Intravascular Ultrasound for Guidance and Optimization of Percutaneous Coronary Intervention

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KEYWORDS

• Intravascular ultrasound • Percutaneous coronary intervention • Drug-eluting stent
• Major adverse cardiac events • Minimum lumen diameter • Minimum lumen area • Planimetry

KEY POINTS

- Conventional angiography provides a 2-dimensional silhouette that delivers a suboptimal assessment of true physiologic coronary artery stenosis.
- Intravascular ultrasound allows visualization of the trilaminar coronary vasculature, permitting better delineation of the quantity and quality of plaque burden.
- Clinical outcomes with intravascular ultrasound-guided interventions have revealed improved results, especially for complex and long coronary artery lesions.
- Parameters measured by intravascular ultrasound show modest correlation with other investigatory modalities.
- The use of intravascular ultrasound during routine percutaneous coronary intervention is not widely adopted, which may be in part due to equipment costs and increased procedural times.

BACKGROUND

Coronary angiography with percutaneous coronary intervention (PCI) is considered the reference standard for management of symptomatic stable coronary artery disease refractory to optimal medical management, and acute coronary syndromes.[1,2] Although conventional angiography has been used as the predominant technique to define the coronary anatomy and guide PCI, several shortcomings of this modality hinder achieving optimal results. Questions about the accuracy of coronary angiography dates to the 1970s, when researchers investigated discrepancies between a coronary lesion's appearance on angiography compared with its true physiologic effects on the myocardium.[3,4] Conventional angiography is limited by a 2-dimensional projection of the arterial lumen as well as complexity of coronary lesions, such as tortuosity or overlap of structures.[5,6] Studies have shown that there is a large degree of

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interobserver and intraobserver variability in assessing the degree of coronary stenosis.[7–9] The conventional methodology of quantifying stenotic lesions via their angiographic appearance relies heavily on the surrounding "nondiseased" lumen, which serves as the reference segment. However, because of diffuse involvement of the atherosclerotic disease process, a reference "nondiseased" segment is often unavailable.[10,11] The 2-dimensional planar silhouette during angiography in conjunction with a diffuse and symmetrically diseased artery poses a challenge for true physiologic assessment of a stenotic coronary lesion. Furthermore, this suboptimal visualization of stenotic lesions is compounded when PCI is performed under angiographic guidance. Conventional angiographic guidance may prohibit accurate deployment of balloons and sizing of stents, which may result in downstream complications, such as in-stent restenosis (ISR) or late stent thrombosis.[12–14] Because of the need for better visualization and improved understanding of the anatomic alterations that occur during PCI, intravascular ultrasound (IVUS) emerged as a valuable adjunct to conventional angiography.

ADVANTAGES OF INTRAVASCULAR ULTRASOUND

The use of IVUS as an adjunct imaging modality offers several advantages over conventional angiography. Compared with the 2-dimensional luminal silhouette created during angiography, IVUS offers visualization of the full circumference of the vessel wall. This improved visualization offers better characterization of coronary plaque via accurate assessment of the severity, length, morphology, and composition of the plaque. The direct cross-sectional view of the arterial wall produced by this technology provides higher sensitivity in detection of coronary artery disease. IVUS allows the operator to reliably detect complex coronary lesions, dissections, small thrombi, positive arterial wall remodeling during early atherosclerosis, and even diffuse advanced disease within the vessel wall that are otherwise challenging to detect only under angiographic guidance.[15]

In addition, IVUS offers more precise stent deployment during PCI by ensuring proper expansion, length, and apposition of the stent. Multiple studies have demonstrated the importance of these measures during PCI. Two major predictors of ISR and stent thrombosis include stent underexpansion and "geographic miss."[16,17] Smaller intrastent minimum lumen area (MLA) results from stent-underexpansion, whereas the concept of "geographic miss" refers to residual plaque edge that remains uncovered after stent deployment. Multiple analyses have shown that adjunctive use of IVUS during PCI resulted in larger stent sizes, greater final angiographic minimum lumen diameter (MLD), and larger minimum stent area.[18,19] When compared with dilation under angiographic guidance, the use of IVUS resulted in additional stent postdilation in as high as 80% of the cases.[20] All of these findings may be attributed to more accurate assessment of stent geometry, as visualized under IVUS guidance. IVUS-guided PCI has also been shown to use less contrast during stent deployment, which is advantageous in patients with renal insufficiency and in prevention of contrast-induced nephropathy.[21,22] Finally, perhaps one of the major benefits of IVUS-guided stenting is that the enhanced information from IVUS imaging may convince the operator that the result is already optimal, and that more intervention is no longer necessary. As the saying goes, "The enemy of 'good' is 'better'"; problems of inappropriate intervention may be averted by using IVUS imaging.

TECHNIQUE AND BASIC MEASUREMENTS

The IVUS catheter diameter ranges from 2.6 to 3.5 French with a miniaturized ultrasound transducer at its end, which is advanced over a guidewire and positioned to analyze the target lesion. High ultrasound frequencies, usually between 20 and 60 MHz, are used to provide grayscale images from the backscatter amplitude of the signal as the transducer rotates at 1800 rpm. Instead of a mechanically rotating transducer, images can be obtained with a synthetic aperture, but the image quality is not equal to the mechanically rotating transducer devices. Standard catheter delivery technique is used for IVUS examination, whereby the target coronary artery is cannulated, the IVUS probe is slowly advanced over the guidewire, and motorized or manual pullback is performed to record the desired segment.[23]

A normal arterial appearance is generated as a result of an abrupt change in acoustic impedance at the tissue interface within the trilaminar vessel wall. The first interface observed is at the border between blood and the leading edge of intima that appears bright. The second interface occurs at the external elastic membrane (EEM), which comprises the junction between media and adventitia. The muscle layer of the tunica media has a sonolucent appearance, whereas the outer adventitia layer appears bright or white on a grayscale image (Fig. 1).