Incidental findings are an important topic in diagnostic imaging. Because of the comprehensive nature of computed tomography (CT) scanning, incidental findings are seemingly found on almost every CT scan performed for a wide variety of reasons in a radiology department. Many of these incidental findings such as a liver cyst are benign and immediately dismissed. Other findings require more extensive interpretation and management. In regard to coronary CT angiography (CCTA), a similar problem exists. Even though we have a primary interest in the heart, the CT scanner delivers radiation to all tissues of the chest such as the bones, lung parenchyma, and breast tissue. Extracardiac findings are reported to occur in 15% to 67% of CCTA examinations, and the vast majority (~80%) represent pulmonary nodules.

The justifications for option 1 or 2 tend to be along medical or ethical lines of reasoning. For example, medically, there may be no clinical indication to look at the lungs in the first place; the ordering physician asked only that the coronary arteries be evaluated. In this scenario, evaluation of the lungs requires additional effort that may not be reimbursed by payers.

The study by Goehler et al in this issue of Circulation approaches the problem of incidental pulmonary nodules from an economic and, indirectly, an ethical perspective to estimate the potential cost burden to society to evaluate incidental pulmonary nodules on CCTA scan. They used data from a CCTA clinic at the Massachusetts General Hospital (MGH) as the basis for the MGH Lung Cancer Policy Model. The Lung Cancer Policy Model projected the development and progression of lung cancer over time and the likelihood of detection of nodules with diagnostic follow-up care and therapeutic treatment. The economic model takes into account death resulting not only from lung cancer but also from other causes such as coronary artery disease. At the MGH, 591 of 3665 patients (16%) undergoing CCTA had pulmonary nodules that required follow-up. Even though 5.8% of patients were projected to have lung cancer, the majority (94%) were projected to die of other causes, including coronary artery disease. Thus, as viewed from an economic perspective, the workup of a pulmonary nodule had little consequence in improving the health of society. The workup of all patients to find the minority (6%) who were at greatest risk was costly, between $129 800 and $154 700 per quality-adjusted life-year (QALY). The authors concluded that this cost was greater than the generally accepted threshold for approval or payment of medical interventions, which the authors refer to as $100 000 per QALY.

Most physicians are very aware of the increasing implementation of low-radiation-dose CT screening programs for surveillance of patients at high risk for lung cancer. In this case, the pulmonary nodules are not incidental but rather the goal of the CT scanning. The basis for such programs is the National Lung Screening Trial (NLST), which enrolled 53 454 individuals at high risk for lung cancer and demonstrated that CT screening reduces mortality of lung cancer compared with chest x-ray. The NLST trial included patients who were 55 to 74 years of age and who had smoked at least 30 pack-years in their lifetime. In this trial, a 20% reduction in lung cancer mortality was demonstrated compared with screening with chest x-ray radiography. The cost of lung cancer screening has been

**Editorial**

Coronary Computed Tomographic Angiography and Incidental Pulmonary Nodules

David A. Bluemke MD, PhD

Incidental findings are an important topic in diagnostic imaging. Because of the comprehensive nature of computed tomography (CT) scanning, incidental findings are seemingly found on almost every CT scan performed for a wide variety of reasons in a radiology department. Many of these incidental findings such as a liver cyst are benign and immediately dismissed. Other findings require more extensive interpretation and management. In regard to coronary CT angiography (CCTA), a similar problem exists. Even though we have a primary interest in the heart, the CT scanner delivers radiation to all tissues of the chest such as the bones, lung parenchyma, and breast tissue. Extracardiac findings are reported to occur in 15% to 67% of CCTA examinations, and the vast majority (~80%) represent pulmonary nodules.

**Article see p 668**

For diagnostic radiologists, evaluation of all tissues in the x-ray path has long been the standard of care. If an x-ray of the shoulder includes the lateral lung fields, the diagnostic radiologist evaluates that portion of the lung for an infiltrate or lung mass. Similarly, for CT scanning, if the primary request is to evaluate for pulmonary embolus (pulmonary arteries) or lymphadenopathy (mediastinum), we also expect the radiologist to evaluate all tissues that are exposed to the x-ray beam, including the lungs.

Cardiologists who interpret CCTA examinations may not have training that allows diagnostic evaluation of all tissues within the field of view of the x-ray beam. This results in 2 different strategies to deal with extracardiac tissues beyond the coronary arteries:

1. The CCTA images can undergo a separate evaluation by a radiologist for interpretation of extracardiac tissues. This approach requires additional time and effort that may not be fully reimbursed. Some office-based practices may not have radiology expertise available. A potential solution is to acquire sufficient training to allow confident handling of such findings.

2. Tissues beyond the heart can be (mostly) removed in an automatic manner by the CT scanner software (Figure). Noncardiac data may be digitally discarded. This digital deletion approach is only partially successful because some lung tissue invariably remains in the field of view. According to an expert consensus statement, the digital deletion approach reduced the number of incidental non-coronary findings from 20% to 2%.

The justifications for option 1 or 2 tend to be along medical or ethical lines of reasoning. For example, medically, there may be no clinical indication to look at the lungs in the first place; the ordering physician asked only that the coronary arteries be evaluated. In this scenario, evaluation of the lungs requires additional effort that may not be reimbursed by payers.

The study by Goehler et al in this issue of Circulation approaches the problem of incidental pulmonary nodules from an economic and, indirectly, an ethical perspective to estimate the potential cost burden to society to evaluate incidental pulmonary nodules on CCTA scan. They used data from a CCTA clinic at the Massachusetts General Hospital (MGH) as the basis for the MGH Lung Cancer Policy Model. The Lung Cancer Policy Model projected the development and progression of lung cancer over time and the likelihood of detection of nodules with diagnostic follow-up care and therapeutic treatment. The economic model takes into account death resulting not only from lung cancer but also from other causes such as coronary artery disease. At the MGH, 591 of 3665 patients (16%) undergoing CCTA had pulmonary nodules that required follow-up. Even though 5.8% of patients were projected to have lung cancer, the majority (94%) were projected to die of other causes, including coronary artery disease. Thus, as viewed from an economic perspective, the workup of a pulmonary nodule had little consequence in improving the health of society. The workup of all patients to find the minority (6%) who were at greatest risk was costly, between $129 800 and $154 700 per quality-adjusted life-year (QALY). The authors concluded that this cost was greater than the generally accepted threshold for approval or payment of medical interventions, which the authors refer to as $100 000 per QALY.

Most physicians are very aware of the increasing implementation of low-radiation-dose CT screening programs for surveillance of patients at high risk for lung cancer. In this case, the pulmonary nodules are not incidental but rather the goal of the CT scanning. The basis for such programs is the National Lung Screening Trial (NLST), which enrolled 53 454 individuals at high risk for lung cancer and demonstrated that CT screening reduces mortality of lung cancer compared with chest x-ray. The NLST trial included patients who were 55 to 74 years of age and who had smoked at least 30 pack-years in their lifetime. In this trial, a 20% reduction in lung cancer mortality was demonstrated compared with screening with chest x-ray radiography. The cost of lung cancer screening has been
This cost is similar to that identified by Goehler et al. The acceptance of lung cancer screening programs by CT is gaining traction in the United States. Algorithms such as the MGH Lung Cancer Policy Model are only as good as the data and assumptions that feed the computations. A key data element for the Lung Cancer Policy Model was the Fleischner Society policy statement for the evaluation of incidental pulmonary nodules. In 2005, the approach to dealing with incidental pulmonary nodules was significantly influenced by a statement from the Fleischner Society, a think tank of academic chest radiologists with vast expertise in the field. Guidelines exist for both solid pulmonary nodules and subsolid nodules. The MGH Lung Cancer Policy Model used the Fleischner guidelines for the more common solid pulmonary nodule (Table). For solid pulmonary nodules, these guidelines divide patients into either low-risk patients (minimal or absent history of smoking or other known risk factors) or high-risk patients (history of smoking or other known risk factors). Overall, adherence to these guidelines is only moderate, ≈35% to 60% among practicing radiologists. The clarity of the Fleischner guidelines is compelling. At my institution, all of our CT scanners can routinely reconstruct a CT image at a slice thickness of ≈0.5 mm, resulting in frequent detection of nodules below the 4-mm threshold suggested by the Fleischner guidelines. For low-risk patients, the mental relief that a large fraction of detected nodules do not require follow-up is very significant to the practicing radiologist. On the other hand, what exactly do we know about the behavior of a 4-mm nodule versus a 5- or 6-mm nodule? In addition, the follow-up intervals by the Fleischner guidelines give considerable latitude to the practitioner: Should a nodule be followed up at 6- or 12-month intervals, and what is the impact on diagnosis (and cost)? Like other expert statements, the Fleischner guidelines have been generated in part by expert experience when clinical trial data are not available. Validation of these guidelines has not been prospectively performed.

The foundations of the Fleischner guidelines included knowledge about the growth rate and biology of lung cancer, the relative risk of smoking, and the characteristics of modern CT scanners. The Fleischner statement authors did not directly evaluate the economic impact of their recommendations using metrics such as QALY. Because both the Fleischner guidelines and the MGH Lung Cancer Policy Model make many assumptions about lung cancer growth rates, the question of whether the assumptions are the same in both the guidelines and the model remains. Assuming no contradictions between the 2, the results of Goehler et al present an interesting opportunity to test the cost-effectiveness of Fleischner guidelines. Could economic models help us refine our guidelines in the future? Currently, metrics such as QALY are not used in appropriate-use guidelines from our major professional societies.

Besides the Fleischner guidelines, there are other assumptions by Goehler et al that would be interesting to subject to a sensitivity analysis. For example, if one presumed that a threshold cost was $100 000 per QALY, what would the costs of the various medical services need to be to attain that QALY goal? Alternatively, how sensitive is the MGH model to the success of treatment of lung cancer? In the typical regression model, the β coefficients characterize the magnitude of the effect sizes. But in the economic model from Goehler et al, the relative contributions of various assumptions are not readily visualized. From their Table 3, the mortality results appear quite dismal: Lung cancer mortality was projected at 6.4% without any follow-up of nodules. But medical intervention appears to have little effect—only a reduction of 0.3% if lung nodules are followed up and receive intervention. At the same time, most patients (94%) die of other causes, including coronary disease. The results of Goehler et al seem to point to the current futility of the treatment of lung cancer combined with

---

**Table. Fleischner Society Guidelines for Solid Pulmonary Nodules Detected Incidentally in People Aged ≥35 Years**

<table>
<thead>
<tr>
<th>Nodule Size, mm</th>
<th>Low-Risk Patient (Minimal or Absent History of Smoking or Other Risk Factors)</th>
<th>High-Risk Patient (History of Smoking or Other Risk Factors)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤4</td>
<td>No follow-up</td>
<td>Follow-up CT at 12 mo; if unchanged, no further follow-up</td>
</tr>
<tr>
<td>&gt;4–6</td>
<td>Follow-up CT scan at 12 mo; if unchanged, no further follow-up</td>
<td>Follow-up CT at 6–12 mo and then at 18–24 mo if no change</td>
</tr>
<tr>
<td>&gt;6–8</td>
<td>Follow-up at 6–12 mo and then at 18–24 mo if no change</td>
<td>Follow-up CT at 3–6 mo and then at 9–12 and 24 mo if no change</td>
</tr>
<tr>
<td>&gt;8</td>
<td>Follow-up CT at 3, 9, and 24 mo; contrast CT, PET, or biopsy</td>
<td>Follow-up CT at 3, 9, and 24 mo; contrast CT, PET, or biopsy</td>
</tr>
</tbody>
</table>

CT indicates computed tomography; and PET, positron emission tomography. Adapted from MacMahon et al. Authorization for this adaptation has been obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.
the fact that patients die of many other causes (eg, infections or a wide variety of ailments).

The limitations of a strictly economic approach to pulmonary nodule evaluation are quite straightforward. Given 100 individuals with nodules, the model cannot determine a priori which 6 people will have lung cancer. Those 6 people stand an excellent chance of cure of their lung cancer because it is detected at an early stage. Unfortunately, the MGH Lung Cancer Policy Model says that to find those 6 people, we invariably harm 94 people with unnecessary testing and procedures, at a relatively high financial cost to society. Medically, it is difficult to potentially ignore the 6 people we could help. On the other hand, the diagnostic imaging community is probably relatively poor at providing information to the other 94 patients about the risks of CCTA testing in relationship to incidental findings.

Although Goehler et al address the issue of pulmonary nodules, we will soon see yet another paradigm shift in CT technology that may be more wide reaching. The latest generation of CT scanners being delivered to sites in the United States and worldwide is so fast that special coronary CT settings may not be required in all cases. In other words, routine screening CT of the chest for conditions such as adenopathy and infection will soon contain sufficient information for full 3-dimensional reconstruction of the coronary arteries at 0.5-mm spatial resolution. Coronary artery questions could arise frequently; routine CT chest studies are performed at least 100-fold more frequently than dedicated CCTA studies. Instead of the quandary of cardiologists interpreting pulmonary nodules, it is conceivable that the general diagnostic radiologist would face the decision of whether to interpret the coronary arteries seen on a routine chest CT. Currently, the large vessels (aorta, pulmonary arteries) are evaluated; why not smaller coronary arteries also? One could argue that the impact of incidental coronary artery stenosis is much greater than that of incidental pulmonary nodules: Ischemic heart disease has a high prevalence and is the leading cause of morbidity and mortality worldwide. Perhaps we should subject such questions to economic modeling such as that presented by Goehler et al. Overall, the work of Goehler et al is extremely interesting and thought provoking. My own conclusion is that our current guidelines for treatment and diagnosis of incidental pulmonary nodules have not caught up with the proliferation of CCTA testing. Should we at least temporarily ignore the lung findings until therapies for lung cancer therapies improve? As a physician and radiologist, I am quite biased against that approach. In medicine, a busy practitioner in almost any discipline encounters dozens of patients a week for whom optimal decision patterns are unknown. For CT scanning, we can digitally delete lung nodules to avoid the lung findings until therapies for lung cancer therapies increasingly improve. For CT scanning, we can digitally delete lung nodules to avoid the lung findings until therapies for lung cancer therapies increasingly improve.

Disclosures
Dr Bluemke reports research agreements with Philips Healthcare and Siemens Medical Systems.

References
4. McMahon PM, Kong CY, Bouzan C, Weinstein MC, Ciripiano LE, Tramontano AC, Johnson BE, Weeks JC, Gazelle GS. Cost-effectiveness of computed tomography screening for lung cancer in the United States and worldwide is so fast that special coronary CT settings may not be required in all cases. In other words, routine screening CT of the chest for conditions such as adenopathy and infection will soon contain sufficient information for full 3-dimensional reconstruction of the coronary arteries at 0.5-mm spatial resolution. Coronary artery questions could arise frequently; routine CT chest studies are performed at least 100-fold more frequently than dedicated CCTA studies. Instead of the quandary of cardiologists interpreting pulmonary nodules, it is conceivable that the general diagnostic radiologist would face the decision of whether to interpret the coronary arteries seen on a routine chest CT. Currently, the large vessels (aorta, pulmonary arteries) are evaluated; why not smaller coronary arteries also? One could argue that the impact of incidental coronary artery stenosis is much greater than that of incidental pulmonary nodules: Ischemic heart disease has a high prevalence and is the leading cause of morbidity and mortality worldwide. Perhaps we should subject such questions to economic modeling such as that presented by Goehler et al. Overall, the work of Goehler et al is extremely interesting and thought provoking. My own conclusion is that our current guidelines for treatment and diagnosis of incidental pulmonary nodules have not caught up with the proliferation of CCTA testing. Should we at least temporarily ignore the lung findings until therapies for lung cancer therapies improve? As a physician and radiologist, I am quite biased against that approach. In medicine, a busy practitioner in almost any discipline encounters dozens of patients a week for whom optimal decision patterns are unknown. For CT scanning, we can digitally delete lung nodules to avoid the lung findings until therapies for lung cancer therapies increasingly improve.

Disclosures
Dr Bluemke reports research agreements with Philips Healthcare and Siemens Medical Systems.

Key Words: Editorials angiography coronary artery disease computed tomography, x-ray computed
Coronary Computed Tomographic Angiography and Incidental Pulmonary Nodules
David A. Bluemke

Circulation. 2014;130:634-637; originally published online July 11, 2014;
doi: 10.1161/CIRCULATIONAHA.114.011634
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2014 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the
World Wide Web at:
http://circ.ahajournals.org/content/130/8/634

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published
in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial
Office. Once the online version of the published article for which permission is being requested is located,
click Request Permissions in the middle column of the Web page under Services. Further information about
this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org/subscriptions/