Computed tomography (CT) based calcium scoring in the diagnosis and prognostication of coronary artery disease (CAD)

Jai Prashanth Jayakar (Meds 2013), Adrian Matthews (Meds 2013), Joshua Rosenblat (Meds 2014)
Faculty Reviewer: Dr. Aashish Goela, MD MSc FRCP(C) (Department of Medical Imaging)

Invented by Sir Godfrey Hounsfield in the 1970s, computed tomography (CT) has greatly strengthened the arsenal of imaging technologies that is available to physicians to detect, prognosticate, and treat disease. The fundamental principle underlying CT scanning is the exposure of biological tissues to rotating fine beam X-rays, followed by the detection and processing of the radiation that these tissues attenuate to create a computerized image. The two major types of CT scanning are helical CT and conventional non-overlapping CT. Since its introduction, various enhancements have been made to CT technology which has allowed application across varied medical fields. In cardiac imaging, coronary CT angiography has recently risen to the forefront. As it is a newer technology, data in the literature lags behind the well-studied methods to quantify the amount of calcium inside coronary arteries using information obtained from cardiac CT scans, known as calcium scoring. In this article, we explore the use of this specialized CT technology and highlight its advantages and limitations in the diagnosis and prognostication of coronary artery disease.

CT BASED CALCIUM SCORING

In coronary arteries, CT based calcium scoring methods quantify calcium as a parameter termed coronary artery calcification (CAC). Calcium scoring is used to evaluate coronary artery disease since calcium build up in plaques is a key process in atherosclerosis. It should be noted that there is evidence non-calcified plaques are also important, however, they are not evaluated by this method and are thus outside of the scope of this review. Electron beam CT (EBCT) has been a popular method for the assessment of coronary calcium since its development in the 1980s. Nowadays, calcium scoring can also be performed with multidetector or multislice CT scanners (MDCT and MSCT). There is some agreement that the calcium scores obtained from both methods are similar, though this has not been extensively studied. Various methods have been used to compute calcium scores; for example, the Agatston score assigns a weighted value based on the highest density of calcification in the plaque and then multiplies this by the area of calcification. Such scores for all calcifications in all CT slices taken are summed up to provide a CAC score for all the coronary arteries.

Due to certain limitations with Agatston scoring, most notably inconsistent inter-scanner comparability, newer methods such as the volume score and calcium mass score were developed and compared with the Agatston score. Some studies indicate that these methods may be equivalent to the Agatston method in terms of reproducibility. A more recent method of calcium scoring is known as the lesion specific calcium score in which more specific parameters related to each calcified lesion are included in the final calcium score, such as width, density and distance from major coronary arteries. There is emerging evidence to indicate that the lesion-specific calcium scoring method maybe more accurate than the Agatston method for some purposes; for example, the sensitivity, specificity, and accuracy of the lesion specific calcium score method were shown to be superior to the traditional Agatston score in detecting angiographically confirmed obstructive coronary artery disease.

CORONARY ARTERY CALCIFICATION (CAC) AND CORONARY ARTERY DISEASE

Many studies have shown the association between CAC and coronary artery disease as detected by histopathological or angiographic methods. For example, one histopathological study on autopsied coronary arteries showed that the EBCT calcium scores correlated well with plaque area. A clinical study of more than 700 patients showed that EBCT calcium scoring had 95% sensitivity in picking up angiographically significant coronary artery disease. CAC has also been studied in relation to myocardial ischemia. Myocardial ischemia most often manifests silently, and this can be detected as stress-induced ischemia with stress testing. One study showed that the likelihood of stress-induced myocardial ischemia increased with a higher CAC score, although the majority of patients (78%) with detectable CAC did not have stress-induced ischemia suggesting a poor positive predictive value of prognosis with CAC scoring. A report from the prospective cohort study known as the multiench mediterranean study of atherosclerosis (MESA) evaluated the relationship between CAC and myocardial ischemia in an asymptomatic population. This study showed that the coronary vasodilatory response (myocardial blood flow with stress) was reduced with a higher CAC, but the resting myocardial blood flow was not affected by increased CAC. These studies provide some indication that CAC maybe associated with impaired myocardial perfusion in a subclinical atherosclerotic state. Overall, there is a good body of evidence to suggest that CAC is associated with structural and functional coronary artery disease.

PROGNOSTIC VALUE OF CAC

Studies have assessed the prognostic value of CAC in both symptomatic and asymptomatic patient populations. There is reasonable evidence to indicate that CAC has good prognostic value in asymptomatic patients. For example, a study of more than 5000 low-intermediate risk, middle-aged adults over a 3 year follow up period found that higher EBCT CAC scores at baseline were associated with a higher risk of developing cardiac events later on in both genders. Another study of more than 1000 patients over a 19 month follow up period showed that higher cut-off levels for EBCT CAC scores were associated with better specificities for predicting cardiac events. Incremental prognostic value of EBCT CAC was observed, in addition to that provided by conventional cardiac risk factors.
One study in a symptomatic patient population consisting of 491 participants referred for coronary angiography found that EBCT CAC scores were moderately predictive of angiographically confirmed coronary artery stenoses and that higher scores were associated with a higher incidence of coronary artery related cardiac events. A similar study on patients referred for coronary angiography followed up after an average time of 7 years found that among conventional risk factors and EBCT CAC, only EBCT CAC (risk ratio 1.72) and age (risk ratio 1.88) were predictive of future hard cardiac events (hard events include non-fatal myocardial infarction and cardiac death). Furthermore, patients with an EBCT CAC score of less than 100 had significantly higher event-free survival rates. Taken together, the prognostic value of CAC has been shown to have a high negative predictive value and a moderate positive predictive value for major adverse coronary events (MACE). Thus, CAC shows promise for aiding in risk stratification.

LIMITATIONS OF CALCIUM SCORING

Although the above discussion has highlighted the value of calcium scoring in detecting and providing prognostic information about coronary artery disease, certain caveats of calcium scoring exist. For example, some results suggest that there is a threshold level of calcium accumulation beneath which EBCT CAC is not predictive of plaque area or severity. Furthermore, studies have reported that EBCT CAC has very good sensitivity for picking up significant angiographic stenoses (greater than 50%), but only moderate specificity. This was confirmed by a consensus document released by the American College of Cardiology in which, based on a meta-analysis by the working group, the sensitivity and specificity of EBCT in detecting coronary artery stenoses were 91% and 47% respectively. Studies have also evaluated whether treating asymptomatic patients with high calcium scores with pharmacotherapy improves outcomes. For example, the St. Francis heart study randomized controlled trial showed that treatment of patients having high calcium scores with statins and antioxidants did not reduce the progression of coronary calcification or the rates of atherosclerotic cardiovascular disease events.

Interestingly, another randomized controlled trial showed that using results from EBCT calcium scores to motivate behavioural change was not successful, as reflected by a lack of improvement in composite cardiac risk measured by 10 year Framingham risk scores. This raises concerns about the utility of EBCT calcium scoring in being an effective screening tool that affects outcomes, but more studies are required in this regard. In addition, there are practical, unresolved concerns about the application of EBCT CAC from a screening perspective; for example, its cost effectiveness and the negative effects associated with false positive tests and radiation exposure are potentially worrisome.

CLINICAL RECOMMENDATIONS FOR USE OF CALCIUM SCORING

The American College of Cardiology Foundation (ACCF) published a consensus document in 2007 to synthesize the evidence and make recommendations regarding the clinical use of CT based calcium scoring. For example, one of the recommendations states that it is helpful to use CAC to risk stratify asymptomatic patients that have an intermediate 10 year risk of developing cardiac events (10-20%), since this may affect how aggressively patients are managed. However, this use of calcium scoring is not recommended for low risk (<10%) asymptomatic patients since these patients are likened to the general population and there is no evidence to support screening the general population with CAC. CAC measurements were also not recommended for high risk (>20%) asymptomatic patients since intensive medical therapy is already suitable for these patients. Also, owing to insufficient evidence, a recommendation was made to not reduce treatment intensity of intermediate risk patients that had zero calcium scores. Furthermore, the recommendations caution against extrapolating findings to populations that have not been well studied; the evidence appears strongest for Caucasian, non-Hispanic men.

CONCLUSION

Despite some limitations in its specificity and concerns about its applicability to patients of varying ethnicities and risk statuses, CT based calcium scoring of coronary artery calcification has emerged as a useful tool that provides added prognostic and screening value, especially in asymptomatic patients with intermediate coronary heart disease risk. Given the prevalence of coronary artery disease and its unparalleled impact on mortality and morbidity, better and innovative methods of cardiac disease screening and prognostication, including calcium scoring, will become increasingly important in providing patient-centred care.

REFERENCES


North Perth Family Health Team

Helping You to Health Yourself

North Perth Family Health Team/Listowel Clinic is recruiting two family physicians. We are a Medical Community of 10 Family Physicians providing a full range of services including ER/OR/OB/Inpatient/Office practice with comprehensive electronic medical records that links Listowel Memorial Hospital, Wingham Hospital & London Hospitals. We have under serviced designation and are located 30 minutes from Stratford and 40 minutes from Kitchener-Waterloo.

A new hospital wing for our 50 bed facility (ER, OR and Diagnostic imaging) was completed in the past 3 years and has attracted a full compliment of surgical, pediatric and internal medicine consultants who regularly visit our site. A new Family Health Facility is being built with a completion date of early 2012. We enjoy the full support of our local community, Family Health Team and Hospital, in this diverse & challenging rural practice.

For more information please visit our FHT website at www.npflht.ca or contact us – 519-291-4200.