Incidental Findings of Pulmonary and Hilar Malignancy by Low-Resolution Computed Tomography Used in Myocardial Perfusion Imaging

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Background: Low dose, low-resolution computed tomography (CT) is used for attenuation correction to improve the quality of single-photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI). Because of its low resolution, these CT images are considered nondiagnostic and are not routinely or uniformly reviewed or interpreted by a cardiologist. On the other hand, low-dose CT has been used for lung cancer screening to reduce lung cancer mortality and is recommended for annual screening of high-risk patients by the US Preventive Services Task Force.

Methods: Siemens Symbia Intevo Excel SPECT/CT scanners, used primarily for cardiac MPI, were used in the study. The study was intended to report incidental findings of pulmonary and hilar malignancy detected by these CT images during cardiac evaluation. It included 1,098 consecutive patients who had SPECT MPI from September 1, 2017 to August 31, 2018. When suspicious pulmonary nodules or abnormalities were identified, primary care providers were notified of the findings and recommendations for further evaluation.

Results: Five patients were found to have lung cancer (all male with substantial smoking history, aged 64-75 years), 1 had mantle cell lymphoma. Six of 1,098 (0.55%) patients were found to have incidental pulmonary/hilar malignancy, which is comparable to the yield (0.65%/year) of detecting lung cancer using low-dose CT for screening in The National Lung Screening Trial.

Conclusions: Routine review and report of incidental findings on low-resolution CT during cardiac MPI by physicians skilled in CT interpretation is necessary to identify incidental but clinically important findings, including malignancies.

Single-photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI) is a well-established technique for the evaluation of coronary artery disease (CAD).[1] To improve image quality, low-resolution computed tomography (CT) is used commonly for anatomical correct and artifact attenuation during SPECT MPI.[2] The low resolution, unenhanced CT images are considered low quality and are, therefore, labeled by the manufacturer as nondiagnostic. The CT portion of the MPI in many centers is used only for image fusion and attenuation correction, and these images are not routinely reviewed or reported by cardiologists.

Incidental findings by these low-resolution CT were frequent. However, clinically significant findings, including lung cancer, although relatively infrequent, were serious enough for major clinical management.[3-5] Currently, there are no consensus recommendations for reviewing low-resolution CT images or the interpretation of such incidental findings during cardiac MPI.[6] Clinically, low-dose CT were used for early detection and screening of lung cancer and were associated with reduced lung-cancer and any cause mortality in National Lung Screening Trial (NLST).[7,8] Therefore, low-dose CT is recommended for lung cancer screening of high-risk patients by the US Preventive Service Task Force (USPSTF).[9] In the veteran population, current and past smoking history are more common when compared with the general population; therefore, veterans are potentially at increased risk of lung cancer.[10] In this study, we did not intend to use low-resolution CT for lung cancer screening or detection but rather to identify and report incidental findings of pulmonary/hilar malignancy detected during cardiac MPI.

METHODS

The Siemens' (Munich, Germany) Symbia Intevo Excel SPECT/CT MPI cameras with dedicated cardiac collimators were used at both the Dwight D. Eisenhower VA Medical Center (VAMC) in Leavenworth, Kansas and Colmery-O'Neil VAMC in Topeka, Kansas. The integrated CT scanner (x-ray tube current 30 to 240 mA; voltage 110 Kv with a 40 kW power generator) has the capability to image up to a 2-slice/rotation, each of 5.0 mm per slice with a scan time of about 30 seconds. The SPECT/CT gamma camera has a low energy (140 KeV), high resolution, parallel hole collimator with IQ SPECT capabilities.

The radiation dose received by the patients were expressed in dose length

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TABLE Patients With Malignancies Characteristics

		Smoking history				
Case	**Age, y**	**Pack Years**	**Years Since Cessation**	**CTAC Findings**	**CT Findings**	**Biopsy or Surgical Findings**
1	73	30	22	RUL 2.6 cm, spiculated	RUL 2.7x2.8x2.6 cm^3 mass/ bronchogram	Biopsy: squamous cell cancer
2	72	27	32	Mass in subcarinal region	4.5x8.2x10 cm^3, subcarinal mass	Biopsy: mantle cell lymphoma
3	71	20	30	LLL 1.6 cm density	LLL 1.6 cm spiculated	Surgery: invasive moderately differentiated adenocarcinoma
4	75	> 100	Current smoker	RUL 2.5 cm spiculated	RUL 2.4x2.3 cm^2, spiculated	Biopsy: mixed adeno-squamous cancer
5	64	> 50	Current smoker	LUL 0.9 cm nodule	LUL 2.7x3.1 cm^2 nodule	Biopsy: poorly differentiate adenocarcinoma
6	75	50	5	RLL density	RLL 1.1x3.9 cm^2 mass/ pleural based mets	Biopsy: small cell cancer

Abbreviations: CT, computed tomography; CTAC, CT attenuation correction; LLL, left lower lobe; LUL, left upper lobe; RLL, right lower lobe; RUL, right upper lobe.

product (DLP), which reflects the total energy absorbed by the patient and represents integrated dose in terms of the total scan length. Additionally, each patients received 2 injections of Technetium Tc 99m sestamibi (1-day Protocol: 10 mCi rest injection, 30 mCi stress injection: 2-day Protocol for patients weighing > 350 pounds: 30 mCi at rest injection and 30 mCi at stress injection) for myocardial perfusion imaging.

All CT images and cardiac MPI findings were reviewed and reported contemporaneously by 1 of 2 experienced, board-certified radiologists who were blinded to patients' clinical information except the indication for the cardiac stress testing. When suspicious pulmonary/hilar nodules or masses were detected, these findings and recommendations for further evaluation were conveyed to primary care provider or ordering physician via the electronic health record system.

All CT images were reviewed with cardiac MPI from September 1, 2017 to August 31, 2018. When pulmonary/hilar malignancies were identified, the health records were reviewed. Patients with known history of prior pulmonary malignancy were excluded from the study.

RESULTS

A total of 1,098 patients underwent cardiac MPI during the study period. When the CT imaging and cardiac MPI were reviewed, incidental findings led to the diagnosis of lung cancer in 5 patients and hilar mantle cell lymphoma in 1 patient. Their clinical characteristics, CT findings, and types of malignancies for these 6 patients are summarized in the Table and Figure. Only 0.55% (6 of 1,098) patients were found to have incidental pulmonary/hilar malignancy with the cardiac evaluation low-resolution CT. Four patients with prior, known history of lung cancer were excluded from the study.

For the 6 patients found to have cancer, the average CT radiation dose during the cardiac MPI was 100 mGy-cm (range, 77 -133 mCy-cm). The subsequent chest CT with or without contrast delivered a radiation dose of 726.4 mGy-cm (range, 279.4 - 1,075 mGy-cm).

A total of 79 (7.2%) patients were found to have significant pulmonary nodules that required further evaluation; after CT examination, 32 patients had findings of benign nature and required no further follow-up; the other 47 patients are being followed according to the Fleischner Society 2017 guidelines for pulmonary nodules.[11] The follow-up findings on these patients are not within the scope of this report.

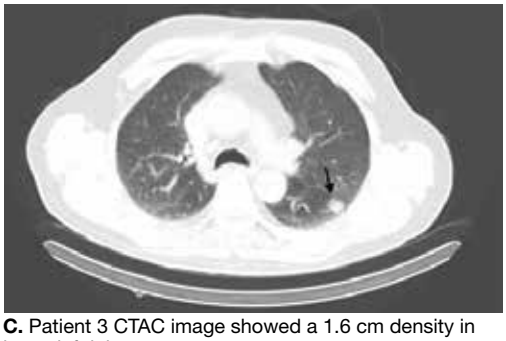
DISCUSSION

Although incidental findings on low-resolution CT during cardiac MPI are frequent, clinically significant findings are less common. However, some incidental findings may be of important clinical significance.[3-5] A multicenter analysis by Coward and colleagues reported that 2.4% findings on low-resolution CT were significant enough to warrant follow-up tests, but only 0.2% were

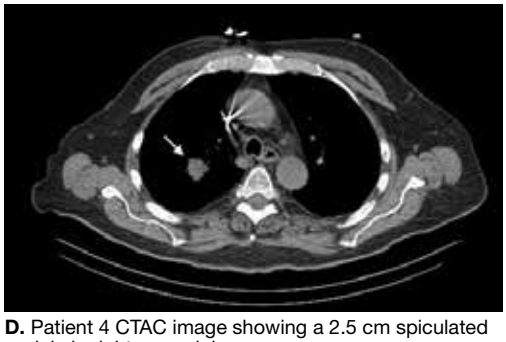
FIGURE Attenuation Correction Computed Tomography Images for Patients

A. Patient 1 attenuation correction computed tomography (CTAC) image demonstrating a spiculated, pleural-based right upper lobe lung mass (2.6 cm in diameter) with some central cavitation.

B. Patient 2 CTAC image demonstrating a large mass in subcarinal region.

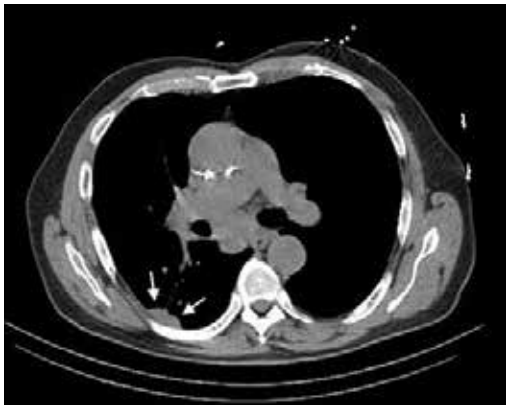


C. Patient 3 CTAC image showed a 1.6 cm density in lower left lobe.



D. Patient 4 CTAC image showing a 2.5 cm spiculated nodule in right upper lobe.

E. Patient 5 CTAC image demonstrating a small 0.9 cm nodule in left upper lobe.



F. Patient 6 CTAC image showing a density in right lower lobe.

deemed potentially detrimental to patient outcomes (ie, pathology confirmed malignancies).[12] Thus, the authors suggested that routine reporting of incidental findings on low-dose CT images was not beneficial.[12,13]

Currently, the majority of cardiac MPIs are reviewed and interpreted by nuclear cardiologists, the use of hybrid SPECT/CT for attenuation correction give rise of issue of reviewing and interpreting these CT images during cardiac MPI. Since low-dose, low-resolution CT are considered nondiagnostic, these images are not routinely and readily reviewed by cardiologists who are not trained or skilled in CT interpretations.

Studies of high-resolution cardiac CT (including multidetector CT with contrast) suggest that incidental extracardiac findings should always be reported as there was a 0.7% incidence of previously unknown malignancies, while others have argued against "performing large field reconstructions

for the explicit purpose of screening as it will lead to additional cost, liability and anxiety without proven benefits."[14-16] A review of incidental findings of cardiac CT by Earls suggested that all cardiac CT should be reconstructed in the maximal field of view available and images should be adequately reviewed to detect pathological findings.[17] This led to an interesting discussion by Douglas and colleagues regarding the role of cardiologists and radiologists in this issue.[18] Currently there is no uniform or consensus recommendations regarding incidental findings during cardiac CT imaging. Guidances range from no recommendations to optional reporting or mandatory reporting.[19-23]

Risk Factors for Veterans

Lung cancer is the second most common cancer and the leading cause of cancer-related death in the US.[24] Smoking is the most important risk factor for lung cancer and CAD.[25] Current or past smoking are more common among the veterans.[10] According to a report for the US Centers for Disease Control and Prevention report, about 29.2% US veterans use tobacco products between 2010-2015, which is similar to the rate reported in 1997.[26]

When low-dose CT was used for lung cancer screening, it was associated with a 20.0% reduction in lung cancer mortality and a 6.7% reduction in any cause mortality.[7] Currently, the US Preventive Services Task Force (USPSTF) recommends annual low-dose CT screening for lung cancer in high-risk adults that includes patients aged 55 to 80 years who have a 30-pack-year smoking history and currently smoke or have quit within the past 15 years.[8]

It is likely that the cardiac patients in this study might have pulmonary malignancy mortality similar to those reported in the NLST. While other studies have shown a low incidence (0.2%) of detection of malignancy by low-resolution CT during cardiac MPI,[12,13] in this study we found pulmonary or hilar malignancy in 0.55% of patients. The higher incidence of malignancy in our study might be due in part to differences in the patient population studied (ie, our veterans patients have a higher proportion of current or past smoking history).[10]

The CT used in this study is part of the cardiac imaging process. Therefore, there was no additional radiation exposure besides that of the cardiac MPI for patients. Despite the limitations of low-resolution CT, which may miss small lesions, this study showed 0.55% incidence of incidental detection of pulmonary/hilar malignancy. This is comparable with 0.65%/year of diagnosing lung cancer using low-dose CT for lung cancer screening in NLST.[8]

Two of the 5 study patients who were found to have lung cancer, had quit smoking > 15 years previously and thus would not be considered as high-risk for lung cancer screening according to USPSTF guideline. These patients would not have been candidates for annual low-dose CT lung cancer screening. This study suggests that it is appropriate and necessary to review the low-resolution CT images for incidental findings during cardiac MPI.

Limitations

The study was retrospective in nature and limited by its small number of patients. The CT modality used in the study also has limitations, including low resolution, respiratory motion artifacts, and scans that did not include the entire chest area. Therefore, small and apical lesions may have been missed. However, both sets of CT at rest and after stress were reviewed to reduce or minimize the effects of respiratory motion artifacts. The true prevalence or incidence of pulmonary/hilar malignancies may have been higher than reported here. Our study population of veterans may not be representative of the general population with regards to gender (as most of our veteran patient population are of male gender, vs general population), smoking history, or lung cancer risk, thus the results should be interpreted with caution.

CONCLUSION

Low-resolution CTs used for attenuation correction during cardiac MPI should be routinely reviewed and interpreted by a physician or radiologist skilled in CT interpretation in order to identify incidental findings of pulmonary/hilar malignancy. This would require close collaboration between cardiologists and radiologists in the field to ensure unfragmented and high-quality patient care.

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Disclaimer

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