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STATE-OF-THE-ART REVIEW

Percutaneous Transcatheter Assessment of the Left Main Coronary Artery

Current Status and Future Directions

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ABSTRACT

Accurate assessment of the left main coronary artery (LMCA) is critical in determining treatment strategies and delineating revascularization options to improve prognosis. There has been an evolution in invasive techniques that allow detailed assessment of both function and anatomy. As technologies advance, there is an increasing amount of evidence supporting the use of percutaneous coronary intervention for the LMCA. This state-of-the-art paper provides an in-depth exploration of intravascular ultrasound, fractional flow reserve, and optical coherence tomography. A discussion is provided that explores the basis for application of these technologies, the body of evidence for each modality and its use in LMCA assessment, and the potential role in post-PCI optimization in what is a dynamically changing field.
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Significant left main coronary artery (LMCA) atherosclerotic disease is increasingly viewed as being treatable by percutaneous coronary intervention (PCI) in selected groups. With evolving technologies and techniques, a number of randomized control trials have suggested that specific groups of patients may achieve favorable outcomes with PCI compared with coronary artery bypass grafting (CABG). There is also an increasing awareness of the need for accurate assessment and evaluation of the true significance of LMCA lesions, particularly if angiographically moderate or equivocal. Angiography and conventional grayscale intravascular ultrasound (IVUS), the mainstays of LMCA assessment for some time, are increasingly being supported by the complementary use of other advanced intravascular modalities of assessment, namely fractional flow reserve (FFR) and optical coherence tomography (OCT). These varied and improved techniques also allow for further optimization of PCI of the LMCA, with the potential for improvements in patient outcomes.

This review therefore examines the current status of percutaneous assessment of the LMCA using the currently available technologies, with an emphasis on their relative strengths and limitations, and likely future directions in what is a rapidly changing field of interventional cardiology.

LMCA DISEASE: AN OVERVIEW

It has been recognized for over one-half century that significant LMCA disease is associated with a poor prognosis, with 3-year mortality rates in the pre-revascularization era as high as 63% in high-risk subgroups (1). This is due to the large amount of myocardium at risk if there is significant flow limitation, as the LMCA supplies up to 84% of the blood flow to the left ventricle in a right-dominant coronary system (2). The mortality benefit with surgical revascularization has been well established, and thus it has long been the standard of care.

The LMCA itself may be divided into the ostium, trunk, and distal vessel. IVUS studies assessing plaque

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ABBREVIATIONS AND ACRONYMS

CABG = coronary artery bypass grafting

FFR = fractional flow reserve

IVUS = intravascular ultrasound

LAD = left anterior descending artery

LCx = left circumflex artery

LMCA = left main coronary artery

MLA = minimal luminal area

OCT = optical coherence tomography

PCI = percutaneous coronary intervention

composition in the LMCA suggest atherosclerotic plaque of the LMCA is qualitatively different from elsewhere in the coronary tree, with minimal necrotic core content (3) and less thin cap fibroatheroma (TCFA) than the proximal segments of the other coronary arteries (3,4), particularly the left anterior descending artery (LAD), which is more prone to plaque ruptures (5,6). In addition, the distribution of atherosclerosis may also be different in the LMCA, with distal disease that encroaches on the bifurcation into the LAD and left circumflex artery (LCx) more common than proximal or midvessel disease (7). This increased frequency of distal LMCA disease is associated with greater technical difficulty when undergoing PCI and attendant prognostic implications compared with treatment of ostial or midshaft lesions (8,9). The prevalence of LMCA disease in patients referred for invasive angiography is approximately 4%, with 5% to 10% of these patients having isolated LMCA disease (10,11). In addition to native disease, iatrogenic LMCA disease is rare but well documented and may include dissection or stenosis following catheterization or ostial stenosis after aortic valve surgery (12,13).

PCI VERSUS CABG FOR LMCA DISEASE

CABG has been the mainstay of LMCA disease, although PCI in this setting was first proposed in 1980 (14). Current evidence supporting PCI for LMCA disease is on the basis of 4 randomized controlled trials (RCTs) that were summarized recently (15), which have resulted in a rising prevalence of LMCA percutaneous revascularization. When LMCA PCI is undertaken, there is therefore an increasing need to achieve optimal procedural outcomes using all available technologies.

INVASIVE ASSESSMENT

Accurate assessment of LMCA disease is important to guide appropriate risk stratification and treatment allocation. Conventionally, an angiographic cut-off of ≥50% diameter stenosis (equivalent to ≥75% area stenosis) has been used to indicate hemodynamic significance, which is on the basis of early work in an animal model by Gould that demonstrated a reduction in hyperemic flow across lesions beyond this degree of stenosis. Angiographic assessment of the LMCA is made problematic, however, by inherent difficulties specific to or of increased importance at this site. These include a short vessel segment, lack of a reference vessel, eccentricity, remodeling, potential for missed ostial disease due to deep catheter placement, overlapping daughter branches, and frequent foreshortening on angiography (16,17). Although various techniques such as quantitative coronary angiography (QCA) and 3-dimensional (3D) QCA provide valuable advances in non-LMCA coronary disease (18), they remain subject to many of these inherent anatomical limitations. As a consequence, adjunctive invasive modalities are particularly pertinent for the assessment of LMCA disease (**Figure 1**).

INTRAVASCULAR ULTRASOUND

BACKGROUND. First introduced in 1988, grayscale IVUS has been the mainstay for LMCA assessment in equivocal lesions for over 2 decades and is comprehensively reviewed elsewhere (19).

A number of methods of post-processing have been applied to improve grayscale IVUS image quality and provide so called "tissue characterization." These include virtual histology IVUS and integrated backscatter IVUS, also reviewed in detail elsewhere (20,21). These methods rely on raw radiofrequency analysis of the original image and have been proposed to give further information on tissue characterization, with distinct signals for fibrous, fibrofatty, necrotic, and calcific material (21) that have attendant prognostic implications (22). These techniques have been validated in vitro and in vivo (23), although there remains debate as to their reliability.

LMCA ASSESSMENT. A number of trials have assessed the use of IVUS in evaluating LMCA disease. Early studies proposed a minimal luminal area (MLA) ≤9.0 mm^2 or an area stenosis ≥50% to determine a hemodynamically significant LMCA stenosis (24). This threshold was then reduced by Fassa et al. (25), who determined a lower limit of normal LMCA MLA as 7.5 mm^2 after studying a cohort with angiographically normal LMCA. At 3.3 years, there was no difference in major adverse cardiovascular events between medically managed patients and those who were revascularized using this threshold (25). As well as providing more reliable data than angiography regarding lumen size, IVUS is more readily able to examine ostial disease and, through direct lumen visualization, can overcome difficulties with lesion eccentricity and oblique catheter position that can result in contrast streaming (26). Such precise imaging using IVUS pre-PCI may reduce stent protrusion into the aorta.

Of particular interest is the distribution and nature of plaque within the LMCA, which, as mentioned previously, has less necrotic core and TCFA than the proximal LAD, whereas the preponderance of LMCA