Chapter 4

Analysis of Radiofrequency Ultrasound Signals: Tissue Characterization With Virtual Histology and Palpography

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ABSTRACT

IVUS opened new perspectives in our understanding of human coronary atherosclerosis and triggers of ACS (especially plaque rupture as its most dominant cause). Throughout this chapter we list the shortcomings of conventional (greyscale) IVUS to characterize tissue components of plaques and the potentials of radiofrequency signal processing to overcome these. In recent years, the technology matured, and especially with VH and IB-IVUS, many clinical studies showed accurate plaque estimation. Results of a prospective, natural history study have just been presented and proved the ability of VH to predict ACS. Palpography derives compositional information from functional (strain) measurements. Assessing several characteristics of a given plaque could potentially enhance invasive risk stratification by identifying very high-risk plaques, thereby reducing the number of vulnerable plaques that need to be serially followed and ultimately treated. Moreover, if a safe prophylactic local treatment was available, a sophisticated IVUS procedure would be a part of a “one-stop-shop” in preventive cardiology.
INTRODUCTION

Ischemic heart disease often presents as an acute coronary syndrome (ACS), even in patients with prior percutaneous treatment of a flow-limiting stenosis (Glaser et al., 2005). Pathological substrate for an ACS is a (sub)occlusive thrombus filling the lumen which might stem from a segment of atherosclerotic coronary artery showing mild or borderline stenosis (often with complex morphological pattern) on a previous angiogram (Ambrose et al., 1986; Goldstein et al., 2000). These fragile (prone to rupture) foci of the coronary wall causing subsequent events (Falk, Shah, & Fuster, 1995) have been attributed as “vulnerable plaques” (VP) (Naghavi et al., 2003) and identified as “thin-cap fibroatheromas” (TCFA) as a major substrate by pathologists (Virmani, Burke, Farb, & Kolodgie, 2006). Coronary artery disease (CAD) is a diffuse atheromatous process of the epicardial coronary arteries (sometimes also with flow-limiting stenoses or multiple ruptures (Goldstein et al., 2000)). Accordingly, the number of these VPs (manifesting in non-flow limiting stenosis) might be numerous (Rioufol et al., 2002) and they present variable with time (as acute worsening is related to actual inflammatory alterations) (Goldstein et al., 2000; Libby & Theroux, 2005). These notions may render efforts identification of a VP (before rupture!) in the catheterization laboratory a mission hard to accomplish (Ambrose, 2008). Pathological, imaging and clinical findings demonstrated that occlusive coronary thrombi tend to cluster in the proximal segments of coronary arteries (Wang, Normand, Mauri, & Kuntz, 2004) and pathology study showed TCFAs limited in number (Cheruvu et al., 2007) make the hunt for VP timely identification justified. Moreover, traditional secondary preventive measures are limited in efficacy (Libby, 2005) and local treatment may well prove to be effective in the (near) future (Ramcharitar et al., 2009).

GREYSCALE IVUS FOR VP DETECTION

Coronary Angiography Versus IVUS for VP Detection

Coronary angiography is the gold-standard for imaging CAD. Complex morphology pattern on prior angiogram can foresee instability of a specific lesion (Ambrose et al., 1986; Goldstein et al., 2000) but the severity of a stenosis is not predictive for subsequent myocardial infarction (Little et al., 1988). This inability for identification of a VP is generally attributed to its restriction to visualize coronary lumen and not the vessel wall (Topol & Nissen, 1995).

In contrast, intravascular ultrasound (IVUS) can provide detailed morphologic view of alterations of the vessel wall in vivo, thus introduction of this tomographic visualization to the catheterization laboratory as part of daily practice in interventional cardiology caused really a paradigm shift (Mintz et al., 1995). At the tip of an IVUS catheter, a transducer emits an ultrasound signal and receives the reflected (backscattered) signal from tissue. Precise measurements of different types of atheroma and also the lumen (true extent of stenoses) became feasible (Garcia-Garcia et al., 2010; Topol & Nissen, 1995). Possible indications for use include assessment of angiographically borderline lesions, sizing balloon or stent during of intracoronary procedure, exploring any damage to the vessel wall and others (e.g. optimization of stent expansion in order to avoid restenosis or stent thrombosis). We are not entitled to give details for these, instead refer to contemporary concise reviews (Bonello et al., 2009; Nissen & Yock, 2001) and other chapters of this book.

IVUS has changed our conception about coronary atherosclerosis (Garcia-Garcia et al., 2010; Topol & Nissen, 1995) and later it has been described as a tool for VP detection (DeMaria, Narula, Mahmud, & Tsimikas, 2006). In convent-