A review of the issues surrounding incidental findings on CT attenuation correction (CTAC) images during SPECT myocardial perfusion imaging

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Abstract

Incidental findings are not uncommon on medical imaging with a particularly high prevalence identified in the chest. Pulmonary nodules contribute to a large proportion of incidental findings within the chest and these can often hinder definitive diagnosis because of their indeterminate nature. This is especially true of the incidental findings demonstrated on low-resolution CT images produced during CT attenuation correction (AC), as utilised in single-photon emission tomography (SPECT). The CTAC 'images' are effectively a by-product that were not intended for use in diagnosis.

Although there is the potential for pulmonary nodules to become malignant, the majority will be benign. This gives rise to a high number of false-positive findings for CT imaging of the chest. The high number of false-positive findings identified on CTAC images raises an issue of whether these images should be reviewed. Whilst early detection of cancer could lead to earlier intervention and possibly improve prognosis, the high number of false-positive findings on CTAC images increases risks to the patient and does not necessarily raise the benefits. The non-diagnostic quality of CTAC images usually necessitates further diagnostic tests and possibly intervention before a definitive diagnosis can be reached.

A balanced decision needs to be made on whether to interpret CTAC chest images, given the high number of false-positive findings, the potential psychological effects and harms to the patient. The recommendation of this review is that caution should be taken if routine reporting of CTAC images is to occur.

Introduction

Radiological imaging has advanced greatly since the discovery of x-rays by Wilhelm Roentgen in 1895. A broad range of imaging modalities are available that together can provide functional and anatomical detail (1). Using a combination of imaging

modalities, it is possible to demonstrate normal anatomy, pathology and disease process.

Previously, when multiple imaging modalities were used in this way, image correlation was performed manually but it is becoming more common place now to integrate two modalities, one with functional capability and the other with anatomical capability, in the form of hybrid imaging. An example of hybrid imaging would be in the combination of single-photon emission tomography (SPECT) and computerised tomography (CT). Integration of the SPECT and the CT modalities provides for both functional and anatomical detail during one imaging session and, as such, minimises image mis-registration of image datasets (1),(2).

The CT portion of SPECT-CT can be used to characterise pathology, to localise anatomy and pathology and for attenuation correction of the SPECT images. Characterisation of pathology usually requires a diagnostic quality scan and can involve the use of intravenous contrast agent. It typically involves a higher ionising radiation dose to the patient than a localisation scan or a CT performed for attenuation correction (CTAC).

The focus of this article will be specifically to CTAC images produced during SPECT-CT for myocardial perfusion imaging (MPI). The CTAC acquisition uses a low-dose technique that produces low-resolution (low-quality) images. These CTAC images of the chest are prone to movement artifact because the patient is not required to breath-hold during the acquisition and the information gained is limited to a range through the cardiac area of the chest. The acquisition is performed purely for attenuation correction of SPECT image data and not with the intention of an image being viewed for diagnosis. However, CTAC images, which are essentially a by-product of the process, often reveal incidental findings.

Incidental findings

An incidental finding is an unsuspected abnormality or anomaly that is not related to the clinical reason for the investigation (3),(4). Incidental findings can be classified as clinically significant, clinically insignificant or indeterminate. Radiologically, using

the CTAC chest images it is often not possible to determine this definitively with the initial investigation. True incidental findings (that are not known about prior to the investigation) and fall into the clinically significant or indeterminate category, will usually require follow-up diagnostic tests.

Incidental findings within the chest are common and are frequently detected on low-resolution CTAC images (5). A high number incidental findings detected on CTAC images are classified as clinically significant or indeterminate at the time of the radiological report but, despite this, very few incidental findings remain clinically significant at definitive diagnosis. This leads to a high number of false-positive findings. Table 1 lists some of the common incidental findings demonstrated on CTAC images.

A large proportion of incidental findings within the chest are pulmonary nodules (6), which are often benign but can present radiologically as indeterminate or clinically significant. This results in follow-up diagnostic investigations in order to reach definitive diagnosis.

Significance of incidental findings on CTAC images

Incidental findings that are known about from previous imaging are usually less of an issue than unknown incidental findings. This is because, if it is considered necessary, there will usually be a management plan in place at the time of CTAC acquisition. Unknown incidental findings can prove more of a problem because decisions about further management will have to be made and these might not relate to the initial clinical indications for MPI imaging.

Lung cancer has a poor prognosis, especially small cell lung cancer (SCLC). Non-small cell lung cancer (NSLC) has a better prognosis if detected at an early stage (7), (8). There is an argument then for detecting and following up lung nodules that are considered to be clinically significant at the time of CTAC imaging if it is likely to improve prognosis. However, follow up diagnostic tests and interventions carry with them potential risks as well as benefits to the patient.

Results of lung cancer screening trials suggest that there needs to be a balance between early intervention to reduce mortality and risks of early morbidity and mortality from unnecessary intervention; mortality must be reduced and the benefits to the patient must outweigh the risks (6),(7). Lung cancer screening with CT has not been adopted universally because of the high rate of false-positive findings and over-diagnosis of indolent tumours that might not have become significant in a patient's lifetime. These findings have cost implications as well as increasing patient anxiety and morbidity (9).

The lack of clarity surrounding lung cancer screening with CT raises the question of whether incidental findings should be looked for on CTAC images. Whilst early diagnosis of pathology could potentially enable a better prognosis, detection of incidental findings can increase the risk to the patient without benefit. Studies have shown that only a small percentage of incidental findings that are initially thought to be clinically significant on CTAC for SPECT MPI are actually clinically significant at definitive diagnosis. The diagnostic examinations necessary to reach that definitive diagnosis often have risks associated with them that can cause physical or psychological harm to the patient as well as an increase in ionising radiation dose.

Image quality

CT image quality is dependent upon the acquisition parameters used and the way the data is reconstructed and viewed. Although it would be desirable to achieve the best possible image quality, this often comes with the detriment of increased ionising radiation dose to the patient. Therefore, image acquisition tends to be optimised (10) to the requirements of the examination so that the required image quality is achieved at the lowest radiation dose achievable.

CTAC images are not considered to be diagnostic quality because of the typical acquisition parameters used. The acquisition is purely for attenuation correction and not with the intention of image production. This enables the radiation dose to the patient to be kept as low as reasonably practicable (ALARP). Typically, the CTAC acquisition uses a wide slice width and a low tube current (mA) that results in noisy images with poor contrast and poor spatial resolution. In addition, the acquisition time is usually much longer than that of diagnostic CT and so patients are not

required to breath-hold. Images are therefore prone to motion artifact from breathing.

Do CTAC MPI images have a diagnostic value?

CTAC images tend to be low-resolution but incidental findings can still be detected. Some contemporary hybrid scanners have technical CT capabilities similar to those used for diagnostic imaging rather than the fixed acquisition parameters of earlier scanners. Therefore, it is possible, on some scanners, to improve the image quality by changing the acquisition parameters. Protocols and imaging techniques can vary not just between different departments but also between different scanners. This means that CTAC images from some scanners will be of better quality, and potentially more diagnostic, than from others (11).

In non-clinical studies, lesion detection performance has been conducted using the Free-response Receiver Operating Characteristic (FROC) method to investigate detection of pulmonary nodules on a chest phantom using different acquisition parameters. A study on one SPECT-CT system demonstrated that there was no statistically significant difference in lesion detection performance at different mA values when all other parameters remained unchanged (12). In another lung phantom study involving a range of SPECT-CT systems, lesion detection varied relative the CT capability (13). The same chest phantom was used in a study using two different SPECT-CT systems in which lesion detection was found to be more reliable on one of the systems but this was due to the reconstruction algorithms specific to that system rather than the acquisition parameters used (14). However, these studies were all performed with a stationary phantom and so are not truly representative of a clinical study.

In a 2-year multi-centre study in four nuclear medicine departments in the UK, incidental findings on CTAC images during SPECT-MPI were evaluated (15). Positive findings were identified on the CTAC images of 962 (28%) of 3485 patients of which 824 (24%) were new findings. Eighty-four (2.4%) patients had findings that were considered to be clinically significant at the time of imaging that were not

known about previously. Only 10 (0.29%) patients had findings that were confirmed to be clinically significant at definitive diagnosis. In this study, 74 out of 84 patients had false-positive findings that involved follow up diagnostic tests and possibly intervention before a definitive, negative outcome was reached.

The positive predictive value (PPV) across all the centres was low and statistically there was no significant difference between the PPV for CTAC images acquired using low resolution and better resolution machines. The question of whether CTAC images should be reviewed was raised and the conclusion of the study was that routine reporting of CTAC images in this particular situation was not beneficial.

Discussion

There is the potential that early diagnosis of disease can reduce patient mortality. However, this is not always the case. Early detection of lung cancer, in some cases, can lead to early intervention; in other cases the disease will have progressed too far by the time of diagnosis for curative intent to be an option. Along with this, the indeterminate nature of some lung nodules necessitates surveillance. This can be a lengthy process of up to 3 years (16) and can increase patient risks and anxiety.

Only a very small percentage of findings on CTAC images have been found to be malignant or detrimental to the patient at definitive diagnosis. None-the-less, a high percentage of findings will require further imaging or intervention until a definitive diagnosis has been reached. Again, this can increase risks to the patient and increase morbidity.

Screening programmes and other imaging programmes often have a structured support system in place for patients to help them cope with their diagnosis. In case of incidental findings, there is often a lack of support due to the unexpected nature of the finding. Given that incidental findings on CTAC during SPECT-MPI are common, there are likely to be a significant number of patients who would benefit from extra support. False-positive findings or over diagnosis can greatly increase

patient anxiety and patients often have a natural assumption that any incidental finding is cancer (17).

Conclusion

Until now CTAC images from SPECT MPI studies are low-resolution and not considered to be diagnostic. Demonstration of pathology and incidental findings is possible but there is also the potential to miss pathology that has not been sufficiently demonstrated or not demonstrated at all on CTAC images.

Producing a routine report for CTAC images from CTAC images arising from SPECT-MPI has been called into question (18). Consequnetly caution should be taken when reporting CTAC images and the report should state clearly that the images are low-resolution and not intended for diagnostic purposes. The potential impact to the patient for any incidental findings should be considered during this process.

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Table 1 – Examples of incidental findings on SPECT-CT images of the chest

Incidental Finding
Coronary vessel calcification
Vascular anomalies
Valve replacement
Pacemaker
Atelectasis
Effusion
Consolidation
Lobar collapse
Nodules
Mass
Pulmonary metastases

Ground glass opacities

Aortic aneurysm

Source: Adapted from (Coward et al, 2014)