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SHORT COMMUNICATION

Multicentre analysis of incidental findings on low-resolution CT attenuation correction images: an extended study

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Objective: To review new incidental findings detected on low-resolution CT attenuation correction (CTAC) images acquired during single-photon emission CT-CT myocardial perfusion imaging as an extension to our initial study.
Methods: CTAC images acquired as part of myocardial perfusion imaging performed using single-photon emission CT at four UK nuclear medicine centres were evaluated as part of a multicentre study. New incidental findings that were considered to be clinically significant were evaluated further. Positive-predictive value (PPV) was determined at the time of definitive diagnosis.
Results: Out of 3485 patients, 962 (28%) patients had a positive finding on the CTAC image, of which 824 (24%) were new findings. 84 (2.4%) patients had findings that were considered clinically significant at the time of the CTAC report and which had not been previously diagnosed. However, only 10 (0.29%) of these had findings that were confirmed as clinically significant, with the potential to be detrimental to patient outcome, after follow-up and definitive diagnosis.
Conclusion: The overall PPV from all centres over the 2-year period was 12%. Each centre achieved what we considered to be low PPVs with no significant difference between the present and initial studies. The additional data from the combined studies show that, statistically, there is no significant difference between the PPVs from any of the centres. We conclude that routine reporting of CTAC images is not beneficial.
Advances in knowledge: This study combined with the previous study offers a unique evaluation of new clinically significant incidental findings on low-resolution CT images in an attempt to determine the benefit of reporting the CTAC images.

INTRODUCTION

CT attenuation correction (CTAC) is frequently used to correct single-photon emission CT (SPECT) images during myocardial perfusion imaging (MPI).[1,2] A low-dose CT acquisition is performed through the area of the heart to match the range of the SPECT scan. Although CT is performed for attenuation correction purposes only, a by-product of the process is the availability of low-resolution CT images of part of the chest. It is known that these images can demonstrate incidental findings,[3] but what is currently unknown is the significance of these findings.

Previously, we have reported on a 1-year study which reviewed the CTAC images from SPECT MPI from four nuclear medicine centres.[4] This initial study revealed varied results. Out of 1819 patients studied, 497 (27%) patients had a positive finding, of which 423 (23%) were new findings. 51 (2.8%) patients had findings that were considered clinically significant at the time of the CTAC report and which had not been previously diagnosed. However, only four (0.2%) of these findings had the potential to be detrimental to patient outcome. For the four centres, the overall positive-predictive value (PPV) was 8%. However, the PPV from the individual centres varied from 0% to 67%, and this was thought to be due to the varying image qualities produced by CT scanners of different specifications utilized across the centres. The initial study concluded that further research was needed to establish the actual diagnostic value of CT used for attenuation correction in MPI, especially in the case of the medium-resolution CT

Table 1. Scan parameters of the single-photon emission CT-CT systems

Centre	1	2 and 3	4
Scanner	GE Infinia Hawkeye™ single-slice CT	GE Infinia Hawkeye 4-slice CT	Philips Precedence 16-slice CT
kV	120	120	120
mA	2.5	1.5	~33
Rotation time (s)	18	30	1.5
Effective mAs	45	24	50
Acquired slice thickness (mm)	10	5	1.5
Reconstructed slice (mm)	10	6.1	5
Pitch	1.0	1.9	0.98
Contrast-to-noise ratio	2.4	2.2	0.74
Low-contrast resolution (mm)	3	4	4
High-contrast resolution (lp/cm)	≥4	≥3	≥24

GE Infinia Hawkeye manufactured by GE Healthcare (Little Chalfont, UK); Philips Precedence manufactured by Philips Healthcare (Guildford, UK).

subsystems.[4] Therefore, a further year's data have now been evaluated in the present study.

The objective of the study was to review the new incidental findings, from a multicentre study, that were detected on low-resolution CTAC images acquired during SPECT-CT MPI that were considered to be clinically significant at the time of reporting. The results will be compared with, and combined with, the results from our initial study to give data over a 2-year study period.

METHODS AND MATERIALS

The present multicentre study was carried out in the same four UK nuclear medicine centres, using the same method as our initial study.[4] During a further period of 1 year, data from additional 1666 patients were collected. The low-resolution CTAC images acquired as part of SPECT MPI studies were evaluated, and the number of incidental findings was determined.

The CTAC images were reviewed on a variety of CT window settings to demonstrate the lung, bone and soft tissue. For consistency, the images were evaluated and reported by the same four consultant radiologists as in our initial study. The radiologists used a *pro forma* informed by guidance from the Royal College of Radiologists[5] to structure the written reports. Each report stated that the images were from a low-resolution/low-quality CT that had been performed as part of a nuclear medicine MPI study and, as such, it was clear to referring clinicians that the images were not meant for diagnosis.

Approval was gained locally from each participating hospital as either service evaluation or audit. Ethical approval was obtained from the University of Salford.

The CT scan parameters of the SPECT-CT equipment used in each centre are shown in Table 1.

Image evaluation

The CTAC images from the additional 1666 patients in the present study were evaluated in the same manner as in the initial study. Where both stress and rest studies were performed, it was considered to be one examination. Only written reports which included previously unknown pathology were included in the final evaluation, and these findings were described as being new positive findings. New positive findings were classified according to the clinical significance at the time of report. The classification system was adapted from the one used by Goetze et al[6] and is shown in Table 2.

Findings that were classified as major were considered to be clinically significant. Every major finding was followed up by the hospital concerned as they could potentially affect the clinical management of the patient. These patients were subsequently followed up with diagnostic imaging or interventional procedures for a period of up to 2 years or until a definitive diagnosis was made.[4] All other findings were considered to be insignificant and have not been included in our analysis.

The PPVs of the CTAC images for patients with clinically significant new positive findings from each centre were determined. These were then compared with the PPVs from the results of our initial study.[4]

The PPV was calculated at the time of the definitive diagnosis rather than at the time of the CTAC report. Therefore, PPV was calculated as the percentage of new significant findings that could ultimately affect patient outcome.

Table 2. Classification of findings

Classification	Description
Major (clinically significant)	Requires further investigation in view of clinical information and history. This includes findings such as pleural effusions or lung nodules
Minor	Less significant than major findings; however, they do have clinical significance. For example, cardiomegaly, liver lesions or hiatus hernia
Minimal	Less significant than minor findings, minimal or no clinical significance given patient history. These include degenerative changes
Equivocal	Findings unclear. These include abnormalities in the liver that cannot be characterized

Table 3. Number of incidental CT attenuation correction findings in the present study

Centre	1	2	3	4	Total
Total number of patients in study	185	870	312	299	1666
Number of positive findings	112	240	75	38	465
Number of new positive findings	109	201	55	36	401
Clinically significant findings	4	4	11	14	33
Confirmed clinically significant findings	0	1	3	2	6
Positive-predictive value (%)	0	25	27	14	18

RESULTS

Table 3 summarizes the findings of the present study. Out of 1666 patients, 465 (28%) patients had a positive finding, of which 401 (24%) were new findings. 33 (2%) patients had findings that were considered clinically significant at the time of the CTAC report and which had not been diagnosed previously. However, only 6 (0.36%) of these patients had findings that were confirmed as significant, with the potential to be detrimental to patient outcome, when a definitive diagnosis was made.

DISCUSSION

When data from our initial study[4] are combined with the present study, a total of 3485 patients were included. Of these, 962 (28%) patients had a positive finding on the CTAC image, of which 824 (24%) were new findings. 84 (2.4%) patients had findings that were considered clinically significant at the time of the CTAC report and which had not been diagnosed previously. However, only 10 (0.29%) patients had findings that were confirmed as clinically significant, with the potential to be detrimental to patient outcome, after follow-up and definitive diagnosis.

We can now compare results of the present and initial studies. In the present study, at the time of the radiological CTAC report, 33/1666 (2%) were considered to have new clinically significant findings, but after follow-up, only 6 (0.36%) patients had confirmed clinical findings that were considered to be detrimental to patient outcome. This compared with a rate of confirmed positive findings of 4/1819 (0.22%) that were detrimental to patient outcome in our initial study.[5] The difference between the initial and present study was not significant ($p = 0.53$, Fisher's exact test). The overall rate of confirmed positive findings from our initial and present studies combined was 10/3485 (0.29%).

Of the 33 (2%) patients who were followed up in the present study as a result of having clinically significant findings at the time of the CTAC report, 27 (1.64%) patients did not have confirmed significant findings. An example of this can be seen in Figure 1. A solid lesion was reported in the patient's right breast, which was suspicious of malignant pathology. Whilst appearance on CT was that of a solid lesion, the definitive diagnosis was a benign cyst.

Table 4 illustrates the individual and total PPVs and the confirmed positive rates from the present, initial and combined studies. In the present study, there was an overall PPV of 18% when all four centres were combined. Statistically, this was not significantly different to the overall PPV of the initial study ($p = 0.18$ using Fisher's exact test). The PPVs at the individual centres varied.

The PPV at Centre 1, which used a Hawkeye™ (GE Healthcare, Little Chalfont, UK) single-slice CT, was 0% in the present study. This was consistent with the findings of the initial study. There were no confirmed clinically significant findings at Centre 1, and consequently, CTAC images from this low-specification CT scanner are no longer reported by this centre.

The PPV at Centre 2, which used a GE Infinia (GE Healthcare) with Hawkeye 4-slice CT, was 25% in the present study. Of the four clinically significant findings reported at the time of CTAC imaging, only one of these was later confirmed as being detrimental to patient outcome; this was a lung cancer staged as T2 N1 M0. One patient had a suspected hamartoma, a benign lesion, but the patient left the country prior to confirmation. Furthermore, one patient died before follow-up, and the medical notes were no longer available. The final patient had findings

Figure 1. A breast lesion that appeared solid on CT but was a benign cyst.

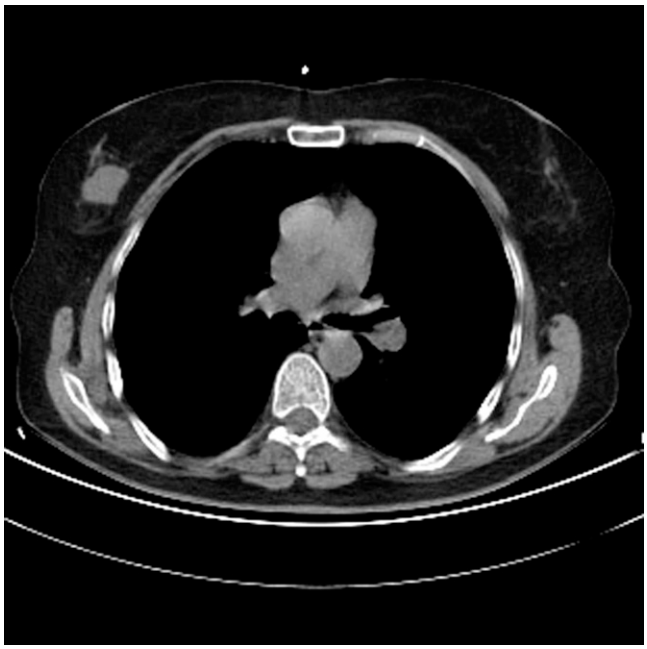


Table 4. Positive-predictive values (PPVs) and confirmed positive rates of the initial, present and combined studies

Centre	1	2	3	4	Total
Total number of patients in study	507	1881	587	510	3485
PPV (initial) (%)	0	6	0	67	8
Confirmed positive rate (%)	0	0.2	0	0.95	0.22
PPV (present) (%)	0	25	27	14	18
Confirmed positive rate (%)	0	0.1	0.96	0.67	0.36
PPV (combined) (%)	0	9	19	24	12
Confirmed positive rate (%)	0	0.16	0.51	0.78	0.29

that resolved over time. The PPV in the present study was not significantly different to the initial study PPV of 6% ($p = 0.31$ using Fisher's exact test). The overall PPV from the combined data from this centre was 9%.

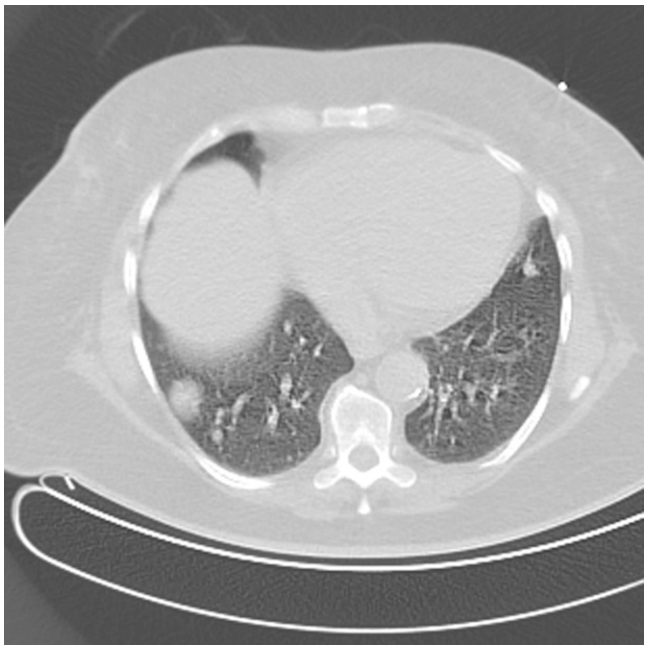
The PPV at Centre 3, which also used a GE Infinia with Hawkeye 4-slice CT, was 27%. Of the 11 patients who had significant clinical findings at the time of the CTAC report, 3 were confirmed as being significant. One patient had a confirmed dilated ascending aorta with left ventricular outflow tract dilatation. This patient subsequently received regular follow-up imaging. Another patient had a hiatus hernia with both herniation of the stomach and splenic flexure of the colon that, subsequently, was repaired. The third patient had a confirmed descending thoracic aortic aneurysm. Although the two patients with aortic aneurysms had significant findings, it is not certain whether these patients were asymptomatic or whether they had symptoms related to the clinical indications for undergoing MPI. In that sense, these two differ from other findings in the study that were true, asymptomatic incidental findings. The PPV in the present study was not significantly different from the PPV of 0% in our initial study ($p = 0.51$ using Fisher's exact test). The overall PPV from the combined data from this centre was 19%.

The difference in PPV between Centres 2 and 3, both of which used the same equipment, is not significant ($p = 0.36$ using Fisher's exact test). The combined PPV for all data from these two centres was 12%.

The PPV at Centre 4, which used a Philips Precedence (Philips Healthcare, Guildford, UK) 16-slice CT system, was 14%. Of the 14 patients who had significant clinical findings at the time of the CTAC report, 2 patients were confirmed as being significant. One patient (Figure 2) was too unstable for biopsy but was diagnosed radiologically and clinically with lung cancer. The other patient was diagnosed with metastases from a primary uterine leiomyosarcoma. Our initial study (PPV 67%) suggested that it might be beneficial to report the CTAC images produced at Centre 4, which had been produced with acquisition parameters potentially leading to superior image quality. However, although the initial study showed a higher PPV, this was not significantly different statistically to the present study ($p = 0.12$ using Fisher's exact test). The overall PPV for the combined data from Centre 4 was 24%, which was not significantly different to that from Centres 2 and 3 combined ($p = 0.25$ using Fisher's exact test).

There was no significant change in the number of clinically significant findings between the initial and the present studies for Centres 1 and 3. Centre 2 had a highly significant (0.001%) reduction in the number of clinically significant findings from 31/1011 in the initial study to 4/870 in the present study. This could possibly reflect learning by experience of the reporter. Centre 4 had a just significant increase ($p = 0.047$) in the rate of clinically significant findings from 3/211 in the initial study to 14/299 in the present study. This has, no doubt, had an impact on the PPV at this centre. It is possible that this is related to an increase in confidence which has led to overreporting. It could also be due to the types of pathology in this study which have been classified as significant. In the initial study, the three patients with confirmed significant findings had either lung nodules or lung cancers. In this study, there were a number of pathologies that resolved over time.

Figure 2. Clinical and radiological diagnoses of progressing lung cancer.



This is potentially true for all the centres and could increase the number of false positives identified.

Our study has raised the question of what should be considered as an acceptable PPV for this type of examination. We have considered the combined PPV of 12% as being low. However, Nice guidance[7] has published a reduction in threshold PPV from 4% to 3% for symptomatic patients attending primary care. The patients in our study were non-symptomatic and their incidental findings had been detected as part of an unrelated cardiac study. It is worth noting that cardiac diseases share certain risk factors with lung cancer and so it is likely that there would be a higher prevalence of lung cancer in these patients and so a higher PPV would be expected. Most importantly, these patients have findings that were unexpected or had false-positive incidental findings that necessitated follow-up. This is a very different situation than for patients who are being investigated for a disease for which they have related symptoms. The psychological impact to patients receiving false-positive unexpected results is unknown.

CONCLUSION

The overall PPV from all centres over the 2-year period was 12%. Each centre achieved what we considered to be low PPVs with no significant difference between present and initial studies. Results from the initial study demonstrated that there was no value reporting CTAC images from Centre 1. The additional data from the combined studies show that, statistically, there is no significant difference between the PPVs from any of the centres. It would appear that Centre 4, which was initially thought to have a much higher PPV, was actually performing at a similar level.

Whilst the results revealed that 2.4% of findings were significant enough to warrant follow-up tests, only 0.29% were actually confirmed as having the potential to be detrimental to patient outcome. We conclude that routine reporting of CTAC images is not beneficial. Patient anxiety related to false-positive incidental findings is an area that the authors intend to consider in future work.

REFERENCES

1. Sharma P, Patel CD, Karunanithi S, Maharjan S, Malhotra A. Comparative accuracy of CT attenuation-corrected and non-attenuation-corrected SPECT myocardial perfusion imaging. *Clin Nucl Med* 2012; **37**: 332–8. doi: 10.1097/RLU.0b013e31823ea16b
2. Pazhenkottil AP, Ghadri JR, Nkoulou RN, Wolfrum M, Buechel RR, Kuest SM, et al. Improved outcome prediction by SPECT myocardial perfusion imaging after CT attenuation correction. *J Nucl Med* 2011; **52**: 196–200. doi: 10.2967/jnumed.110.080580
3. Budoff MJ, Fischer H, Gopal A. Incidental findings with cardiac CT evaluation: should we read beyond the heart? *Catheter Cardiovasc Interv* 2006; **68**: 965–73. doi: 10.1002/ccd.20924
4. Coward J, Lawson R, Kane T, Elias M, Howes A, Birchall J, et al. Multi-centre analysis of incidental findings on low-resolution CT attenuation correction images. *Br J Radiol* 2014; **87**: 20130701. doi: 10.1259/bjr.20130701
5. *Standards for the reporting and interpretation of imaging investigations*. London, UK: Royal College of Radiologists; 2006.
6. Goetze S, Pannu HK, Wahl RL. Clinically significant abnormal findings on the "non-diagnostic" CT portion of low-amperage-CT attenuation-corrected myocardial perfusion SPECT/CT studies. *J Nucl Med* 2006; **47**: 1312–18.
7. National Institute for Health and Clinical Excellence (NICE). Suspected cancer: recognition and referral NICE guideline. National Institute for Health and Clinical Excellence site [internet]. [Updated June 2015; cited 29 June 2015.] Available from: http://www.nice.org.uk/guidance/ng12/informationforpublic/