Recognition of Noncardiac Findings on Cardiac Computed Tomography Examination

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Multislice computed tomography (CT) is rapidly emerging as a novel technique for the evaluation of coronary artery disease. It is anticipated that with increasing acceptance of this imaging technique, CT for calcium scores and CT angiography will be performed in ever greater numbers. Thus, it is all but inevitable that clinicians will stumble upon incidental findings given the sheer number of vital organs and blood vessels that are imaged in the field of view. This article reviews the literature on incidental findings on cardiac CT with a focus on pulmonary nodules, ethical aspects of following up such findings, and cost implications.
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Key words: Cardiac CT • CT angiography • Noncardiac findings • Pulmonary nodules • Triple rule-out

Multislice computed tomography (CT) is rapidly emerging as a novel technique for the evaluation of coronary artery disease (CAD). The field of diagnostic radiology has been revolutionized since the advent of the first commercial CT scanner by Sir Geoffrey Hounsfield in 1972. Innovation in the field of CT has proceeded at a dizzying pace, culminating in newer scanners that are able to perform up to 256 (Brilliance iCT; Philips Healthcare, Andover, MA) or 320 (Aquilon® ONE; Toshiba America Medical Systems, Inc., Tustin, CA) slices. There is a wealth of data suggesting that calcium scores obtained at CT are superior to conventional risk stratification algorithms such as Framingham or Procam risk scorers. In the coming decade, it is anticipated that with increasing acceptance of this imaging technique, CT for calcium scores and CT angiography (CTA) will be performed in ever greater numbers. Thus, it is all but inevitable that clinicians will stumble upon

incidental findings given the sheer number of vital organs and blood vessels that are imaged in the field of view (FOV). This creates a situation in which the radiologist or cardiologist may find something that he or she was "not looking for." Various investigators have addressed this issue to determine whether such incidental findings lead to unnecessary and quite often expensive testing, with the financial burden on the patient and payer systems. The emotional impact on patients from such findings is also not trivial and leads to excessive worry regarding malignancy, and causes lost wages and productivity. This article reviews the literature on incidental findings on cardiac CT with a focus on pulmonary nodules, ethical aspects of following up such findings, and cost implications.

The Magnitude of the Problem

A cardiac CT (contrast or noncontrast) typically begins at the level of the carina and extends through the base of the heart, thus irradiating the entire midthorax. A dedicated cardiac CT generates information pertaining to the heart, great vessels, pericardium, lungs, chest wall, spine, and sometimes the upper abdomen, in addition to the coronary arteries.[1] An important point to consider while evaluating this topic is FOV. The factor that affects the amount of data generated pertaining to extra cardiac structures is tethered with the FOV used with regard to the scan. The FOV of an axial image is the diameter of the area that is depicted in the image. Most scans for calcium scoring have used an FOV of 260 to 360 mm and 150 to 180 mm for CTA.[2,3] The FOV used in cardiac CT makes the detection of mediastinal and pleural pathology such as pleural effusions, pulmonary, nodules, and pulmonary neoplasms, very likely. Aglan and colleagues[4] studied the impact of small FOV (160-190 mm) versus full FOV (> 320 mm), on the prevalence of extracardiac findings and concluded that the detection rate of clinically significant findings was higher by using full FOV compared with small FOV (25.6% vs 15.4%).[4]

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One of the earliest studies to focus on this matter was performed by Hunold and coworkers[5] in 2001. They observed noncoronary pathology in 53% of their patients (n = 1812) who underwent electron beam computed tomography (EBCT) for coronary artery calcification. It has to be emphasized that this study did not image the entire chest and used an FOV of 26 cm^2. Haller and coauthors[6] studied the incidence of extra cardiac findings on contrast-enhanced multidetector computed tomography (MDCT) of the coronary arteries and they assessed the effect of different FOV settings. They showed that image reconstruction with a larger FOV (without additional radiation exposure) might reveal extracardiac findings that were not visible earlier. Hong and colleagues[2] noted this effect when they used a larger FOV when obtaining calcium scores by CT. It is important to note that for cardiac CT, a full FOV raw scan is commonly done as a "scout image" and thus can potentially identify many incidental findings.

Studies on Prevalence of Extracardiac Findings on Cardiac CT

Numerous investigators have looked at the issue of noncardiac findings on CT scans performed for either calcium scores or CTA. In one of the earliest studies on this matter, Hunold and associates[5] reported over 2000 noncoronary pathologic findings in 53% of their patients. Horton and colleagues[7] reported noncardiac pathology in 7.8% of their patients who underwent EBCT for coronary artery calcification. All these patients required additional imaging or clinical follow-up; that is, the findings were deemed to be "significant." Schragin and associates[8] performed a retrospective study of 1356 subjects who underwent population-based EBCT for calcium scoring and reported that up to 20.5% of the studies revealed noncardiac, thoracic, and abdominal pathology and at least 4.2% of the subjects required further diagnostic evaluation. The cohort in this particular study was a low-risk one (with regard to smoking) and thus the prevalence of such findings could be higher in a cohort with more risk factors.

Haller and coworkers[6] detected noncoronary pathology in 24.7% of their study subjects. They further classified these findings into major (4.8%) and minor (19.9%) depending on the impact of the finding on patient management or treatment. In a smaller study of over 500 subjects, Onuma and colleagues[9] showed that the prevalence of new noncardiac findings in patients who underwent MDCT cardiac imaging was 58.1% with 22.7% clinically significant findings that included malignancy. Mueller and coauthors[10] performed a retrospective analysis on CTA examinations done after coronary artery bypass graft (CABG) and concluded that 13.1% of

Table 1
Major Studies on Prevalence of Noncardiac Findings on Cardiac CT

Study	Prevalence (%)	Comments
Hunold P et al.[5]	53	FOV 26 cm^2
Horton KM et al.[7]	7.8	These were "significant"
Schragin JG et al.[8]	20.5	Clinically low risk cohort; 4.2% required further evaluation
Haller S et al.[6]	24.7	70.3% of the chest was visible; raw data were reconstructed with the maximal FOV
Onuma Y et al.[9]	58.1	MDCT; smaller study (N = 503) but 0.8% had malignancy
Mueller J et al.[10]	13.1	CTA in post CABG patients; overall 20% had new findings

CABG, coronary artery bypass graft; CT, computed tomography; CTA, computed tomography angiography; FOV, field of view; MDCT, multidetector computed tomography.

the study group had a noncardiac finding. Jacobs and colleagues[11] performed a systematic review of 11 chest CT screening studies and found that 7.7% of patients undergoing CAD screening and 14.2% of patients undergoing lung cancer screening with CT were found to have clinically significant incidental findings requiring additional investigations. The major studies and their results are summarized in Table 1.

Common Noncardiac Findings on Cardiac CT

Cardiac CT frequently reveals noncardiac findings such as mediastinal lymphadenopathy, pulmonary nodules, hiatal hernias, vascular anomalies, and lesions of the adrenal glands and liver, to name a few (Table 2).[12]

The prevalence of noncardiac findings is dependent on the type of CT protocol used, whether the patient is symptomatic, and the age of the patient (Table 3). Symptomatic elderly patients are more likely to manifest abnormalities on CT.[13]

Solitary Pulmonary Nodules

From a pathologic perspective, the term "nodule" refers to a small, spherical, circumscribed focus of abnormal tissue.[14] In radiology the term refers to a round opacity that is well marginated and not greater than 3 cm in diameter.[15,16] The risk of malignancy increases with increasing size of the lung nodule. Noncalcified lung nodules are by far the most common incidental finding on cardiac CT that is worked up. Nodules are characterized with respect to their appearance by size, density, border, location, and calcification.[17,18] Other key points that help in differentiating malignant from benign solitary pulmonary nodules (SPNs) include rate of growth (doubling time for malignant lesions is usually 20-400 days), edge characteristics (speculation or corona radiata is suggestive of malignancy), internal characteristics, attenuation on noncontrast CT, and contrast enhancement of lesion (Figure 1).[19-24]

The Early Lung Cancer Action Project was a study that involved 1000 symptom-free men over the age of 60 with no history of cancer who had at least a 10 pack per year history of

Table 2
Common Noncardiac Findings on Cardiac CT

Mediastinum	Clinical Significance	Follow-Up
Lymph nodes	Enlarged > 1 cm short axis length	Benign, indeterminate, or potentially malignant
Hiatal hernia	Cause for chest discomfort	May need referral to gastroenterologist
Pulmonary nodule	< 3 cm diameter, completely surrounded by lung parenchyma	Density: solid, nonsolid, part solid
Vascular anomalies	PDA, aneurysmal dilatation	May need vascular surgery evaluation
Aortic calcification	Surrogate for CAD	May need invasive or noninvasive cardiac testing
Pulmonary embolism	Incidental PE	Warrants anticoagulation
Upper Abdomen		
Adrenal masses	"Incidentalomas" versus pathologic	May require needle biopsy and endocrine tests
Liver lesions	Metastases versus benign	May need further work-up

CAD, coronary artery disease; CT, computed tomography; PDA, patent ductus arteriosus; PE, pulmonary embolism.
Data from Sosnouski D et al.[12]

Table 3
Prevalence of Noncardiac Findings Based on CT Protocol Used

CT Protocol Used	Prevalence of Noncardiac Findings (%)
Calcium scoring	7-12
Coronary CTA	22.7
Cardiac CT for bypass graft evaluation	27
Cardiac CT for pulmonary vein ablation	30

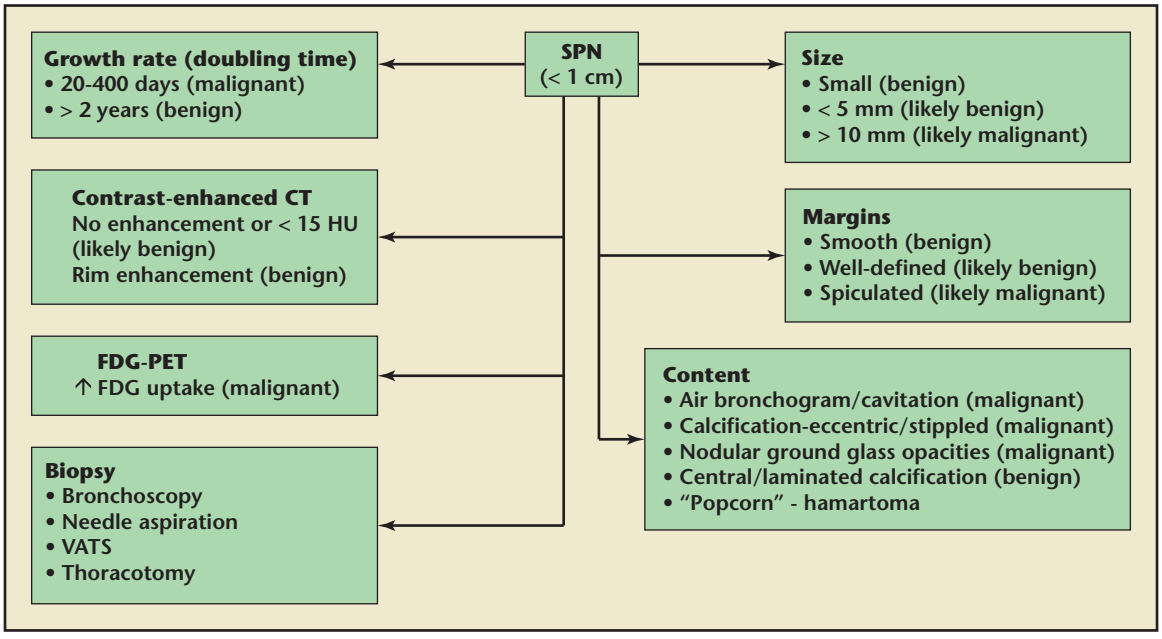
CT, computed tomography; CTA, CT angiography.

tobacco smoking.[25] The main goal of this study was to define the curability of lung cancers detected on CT based on their size at the time of detection. The authors argue that low-dose CT can improve the detection of small noncalcified lung nodules, and thus of lung cancer at an earlier stage that could potentially be curable.

The Mayo Lung Project, which evaluated lung cancer incidence and mortality in a population that was offered chest radiographs and sputum cytologic screening examinations, failed to demonstrate any mortality benefit attributable to screening after 6 years of observation and at least 1 year of follow-up.[26,27] McMahon and colleagues[28] studied the long-term effectiveness of lung cancer screening with CT scan in the Mayo CT screening study in 1520 current or former smokers and reported that lung cancer-specific mortality may be lowered up to 28% at 6-year follow-up.

There is considerable disagreement about the cost benefits of lung cancer screening. Three-year results from the DANTE trial, a randomized study of lung cancer screening with spiral CT, showed that the mortality benefit from lung cancer screening by spiral CT might be far smaller than anticipated.[29] The above arguments regarding the work-up of SPNs have to be viewed in the backdrop of numerous studies that have given us conflicting data regarding mortality benefits from lung cancer screening. Mahadevia and associates[30] used modeled data consisting of hypothetical cohorts of 100,000 current, quitting, and former heavy smokers, aged 60 years, to evaluate lung cancer screening and cost effectiveness. The authors concluded that current uncertainty regarding the benefits, coupled with the harms from invasive testing, not to mention the high costs associated with screening, implies that direct-to-consumer marketing of helical CT is not advisable. Solitary pulmonary nodules (SPNs) continue to pose a challenge in terms of management. A multidisciplinary approach consisting of pulmonologist, radiologist, and

Figure 1. *Solitary pulmonary nodule (SPN). Features suggestive of malignancy. CT, computed tomography; FDG-PET, fluorodeoxyglucose positron emission tomography; VATS, video-assisted thoracoscopic surgery.*



a thoracic surgeon may offer the best outcome.[31]

Pulmonary Embolism

Data are scant on the diagnostic accuracy of cardiac-specific CTA protocols in the evaluation of pulmonary embolism. Dodd and coworkers[32] have shown that emergency cardiac CT, although quite satisfactory for assessing coronary arteries and proximal ascending aorta, is suboptimal for depiction of pulmonary vasculature and the exclusion of pulmonary emboli. An electrocardiogram-gated chest CTA protocol is capable of diagnosing right ventricle dysfunction in patients with pulmonary embolism, which is a prognostic factor in these patients.[33] CTA is capable of detecting a multitude of nonvascular causes of acute chest pain such as pneumonia, pericarditis, or fractures.[34]

Triple Rule-Out and Emergent Dedicated Cardiac CT

Chest pain that accounts for a large number of visits to the emergency department is a highly contentious issue, and acute coronary syndrome (ACS) is identified in approximately 15% to 25% of patients with acute chest pain who are evaluated in emergency rooms.[35] Fast volume coverage on CTA has garnered tremendous attention recently in patients with chest pain, wherein the coronary and pulmonary arteries and the aorta are imaged in a single breath hold, the so-called "triple rule-out" (see also Figure 2).[36-38] The ability to evaluate 3 major life-threatening conditions (ACS, pulmonary embolism, and dissecting aortic aneurysm) in a single scan is an unbeatable advantage of this test. A dedicated CTA, however, uses an FOV of 220 as opposed to 400, which is 35.5% less for a triple rule-out. Lee and coauthors[39] point out that although this is the case, the limited FOV in a CTA is a step in the reconstruction phase and not the acquisition phase.

In a study of 395 patients who underwent CTA, Lehman and associates[40] reported incidental findings in 44.8%, of which the most common finding was noncalcified pulmonary nodules. The authors note that this number, although significant, is lower than the 58% reported by Onuma and colleagues.[9] This highlights an important point raised by the authors that the detection rates for incidental findings are always going to depend on whether the population being evaluated is symptomatic, high risk versus low risk, whether the test is being done for screening purposes, and population age. Furthermore, because these studies use contrast they are able to afford greater spatial resolution and thereby enable detection of many more abnormalities than a noncontrast study.

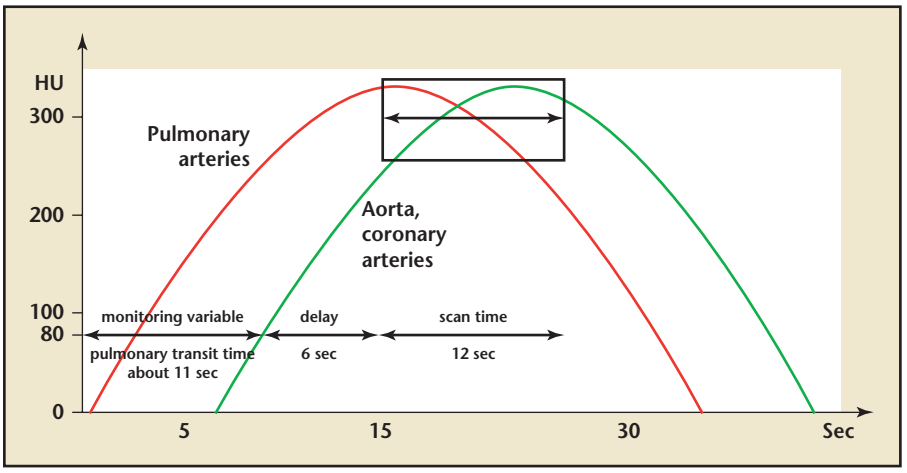


Figure 2. *Triple rule-out computed tomography is aimed at a simultaneous, homogenous, and high-contrast attenuation (> 250 HU) of the pulmonary arteries, the aorta, and the coronary arteries, and requires the use of a dedicated contrast-medium application protocol. This must take into account the transit time between the pulmonary and aortic/coronary opacification that normally lasts about 11 seconds. With kind permission from Springer Science+Business Media:* Eur Radiol. *Triple rule-out CT in the emergency department: protocols and spectrum of imaging findings. Vol. 19, 2009, 789-799, Frauenfelder T et al.*

Fast volume coverage on CTA has garnered tremendous attention recently in patients with chest pain, wherein the coronary and pulmonary arteries and the aorta are imaged in a single breath hold, the so-called "triple rule-out."

Cost Considerations

Cardiac CT is in the throes of coming to the forefront as a "gatekeeper" to the heart catheterization laboratory and a triage tool for emergency department physicians (triple rule-out), thus obviating further expensive and multiplicative diagnostic tests. Reimbursement issues and cost considerations have prevented ascendancy and further strengthening of CT in these practice scenarios.

Law and coworkers[41] reviewed findings from 295 consecutive patients who underwent multislice coronary CTA examinations and 140 consecutive patients who had separate coronary calcium scoring examinations; 19% of the CTA group and 8% of the calcium scoring group had significant extracoronary findings requiring follow-up.

Ethical Considerations

The majority of the medicolegal arguments surrounding the detection of noncardiac findings on cardiac CT dwell on what constitutes a "clinically significant" finding. This depends on the clinical context under which the test is being pursued, the patient population, and the expected outcome or impact from the performance of the test in question.

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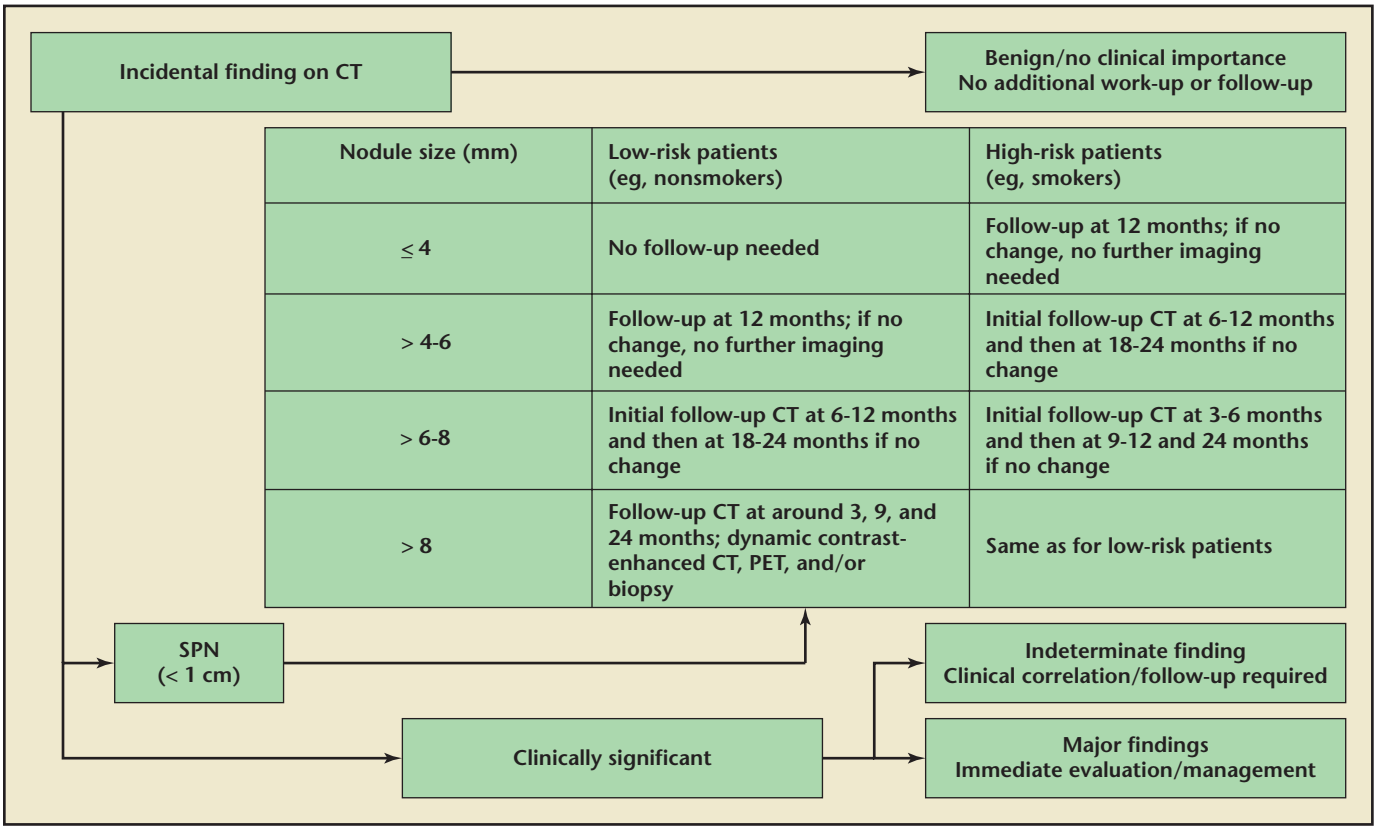
Certainly ethical considerations arise in the gray zones that we are about to navigate. In their poignant article on ethical considerations of CTA, Wann and colleagues[42] suggest that there may be a clear benefit when an unexpected abnormality is detected and treated, but in other cases the benefit may be less straightforward. In fact, in certain circumstances detection of an incidental finding can lead to excessive patient anxiety, unnecessary and expensive diagnostic testing with resultant physical harm, monetary losses, and lost productivity.

A common point in consideration is the lung nodule detected as an incidental finding on cardiac CT. Great fear exists in both the minds of the clinician and the patient regarding the potential for malignancy in such nodules. The Fleischner Society recommendations (Figure 3) are a useful tool that helps in the follow-up of incidental pulmonary nodules.[43] Furthermore, multiple approaches exist and are described for the management of the indeterminate nodule, such as Bayesian analysis, artificial intelligence, and artificial neural networks.[44]

Peculiar to the current discussion is the fact that cardiac CT scans are interpreted differently by cardiologists and radiologists. This is the direct result of training and the exposure to extracardiac pathology that is encountered during practice. Douglas and associates[45] have noted that radiologists have the most extensive training in interpreting extracardiac

Figure 3. *Suggested algorithm for work-up of incidental findings on cardiac CT (includes Fleischner Society recommendations with respect to pulmonary nodules). CT, computed tomography; PET, positron emission tomography; SPN, solitary pulmonary nodule. Reprinted with permission from McMahon PM et al.* Radiology. *2008;248:278-287. Copyright © 2008 Radiological Society of North America.*



findings associated with cardiovascular imaging. Predictably, the reverse is true for cardiologists, as they are more fluent in cardiac anatomy and cardiovascular disease states.

Because there appears to be a difference in focus based on discipline some centers appear to endorse a team approach in which cardiologists and radiologists work together.[42] Training guidelines have been published by the major cardiac and imaging societies such as the American College of Cardiology, Société Nucléaire Canadienne, Society for Cardiac Angiography and Interventions, and the Society of Cardiovascular Computed Tomography, all of which recommend that due attention be paid to the recognition of incidental noncardiac findings on cardiac CT.

Conclusions

It is hard to draw a meaningful conclusion or generate comprehensive clinical guidelines with regard to the management of incidental findings detected on cardiac CT based on the current literature. This results from a combination of paucity of studies pertaining to this problem and difficulties in defining what constitutes a clinically significant finding. Cardiac CT itself is evolving rapidly and its place in clinical algorithms for work-up and management of ACS and CAD is being hotly debated.

The most recent American College of Cardiology Foundation/American Heart Association guidelines recommend that current radiology guidelines be considered when determining the need for follow-up of incidental findings for noncardiac pathology detected on cardiac CT.[43,46] ■

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Main Points

- Multislice computed tomography (CT) is rapidly emerging as a novel technique for the evaluation of coronary artery disease.
- Increasing use of CT for calcium scores and CT angiography will inevitably result in the discovery of incidental extracardiac findings.
- Some studies show that the prevalence of new noncardiac findings in patients who underwent cardiac CT imaging was as high as 50%.
- Cardiac CT is coming to the forefront as a "gatekeeper" to the heart catheterization laboratory and a triage tool for emergency department physicians, thus obviating further expensive and multiplicative diagnostic tests.
- The majority of the medicolegal arguments surrounding the detection of noncardiac findings on cardiac CT dwell on what constitutes a "clinically significant" finding. In fact, in certain circumstances detection of an incidental finding can lead to excessive patient anxiety, unnecessary and expensive diagnostic testing with resultant physical harm, monetary losses, and lost productivity.

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