Computed Tomography Imaging of Coronary Artery Plaque

Characterization and Prognosis

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KEYWORDS

• Coronary computed tomography • Coronary plaque • Coronary artery disease • Characterization • Prognosis

KEY POINTS

- Coronary computed tomographic angiography (cCTA) is well established as a tool for excluding coronary artery disease (CAD) in patients with low to intermediate cardiovascular risk and acute chest pain.
- cCTA is highly sensitive for the detection of CAD and accurate for the quantification of coronary artery luminal area, atherosclerotic plaque area, plaque volume, and percentage stenosis.
- cCTA has also demonstrated good correlation with invasive methods in terms of plaque characterization, with specific features found to correlate with vulnerable plaque and subsequent events.
- Thus, cCTA has the ability to provide incremental diagnostic and prognostic value above traditional clinical risk factor models. Continued technological improvements will likely help further define the role of cCTA in coronary plaque assessment.

INTRODUCTION

As a concept, "vulnerable plaque" was first described in 1990 as a coronary lesion having the "potential to become thrombogenic if exposed to the appropriate triggering stimulus."[1] Much of the early work with these rupture-prone plaques was targeted at severely stenotic lesions, but subsequent studies demonstrated that most cases of acute coronary syndrome occur in areas of nonobstructive disease.[2] Autopsy series have helped identify unifying characteristics of these vulnerable plaques, the most common being a thin-cap fibroatheroma (TCFA).[3] Although current clinical risk stratification can identify the vulnerable

Conflict of Interest Disclosure: U.J. Schoepf is a consultant for and/or receives research support from Bayer, Bracco, GE Healthcare, Medrad, and Siemens Healthcare. D.H. Steinberg is a consultant for Boston Scientific and St. Jude.

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Radiol Clin N Am 53 (2015) 307–315

http://dx.doi.org/10.1016/j.rcl.2014.11.008

0033-8389/15/$ – see front matter

patient, the standard invasive (coronary angiography) and noninvasive (nuclear stress cardiac scintigraphy) tests are poorly suited for the identification of vulnerable plaque.[4]

Advances in multimodality imaging of atherosclerotic cardiovascular disease have enhanced the understanding of intracoronary plaque and subsequent progression.[5] Primary among these is intravascular ultrasonography (IVUS) and its related iterations. These modalities provide real-time, high-resolution in vivo assessments of coronary atherosclerotic burden and plaque composition, but are limited by being inherently invasive. Noninvasive imaging techniques such as computed tomography (CT) are therefore both intuitively attractive and clinically relevant provided they provide accurate information. This article reviews the current state of vulnerable plaque imaging, with a focus on coronary CT as a rapidly evolving and increasingly important modality.

INVASIVE PLAQUE IMAGING MODALITIES

The pathobiology of high-risk plaque is reasonably well understood from autopsy and animal series. In general, these plaques have varying degrees of 4 features: Positive remodeling (defined as a ratio of the vessel area at site of plaque compared with the area at a normal reference site >1.0[6]), a thin fibrous cap (<65 μm), large necrotic core, spotty calcification (calcium deposits with an arc of <90°[7]), and intraplaque vaso vasorum.[8] Several imaging modalities (**Table 1**) are currently available to identify such plaque, each possessing inherent advantages and limitations.

The most widely studied method for invasive intracoronary imaging is intravascular ultrasonography (IVUS). With ultrasound frequencies of 20 to 45 MHz depending on the specific technology, IVUS provides real-time in vivo assessment of intracoronary architecture at 6 to 8 mm depth with an axial resolution of 80 to 100 μm and a lateral resolution of 200 to 250 μm.[9,10] IVUS is especially well suited for characterization of plaque morphology (fibrofatty, fibrotic, and calcified). IVUS can further characterize vessel remodeling and tissue attenuation, 2 features that have been demonstrated to correlate with cardiovascular events. Limitations of IVUS include the fact that the technology cannot demonstrate TCFA, as the threshold cap thickness is below the catheter resolution. In addition, although the sensitivity of gray-scale IVUS in detecting lipid core is very high, the specificity is limited with regard to low echo-attenuation areas representing necrotic lipid core, intraplaque hemorrhage, or intraluminal hematoma.[4,11]

Several iterative advances beyond gray-scale IVUS have been developed with the goal of better identifying high-risk plaque. These modalities include IVUS with virtual histology (IVUS-VH), elastography, and near-infrared spectroscopy (NIRS); relevant examples of normal and high-risk plaque are shown in **Fig. 1**. IVUS-VH incorporates the addition of frequency spectral analysis. With IVUS-VH, a reconstructed color-coded map is generated and superimposed over the cross-sectional gray-scale images. High-risk IVUS-VH characteristics include large necrotic core abutting the lumen, a plaque burden of at least 70%, and a minimal luminal are of at least 4 mm.[12] Elastography incorporates the principle that soft tissue will deform more readily than hard materials when force is applied, allowing for the differentiation of plaque based on composition (fibrous vs fatty vs calcific).[13] Previous studies have demonstrated the ability of elastography to identify vulnerable plaque (defined as a region demonstrating high strain with adjacent low-strain regions) with higher

Table 1
Comparison of invasive imaging modalities

	Resolution (μm)	Tissue Penetration (mm)	Visualize TCFA	Plaque Composition Discrimination
IVUS	Axial 80–100 Lateral 200–250	4–8	No	++
IVUS-VH	Axial 80–100 Lateral 200–250	4–8	No	+++
Intravascular elastography	Axial 80–100 Lateral 200–250	4–8	No	++
OCT	Axial 12–18 Lateral 20–90	1–3	Yes	+++

Abbreviations: IVUS, intravascular ultrasonography; IVUS-VH, IVUS with virtual histology; OCT, optical coherence tomography; TCFA, thin-cap fibroatheroma.