The Napkin-Ring Sign: CT Signature of High-Risk Coronary Plaques?

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HISTOPATHOLOGY HAS DEMONSTRATED THAT RUPTURE OF CORONARYATHEROSCLEROTIC PLAQUES WITH subsequent intraluminal formation of thrombi is the most frequent cause of acute myocardial infarction (1).

Furthermore, it has been shown that plaque ruptures resemble plaques that are histologically classified as thin cap fibroatheroma (TCFA). TCFA have distinct histological characteristics, including a large necrotic core with an overlying thin intact fibrous cap, macrophage infiltration, and often increased number of intraplaque vasa vasorum (2). These lesions have been designated as vulnerable plaques indicating the increased probability of rupture.

The noninvasive identification of vulnerable coronary plaques represents one of the ultimate goals of coronary imaging because it could significantly improve risk stratification of both symptomatic and asymptomatic patients (3). The advances in cardiac computed tomography (CT) imaging now enable the noninvasive visualization of the coronary lumen and atherosclerotic plaques. Moreover, CT studies investigating patients with acute coronary syndrome described high-risk plaque features characteristic to culprit lesions, such as low plaque attenuation (<30 Hounsfield units [HU]), positive remodeling, and spotty calcification (4,5).

Recently, studies have described specific attenuation pattern of atherosclerotic plaques on coronary CT images characterized by a plaque core with low CT attenuation surrounded by a rim-like area of higher CT attenuation as napkin ring like (6–9). The authors speculated whether this appearance could indicate the presence of deep micro-califications, intramural thrombus, intraplaque contrast enhancement due to the presence of neovascularization, or represent a large central lipid core surrounded by fibrous plaque tissue. Notably, these signs have been described in patients with acute coronary syndromes potentially representing a culprit coronary lesion (6–8).
However, the histopathological features of atherosclerotic plaques characterized by a plaque core with low attenuation surrounded by a rim-like area of higher attenuation on coronary CT images remain unclear. In this report, we demonstrate a possible CT signature of high risk coronary atherosclerotic plaques with histopathological correlate.

Figure 1. Ex Vivo Donor Heart and Corresponding Volume-Rendered CT Image
(A) The heart of a 54-year-old man who died from acute subarachnoidal hemorrhage was investigated. The patient’s past medical history included hypertension and hyperlipidemia, which had been diagnosed 5 years earlier and treated since then. The patient did not have any previously known coronary artery disease. The heart was transferred to our institution in Histidine-tryptophan-ketoglutarate solution packed in wet ice. The cold ischemic time was 12 h. The right and left coronary arteries were selectively canulated and filled with methylcellulose-based iodinated contrast solution to achieve an average attenuation of 250 Hounsfield Units within the coronary vessels. (B) The CT data acquisition was performed with a 64-detector row CT scanner (Discovery High Definition 750, General Electrics, Milwaukee, Wisconsin) using the following parameters for both the nonenhanced and contrast-enhanced scans: 64/1100 0.625 collimation; 0.35 s rotation time; tube voltage of 120 kV; tube current of 500 mAs. A simulated ECG signal was used for prospective triggering. The entire dataset was reconstructed with a 0.625 mm slice thickness and 0.625 mm increment using a clinically available, raw data based adaptive statistical iterative reconstruction with a 0.28 mm × 0.28 mm pixel spacing. The open arrowheads indicate coronary canules; the white arrowheads indicate coronary plaques. Ao = Aorta; CT = computed tomography; LAD = left anterior descending artery; LV = left ventricle; RCA = right coronary artery; RV = right ventricle.

Figure 2. Curved Multiplanar Reformation of the Right Coronary Artery
The curved multiplanar reformatted CT image of the RCA demonstrates two large, predominantly noncalcified atherosclerotic plaques with spotty calcification (open arrowheads) in the proximal segment of the RCA. The bars indicate cross sections within the coronary plaques that were compared with histopathology. The white arrow points to the canulated ostium of the RCA. Following the CT data acquisition, the coronary arteries were excised and fixed in formalin. Histological sections were obtained in every 1 mm throughout the entire length of the coronary artery. Sections were stained with Movat’s pentachrome and H&E. The CT cross sections and the histopathological slides were aligned based on absolute distance measurements and on identification of fiduciary markers (side branches, bifurcations, and vessel wall morphological features). Abbreviations as in Figure 1.
Discussion

Our report suggests that the napkin-ring sign, which is considered a CT signature of high-risk coronary atherosclerotic plaque, may be caused by the difference in attenuation between a lipid-rich necrotic core (corresponding to the central low attenuation area in CT) and fibrous plaque tissue (corresponding to the rim of high CT attenuation). In this ex vivo study, we can exclude the possibility of the high-attenuation representing uptake of contrast, as the CT attenuation values were similar in the noncontrast and contrast-enhanced CT datasets. Interestingly, the average CT attenuation of napkin-ring plaques (approximately 50 to 60 HU) was higher than the previously suggested cutoff value (<30 HU) for high-risk lesions.

Figure 3. Cross Sections of a Coronary Atherosclerotic Plaque With Napkin-Ring Sign and Spotty Calcification

The cross-sectional CT images show a coronary plaque with napkin-ring–like attenuation pattern and spotty calcification. The circumferential outer rim (red dashed line) of the noncalcified plaque has a higher CT attenuation in both the noncontrast (A) and contrast-enhanced (B) images (44.0 ± 8.8 HU, range 23.0 to 61.0 HU vs. 48.6 ± 5.8 HU, range 34.0 to 60.5 HU; respectively) as compared to the attenuation within the central part of the plaque (27.9 ± 4.2 HU, range 20.7 to 36.4 HU and 31.0 ± 6.6 HU, range 19.0 to 44.0 HU on noncontrast and contrast-enhanced images; respectively). The average noncalcified plaque attenuation on nonenhanced CT was 42.2 ± 9.9 HU versus 44.7 ± 10.0 HU on the contrast-enhanced image. The corresponding histological section (panels C, D, and E) revealed a late fibroatheroma, with spotty calcification (E). The lesion is characterized by a necrotic core (star), which is consistent with the low attenuation core of the plaque and a significant amount of fibrous plaque tissue, which is consistent with the high attenuation rim on the CT images (red dashed line). The arrowheads indicate the vasa vasorum. HU = Hounsfield units; L = lumen; other abbreviations as in Figure 1.

Figure 4. Cross Sections of a Coronary Atherosclerotic Plaque With Napkin-Ring Sign

The CT images show a larger noncalcified coronary plaque with more pronounced napkin-ring–like attenuation pattern as compared to Figure 3. The circumferential outer rim (red dashed line) of the plaque has a higher CT attenuation in both the noncontrast (A) and contrast-enhanced (B) images (57.2 ± 8.8 HU, range 40.0 to 81.0 HU vs. 57.9 ± 8.7 HU, range 35.0 to 76.0 HU; respectively) as compared to the attenuation within the central part of the plaque (21.8 ± 4.3 HU, range 13.5 to 31.6 HU and 26.0 ± 2.0 HU, range 22.0 to 31.0 HU on noncontrast and contrast-enhanced images; respectively). The average plaque attenuation on nonenhanced CT was 48.1 ± 14.2 HU versus 52.2 ± 14.0 HU on the contrast-enhanced CT. The corresponding histopathological section (C) demonstrates a late fibroatheroma. Again, the plaque contains a necrotic core (stars), which correlates to the low attenuation plaque core on the CT images. Notably, the necrotic core is larger than in the plaque shown in figure 3, which is in line with the CT morphology. Similar to Figure 3, the outer portion of the plaque (red dashed line) contains a significant amount of fibrous plaque tissue correlating to the high attenuation CT rim. Moreover, the histopathological analysis revealed significant vasa vasorum (C; arrowheads) accompanied by macrophage infiltration in the basal plaque area. Abbreviations as in Figures 1 and 3.
Of course, we only present a small number of plaques in a single patient. In other patients, and in the in vivo situation, other mechanisms, such as a central thrombus surrounded by contrast agent, vasa vasorum, hemorrhage, or microcalcification may also lead to a ring-like pattern of vulnerable or ruptured plaques. The limited spatial and contrast resolution of CT may not be sufficient to allow distinction of these entities. Additional studies are warranted to verify this observation in clinical CT datasets and to determine whether this feature may have incremental prognostic value over the established plaque attenuation measurements (Figs. 1–6).

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REFERENCES


