MDCT evaluation of atherosclerotic coronary artery disease: what radiologists should know?

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Learning objectives

Proper measurement of degree of coronary stenosis is quite important as misinterpretation directly leads to a significant consequence [i.e., unnecessary downstream testing such as coronary catheterization or myocardial perfusion imaging versus delayed diagnosis of coronary artery disease (CAD)]. However, it is not easy for inexperienced radiologists to interpret the degree of coronary stenosis precisely in the routine clinical practice. Therefore, the purposes of this article are to provide a clinical and radiological overview of coronary atherosclerosis, and a practical guideline about how to interpret degree of stenosis on coronary CTA.
Background

Atherosclerotic coronary artery disease comprises acute coronary syndrome (ACS) and stable angina. ACS caused by rupture of vulnerable plaque is a leading cause of death in the world. Numerous coronary revascularization procedures (i.e., percutaneous coronary interventions or coronary artery bypass graft surgeries) are performed for the purpose of relieving chest pain caused by stable angina, resulting in enormous cost and hospitalization. As an important tool for diagnosing ACS and stable angina, coronary CT angiography (CTA) has been increasingly being performed in patients presenting with atypical chest pain. In order to help treating physicians more efficiently, it is crucial for radiologists to have a comprehensive understanding about mechanisms and clinical aspects as well as CT findings of coronary atherosclerosis per se.
Findings and procedure details

Mechanism of coronary atherosclerosis (the concept of plaque inflammation)

Pathologic findings of vulnerable plaque leading to ACS are characterized by positive remodeling, a large lipid core, and thin fibrous cap. In contrast, plaques demonstrated in patients with stable angina lack such features. Plaque inflammation has been considered to have a crucial role in the formation of thin-cap fibroatheroma (TCFA). Collagen fibers which are produced by smooth muscle cells in the vascular wall are mainly responsible for the tensile strength of the fibrous cap covering atherosclerotic plaque. Plaque inflammation produces a fibrous cap thinning and friability due to decreased production or increased destruction of collagen fibers. Interferon-gamma derived from helper T lymphocyte (i.e., one of the inflammatory cells) induces vascular smooth muscle cells to reduce production of collagen fibers. At the same time, activated macrophages (i.e., one of inflammatory cells) secrete collagenase that leads to increased destruction of collagen fibers. Once the thin and friable fibrous cap ruptures, potent thrombogenic materials within the lipid core leak into the blood stream containing large amounts of coagulation factors. This combustible combination is analogous to setting a fire (i.e., leakage of lipid core) near inflammable chemicals (i.e., coagulation factors in the blood stream). The coronary artery may be occluded by rupture of the vulnerable plaque with sudden thrombosis. Certain medications that target this process may be valuable to selectively decrease plaque inflammation and can be used for preventing ACS. Statin therapy has the potential to reduce cardiac events through its anti-inflammatory action rather than its lipid lowering action. A study using optical incoherence tomography demonstrated an increase in the thickness of a fibrous cap after statin treatment compared to pre-treatment state. Although administration of statins has a potential to reduce future cardiac events, it has been suggested that it only reduces by one-third of all cardiac events. One study indicated that the combined use of anti-inflammatory drugs (e.g., statin plus low dose colchicine) may have additional benefit reducing future cardiac events compared with statins alone.

What does calcium score tell you?

How to calculate Agatston calcium score

The traditional method for measuring coronary artery calcium score (CACS) is the Agatston score. In the Agatston scoring system, positive calcium is defined as an area of the coronary arteries which has $\#_{130}$ Hounsfield unit (HU) and an area $\#_{1}$ mm$^2$. The scanning protocol of standard CACS CT is as follows: 120 kV; 3 mm collimation; non-overlapping prospective gating. The same kV setting should be maintained for follow-up
studies. If a low kV setting (e.g., 100 kV) is used instead of standard 120 kV, image noise and small calcium can be difficult to distinguish, leading to the risk of a falsely increased calcium score (Fig. 1 and 2).

Fig. 1: An example of a false positive coronary calcium mark on a coronary artery calcium score (CACS) CT obtained with a low voltage setting (100 kV) in a 50-year-old male subject. CACS CT was mistakenly obtained using 100 kV, instead of 120 kV. The Agatston score was reported as 4 at that time. Note high attenuations (arrows) (Fig. 1) in the left main and left anterior descending coronary artery.

References: - Bundang/KR
Fig. 2: Follow-up CACS CT two years later was performed with 120 kV. There is no evidence of coronary artery calcium on the follow-up CT (Fig. 1B). The high attenuation areas noted on the previous CT are due to noise caused by low kV.

References: - Bundang/KR

CACS CT was initially developed using electron beam CT which has high temporal resolution but limited spatial resolution. Although multi-detector CT (MDCT) has replaced electron beam CT for the purpose of performing CACS CT, by convention 3 mm thick collimation is still used because most data to predict future cardiac events were obtained with electron beam CT. The Agatston score uses a weighting factor assigned to the highest attenuation valve within a calcified plaque; 1 for 130-199 HU; 2 for 200-299 HU; 3 for 300-399 HU; 4 for >400 HU This weighting value is multiplied by the area of coronary calcium (mm²). For example, if a speck of coronary calcification in the left
anterior descending coronary artery has an area of 4 mm² and peak density of 270 HU, the Agatston score is 8 (i.e., 4 mm² x 2).

**Clinical indication for coronary artery calcium score CT**

The Framingham risk score (FRS) is used to estimate cardiac events for the next 10-year period by using conventional risk factors for CAD (i.e., chronologic age, sex, serum lipid level, smoking history, and hypertension). With the FRS, a subject is classified in the low, intermediate, or high risk group based on the estimated risk. The low, intermediate, and high risk groups indicate <10%, 10% -20%, and >20% rate, respectively, for a cardiac event over the next 10-years. Patients in the high risk group should be treated equivalently as those with known CAD (i.e., administration of statin and aspirin as well as strict control of CAD risk factors). In contrast, life style modification only is indicated in patients with a low FRS. However, there is no definite guideline for the intermediate risk group which consists of approximately 40% of the adult US population. As life-long administration of aspirin and statin may have a potential risk of bleeding and require a high cost, it is impractical to treat all individuals with intermediate FRS routinely. Therefore, it is reasonable to further classify intermediate risk group into low or high risk group based on further testing. According to the 2010 ACCF/AHA guidelines, it is appropriate to use CACS CT in patients with intermediate FRS. For example, in a patient with intermediate FRS and no coronary artery calcium, life style modification only is indicated. In contrast, in a patient with same FRS and a high Agatston score (>400), administration of aspirin and statin as well as life style modification should be considered.

**Clinical meaning of coronary artery calcium score**

A positive CACS indicates the presence of coronary atherosclerosis, even in asymptomatic subjects. Most men over 55 and women above 65 years of age have a positive CACS. The amount of coronary calcium is a surrogate of atherosclerotic burden in the coronary arteries. Agatston score (i.e., absolute score) or age-sex matched percentile (i.e., relative score) can be used to predict future cardiac events. The absolute score can be categorized as follows: 0, minimal burden (#10), moderate (11-#100), increased (#101-400), and extensive (>401). A zero CACS indicates a very low risk for future cardiac events. However, a negative CACS does not necessarily indicate the absence of significant coronary stenosis (defined as #50%) in patients with chest pain, although it is quite rare. Thus, coronary CTA should be performed in patients with chest pain, even if the CACS is negative (Fig. 3).
Fig. 3: An example of a zero calcium score (image not shown) but significant coronary artery stenosis in a 64-year-old female patient. Critical stenosis (>70%) with hourglass deformity is noted in the proximal left anterior descending coronary artery on volume rendered (arrow) (Fig. 3) and curved multi-planar reformatted image (arrow) (Fig. 4).

References: - Bundang/KR
Fig. 4: An example of a zero calcium score (image not shown) but significant coronary artery stenosis in a 64-year-old female patient. Critical stenosis (>70%) with hourglass deformity is noted in the proximal left anterior descending coronary artery on volume rendered (arrow) (Fig. 3) and curved multi-planar reformatted image (arrow) (Fig. 4).

**References:** - Bundang/KR

However, high CACS (#101) is associated with a higher risk for future cardiac events compared with a lower CACS (<100). One study reported a high prevalence (87%) of #50% stenosis involving at least one coronary artery in patients with >400 CACS. However, there is not a one-to-one correlation between the location of heavily calcified plaque and #50% stenosis.
A high age-sex matched percentile (i.e., >75 percentile) can be also used as a cut-off value for identification of high risk group (Table 1). Therefore, radiologists should mention presence or absence of Agatston score #101 or >75 age-sex matched percentile in their radiologic report as a cut-off value for a high risk of future cardiac events. Administration of statin and aspirin as well as CAD risk modification may be considered in this subgroup. One study suggested that absolute score rather than age-sex matched percentile predicts future cardiac events more precisely. This is because the absolute coronary atherosclerotic burden (i.e., absolute Agatston score) is more closely related to future cardiac events than relative atherosclerotic burden (i.e., age-sex match percentile). For example, a 50-year-old woman with an Agatston score of 50 (>75 age-sex matched percentile, but Agatston score<100) has a lower risk of a future cardiac event compared with 80-year-old man with an Agatston score of 1000 (Agatston score>100, but <75 age-sex-matched percentile).

**Limitations of the Agatston score**

One important limitation is that the Agatston score has inter-scan variability. As the Agatston score uses peak HU, threshold HU, and relatively thick collimation (3 mm), inter-scan variability appears to be inevitable. Therefore, the Agatston score cannot be used to determine progression or regression of coronary atherosclerosis after administration of statins (Fig. 5 and 6).

![Previous CAC result](image)

**Fig. 5:** An example of inter-scan variability noted on coronary artery calcium score (CACS) CT. As the Agatston scoring system uses peak Hounsfield unit (HU), threshold HU, and thick collimation (3 mm), inter-scan variability occurs frequently. The Agatston score was 117 on CACS two years earlier, whereas the follow-up score is 111 in an asymptomatic subject (Fig. 5 and 6). Agatston score can be different depending on how a particular calcified coronary plaque is scanned (i.e., presence or extent of partial volume averaging). Therefore, CACS CT does not usually reliably determine progression or regression of coronary atherosclerosis after administration of statins.

**References:** - Bundang/KR
Fig. 6: An example of inter-scan variability noted on coronary artery calcium score (CACS) CT. As the Agatston scoring system uses peak Hounsfield unit (HU), threshold HU, and thick collimation (3 mm), inter-scan variability occurs frequently. The Agatston score was 117 on CACS two years earlier, whereas the follow-up score is 111 in an asymptomatic subject (Fig. 5 and 6). Agatston score can be different depending on how a particular calcified coronary plaque is scanned (i.e., presence or extent of partial volume averaging). Therefore, CACS CT does not usually reliably determine progression or regression of coronary atherosclerosis after administration of statins. 

References: - Bundang/KR

If thinner collimation (e.g., 1 mm collimation) is used for CACS CT, inter-scan variability is reduced, but this may cause difficulty in discriminating image noise from true calcification. Other methods such as volume or mass calcium score has been developed to reduce inter-scan variability. However, these are less commonly used because of their complexity and the lack of large-scale published data about future cardiac events. Secondly, non-calcified plaque including vulnerable plaque cannot be evaluated on CACS CT.

Common errors in calculating the Agatston score

The technologist who calculates the Agatston score on the workstation can mistakenly omit a true coronary calcification or include calcifications other than the coronary artery (e.g., lymph node or mitral annular calcification), leading to inaccuracy in estimating the risk of future cardiac events. Therefore, radiologists should carefully check whether coronary artery calcification is correctly delineated on the axial CT images.

How to precisely measure degree of coronary stenosis?

What do clinicians expect from coronary CT angiographic report?

The degree of coronary stenosis is measured by the following formula: percent diameter stenosis=[(diameter of reference coronary segment)-(diameter of stenotic portion)/(diameter of reference coronary segment)] x 100. In a practical sense, coronary CTA reports should address the following three questions. The clinician's first question is
whether coronary angiography is necessary or not. Although CT stress myocardial perfusion imaging and CT fractional flow reserve has recently become available (but still is used mainly for research purposes), coronary CTA itself does not have any functional information (i.e., only providing information about anatomical stenosis). Therefore, the decision about whether coronary angiography will be performed should be determined based on a degree of stenosis on coronary CTA. In general, ≥70% stenosis indicates the need for conventional angiography. In contrast, <40% stenosis obviates the necessity of invasive angiography. Stress myocardial perfusion imaging [i.e., cardiac single positron emission computed tomography (SPECT), stress echocardiography, or cardiac MRI] may be necessary in patients with indeterminate coronary stenosis (i.e., 40-70% stenosis) on CTA. The second question is the number of vessels that have ≥50% stenosis. Coronary bypass surgery should be considered as a treatment option in patients with three-vessel disease on CT. The third question is the ease of performance of percutaneous coronary intervention. The following features of coronary stenosis make percutaneous coronary intervention difficult to perform; long segment stenosis (> 2 cm in length), severe angulation, a lesion at the bifurcation or multiple lesions.

**How to precisely interpret degree of coronary stenosis?**

How is the degree of coronary stenosis interpreted with precision? First, the degree of stenosis should be primarily assessed based on axial CT images. Although the curved multi-planar reformatted (c-MPR) image is an excellent method to evaluate degree of coronary stenosis, a side branch stenosis may be missed if all side branches are not traced with c-MPR image reconstruction. In addition, the thinnest collimation of less than 1 mm is available on axial images, so that best spatial resolution is provided. Second, interpreting radiologists should interactively evaluate a short segment c-MPR image (i.e., magnified c-MPR) produced on their own to enhance the precise measurement of indeterminate coronary stenosis found on axial images. In general, the pre-rendered c-MPR image is made by technologists and includes the entire coronary artery from the ostium to the most distal portion. Because of this, a suspicious coronary segment (i.e., suspicious of 40-70% stenosis or more on axial CT image) may be made too small for careful evaluation and a stenosis may be overlooked. Therefore, combined analysis using axial and interactive short segment c-MPR image is the best option for precisely determining the degree of coronary artery stenosis. Third, although volume rendered imaging (VR) provides an intuitive overview of coronary anatomy, it should be used only as one point of reference because VR images undergo substantial post-processes leading to potentially misleading results. Finally, in a retrospectively-gated coronary CTA, if there are blurred segments in the primary phase used for assessment, radiologists should use images from alternative phases to get a more accurate picture of the blurred segment (Fig. 7 and 8).
Fig. 7: Use of alternative phases for removing coronary motion artifact. The standard phase for reconstruction in patients with a low heart rate (<60 bpm) is a mid-diastolic phase (i.e., 70-80% of the RR interval). However, in this patient, distal right coronary artery shows a significant motion blurring on axial CT (arrow) (Fig. 7) obtained with mid-diastolic phase, but no motion blurring on an alternative phase image (80-90% of the RR interval) (arrow) (Fig. 8).

References: - Bundang/KR
Fig. 8: Use of alternative phases for removing coronary motion artifact. The standard phase for reconstruction in patients with a low heart rate (<60 bpm) is a mid-diastolic phase (i.e., 70-80% of the RR interval). However, in this patient, distal right coronary artery shows a significant motion blurring on axial CT (arrow) (Fig. 7) obtained with mid-diastolic phase, but no motion blurring on an alternative phase image (80-90% of the RR interval) (arrow) (Fig. 8).

References: - Bundang/KR

It is important to correctly identify a <40% coronary stenosis on axial CTA image to avoid invasive coronary angiography. If there is a wide contrast column in a coronary artery segment with atherosclerotic plaque on axial CT image, it can be considered a plaque that does need subsequent invasive coronary angiography (Fig. 9).
Fig. 9: A case of <40% coronary stenosis with a wide contrast column on axial CT image. Note a wide contrast column (arrow, Fig. 10 and 11) demonstrated on images through the lower portion of the proximal right coronary artery. In contrast, a narrow contrast column (arrow) is only visible on Fig. 9. Short segment curved multi-planar reformatted image (c-MPR) image also demonstrates a wide contrast column (arrow) (Fig. 12) in the proximal right coronary artery. The calcified plaque on the c-MPR image is adherent to the wall, not resulting in a significant stenosis.

References: - Bundang/KR
Fig. 10: A case of <40% coronary stenosis with a wide contrast column on axial CT image. Note a wide contrast column (arrow, Fig. 10 and 11) demonstrated on images through the lower portion of the proximal right coronary artery. In contrast, a narrow contrast column (arrow) is only visible on Fig. 9. Short segment curved multi-planar reformatted image (c-MPR) image also demonstrates a wide contrast column (arrow) (Fig. 12) in the proximal right coronary artery. The calcified plaque on the c-MPR image is adherent to the wall, not resulting in a significant stenosis.

References: - Bundang/KR
**Fig. 11:** A case of <40% coronary stenosis with a wide contrast column on axial CT image. Note a wide contrast column (arrow, Fig. 10 and 11) demonstrated on images through the lower portion of the proximal right coronary artery. In contrast, a narrow contrast column (arrow) is only visible on Fig. 9. Short segment curved multi-planar reformatted image (c-MPR) image also demonstrates a wide contrast column (arrow) (Fig. 12) in the proximal right coronary artery. The calcified plaque on the c-MPR image is adherent to the wall, not resulting in a significant stenosis.

*References:* - Bundang/KR
Fig. 12: A case of <40% coronary stenosis with a wide contrast column on axial CT image. Note a wide contrast column (arrow, Fig. 10 and 11) demonstrated on images through the lower portion of the proximal right coronary artery. In contrast, a narrow contrast column (arrow) is only visible on Fig. 9. Short segment curved multi-planar reformatted image (c-MPR) image also demonstrates a wide contrast column (arrow) (Fig. 12) in the proximal right coronary artery. The calcified plaque on the c-MPR image is adherent to the wall, not resulting in a significant stenosis.

References: - Bundang/KR

In contrast, if there is no a wide contrast column on axial coronary CTA, it can be considered as at least 40-70% stenosis (Fig. 13).
**Fig. 13:** A case of intermediate coronary stenosis (40-70%) without a wide contrast column on axial CT image. Note that there is no wide contrast column (arrow on Fig. 13, 14, and 15) in the left main coronary artery. A short segment curved multi-planar reformatted image also demonstrates no evidence of a wide contrast column (arrow) (Fig. 16) in the left main coronary artery.

**References:** - Bundang/KR
**Fig. 14**: A case of intermediate coronary stenosis (40-70%) without a wide contrast column on axial CT image. Note that there is no wide contrast column (arrow on Fig. 13, 14, and 15) in the left main coronary artery. A short segment curved multi-planar reformatted image also demonstrates no evidence of a wide contrast column (arrow) (Fig. 16) in the left main coronary artery.

**References**: - Bundang/KR
**Fig. 15**: A case of intermediate coronary stenosis (40-70%) without a wide contrast column on axial CT image. Note that there is no wide contrast column (arrow on Fig. 13, 14, and 15) in the left main coronary artery. A short segment curved multi-planar reformatted image also demonstrates no evidence of a wide contrast column (arrow) (Fig. 16) in the left main coronary artery.

**References**: Bundang/KR
Fig. 16: A case of intermediate coronary stenosis (40-70%) without a wide contrast column on axial CT image. Note that there is no wide contrast column (arrow on Fig. 13, 14, and 15) in the left main coronary artery. A short segment curved multi-planar reformatted image also demonstrates no evidence of a wide contrast column (arrow) (Fig. 16) in the left main coronary artery.

References: - Bundang/KR

In such cases, a short segment c-MPR image should be made to evaluate more precisely the degree of stenosis. If only a thin contrast column is demonstrated in a segment with atherosclerotic coronary plaque, it can be considered a tight coronary stenosis (>70%) (Fig. 17, 18, and 19), indicating the need for invasive coronary angiography.
Fig. 17: A case of >70% coronary stenosis with a thin contrast column on axial CT image. Note the very thin contrast column (arrow on Fig. 17, 18, and 19) caused by non-calcified plaque in the proximal left anterior descending coronary artery.

References: - Bundang/KR
**Fig. 18:** A case of >70% coronary stenosis with a thin contrast column on axial CT image. Note the very thin contrast column (arrow on Fig. 17, 18, and 19) caused by non-calcified plaque in the proximal left anterior descending coronary artery.

**References:** - Bundang/KR
Fig. 19: A case of >70% coronary stenosis with a thin contrast column on axial CT image. Note the very thin contrast column (arrow on Fig. 17, 18, and 19) caused by non-calcified plaque in the proximal left anterior descending coronary artery.

References: - Bundang/KR
Coronary CTA cannot reliably discriminate near total from total occlusion (Fig. 20).
Fig. 20: A case of total occlusion of the proximal distal left circumflex coronary artery caused by acute myocardial infarction. Note complete obstruction of the proximal distal circumflex coronary artery (arrow on Fig. 20) with non-calcified plaque or acute thrombus on a curved multi-planar reformatted image. Subendocardial hypoperfusion (arrowheads on Fig. 21) in the territory of the left circumflex coronary artery is noted without myocardial thinning, suggesting acute myocardial infarction.

References: - Bundang/KR
Fig. 21: A case of total occlusion of the proximal distal left circumflex coronary artery caused by acute myocardial infarction. Note complete obstruction of the proximal distal circumflex coronary artery (arrow on Fig. 20) with non-calcified plaque or acute thrombus on a curved multi-planar reformatted image. Subendocardial hypoperfusion (arrowheads on Fig. 21) in the territory of the left circumflex coronary artery is noted without myocardial thinning, suggesting acute myocardial infarction.

References: - Bundang/KR
Collateral supply can be seen on coronary CTA in cases of chronic total occlusion, but is inconstantly demonstrated because of the small size of the collateral arteries.

*Major limitations to precise interpretation of the degree of stenosis on coronary CT angiography*
An important limitation to accurate interpretation is coronary motion blurring. It is a potential source of both false positive and negative results. This artifact can be partly overcome by performing coronary CTA on scanners with a high temporal resolution such as the second generation dual source CT (DSCT, temporal resolution=75m/s). As previously noted, if coronary CTA is performed with retrospective gating, and there is a segment with a significant coronary motion artifact, all phases of the study should be evaluated to identify the phase with least coronary motion artifact.

A second limitation is blooming artifact caused by calcified plaque. This is the primary cause of falsely identifying a #50% stenosis on coronary CTA. You may under-call the degree of stenosis to avoid false positive readings when evaluating a segment with substantial calcified coronary plaque. However, this approach can conversely induce a false negative result. One study indicated that accuracy of CT in excluding a #50% coronary stenosis sharply decreases in patients with a high calcium score (Agatston score>400) [i.e., only 20% (3/15) specificity]. 80-90% of patients with an Agatston score >400 have at least one coronary artery with #50% stenosis. In order to justify the use of coronary CTA in such patients, CT should identify 10-20% patients with <50% stenosis precisely, thus avoiding invasive coronary angiography. However, this is difficult due to the blooming artifact caused by calcified plaque. Therefore, coronary CTA appears not to be a good indication in patients with a high calcium score.

In one recent study, iterative reconstruction performed by 2nd generation DSCT demonstrated reduced blooming artifact. Iterative reconstruction compared with filtered back projection can reduce the blooming artifact by increasing spatial resolution without increasing image noise (i.e., uncoupling between spatial resolution and image noise).

**What is the predictive ability of coronary stenosis on CT angiography?**

If coronary CTA shows no plaque in symptomatic patients, the future cardiac event rate is low (mortality rate=0.34%/year). In contrast, the presence and extent of #50% coronary stenosis is closely associated with a higher future cardiac event rate. One important question is whether radiologists should report all <50% stenoses. Although it may be bothersome, all non-significant coronary stenoses should be mentioned in the CT report as the presence and extent of <50% coronary stenoses is also strongly associated with future cardiac event rates.

**To what extent can CT identify vulnerable plaque?**

Motoyama et al reported CT features of vulnerable plaque. In their study, these features included positive remodeling, low attenuation plaque (<30 HU), and spotty calcification. Most of cases of ACS were associated with two plaque features (i.e., positive remodeling...
and low attenuation plaque). There were no cases of ACS arising from plaques lacking positive remodeling and low attenuation plaque.

CT can identify and quantify positive remodeling. However, although coronary CTA has the potential to identify vulnerable plaque, current CT cannot identify vulnerable plaque precisely. CT cannot discriminate TCFA from thick cap fibroatheroma. The thickness of TCFA is <64 micron, whereas the spatial resolution of the most advanced CT scanners is at best 0.5 mm. Therefore, a spatial resolution at least 10 times that is currently available is necessary to reliably discriminate TCFA and thick-cap fibroatheroma. Moreover, CT cannot differentiate lipid and fibrous plaque reliably as there is significant overlap of HU between the two plaque types on coronary CTA. This overlap may be caused by enhancement of coronary plaque after contrast administration. One study indicated that vasa vasorum is a potential source of plaque enhancement on CTA. Partial volume averaging is an additional possibility to explain the overlap between the two types of plaque. This phenomenon may be caused by the fact that the lipid core is located just below the intracoronary contrast column. One study demonstrated that plaque attenuation is different depending on the degree of intracoronary enhancement. A final consideration is that the CT attenuation of atheromatous plaque can be changed depending on the different kV setting (i.e., 135, 120, or 100 kV). Consequently, we are still unable to precisely identify vulnerable plaque on CT.

**Future directions**

Due to the rapid advancement in CT technology, the radiation dose of coronary CTA has been markedly decreased. We are now in the era of ultrafast and ultralow dose CT (i.e., dedicated coronary CTA <1 mSv on high pitch mode of the second generation DSCT). Indeed, the radiation dose of coronary CTA is approaching that of CACS CT. However, in comparison to CACS CT, coronary CTA has the important advantage that it can evaluate non-calcified plaque (i.e., the vulnerable plaque). Approximately 50% of acute myocardial infarctions and cases of sudden cardiac deaths occur without warning. This fact may suggest a need for screening of CAD by using coronary CTA in order to decrease the mortality, although convincing evidence is still lacking. Breast cancer screening which is relatively well established may be a good model for the use of coronary CTA to screen for asymptomatic at-risk patients. Radiation dose of screening mammography is about 0.4-0.5 mSv. In comparison, coronary CTA can be obtained with approximately 1 mSv with high pitch mode. If there is a further decrease of radiation dose made possible with iterative reconstruction or other technologic innovation, radiation exposure by coronary CTA may not be a major obstacle for CAD screening in the near future. In order to replace CACS CT with coronary CTA, future studies that demonstrate the accuracy of screening coronary CTA to predict future cardiac events and allow reduced mortality are necessary.

The ultimate goal of coronary CTA is not merely measurement of degree of coronary stenosis, but identification of vulnerable plaque (Fig. 9) that is a major cause of ACS.
Fig. 22: A case of acute myocardial infarction caused by rupture of vulnerable plaque demonstrated on coronary CT angiography (CTA). Vulnerable plaque (arrow) with positive remodeling and low attenuation plaque is demonstrated on axial (Fig. 22) and curved multi-planar reformatted image (Fig. 23) images of a screening coronary CTA in a 43-year-old male patient. Two months later, the patient presented to emergency department with an acute chest pain. Invasive coronary angiography demonstrated complete occlusion (arrow, Fig. 24) in the mid-portion of the right coronary artery by acute thrombus. Hounsfield unit measured at the low attenuation plaque (Fig. 25) was less than zero, indicating a lipid core.

References: - Bundang/KR
Fig. 23: A case of acute myocardial infarction caused by rupture of vulnerable plaque demonstrated on coronary CT angiography (CTA). Vulnerable plaque (arrow) with positive remodeling and low attenuation plaque is demonstrated on axial (Fig. 22) and curved multi-planar reformatted image (Fig. 23) images of a screening coronary CTA in a 43-year-old male patient. Two months later, the patient presented to emergency department with an acute chest pain. Invasive coronary angiography demonstrated complete occlusion (arrow, Fig. 24) in the mid-portion of the right coronary artery by acute thrombus. Hounsfield unit measured at the low attenuation plaque (Fig. 25) was less than zero, indicating a lipid core.

References: - Bundang/KR
**Fig. 24**: A case of acute myocardial infarction caused by rupture of vulnerable plaque demonstrated on coronary CT angiography (CTA). Vulnerable plaque (arrow) with positive remodeling and low attenuation plaque is demonstrated on axial (Fig. 22) and curved multi-planar reformatted image (Fig. 23) images of a screening coronary CTA in a 43-year-old male patient. Two months later, the patient presented to emergency department with an acute chest pain. Invasive coronary angiography demonstrated complete occlusion (arrow, Fig. 24) in the mid-portion of the right coronary artery by acute thrombus. Hounsfield unit measured at the low attenuation plaque (Fig. 25) was less than zero, indicating a lipid core.

**References**: - Bundang/KR
Fig. 25: A case of acute myocardial infarction caused by rupture of vulnerable plaque demonstrated on coronary CT angiography (CTA). Vulnerable plaque (arrow) with positive remodeling and low attenuation plaque is demonstrated on axial (Fig. 22) and curved multi-planar reformatted image (Fig. 23) images of a screening coronary CTA in a 43-year-old male patient. Two months later, the patient presented to emergency department with an acute chest pain. Invasive coronary angiography demonstrated complete occlusion (arrow, Fig. 24) in the mid-portion of the right coronary artery by acute thrombus. Hounsfield unit measured at the low attenuation plaque (Fig. 25) was less than zero, indicating a lipid core.

References: - Bundang/KR
With screening coronary CTA using a very low radiation dose, precise identification of patients with a very high risk (i.e., >15% coronary event/year) is our final goal.
Conclusion

It is important for radiologists to have a comprehensive understanding of the mechanisms and clinical significance as well as CT angiographic features of coronary atherosclerosis. A thorough understanding and optimal performance of CTA may lead to reduction of unjustified downstream testing. It should be stressed that ultimate goal of imaging is precise identification of vulnerable plaque at the subclinical stage. Such a goal may be realized in the near future through screening coronary CT angiography with a very low radiation dose.
References


