Review article

Intravascular ultrasound in interventional radiology

H. I. Manninen, H. Räsänen
Department of Clinical Radiology, Kuopio University Hospital, Puijonlaaksontie 2, 70210 Kuopio, Finland

Received: 22 May 2000; Accepted: 7 June 2000

Abstract. Intravascular ultrasound (IVUS) imaging provides useful additional information to X-ray angiography in selected cases of balloon angioplasty and stent placement with complex vascular anatomy and unclear findings at angiography. It facilitates accurate measurements of the vessel dimensions and reveals the extent of the disease for the selection of proper angioplasty balloon size, as well as confirms full expansion and attachment of the stent or stent graft to the arterial wall. Intravascular US imaging contributes useful information for the basis of planning surgical or endovascular therapy of aortic dissection and is valuable for guiding percutaneous fenestration of the dissection flap. This imaging modality facilitates placement of vena cava filter without cavography and/or fluoroscopy in patients with contraindication for iodine contrast media and/or X-ray fluoroscopy. Technical development may further increase utility of IVUS imaging in interventional radiology.

Key words: Intravascular ultrasonography – Interventional radiology – Stents – Balloon angioplasty

Introduction

X-ray angiography provides only indirect information of atherosclerotic lesions as a change in the luminal wall profile. Pathological studies have revealed that since there is often compensatory enlargement of the vessel, mild atherosclerotic plaques do not encroach on the lumen until the lesion occupies up to 40% of the combined arterial wall and lumen volume [1]. Intravascular ultrasound (IVUS) imaging is recognized as the method of reference for imaging vessel wall morphology and atherosclerotic plaque [2, 3]. Intravascular US studies on coronary and carotid arteries have shown that IVUS reveals often intimal thickening and concentric plaques in angiographically normal segments [4, 5]. Intravascular US provides also direct information of anatomical layers of the arterial wall and predicts reliably histopathological composition of the atherosclerotic plaque, e.g., presence and thickness of fibrotic cap, calcifications, and possible lipid core [4], all characteristics which are related to the vulnerability and clinical importance of the plaque. Intravascular US provides unique information about the mechanism of various catheter-based treatments of vascular diseases such as balloon angioplasty and atherectomy [6, 7, 8, 9]. Studies have found IVUS characteristics of the atherosclerotic plaque which predict the primary response of the lesion for balloon angioplasty and late restenosis [10]. A recent study indicates that the presence of compensatory enlargement of the artery at the site of the atherosclerotic lesion is associated with higher target lesion revascularization rate after percutaneous transluminal coronary angioplasty (PTCA) [11].

Tortuosity of the artery and overlying branches can seriously hamper the diagnostic reliability of X-ray angiography and IVUS is useful in revealing the hemodynamic significance of intermediate lesions especially in coronary and iliac arteries. Intravascular US imaging demonstrates aortic dissection and provides useful adjunctive information to X-ray angiography for entry and re-entry sites, as well as about the relation of the side branches with the dissection flap [12].

Performance of IVUS imaging requires traversing of the imaging area with a guidewire along which the imaging catheter is advanced to the site of the imaging target. The miniature US probe is attached to the tip of the imaging catheter and IVUS imaging is performed while the catheter is slowly pulled back and registered on super VH Systems tape. To register the exact longitudinal location of the imaging probe inside the vessel, single X-ray exposures have to be taken during the IVUS imaging. In addition to cross-sectional images, postprocessing software of modern IVUS equipment provides also lon-
titudinal reconstructions of the vessel (Fig. 1). Since IVUS is an invasive and relatively costly and time-consuming imaging modality, its use in vascular diagnostics is minor. The major impact of the technique in clinical use is guiding of various catheter-based interventions of vascular diseases. This article provides an overview of the current status of IVUS imaging in various arterial and venous endovascular therapies.

**Intravascular ultrasound-guided balloon angioplasty**

Most studies concerning the utility of IVUS imaging in guiding balloon angioplasty have been published in coronary artery interventions in which tortuosity and overlying side branches often hamper diagnostic accuracy of X-ray angiography. Good hemodynamic result without occlusive dissections and significant immediate elastic recoil is mandatory to avoid late restenosis after PTCA. Preinterventional IVUS imaging can reveal angiographically undetected lesions, e.g., in the left main stem, which changes the treatment strategy from catheter-based intervention to surgical bypass operation (Fig. 2) [13]. Similarly, in cases of additional intermediate lesions IVUS shows accurately the degree of stenosis and facilitates better judgment for the decision whether or not to treat the lesion. Long-term follow-up after IVUS-guided deferred interventions in patients with de novo intermediate coronary artery lesions showed a low event rate [14].

Preinterventional IVUS imaging provides accurate information about the severity, morphology, and length of the lesion, and detects calcifications more sensitively than angiography [4, 15]. On the basis of IVUS information there was a change in the planned intervention in 40% of 313 non-consecutive coronary target lesions in one study [16]. In another series on 100 non-consecutive lesions assessed by IVUS, the information not detected by coronary angiography led to a specific clinical decision or a change in the planned therapy in 74% of lesions [17]. Using IVUS to guide angioplasty offers the possibility of optimizing balloon size by adapting it to the real diameter of the artery as measured from external elastic lamina, rather than to the vascular lumen size as is the case in quantitative angiography [18, 19]. This results in a balloon/artery ratio considerably greater than 1, and is probably one of the reasons why residual stenosis < 30% at the end of the intervention can be more frequently obtained with IVUS-guided PTCA than in conventional angiography guided PTCA. Most importantly, this can be achieved without increasing frequency of complications [20] which is not the case when oversizing of the balloon is based on the angiographic finding [9].

A non-randomized study suggested reduction of restenosis by vessel size adapted PTCA using IVUS imaging [21]. A recent study with 34 patients demonstrated a smaller recurrent restenosis rate after IVUS-guided PTCA of intra-stent restenosis compared with that achieved when balloon size was determined by quantita-