Prevalence and variability in reporting of clinically actionable incidental findings on attenuation-correction CT scans in a veteran population

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Received Dec 11, 2017; accepted Jan 25, 2018
doi:10.1007/s12350-018-1232-9

Background. **Myocardial perfusion imaging (MPI) often employs attenuation-correction computed tomography (CTAC) to reduce attenuation artifacts and improve specificity. While there is no specific guideline on how they should be reported, incidental noncardiac findings identified on these scans may be clinically significant. The prevalence of these findings in veterans is not currently known. In addition, variability in reporting these findings may depend on the interpreting physician's specialty.**

Methods. **To guide future decision-making, CTACs in veterans referred for MPI were prospectively evaluated in a quality-control project for a set of prespecified actionable incidental findings by cardiologists and a radiologist.**

Results. **On the 771 scans performed over eight months, 285 incidental noncardiac findings were identified by the interpreting cardiologists and 378 were identified by the interpreting radiologist. Pulmonary nodules were the most common occurring in 20% of studies read by the radiologist. Interreader agreements between cardiologists and the radiologist were poor for pulmonary nodules ≥ 10 mm and hiatal hernias; fair for pulmonary nodules < 10 mm, extracardiac masses, and aortic aneurysms; and moderate for pleural plaques.**

Conclusion. **Incidental noncardiac findings on CTACs are common in our veteran population. Overall interobserver agreement in identifying these findings between cardiologists and radiologists is fair. Specific guidelines are needed on how CTACs should be read and reported. (J Nucl Cardiol 2019;26:1688–93.)**

Key Words: Incidental findings • attenuation-corrected computed tomography • myocardial perfusion imaging

Abbreviations

MPI	Myocardial perfusion imaging
CTAC	Attenuation-correction computed tomography
PET	Positron emission tomography
SPECT	Single-photon emission computed tomography
CT	Computed tomography
MRI	Magnetic resonance imaging

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s12350-018-1232-9) contains supplementary material, which is available to authorized users.

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1071-3581/$34.00

See related editorial, pp. 1694–1696

INTRODUCTION

Nuclear cardiology procedures, specifically myocardial perfusion imaging (MPI) studies, are widely utilized in the United States. Studies have estimated the number of MPI scans performed in the United States exceeding 1,000 exams per 100,000 people per year.[1] Contemporary MPI scans often employ hybrid imaging, combining the functional information from Single-Photon Emission Computed Tomography (SPECT) or Positron Emission Tomography (PET) with the anatomic information from low-resolution attenuation-correction computed tomography scans (CTAC scans) performed to improve recognition of attenuation artifacts. The identification of incidental noncardiac findings on CTAC images represents a diagnostic and reporting dilemma.[2] While early detection of pathology may be beneficial (see Figure 1), incidental findings on these nondiagnostic CTAC scans are often false positive, or clinically insignificant contributing to patient anxiety and additional testing which increases healthcare costs and exposes patients to additional risk. Prior studies have reported the prevalence of noncardiac findings on CTACs as high as 69% with clinically relevant findings occurring in 34% cases.[3]

The recently published 2017 American Society of Nuclear Cardiology (ASNC) guidelines for the reporting of MPI exams states the report should address incidental findings in free text with an optional priority status.[4] In addition, a 2015 joint position paper on reporting from the European Association of Nuclear Medicine (EANM) and the European Association of Cardiovascular Imaging (EACVI) states incidental extracardiac findings ''must be included'' for gated SPECT MPI studies.[5] Unfortunately, there is no specific guidance on how best to report these incidental findings or whether recommendations for additional testing or patient follow-up should be included.

Accurate identification of incidental CT findings by cardiologists is limited by their lack of formal radiology training. Small retrospective studies have shown significant discordance in identifying clinically significant CT findings between radiologists and cardiologists.[6] Despite this, not all practice environments rely on radiologists to over-read low-dose CTAC scans performed during MPI studies. In addition, the prevalence of incidental noncardiac findings on CTACs in veterans is unknown. Given these uncertainties, to guide our practice, we conducted a single-center, prospective cohort, quality-control project to evaluate the prevalence of clinically actionable noncardiac incidental findings on CTAC images obtained during nuclear MPI studies in our veteran population. In addition, we sought to compare the interreader agreement between cardiologists and an over-reading radiologist in identifying these incidental findings.

METHODS

We conducted a single-center prospective cohort study within the VA Connecticut Healthcare System from October 2015 to May 2016 as part of a nuclear cardiology laboratory clinical quality-control initiative. A total of 822 patients were referred for MPI at the West Haven VA Medical Center during the study period, of which 771 ultimately underwent MPI with CTACs read by both cardiology and radiology readers. MPI studies were performed on a Philips Precedence SPECT-CT 16 slice scanner (Philips Healthcare, Cambridge, Massachusetts USA) or a GE Discovery VCT PET-CT 64 slice scanner (GE Healthcare Waukesha, Wisconsin, USA) using standard exercise or pharmacologic protocols as appropriate. All patients included underwent low-dose CTAC scans (120 kV tube voltage, 30-60 mA current) with contiguous axial slices (3.8 mm for PET-CT, 5 mm for SPECT-CT) through the chest from the level of the aortic root to the diaphragm. These images were separately interpreted by the reading cardiologist (trained and board certified in nuclear cardiology) and a single consultant radiologist who were asked to identify the following extracardiac findings: pulmonary nodule < 10 mm, pulmonary nodule ≥ 10 mm, extracardiac mass of any type, hiatal hernia, aortic aneurysm, and pleural plaque. Anatomical localization of incidental pulmonary nodules was not included. As this was a quality-control project, there was no specific training or guidance provided to the readers regarding criteria for diagnosing these extracardiac findings. Accordingly, the radiologist reader identified and reported aneurysm (aortic diameter ≥ 3.5 cm) using standard methodology. However, the cardiologists widely differed in their approach to diagnosis and reporting of aneurysm. Miscellaneous nonspecified findings were also reported but not analyzed in detail. Identified findings were categorized as new or previously known with correlation to prior CT studies when available. A formal written addendum by the radiologist was included with every myocardial perfusion study report. This addendum explicitly stated that the CT examination was performed utilizing a PET/SPECT CT cardiac protocol and was obtained for attenuation correction purposes only. Commercially available software used for image processing and display included Cedars Sinai AutoQuant and Emory Cardiac Toolbox for cardiologist SPECT-CT and PET-CT interpretations, respectively. The radiologist read CTACs using Carestream Vue, which was also available to the reading cardiologists if needed.

Numerical data are presented as absolute numbers and percentage of patient cohort. Patient age is presented as mean ± SD. Cohen's kappa coefficient (calculated using GraphPad Prism 7) was used to measure the strength of interobserver agreement between cardiologist and radiologist for positive and negative CTAC observations and is reported with values ± standard error. Kappa values 0-0.20 indicate poor to slight agreement, 0.21-0.40 fair agreement, 0.41-0.60

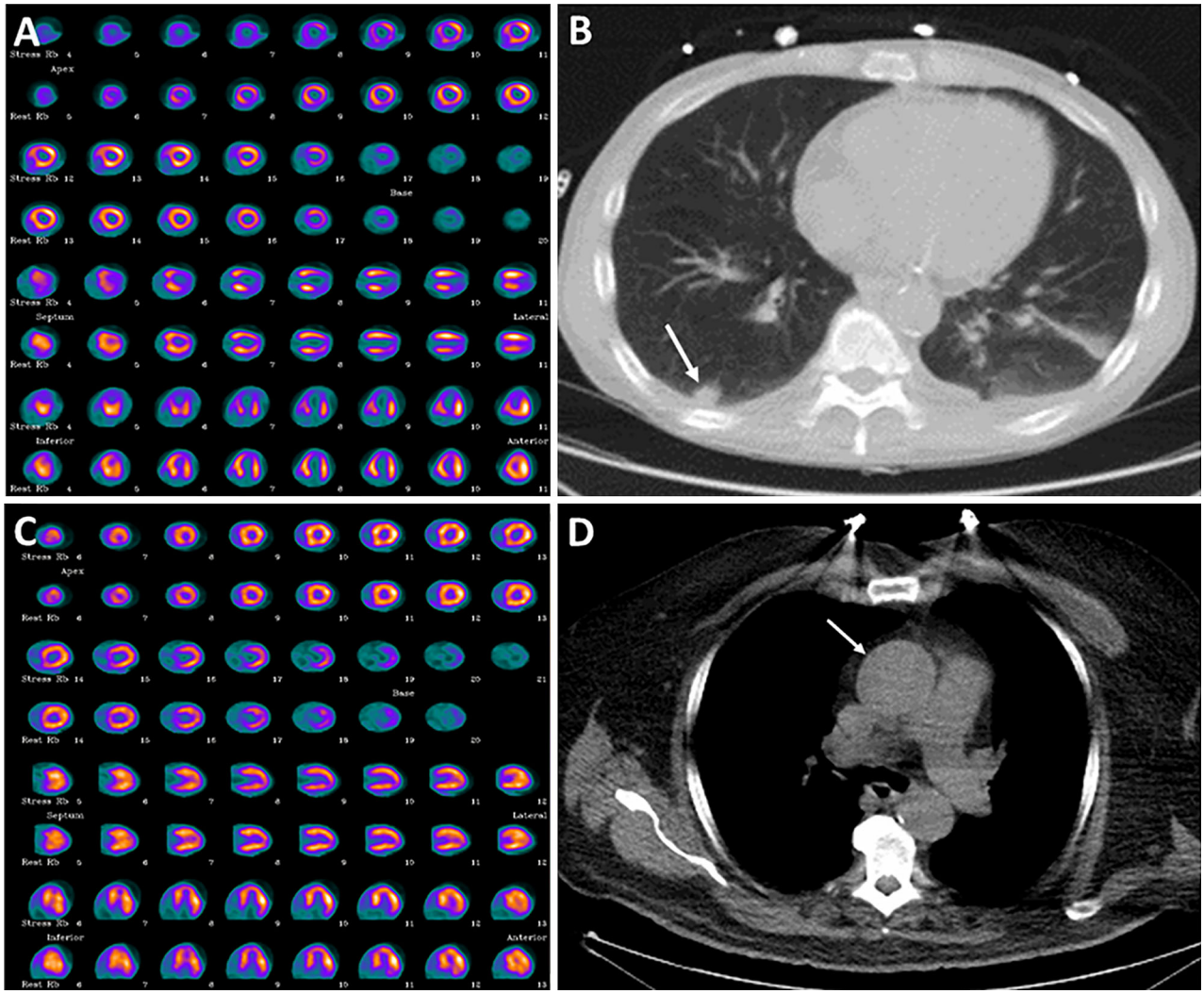

Figure 1. Examples of clinically actionable incidental findings on CTACs. **A** Rb-PET myocardial perfusion imaging in a 51-year-old male with hypertension, recent non-ST elevation myocardial infarction, and wall motion abnormalities on echocardiography showing mixed ischemia and scar involving the mid-apical anterior, mid-apical inferior, and apical lateral and septal walls. **B** CT performed for soft-tissue attenuation correction demonstrating a 1.3 cm right lower lobe lung nodule, biopsy of which showed squamous cell carcinoma. **C** Rb-82 PET MPI in a 77-year-old male with known coronary artery disease, diabetes mellitus, hypertension, obesity, hyperlipidemia, and atypical chest pain demonstrating a small, mild fixed inferoapical defect consistent with scar. **D** CT performed for soft-tissue attenuation correction demonstrating an ascending aortic aneurysm measuring 5.2 cm by 4.6 cm (arrow).

moderate agreement, 0.61-0.80 good or substantial agreement, and 0.81-1.00 very good to almost perfect agreement.[7]

RESULTS

Of the 822 patients enrolled, 774 had CTAC scans interpreted by both a cardiologist and radiologist. Three of these patients did not ultimately undergo diagnostic MPI [due to claustrophobia ($n = 1$), nondiagnostic images ($n = 2$)]. The remaining 771 patients were included in the final analysis. The mean age of the cohort was 68.4 years (range 34-95 year), and the vast majority were men (96%). Demographics of the patient population are summarized in Table 1. MPI was abnormal in 362 patients (47%) and normal in 409 patients (53%).

A total of 285 prespecified incidental noncardiac findings were identified in 235 patients (30%) by the

Table 1. Patient clinical characteristics

Demographics	N	%
Male	742	96.2
Female	29	3.8
h/o Smoking	562	72.9
Active smoking	156	20.2
Diabetes mellitus	305	39.6
Hypertension	612	79.4
BMI $\leq$ 18.5	4	0.5
BMI 18.5 to $<$ 25 (normal)	89	11.5
BMI $\geq$ 25 (overweight)	227	29.4
BMI $\geq$ 30 (obesity)	382	49.5
BMI $\geq$ 40 (severe obesity)	69	8.9
COPD	149	19.3
Cancer history	142	18.4
Cancer active	57	7.4
CT Scan w/in last 12 months	237	30.7
Age (mean, years)	68.4 ± 8.9	

interpreting cardiologists including 171 pulmonary nodules (150 nodules $<$ 10 mm, 21 nodules $\geq$ 10 mm), 12 extracardiac masses, 25 hiatal hernias, 43 aortic aneurysms, and 34 pleural plaques. Previously unknown findings accounted for 51% of the total ($n = 146$). The radiologist identified 378 prespecified incidental CT findings in 318 patients (41%) including 152 pulmonary nodules (133 nodules $<$ 10 mm, 19 nodules $\geq$ 10 mm), 7 extracardiac masses, 69 hiatal hernias, 124 aortic aneurysms, and 26 pleural plaques. Previously unknown findings accounted for 60% of the total ($n = 226$). A total of 278 patients (36%) had previously unknown incidental findings (read by either cardiologist or radiologist), 58 (20%) of whom were identified by both cardiologists and the radiologist.

Interreader agreement between cardiologists and radiologists was poor for pulmonary nodules $\geq$ 10 mm and hiatal hernias, fair for pulmonary nodules $<$ 10 mm, extracardiac masses, and aortic aneurysms, and moderate for pleural plaques. Overall interreader agreement for any abnormal finding on CT was fair with a Kappa value of 0.30 (SE = 0.03, 95% confidence interval 0.23-0.37). Table 2 and Supplemental Table 1 summarize these findings. The prevalence of incidental CT findings was comparable between patients with normal and abnormal MPI scans (Supplemental Table 2).

DISCUSSION

In this prospective single-center study, we evaluated the prevalence of clinically actionable noncardiac findings on CTACs in our veterans referred for MPI. In addition, we examined the interobserver variability between cardiologists and radiologists in identifying these findings. Our results indicate that noncardiac findings on CTACs are frequently observed in this population, occurring in over 40% patients, and the majority were previously unknown. Pulmonary nodules were the most common incidental finding, occurring in more than 20% of the veterans referred. This is especially important as incidental detection and follow-up of lung nodules on CT may reduce lung cancer mortality,[8] an important consideration in a veteran population where lung cancer accounts for 18% of malignancies.[9] Our reported high prevalence of clinically significant incidental findings detected during MPI studies is consistent with a recent publication from H. Kan and colleagues from the Netherlands. In their prospective evaluation of 1397 consecutive patients referred for $^{13}NH_3$ PET/CT, 51% patients had incidental extracardiac findings including 18% deemed clinically relevant.[10] The true incidence of all incidental findings on CTACs in our study population is likely higher as we only reported prespecified findings deemed clinically significant. For instance, mediastinal lymphadenopathy was identified as a miscellaneous finding in four patients by the radiologist, but none of the cases were reported by the cardiologist.

We also found the interreader agreement between cardiologists and the over-reading radiologist ranged from poor to moderate, depending on the incidental finding, and was fair overall. This is particularly relevant in the modern era where hybrid anatomic and functional imaging has become more commonplace requiring interpretations of both cardiac and noncardiac anatomy. Most cardiologists lack the formal training and experience in radiology required to confidently interpret the CT or MRI datasets obtained during hybrid cardiac imaging studies, as underscored by the findings from our analysis. Some centers require radiologists, or equivalently trained physicians, to provide over-reads to ensure proper identification of important noncardiac pathology. This paradigm, however, is not necessarily standard in all practice environments or endorsed by societal guidelines, and issues regarding work allocation and reimbursement remain to be addressed. Although not generalizable, our results may suggest the need for similar quality-control initiatives perhaps as part of laboratory accreditation standards. We believe variabilities in physician training, clinical expertise, and diagnostic thresholds as well as technical differences (scanner equipment, reading software) account for the majority of the interreader discrepancies observed between the cardiologists and radiologist in our analysis. Highlighting this gap, current nuclear cardiology training guidelines do not specify the requirements or skills

Table 2. Prevalence of incidental findings on CTAC and interreader variability

Incidental CT finding	Cardiologist read N (%)	Radiologist read N (%)	Agreement N (%)	Disagreement N (%)	Kappa coefficient (± SE, 95% confidence interval)	Strength of agreement
Any nodule	159 (20.6)	149 (19.3)	599 (78)	172 (22)	0.30 (± 0.04, 0.22 to 0.38)	Fair
Nodule < 10 mm	150 (19.5)	133 (17.3)	612 (79)	159 (21)	0.31 (± 0.04, 0.23 to 0.40)	Fair
Nodule ≥ 10 mm	21 (2.7)	19 (2.5)	737 (96)	34 (4)	0.13 (± 0.08, 0.00 to 0.28)	Poor
Mass	12 (1.6)	7 (0.9)	758 (98)	13 (2)	0.31 (± 0.14, 0.04 to 0.58)	Fair
Hiatal hernia	25 (3.2)	69 (8.9)	699 (91)	72 (9)	0.20 (± 0.06, 0.08 to 0.31)	Poor
Aortic aneurysm	43 (5.6)	124 (16.1)	660 (86)	111 (14)	0.28 (± 0.05, 0.18 to 0.37)	Fair
Pleural plaque	34 (4.4)	26 (3.4)	739 (96)	32 (4)	0.45 (± 0.08, 0.29 to 0.61)	Moderate
Any CT finding	235 (30.5)	318 (41.2)	520 (67)	251 (33)	0.30 (± 0.03, 0.23 to 0.37)	Fair

for interpreting CTACs for noncardiac incidental findings.[11] However, in part based on these findings, we implemented routine over-read of CTACs by a radiologist at our center.

LIMITATIONS

Although this is the first investigation of incidental findings on CTACs in a veteran population, generalizability of our findings is limited as this was a single-center, quality-control study of predominantly males with a high prevalence of comorbidity. In addition, accurate recognition of extracardiac incidental findings on CTACs is dependent on scanner specifications (number of detectors, slice thickness, tube current, etc.) which can impact spatial resolution.[12] Our use of different software platforms for viewing CTAC data by the cardiologists and the radiologist as well as variability in diagnostic criteria among readers represent limitations in our analysis of interreader variability. Practitioners should therefore be familiar with their laboratory's equipment in this regard as well as follow standardized guideline definitions for diagnostic criteria. We also do not have outcomes data to ascertain the true clinical significance of the incidental findings in our study population. However, identification of previously unknown actionable pathology, accounting for 60% of the radiologist-identified findings, should theoretically lead to earlier detection and therapeutic intervention in many cases.

CONCLUSION

Incidental findings on CTAC imaging are common in our veterans and have important clinical implications for patient care. In addition, there is considerable interobserver discordance between cardiologists and radiologists in recognizing these findings. Initiatives to standardize training requirements and laboratory reporting protocols are necessary to improve the accurate detection of these findings and address this gap in cardiovascular imaging.

NEW KNOWLEDGE GAINED

CTAC scans obtained to improve the accuracy of MPI often demonstrate incidental noncardiac findings, a significant percentage of which may be clinically important. Although MPI studies are often interpreted by nuclear-trained cardiologists, there is considerable discordance in identifying noncardiac pathology compared to radiologists.

Acknowledgement

We thank our nuclear cardiology colleagues and cardiology fellows who participated in this quality-control project.

Disclosures

All authors have no conflicts of interests.

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