ORIGINAL ARTICLE

An Update on EBCT (Ultrafast CT) Scans for Coronary Artery Disease
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Abstract:
Objectives: To determine the predictive value of electron beam computerized tomographic scans for calcium in the detection of coronary artery disease.

Design: Literature review and meta-analysis of published studies of electron beam computerized tomographic scans for coronary calcification.

Methods: Six studies comparing EBCT scan and coronary angiography findings comprising 2,717 patients were reviewed. Bayesian analyses were performed for the entire cohort and subgroups. Bayesian analyses plots are presented.

Results: EBCT scans for the detection of coronary artery disease have a sensitivity that ranges from 68% to 100% and a specificity that ranges from 31% to 74% for the presence of significant coronary disease. (Overall, sensitivity = 94%; specificity = 42%) Sensitivities and specificities of EBCT scans for any coronary disease range from 80% to 97% and 52% to 65%, respectively. (Overall, sensitivity = 91%; specificity = 55%).

Conclusions: EBCT scans are being performed with increasing frequency as an adjunctive means to diagnose coronary disease. Although EBCT scans are unlikely to ever become a substitute for direct angiographic visualization of the coronary arteries, in certain instances they can be helpful in excluding or increasing the likelihood of significant coronary disease. The results of EBCT scans should be interpreted in the light of other available evidence, including such information as age, sex, the presence of risk factors for coronary disease, and the results of other tests such as ECG stress tests and imaging procedures. In general, although the presence of coronary artery calcification tends to be of more value in indicating that significant coronary disease is not present. The use of Bayesian analyses plots may prove of value in helping determine the significance of EBCT scan findings.

Although Ultrafast CT scanners became commercially available in 1983, the first study of their use to detect CAD was not published until 1989.¹ The results of two early studies on the use of Ultrafast CT scans in determining whether coronary artery disease (CAD) is present indicated that although an abnormal scan showing the presence of calcium is somewhat helpful in diagnosing CAD, a normal scan is more likely to indicate that significant CAD is not present.²³ Over the last four years, much has been learned about the significance of coronary artery calcification and the value of Ultrafast CT scans. This review attempts to summarize this information.

Coronary Artery Calcification Signifies the Presence of CAD
The presence of proximal coronary artery calcification has long been recognized as indicating the presence of atherosclerotic CAD.⁴ Until recently coronary artery calcification was felt to be the late result of “end-stage” atherosclerotic plaque degeneration. We now know that calcium is present in virtually all stages of plaque formation. We also know that acute myocardial infarction is more likely to be caused by rupture of an unstable and vulnerable plaque than by the progressive narrowing of advanced stenotic lesions.⁵ In the same way that the number of mature stenotic coronary lesions correlates with presence of vulnerable...
plaques, so does the presence of coronary calcium correlate to the total burden of atherosclerosis. In fact, there is evidence to suggest that the amount of coronary calcium may be even a better marker for "total plaque burden" than is the number and severity of coronary stenosis seen at the time of coronary angiography. This is because as atherosclerotic plaques form, the coronary arteries tend to expand to compensate for the presence of plaque. As a result, the lumen of the artery may remain relatively open despite the presence of large amounts of atherosclerotic material. (See figure 1) There is also evidence to suggest that the presence of significant calcium within a plaque may cause the plaque to be more susceptible to rupture.

Figure 1: Cross Section of Normal and Diseased Coronary Arteries

Just as the prevalence of coronary atherosclerosis increases with age, so does the prevalence of coronary artery calcification. Coronary artery calcification begins to be seen by 30 years of age in men, and by age 40 in women. EBCT data indicate that by age 65, the prevalence of coronary artery calcification in women approaches that seen in men. However, EBCT cannot detect all calcium: molecular calcium may go undetected. Thus, as Rumberger et al have stated, calcium detected by EBCT may represent "only the tip of the iceberg."10

Electron Beam Computed Tomography (EBCT)

EBCT was previously referred to as Ultrafast CT. EBCT uses a stationary source and stationary detector. Xrays are produced as a rotating electron beam is caused to sweep over semi-circular targets located beneath the subject. Since EBCT has no moving parts, a tomographic image can be created in 100 ms. This fast scan time allows the entire heart or thorax to be imaged over one to two breath holds. EBCT images also have high resolution. Typically, one pixel measures 0.25 mm$^2$ to 0.34 mm$^2$ and tomographic “slices” measure 1.5 to 3 mm in thickness. Images can be reconstructed to form three dimensional or cross sectional images. The presence of calcium is defined as pixel image density greater than 130 Hounsfield units. In most studies, total calcium is estimated by multiplying calcium area by a calcium density factor ranging from 1 to 4 based upon the maximum calcium density with that area. "Calcium scores" can be calculated for a coronary artery segment, a coronary artery, or more commonly, summed for the entire coronary system.

Studies on the Predictive Value of EBCT for Coronary Disease

The remainder of this review summarizes 5 studies comparing EBCT with coronary angiography and one study on dual-slice helical computed tomography for the detection of coronary disease. Together, these studies consisted of more than 2,700 patients. With rare exception, EBCT and coronary angiography were done because of the suspicion of CAD. Thus, the prevalence of CAD in these studies was high, and it may not be appropriate to extrapolate these results to EBCT scans done for screening purposes. In most studies, significant coronary disease was defined as 50% or greater narrowing of one or more coronary arteries as seen on coronary angiography. In other studies, CAD was defined as any angiographic coronary lumen irregularity suggestive of plaque.

For all five studies combined that looked for the presence of significant coronary artery disease, the sensitivity and specificity of EBCT were 94% and 42%, respectively. The corresponding positive and negative predictive values were 45% and 93% respectively. For the three studies that looked for the presence of
Table 1:
Summary of Studies Comparing EBCT with Coronary Angiography

<table>
<thead>
<tr>
<th>Author</th>
<th>Subjects</th>
<th>Definition of Disease State</th>
<th>N</th>
<th>N with Disease</th>
<th>Test Sensitivity</th>
<th>Test Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detrano</td>
<td>Men and Women</td>
<td>Significant CAD</td>
<td>491</td>
<td>211</td>
<td>95%</td>
<td>31%</td>
</tr>
<tr>
<td>Budoff</td>
<td>Men and Women</td>
<td>Significant CAD</td>
<td>710</td>
<td>427</td>
<td>95%</td>
<td>44%</td>
</tr>
<tr>
<td>Fallavollita</td>
<td>Men and Women</td>
<td>Significant CAD</td>
<td>106</td>
<td>72</td>
<td>85%</td>
<td>45%</td>
</tr>
<tr>
<td>Wong</td>
<td>Men and Women</td>
<td>Significant CAD</td>
<td>1,218</td>
<td>128</td>
<td>92%</td>
<td>43%</td>
</tr>
<tr>
<td>Budoff</td>
<td>Men and Women younger than age 40</td>
<td>Significant CAD</td>
<td>53</td>
<td>19</td>
<td>68%</td>
<td>74%</td>
</tr>
<tr>
<td>Rumberger</td>
<td>Men</td>
<td>Significant CAD</td>
<td>89</td>
<td>47</td>
<td>98%</td>
<td>43%</td>
</tr>
<tr>
<td>Rumberger</td>
<td>Women</td>
<td>Significant CAD</td>
<td>50</td>
<td>18</td>
<td>100%</td>
<td>34%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>2,717</td>
<td>922</td>
<td>94%</td>
<td>42%</td>
</tr>
<tr>
<td>Budoff</td>
<td>Men and Women</td>
<td>Any CAD</td>
<td>710</td>
<td>502</td>
<td>92%</td>
<td>54%</td>
</tr>
<tr>
<td>Fallavollita</td>
<td>Men and Women</td>
<td>Any CAD</td>
<td>106</td>
<td>92</td>
<td>80%</td>
<td>52%</td>
</tr>
<tr>
<td>Rumberger</td>
<td>Men</td>
<td>Any CAD</td>
<td>89</td>
<td>66</td>
<td>94%</td>
<td>65%</td>
</tr>
<tr>
<td>Rumberger</td>
<td>Women</td>
<td>Any CAD</td>
<td>50</td>
<td>34</td>
<td>97%</td>
<td>62%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>955</td>
<td>694</td>
<td>91%</td>
<td>55%</td>
</tr>
<tr>
<td>Broderick</td>
<td>Men and Women</td>
<td>Double Helix CT for Significant CAD</td>
<td>101</td>
<td>68</td>
<td>88%</td>
<td>52%</td>
</tr>
</tbody>
</table>

any CAD, the combined sensitivity and specificity of EBCT were 91% and 55%, respectively. The corresponding positive and negative predictive values were 84% and 69% respectively. From this data it can be appreciated that in a population where CAD is common, the absence of calcium on EBCT is more accurate in excluding significant degrees of CAD than is the presence of calcium in confirming its presence. (see Table 1)

The composite results of these studies are shown graphically in figure 2. The solid lines in this figure represent the composite positive and negative predictive values for EBCT when the pre-test prevalence of CAD ranges from 0 to 100%. The shaded areas represent the range of positive and negative predictive values for EBCT based upon the results of different studies. Also shown in this figure (broken lines) are the positive and negative predictive values for EBCT based upon two early studies by Wong and Fallavollita. Again, it can be seen that EBCT has a mild to moderate positive predictive value for CAD, and a significant negative predictive value. In general, the absence of coronary calcification on EBCT is more helpful in excluding CAD than is the detection of calcium in confirming the presence of CAD.

There is more to the story, however. Since coronary artery calcification begins about a decade later in women compared to men, it should not be surprising that the finding of coronary calcification in women has a somewhat higher positive predictive value than it does in men. Indeed, if high calcium scores are found in a young woman, there is a good chance that she will have significant CAD. (See figure 3). Conversely, if no calcium is found on EBCT in a woman, there is a small likelihood that significant CAD will be present.

On the other hand, since the prevalence of
coronary artery disease and coronary calcification is higher in men and also increases with age, the finding of calcium on EBCT in older men does not increase the post-test probability of CAD significantly compared to the pretest probability (See figure 3). In young men (55 years or younger), the finding of high amounts of calcium increases the likelihood of significant CAD modestly, whereas the absence of calcium in high amounts does not decrease the likelihood of CAD significantly. Even the absence of smaller amounts of calcium does not exclude the possibility of significant CAD in younger men. (See figure 4)

Helical (Spiral) Computed Tomography

Recently, another form of computed tomography, helical or spiral computed tomography, has been developed. In helical tomography, continuous scanning is performed in combination with a continuous table feed. Thus, the x-ray beam traces a spiral path through the patient. Since data is acquired continuously, images can be obtained almost as quickly as with EBCT (700 msec to 1 sec compared to 100ms for EBCT). The entire heart can be imaged within one breath hold (30 sec). Helical CT scanners are substantially less expensive than EBCT scanners, hence they are more commonly available. In August 1996, Broderick, et al published the results of a study of 101 patients who underwent both dual slice helical CT for coronary calcification and angiography. Compared to angiography, the sensitivity and specificity of helical CT was equivalent to that for EBCT. (See table 2).

Mortality and Morbidity Implications of Calcium found on EBCT

In 1996, Detrano et al published the results of a longitudinal study of 491 symptomatic patients who underwent both EBCT and coronary angiography. They compared survival rates for patients having low calcium scores with that of patients having high calcium scores. During a follow-up period of 30 ± 13 months, there were 13 coronary deaths and 8
Bayesian analysis plots may prove to be of value in helping determine the significance of EBCT findings.

In summary, EBCT is being performed with increasing frequency as an adjunctive means to diagnose CAD. In addition, the ready availability of helical CT scanners promises to even further increase the frequency that scans for coronary artery calcifications are done and the frequency that underwriters and insurance medical directors will see these studies. Although EBCT is unlikely to ever become a substitute for direct angiographic visualization of the coronary arteries, EBCT can be helpful in excluding or increasing the likelihood of significant CAD in certain situations.

- The absence of coronary artery calcification substantially decreases the likelihood of significant coronary disease. This is especially true in women.
- The presence of coronary artery calcification tends to somewhat increase the likelihood of coronary disease in men.
- The presence of significant coronary artery calcification in young women makes it likely that coronary artery disease is present.
- In general, a greater amount of coronary calcification indicates a higher likelihood of obstructive coronary disease, but the relationship is not perfect.
- False positive and false negative results do occur.
- The results of EBCT scans should be interpreted in light of other available evidence, including such information as age, sex, the presence of risk factors, and the results of other tests such as ECG stress tests and imaging procedures.
- Bayesian analysis plots may prove to be of value in helping determine the significance of EBCT findings.

References
13. Fallavollita ibid SEE 2 Above.
14. Wong ibid SEE 3 Above.
18. Broderick ibid SEE 17 above.