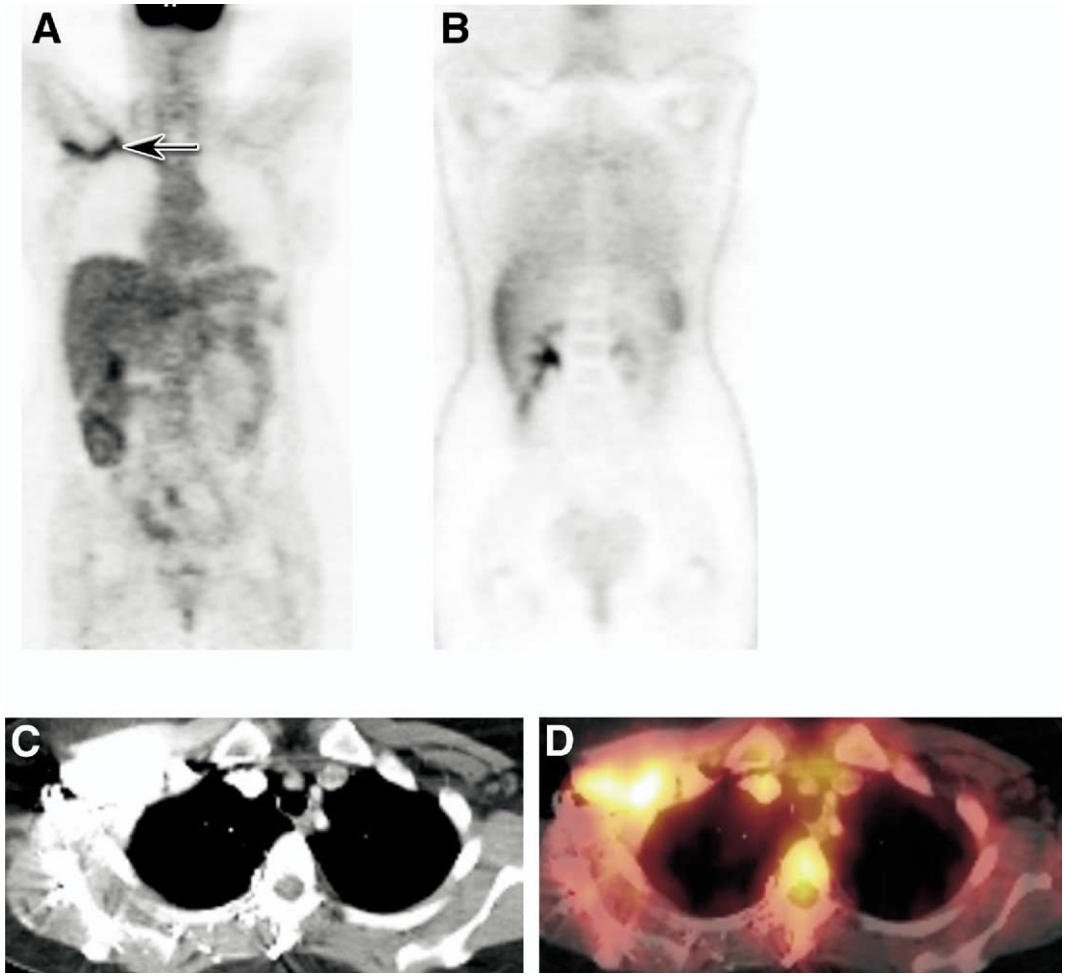

Figure 6 IV contrast AC artifact. (A) Coronal AC PET image shows linear FDG activity in the area of the right subclavian vein (arrow) correlating to IV contrast within the right subclavian vein (C and D). However, inspection of the non-AC PET image (B) shows no evidence of FDG activity, compatible with an AC artifact.

Diaphragmatic Respiratory Artifacts

Non-AC–based artifacts specific to PET/CT imaging also have been observed. Diaphragmatic motion during the CT acquisition can cause portions of the liver to appear displaced into the thorax (Fig. 9).[10,50-52] Because CT typically is acquired with a breathhold at deep inspiration and PET typically is acquired during tidal respiration, there is an inherent mismatch in the diaphragmatic position during data acquisition that is most severe at a breathhold with deep inspiration. The magnitude of these diaphragmatic breathing artifacts is dependent on how long it takes to acquire the data and on patient breathing instructions. Therefore, with slower single- and dual-slice CT scanners, this artifact is seen in as many as 80% of patients when the CT data are acquired with tidal breathing,[10,53] whereas there is significantly less diaphragmatic artifact with 16-slice CT scanners. Another way to reduce breathing artifacts is to use a modified breathing algorithm, as described by Beyer and coworkers,[10] instructing the patient to maintain shallow tidal respiration until the CT detector is near the bottom of the thorax, at which time the patient is instructed to stop breathing wherever he or she is in the respiratory cycle, until the detector has passed through the liver. Breathholding until the CT detectors are through the liver minimizes respiratory motion and thus reduces subsequent diaphragmatic breathing artifacts.

These diaphragmatic artifacts are the most clinically significant when there are lesions in the superior liver or in the lower thorax, potentially causing a liver tumor to be mistaken as a lung tumor, or vice versa (Fig. 10).[54] Radiotherapy applications are more difficult as well because of the mismatch in the anatomical structures.

Arm Positioning

Unlike dedicated CT, where short scan times allows for routine scanning with the arms kept out of the field of view, with PET/CT the arms may often be kept in the field of view to minimize patient discomfort. When the arms are positioned at the side of patients, there can be significant beam hardening and streak artifacts in the CT images (Fig. 11), which can be especially problematic when the artifact overlaps with the area of interest. One potential solution is to scan all patients with arms raised, which reduces the potential for artifacts in the chest and abdomen. In patients with head and neck malignancies or clinical concern of neck involvement, a second

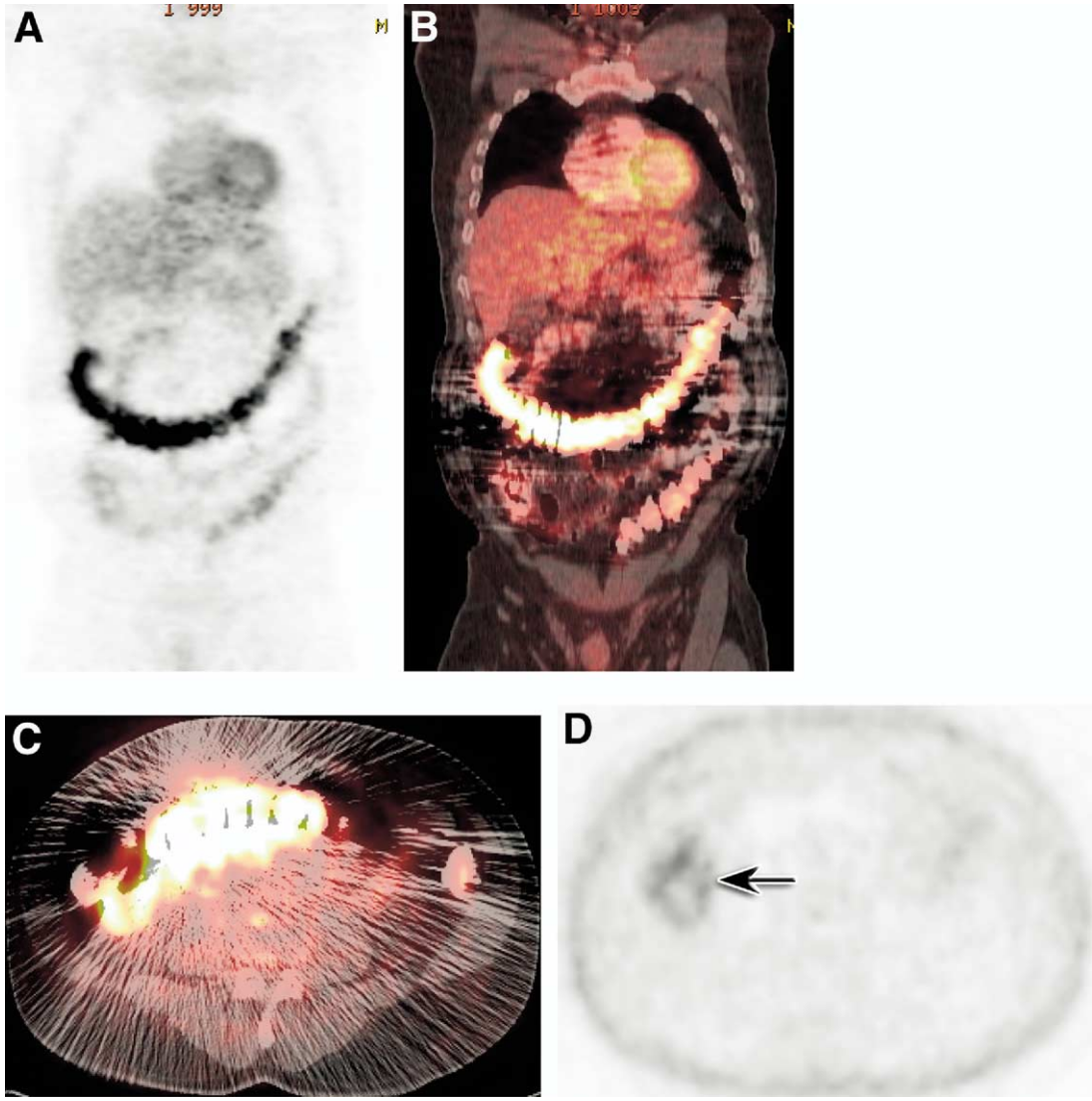

Figure 7 Enteric contrast artifact caused by retained thick barium. Coronal PET (A), fused PET/CT (B), and axial fused PET/CT images (C) show apparent intense FDG activity correlating to high-attenuation contrast material within the colon. Inspection of the axial non-AC PET image (D) shows that there is only minimal FDG activity in the proximal transverse colon (arrow) caused by physiologic activity, and the artifactual intense FDG uptake seen on the other images is artifactual, introduced during the attenuation correction process. Barium-based contrast agents become more concentrated in the colon, especially if given too long before the PET/CT examination.

examination focused on the neck can be performed with the arms down. Faster scanners make more patients able to tolerate having arms raised above their head. Others have recommended placing arms in pillows at various heights by the patient's side.

Reimbursement Issues

New PET/CT codes recently have been developed, including 78,814 (limited area), 78,815 (skull base to mid-thighs), and 78,816 (whole body). These are used for PET acquired on a PET/CT scanner, and the charges/reimbursement are slightly higher than for the dedicated PET codes 78,811, 78,812, and 78,813, reflecting the increased capital cost to purchase the combined device.

In general, diagnostic (contrast-enhanced in most instances) CT studies should not be performed unless medically necessary and ordered by the referring physician. For cases in which a diagnostic CT is performed, The Centers for Medicare and Medicaid Services (CMS) have designated a 59 modifier to be used to charge for the CT portion of the examination in addition to using the appropriate PET/CT billing code. For other third party payers, billing may still revert to the older diagnostic PET and CT codes when a diagnostic CT is performed.

Suggested Protocols

PET and PET/CT are covered by CMS and most third-party payers for several malignancies to evaluate initial diagnosis,

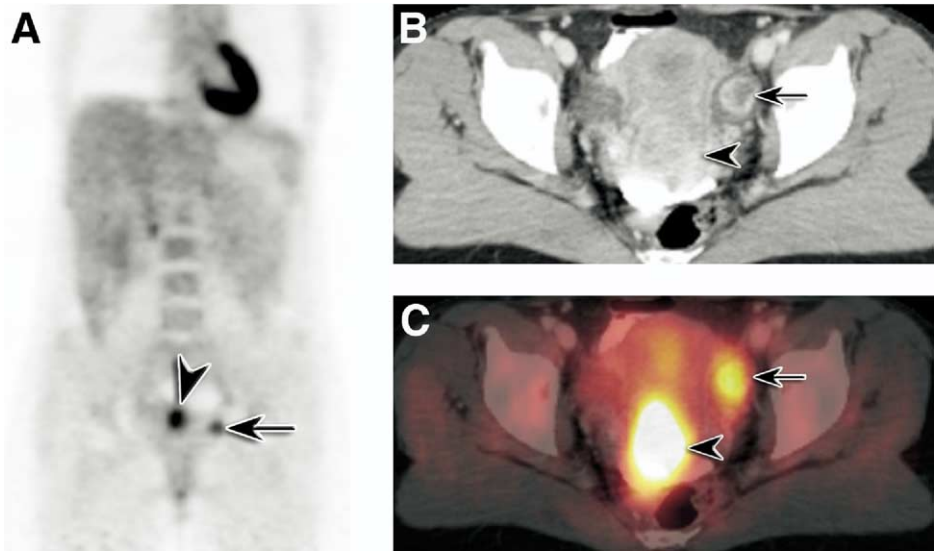

Figure 8 Corpus luteal cyst mimicking a left adnexal metastasis. (A) On coronal PET, abnormal uptake is present within a primary cervical carcinoma (arrowhead), as well as in the left adnexa (arrow). Axial CT and fused PET/CT (B and C) show intense FDG activity within the cervical carcinoma (arrowheads) and less FDG uptake in the left ovary (arrows). The contrast-enhanced CT shows the typical appearance of a corpus luteal cyst with a thick rind of enhancement in an otherwise normal appearing ovary. Subsequent resection of the left ovary confirmed a hemorrhagic corpus luteal cyst rather than a metastatic lesion.

staging and restaging; however, it is not clear whether all patients require a diagnostic CT as part of their PET/CT examination. At the University of Pittsburgh, we have attempted to identify potential patient populations that might be adequately evaluated by a low-dose CT as part of the PET/CT in an attempt to optimize the appropriate use of PET/CT, as well as to decrease overall cost of the examination, without compromising patient care. One potential group of patients in whom a low-dose CT may be sufficient is asymptomatic patients with successfully treated malignancies undergoing surveillance imaging and in whom the overall index of suspicion for viable tumor is low. For example, patients with lymphoma often respond well to therapy with reduced tumor size and decrease in metabolic activity but

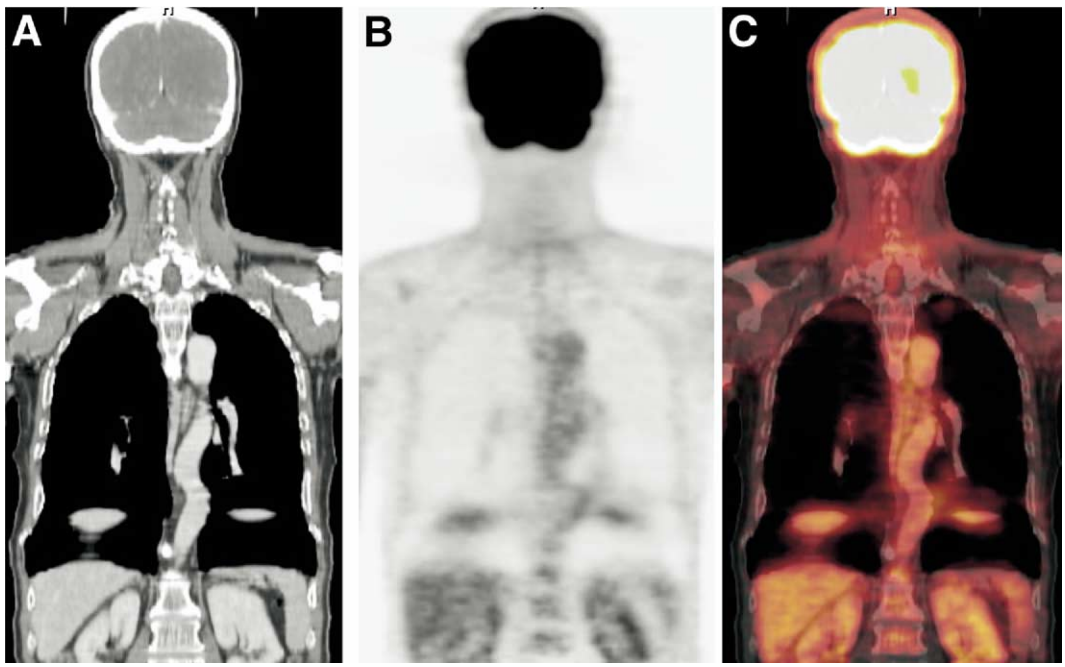

Figure 9 Diaphragmatic breathing artifact. Coronal CT (A), PET (B), and fused PET/CT (C) images show a portion of the superior liver to appear detached into the thorax because of repeat sampling of the same area by the CT detector when the diaphragm is at different positions.

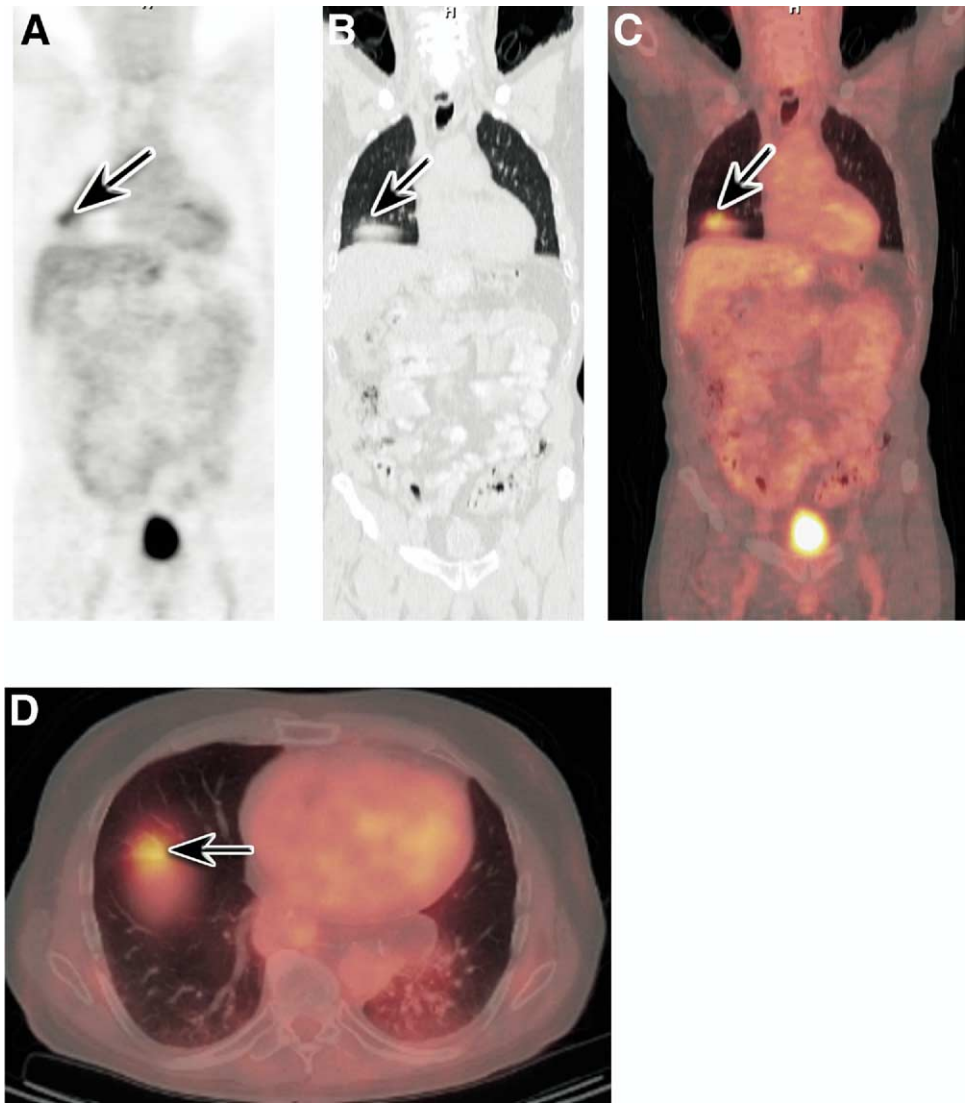

Figure 10 Bronchoalveolar cell carcinoma adjacent to diaphragmatic artifact. Coronal PET (A) shows an area of FDG activity in the lower chest (arrow). Inspection of the coronal CT (B) and PET/CT-fused images (C) shows a subtle mild-to-moderate FDG-avid lesion immediately adjacent to a diaphragmatic breathing artifact from CT acquisition with tidal respiration. Subsequent biopsy showed bronchoalveolar cell carcinoma.

need to be evaluated several times per year for several years because this is the period of highest risk for recurrence. Given a low index of suspicion for viable tumor, a low-dose CT might be used for the PET/CT to reduce the radiation dose and overall cost of the procedures. However, any patient that is suspected of having active disease, regardless of his primary malignancy, is optimally evaluated with a diagnostic contrast-enhanced CT.

Another group of patients that may be sufficiently evaluated with a low-dose CT are patients who are being evaluated for a solitary pulmonary nodule and who have had a good-quality CT scan performed recently (generally no longer than 3-4 weeks). It is likely that a contrast-enhanced or full-dose noncontrast CT would offer little additional information in this subgroup of patients. At our institution, these 2 patient populations (surveillance of lymphoma in asymptomatic patients and solitary pulmonary nodule evaluation in patients with a recent CT) make up approximately 35% of all patients scanned.

Who Should Interpret PET/CT

The issue of who is qualified to interpret a PET/CT scan is controversial and beyond the scope of this review. However, certain observations warrant consideration. Physicians interpreting imaging studies generally are held responsible for recognizing and reporting abnormalities that are present on the images, even if the explicit reason for obtaining the study is outside the expertise of the interpreting physician. For example, orthopedic surgeons interpreting musculoskeletal magnetic resonance scans or cardiologists interpreting cardiac CT or chest radiographs have been found to be medicolegally negligent for missing neoplastic lesions present on the studies performed. Although we are unaware that this prin-

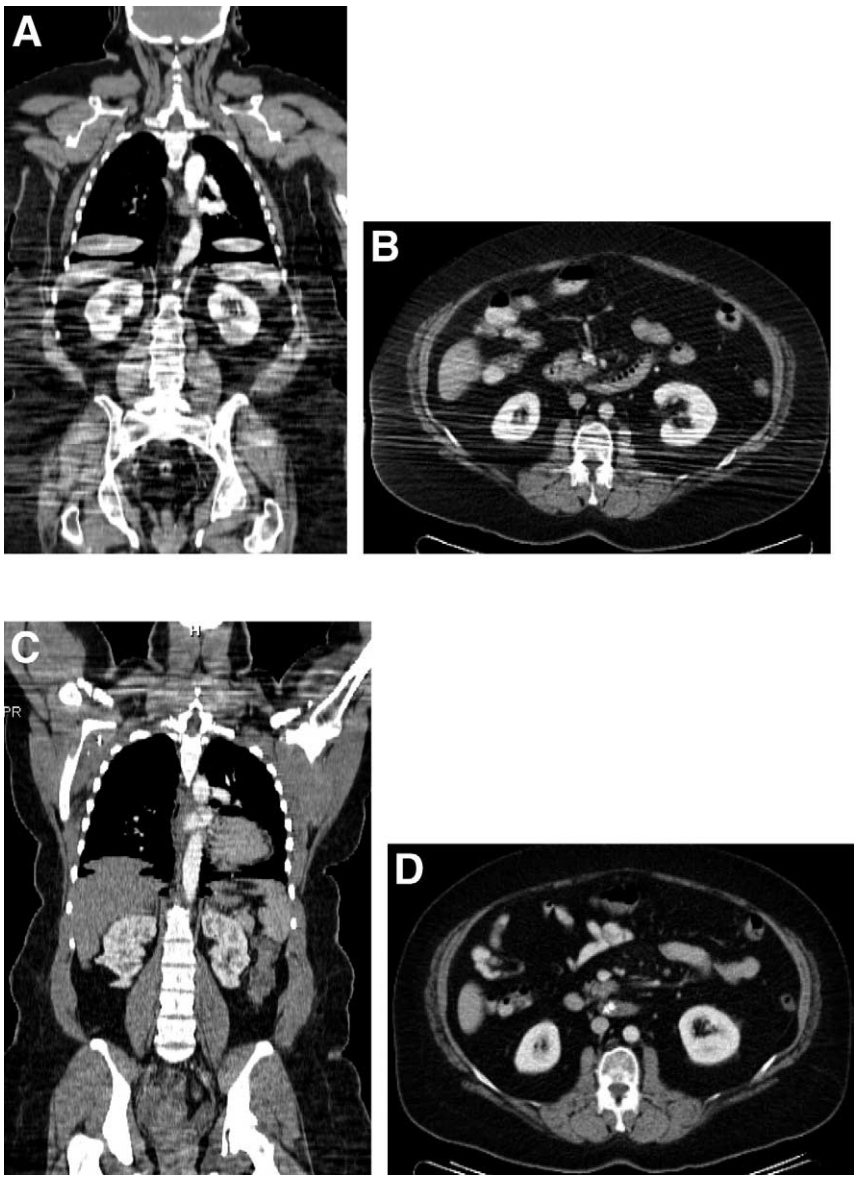

Figure 11 Effect of arm positioning On CT image quality. Coronal (A) and axial (B) CT images from a patient scanned with arms positioned at the patient's side, showing beam-hardening artifacts in posterior abdomen caused by the increased beam attenuation from the upper extremities. CT of the same patient scanned with the arms positioned above the patient (C and D) shows resolution of the artifact in the abdomen but now shows it in the area of the neck.

ciple has yet been tested for PET/CT interpretation, it seems likely that the interpreting physician would be held liable for lesions evident on the CT portion of a PET/CT scan, even if a disclaimer is included stating that the CT was acquired for the purposes of attenuation correction and localization, rather than for diagnostic purposes. If enough information is present on a CT scan to make a diagnosis, it may be regarded as diagnostic by definition, regardless of whether it is of poor quality. Many tumors that are not FDG-avid will be evident on CT but may be overlooked by an interpreting physician unfamiliar with the wide range of appearances of tumors and benign masses on CT scans (Fig. 12). Similarly, one should not interpret the PET portion of the examination without being thoroughly familiar with the range of normal and artifactual FDG-avid "lesions" that may be encountered.

The issue of proper training and credentials for physicians interpreting the PET and CT portions of the examination has been addressed recently by a task force comprised of members of the American College of Radiology and Society of Nuclear Medicine.[55]

Future Direction of CT Protocols

Very few studies have been performed actually comparing noncontrast with contrast-enhanced PET/CT. Even fewer studies have addressed the issue of whether multiphasic enhancement of the CT portion of a PET/CT offers any potential benefit. However, a single phase of contrast enhancement for CT may not be optimal or adequate in some settings. For example, some hepatic tumors are variably FDG–avid and are

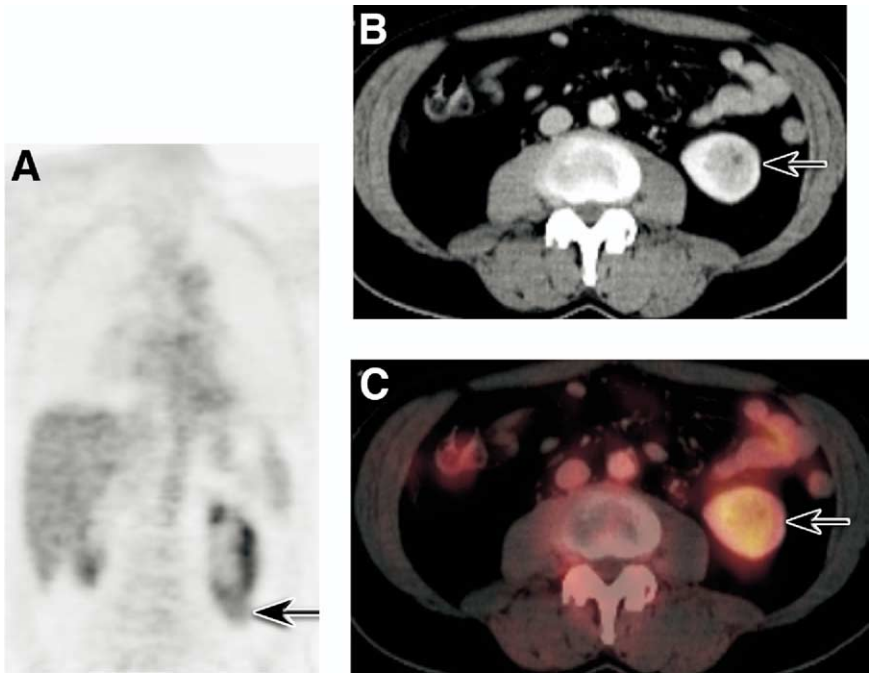

Figure 12 Renal cell carcinoma. Coronal PET (A) is normal and shows no focal abnormal FDG uptake, although there is a slight protrusion of the inferior pole left kidney (arrow). The contrast-enhanced axial CT (B) and fused PET/CT images (C) demonstrate an enhancing solid renal mass (arrow) in the inferior pole left kidney with very little FDG activity compatible with renal cell carcinoma (proven at resection).

well known to be reliably detected only on a particular phase of a contrast-enhanced CT scan. Hepatocellular carcinoma typically is detected optimally on only an "arterial-phase" contrast-enhanced CT scan, whereas cholangiocarcinoma usually is best seen on delayed enhanced CT. Neither arterial nor delayed-phase images acquired routinely on PET/CT examinations; rather, the CT images are acquired during a single phase of parenchymal enhancement, often referred to as the "portal venous" phase. Although it is possible to do a noncontrast, portal venous phase and delayed CT, it is difficult or impossible to obtain arterial and portal venous phases of imaging with the same bolus injection of contrast during a PET/CT examination. Because the software is designed to progress to the PET portion of the examination after a CT, most commercially available PET/CT scanners cannot quickly scan the patient during different phases of parenchymal enhancement. If arterial and portal venous phases are desired for a particular patient, the only current alternative is to perform two bolus injections, one for arterial acquisition and the second for the portal venous phase of imaging. More studies are needed to determine which patients may benefit from multiphase CT imaging in PET/CT.

Conclusion

There is no single "correct" protocol for performing a PET/CT scan. Important variables to be considered include the specific type of tumor and the likelihood of encountering viable abdominal and pelvic malignancy. The use of oral and intravenous contrast media may improve the diagnostic value of the CT component, but can give rise to artifacts that may interfere with interpretation. Artifacts can be minimized by attention to technique and the use of newer faster PET/CT devices.

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