

# The Clinical Dilemma of Incidental Findings on the Low-Resolution CT Images from SPECT/CT MPI Studies

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Incidental findings are common in medical imaging. There is a particularly high prevalence of incidental findings within the thorax, the most frequent being pulmonary nodules. Although pulmonary nodules have the potential to be malignant, most are benign, resulting in a high number of false-positive findings. Low-resolution CT images produced for attenuation correction of SPECT images are essentially a by-product of the imaging process. The high number of false-positive incidental findings detected on these attenuation-correction images causes a reporting dilemma. Early detection of cancer can be beneficial, but false-positive findings and overdiagnosis can be detrimental to the patient. Attenuation-correction CT images are not of diagnostic quality, and further diagnostic tests are usually necessary for a definitive diagnosis to be reached. Given the high number of false-positive findings, the psychologic effect on the patient should be considered. This review recommends caution when the findings on attenuation-correction CT images are routinely reported.

**Key Words:** SPECT; low-resolution CT; myocardial perfusion imaging

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**M**edical imaging uses a range of modalities that yield both anatomic and functional information (1). Visual correlation of images acquired using separate modalities can provide more information than images from a single modality alone, though there is an inevitable risk of misregistration between images that have been acquired during different imaging sessions. The development of hybrid imaging has led to the integration of two modalities in one machine, allowing coregistration of images that have been

acquired in a single session (1,2). This allows direct correlation of anatomic and functional information, increasing sensitivity and specificity while adding clarity to indeterminate cases (3). SPECT/CT offers an excellent example of hybrid imaging, combining the functional ability of SPECT with the anatomic ability of CT.

The strength of SPECT lies in gaining pathophysiologic detail in a minimally invasive way (4). Pathologic processes can be identified by uptake of radiopharmaceuticals, but the precise location is often difficult to ascertain because of low image resolution and a lack of anatomic landmarks. Moreover, uptake on some scans is often nonspecific, revealing abnormalities but not their specific cause. CT can provide a useful means of localization, also enabling additional characterization by virtue of providing a site-specific correspondence between anatomic and physiologic information.

SPECT images are susceptible to artifacts as a result of attenuation deficits due to scatter and absorption of photons (5–7). To improve image quantification and reduce attenuation artifacts, a low-dose CT acquisition can be performed and then used to correct the SPECT images for attenuation. CT attenuation correction is now in common use because it often improves image quality and increases overall diagnostic accuracy (5).

There are therefore 3 distinct reasons why CT may be combined with SPECT: First, CT can be used to characterize an abnormality seen on the SPECT images. This use usually requires a diagnostic-quality (high-resolution) CT scan. Second, CT can be used to localize an abnormality seen on the SPECT images. Third, CT can be used to correct the SPECT images for attenuation. This use requires only a low-resolution CT scan, typically using a much lower ionizing radiation dose than that required for diagnostic-quality CT. Although the images are considered to be nondiagnostic, they often reveal incidental findings.

In this article we discuss incidental findings on the low-resolution CT images produced for attenuation correction of SPECT images, with particular emphasis on myocardial perfusion imaging (MPI).

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## DEFINITIONS AND FREQUENCY OF INCIDENTAL FINDINGS

An incidental finding can be defined as an unsuspected finding that is not related to the clinical reason for performing the diagnostic test (8,9). Examples of incidental findings that can be identified on attenuation-correction CT images of the chest include coronary vessel calcification, vascular anomalies, valve replacement, pacemakers, atelectasis, effusion, consolidation, lobar collapse, nodules, masses, pulmonary metastases, ground glass opacities, and aortic aneurysm (20).

Incidental findings may or may not already be known from previous diagnostic tests. Findings that are already known to the clinician are likely to have a management strategy in place and therefore often do not require further investigation. Previously unknown incidental findings are termed new incidental findings and are likely to fall into 1 of 3 categories: clinically significant, clinically insignificant, or indeterminate. Clinically significant incidental findings are highly suspected of having an underlying pathology that may negatively affect patient wellbeing, requiring further investigation (9).

The frequency of incidental findings on attenuation-correction CT images is particularly high within the thorax (10), possibly because of the inherent contrast resolution and low attenuation of the x-ray beam through this area. Lung cancer shares comorbidities with heart disease—the clinical reason that these patients are being scanned. It is therefore not surprising that extracardiac pathology is frequently detected.

The high number of incidental findings identified on attenuation-correction CT images causes a dilemma. The acquisition is intended for attenuation correction alone and not for evaluation, and the relatively low resolution of the images means that characterization of findings is often not possible. Additionally, unlike diagnostic-quality CT images of the chest and abdomen, attenuation-correction images are likely to have breathing artifacts because patients are not required to hold their breath. The craniocaudal range of the acquisition is also limited to the cardiac area only; detection of incidental findings is therefore also restricted.

### INCIDENTAL FINDINGS ON SPECT/CT MPI

The number of incidental findings on the attenuation-correction CT images produced during SPECT/CT MPI is noteworthy, and the percentage of clinically significant and indeterminate findings can often be as high as 10% (10).

A high proportion of findings are pulmonary nodules (11). Although most lung nodules are benign, they have the potential to develop into lung cancer (12). Attenuation-correction CT images, which often reveal lung nodules as well as other pathologies, were never intended for radiologic reporting but there is growing evidence to suggest that they should be (10).

Lung cancer is the leading cause of death in most countries, including the United States (12,13). Early lung cancer is often asymptomatic, with symptoms usually arising only when the

disease is at an advanced stage. The prognosis for lung cancer is consequently poor (13). However, the prognosis for non-small cell lung cancer improves significantly if it is detected at an early stage when surgical resection is possible (12,13). This is not the case with small cell lung cancer. In the management of pulmonary nodules, the recommendations that have been developed from lung cancer screening trials suggest a necessary balance between early intervention to reduce mortality from lung cancer and the risk of early morbidity and mortality from intervention due to false-positive findings and overdiagnosis (11).

The high prevalence of lung nodules on CT of the chest is of particular concern during SPECT/CT MPI because any such findings will be incidental and may signpost a patient to an alternative or additional-care pathway. Although there is an argument for early treatment of lung cancer, the detection of lung nodules on attenuation-correction CT images does not necessarily result in reduced mortality from lung cancer. A high proportion of lung nodules are ultimately found to be benign, and the patient may not benefit, and may actually be harmed, from follow-up of these nodules.

This sentiment is echoed by the outcomes of lung cancer screening trials; for a screening program to be effective, mortality must be reduced and the benefits to the patient must outweigh the risks (12). The National Lung Screening Trial has demonstrated that it is possible to reduce mortality from lung cancer using low-dose CT screening in place of chest radiography and sputum tests (14). However, in doing so, there is a high rate of false-positive findings and overdiagnosis, as well as an increased radiation burden to the patient (15). Overdiagnosis of indolent tumors that would not have become symptomatic during the patient's lifetime have cost implications as well as raising patient anxiety and morbidity in the same way that false-positive findings might (16). Consequently, several organizations have decided not to implement screening programs. Where screening programs have been implemented, they are focused specifically on the population at high risk (17).

These considerations add to the dilemma of whether clinicians should review the attenuation-correction images. Reviewing them and providing a report may possibly enable early diagnosis of pathology and potentially a better prognosis. However, identifying incidental findings may increase risk to the patient without necessarily providing any benefit. Further diagnostic examinations are often associated with an increase in ionizing radiation dose and possibly invasive procedures that may carry physical risk and cause psychologic harm to the patient (9,18,19). Furthermore, only a small percentage of these incidental findings are significant at definitive diagnosis (9,20,21).

### CONTRAST ISSUES

There is often poor inherent contrast resolution between organs and soft tissues within the body due to relatively small differences in density. The use of contrast agents artificially improves contrast resolution between soft-tissue

structures. The iodination of the contrast agent increases the density within the organs and so will affect the extent to which the x-ray beam is attenuated. Different organs take up contrast at different rates, resulting in an increase in contrast resolution on the CT images. Similarly, pathologic tissue can demonstrate selective uptake of contrast agents; tumors that are highly vascular tend to enhance avidly whereas ischemic tissue tends not to enhance. This selective uptake improves demonstration of pathology in relation to normal tissue and aids characterization of the pathology. For this reason, it is unusual to perform diagnostic CT of the chest, abdomen, and pelvis without the use of an intravenous contrast agent.

The use of intravenous contrast agents with SPECT/CT is not without problems. Contrast agents will attenuate  $\gamma$ -rays in the same way that they attenuate x-rays. The result is degradation of the quality of the SPECT images. Contraindications relating to the use of iodinated intravenous contrast agents also exist.

It is because of the acquisition parameters used, along with the lack of an intravenous contrast agent to enhance contrast resolution, that attenuation-correction CT images are not considered diagnostic.

### IMAGE-QUALITY ISSUES

The quality of attenuation-correction CT images is directly related to how the images have been acquired, typically with a low tube current (mA) and a wide slice. The resulting low-resolution CT images enable attenuation correction to be performed. The long acquisition time results in motion artifacts from breathing. The nature of incidental findings can be difficult to determine, resulting in a high number of false-positive findings.

As technology has progressed, multidetector CT scanners have been utilized in some hybrid systems. Multidetector CT offers increased technologic capabilities with the potential to produce images superior in quality to the attenuation-correction images typically associated with earlier systems. The potential to acquire narrow slices, reduce imaging time, and increase the tube current has provided the option of improving image quality to a level that, in some cases, is comparable to that of diagnostic CT. Having this option has inevitably led to differences in the quality of the attenuation-correction images acquired in different departments, related not only to the

capability of the scanner but also to the way the parameters have been optimized (20). Ethical considerations arise when CT image quality is improved in this way, because there will be an inevitable increase in ionizing radiation dose to the patient in exchange for an uncertain gain.

### Radiation-Dose Considerations

CT image quality is dependent on how the data are acquired, reconstructed, and viewed. Ideally, we would choose the best image quality possible, but this would involve changing the acquisition parameters in a way that would greatly increase the radiation dose to the patient. Therefore, it is necessary to use a technique called optimization (22), the aim of which is to produce the required image quality with the lowest possible radiation dose. The result is not necessarily the best image quality or the lowest radiation dose but a compromise producing images tailored to the purpose for which they are acquired.

Diagnostic CT images are of sufficient quality for a diagnosis to be made. It is usually necessary for these images to have good spatial and contrast resolution and to be free of artifacts. This requirement does not apply to the attenuation-correction CT images acquired for MPI. Because the acquisition is merely for attenuation-correction purposes, the image quality can be significantly lower.

As shown in Table 1, the tube current used for attenuation-correction CT is much lower than that for diagnostic CT, enabling the radiation dose to the patient to be reduced. The resultant CT images will be noisy and have poor contrast resolution. The slices are usually considerably wider for attenuation-correction CT than for diagnostic CT. This greater width also has an effect on image quality, reducing the spatial resolution (ability to determine fine detail) but improving the contrast resolution. The long rotation time frequently associated with some of the older SPECT/CT systems results in a longer overall scanning time, rendering the attenuation-correction images susceptible to motion artifacts, especially within the thorax and abdomen. Although the presence of motion artifacts has no significance in CT images acquired for attenuation-correction purposes, it does become relevant when the intent is to make a diagnosis from the images.

### Diagnostic-Value Considerations

Studies investigating the influence of differences in attenuation-correction CT image quality on detection of

**TABLE 1**  
Differences in Acquisition Parameters Between Diagnostic CT and Attenuation-Correction CT for SPECT/CT MPI

| Parameter            | Diagnostic CT                       | Attenuation-correction CT |
|----------------------|-------------------------------------|---------------------------|
| Voltage (kV)         | 120                                 | 120                       |
| Tube current (mA)    | Automated (~300–400)                | 1.5–33                    |
| Rotation time (s)    | 0.33                                | 1.5–30                    |
| Effective mAs        | 100–130 (dependent on automated mA) | 24–50                     |
| Slice thickness (mm) |                                     |                           |
| Acquired             | 0.5–1                               | 5–10                      |
| Reconstructed        | 3                                   | 5–10                      |
| Pitch                | 0.75–1                              | 1–2                       |

nodules in chest phantoms have been performed using the Free-Response Receiver Operating Characteristic method. This method assesses observer performance and captures observers' ability to decide where the lesion is and to rate their confidence in this decision.

In a lung phantom study, varying the tube current (1, 1.5, 2, and 2.5 mA) of a SPECT/CT system while keeping all the other parameters unchanged had no statistically significant effect on lesion-detection performance (23). In a further lung phantom study involving a range of SPECT/CT systems, there was a difference in lesion detectability relative to the capability of the CT unit (24). These results were reproduced in a study using the same chest phantom on two different SPECT/CT systems. Here, lesion detection was more reliable on one system than on the other and was found to be related to the reconstruction algorithms used on one of the CT units rather than the acquisition parameters (25). The phantom was stationary in all studies and so did not truly represent the clinical situation in which motion artifacts from breathing would degrade the attenuation-correction CT images.

A 2-y multicenter study that took place in 4 nuclear medicine departments in the United Kingdom was granted local approval from each participating hospital and ethical approval from the University of Salford, following advice from the Health Research Authority (26). Positive findings were identified on the attenuation-correction CT images of 962 (28%) of 3,485 patients undergoing SPECT/CT MPI. Of these findings, 824 (24%) were new. Eighty-four patients (2.4%) had findings that were thought to be clinically significant at the time of the imaging and had not been discovered previously, but only 10 patients (0.29%) had findings that were confirmed to be clinically significant at definitive diagnosis. In this study, 74 of 84 patients had false-positive findings that involved follow-up diagnostic tests and possibly intervention before a definitive negative outcome was reached. The implied increased physical and psychologic risk to the patient raises the question of whether the attenuation-correction CT findings should be reported. The positive predictive value across all the centers was found to be low, and one center consequently stopped reporting the attenuation-correction CT findings. Statistically, the positive predictive values did not significantly differ between attenuation-correction CT images acquired on a lower-resolution machine and those acquired on a higher-resolution machine. The study concluded that routine reporting of attenuation-correction CT findings was not beneficial. The information from this study appears to be unique; no other similar clinical studies were identified.

Whether to report attenuation-correction CT findings is a common dilemma because the detection of early pathology can lead to an improved prognosis. However, further investigations to characterize the findings can be costly and can increase the radiation burden and other risks to the patient (27).

## PSYCHOLOGIC EFFECTS

False-positive incidental findings or findings that result in overdiagnosis can increase patient anxiety. Although diagnosis of malignancies at an early stage can potentially reduce patient mortality, only a very small percentage of findings on attenuation-correction CT images have been found to be malignant or detrimental to the patient at definitive diagnosis (28).

There is only limited literature surrounding the psychologic effects on patients who learn of incidental SPECT/CT findings. There is, however, an abundance of literature relating to the psychologic effect of a recent diagnosis of cancer, or the wait for a definitive diagnosis, and some parallels can be drawn to patients with incidental findings.

Patients who have incidental findings on a screening examination or are being imaged because of suspected cancer will usually have a care pathway and support structure in place, typically involving nursing, medical, and other professionals who are available to help patients and their families. This is often not the case for patients who have incidental findings on SPECT/CT. Such patients will receive limited support because of the unexpected nature of the findings.

Pulmonary nodules are one of the most frequent incidental findings on SPECT/CT of the thorax (19,29). These nodules can be single or multiple and can be of unknown significance. Most are benign, but if indeterminate the patient will require surveillance that may continue for 2–3 y (30). Almost all patients who are told they have a pulmonary nodule assume they have cancer (16). Just raising the possibility of cancer can be threatening (17) and can lead to distress until, and possibly beyond, definitive diagnosis (18).

Pulmonary nodules are of particular clinical relevance (8) because they do have the potential to become malignant, although most will be benign (31). Further management of pulmonary nodules is based on their size, with the likelihood of malignancy increasing with the size of the nodule (32,33). The indeterminate nature of pulmonary nodules frequently leads to follow-up CT imaging to monitor any change in the size of the nodule. If its size remains stable over a period of 2 y, it is considered benign. This lengthy period of repeated imaging inevitably increases the radiation burden to the patient along with the anxiety level. Biopsy of pulmonary nodules, which would give a more definitive answer, is often not possible because of their small size and location within the lung (32). Despite reassurance, the patients may believe they have cancer in the absence of a definitive diagnosis.

Lung cancer screening involves harm as well as benefit, and in some circumstances the harm can outweigh the benefit (33). This also applies to patients with incidental findings on attenuation-correction CT images. The harm from overtreatment of false-positive findings should be kept in mind when considering the benefits of reviewing these images (34). Although patients may gain some reassurance from a negative lung cancer screening, a negative

attenuation-correction CT scan from SPECT/CT MPI cannot be equally reassuring because of the limited range of chest MPI. A normal attenuation-correction scan does not exclude pathology that falls outside the limited range of the scan. In addition, early detection of lung cancer does not necessarily mean an improved outcome. Approximately 25%–30% of patients will present with potentially curable disease (35), but lung cancers develop quickly and metastasize early, often leading to a poor prognosis (19). Metastases often are present at the time of initial presentation. This frequently poor prognosis also needs to be balanced against the high rate of benign pathology detected on attenuation-correction CT (19).

The psychologic effects on patients who are diagnosed with false-positive findings can discourage patients from attending screening or diagnostic procedures in the future (33). If they have had a significant misdiagnosis, they are likely to lose trust in diagnostic procedures. Psychologic effects can be transient or more persistent. At initial diagnosis the patient is likely to experience anxiety, but over time this tends to develop into depression. Both anxiety and depression can persist before and after treatment (35).

#### FINANCIAL ISSUES

The financial impact of routinely reporting the findings of attenuation-correction CT, as well as the time required, needs to be considered. A radiologic report takes time to construct and, in the case of clinically significant findings, is likely to affect future management of the patient. The financial impact is justifiable when there is a net patient benefit, but such does not appear to be the case for attenuation-correction CT images, with their high yield of false-positive findings. Similarly, the follow-up examinations that may be needed to reach a definitive diagnosis have a cost and require time yet will not necessarily benefit the patient and may, in fact, be a potential cause of harm (36). Thus, the cost-effectiveness of reporting attenuation-correction CT findings is brought into question, along with whether such reporting will benefit or harm the patient.

#### CONCLUSION

Attenuation-correction CT yields low-resolution images that are not considered diagnostic. Although they can demonstrate pathology and commonly show incidental findings, the potential for missed or wrongly diagnosed pathology is higher than for diagnostic images.

Incidental findings can be numerous on the attenuation-correction CT images from SPECT/CT MPI studies and, regardless of the definitive diagnosis, can cause psychologic distress to the patient. One study has called into question the practice of routinely producing a report for these images (28). If the findings are reported, caution should be used and possibly a rider included to point out that the images are low-resolution and not intended for diagnosis. Careful consideration

should be given to the potential impact on the patient of a reported abnormal finding.

If the attenuation-correction CT findings are reported, a support structure and appropriate education similar to those in place for screening programs may help patients who have a clinically significant incidental finding.

#### DISCLOSURE

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

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