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Review article – *Special issue: Imaging in Coronary Artery Disease*

Intravascular ultrasound, optical coherence tomography and near infrared spectroscopy

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ABSTRACT

Intravascular ultrasound (IVUS), optical coherence tomography (OCT) and near infrared spectroscopy (NIRS) allows for a thorough analysis of the atheroma's morphology *in vivo*. Moreover, it helps to guide coronary intervention and assess the results of stenting. IVUS, OCT and NIRS provide unique data about the analyzed tissue and thus all of them complement each other. Their application in daily clinical practice helps to understand the underlying pathology of disease and may contribute to the improvement of outcomes in coronary interventions.

Contents

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Introduction

The introduction of intravascular imaging opened new horizons for the presentation of coronary atherosclerosis *in vivo*. It became possible to follow the development of atherosclerosis and to detect atheromas that are prone to rupture (vulnerable plaques) known as thin fibrous cap atheromas (TCFA). Moreover, intravascular imaging helps to guide coronary interventions and to assess their results. Nowadays, available intravascular imaging modalities utilize ultrasound and near infrared light (niR). Due to their intrinsic properties, both ultrasound and niR deliver unique information about the analyzed tissue and thus complement each other. The following review presents the basics of intravascular ultrasound (IVUS), optical coherence tomography (OCT) and niR spectroscopy (NIRS) in terms of plaque description, percutaneous coronary intervention (PCI) guidance and clinical application.

Intravascular ultrasound

The intravascular ultrasound (IVUS) is an invasive imaging modality that utilizes ultrasound (20–40 MHz) to present the vessel wall [1]. The dedicated IVUS catheter is advanced into the coronary vessel over a guidewire. The procedure is usually performed as part of standard invasive diagnostic coronary angiography. The IVUS probe is pulled back in the coronary vessel with a constant speed (1 or 0.5 mm/s) and simultaneously provides gray-scale cross-sectional and longitudinal images of the analyzed vessel. The axial resolution of IVUS ranges from 100 to 200 μm, which allows presenting three layers of the vessel at cross-sectional images: intima, media and adventitia. The lumen area, vessel area, plaque burden (the amount of plaque that occupies vessel area) and plaque volume are estimated by IVUS (Fig. 1). Moreover, the IVUS longitudinal analysis describes vessel remodeling. If the maximal vessel area within the plaque is higher then the vessel reference area, the positive vessel remodeling occurs. If maximal vessel area is lower than the vessel size, the lesion is classified as negatively remodeled [2]. Nevertheless, the plaque composition is roughly estimated by gray-scale IVUS. The echo-lucent plaque with shadowing is described as calcified [3] whereas plaques with low echogenity are described as soft and their composition remains unclear [4] (Fig. 1).

More precise analysis of soft plaque composition by IVUS is derived by spectral analysis of its signal, known as Virtual Histology (VH-IVUS). VH-IVUS identifies 4 different types of plaque components: fibrous (green), fibro-fatty (yellow), dense calcium (white) and necrotic core (red) [5] (Fig. 1). Its accuracy has been documented by *in vivo* and *in vitro* studies. Moreover, VH-IVUS is able to detect thin fibrous cap atheroma (TCFA). TCFA is covered with fibrous cap less then 65 μm thick and IVUS resolution does not allow for direct measurement of cap thickness. Hence, the plaque is recognized as TCFA by VH-IVUS if the necrotic core (red color) has a direct contact with the lumen and occupies more then 40% of the plaque in 3 consecutive cross-sectional images. The PROSPECT study

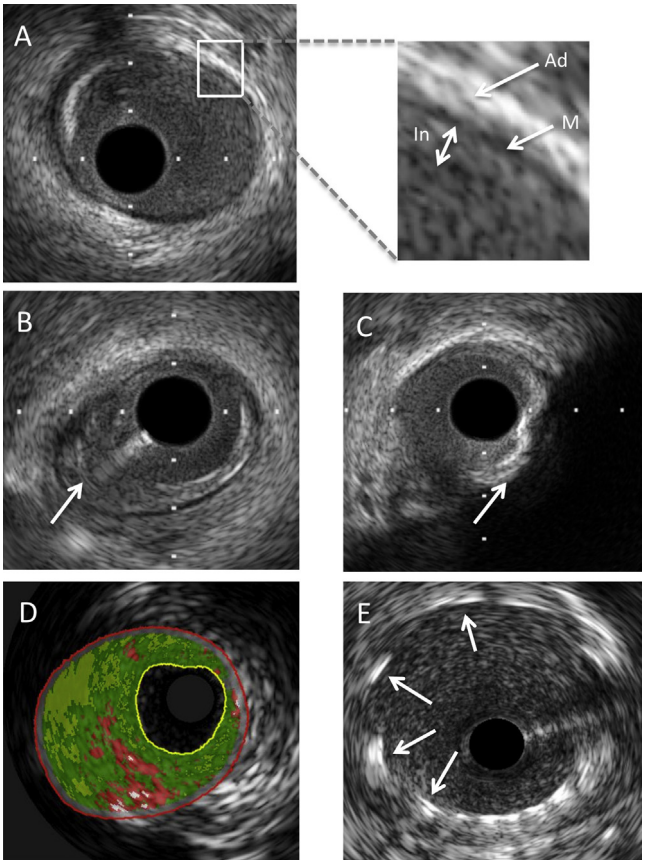

Fig. 1 – Representative images of intravascular ultrasound (IVUS). (A) Cross-sectional gray-scale IVUS (40 MHz probe) image of the healthy segment of coronary artery presenting the intima (In), the media (M) and the adventitia (Ad). (B) Cross-sectional gray-scale IVUS (40 MHz probe) image of the soft plaque (white arrow). (C) Cross-sectional gray-scale IVUS (40 MHz probe) image of calcification (white arrow). (D) Cross-sectional virtual histology IVUS image (20 MHz probe) of thick fibroatheroma. Plaque burden is a space between the yellow line and red line expressed as percentage of area bordered by red line. (E) Cross-sectional gray-scale IVUS (20 MHz probe) image after stent implantation presenting appropriate stent struts apposition (white arrows).

showed that the presence of such recognized TCFA increases the risk of future coronary events [6]. However, the results of the PROSPECT study should be discussed in light of controversies around precision of VH-IVUS. The histology data suggested poor accuracy of VH-IVUS in the necrotic core detection [7].

For many years IVUS imaging also served as a tool to estimate the significance of the intermediate coronary artery stenosis. The cut-off value of lumen area for non-left main (LM) stenosis was 4 mm^2 [8]. However, reports comparing the results of FFR and IVUS suggested that such cut-off value should be less then 3.07 mm^2 in non-LM stenosis, and less then 5.5 mm^2 in LM stenosis [9]. Nowadays, it is only