Clinical Investigations

Evaluation of Directional Atherectomy Studied by Intravascular Ultrasound in Femoropopliteal Artery Stenosis

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Abstract

Purpose: To evaluate the role of intravascular ultrasound (IVUS) before and after directional atherectomy (DA) in the treatment of femoropopliteal artery stenosis.

Methods: In 12 patients with 16 stenoses IVUS was performed before and immediately after an angiographically successful DA. This was defined as a diameter reduction (DR) ≤ 50%, which was calculated using the minimal lumen diameter compared with the diameter of a nearby “normal” segment. In the presence of residual plaque on IVUS an additional DA was performed. Endpoints studied were DR ≤ 30% on IVUS compared with the IVUS findings of the angiographically normal reference segment, or when no additional atherosclerotic material could be removed by further DA passages.

Results: Additional DA (mean 1.6 per lesion) had to be performed in all patients. Initial DA increased the cross-sectional free lumen area (FLA) from 3.8 ± 2.0 mm² to 8.1 ± 2.7 mm² (p = 0.0004). Additional DA increased FLA to 9.3 ± 2.3 mm² (p = 0.002) after the second passage and to 9.8 ± 2.4 mm² (p = 0.09) after the final DA run. The plaque area (PLA) before DA decreased from 18.1 ± 4.2 mm² to 15.4 ± 4.8 mm² (p = 0.002) after the first passage, and to 13.5 ± 5.0 mm² (p = 0.004) and 12.8 ± 4.4 mm² (p = 0.07) after the second and final DA runs, respectively. PLA of the reference segment (9.5 ± 5.7 mm²) was significantly smaller (p = 0.006) than the final PLA of the treated lesion, indicating a large amount of retained plaque. As a result of DA there was an increase in the area bordered by the medial layer, i.e., the total vessel area (from 21.9 ± 4.7 mm² to 23.0 ± 4.7 mm²), significantly in eccentric and soft lesions. On IVUS, dissection and plaque rupture after the final passage was seen in 12 of 16 stenoses; two dissections were seen on the completion angiogram. After the final passage in all stenoses except three, the DR with IVUS was ≤ 30%.

Conclusion: Lumen enlargement following DA is predominantly due to plaque excision. Vessel expansion combined with plaque excision varies in different stenoses and is an important factor in eccentric and soft lesions. Despite additional DA considerable plaque remains.

Key words: Atherectomy — Intravascular ultrasound — Arteriosclerosis — Arteries, extremities — Femoral artery

Balloon angioplasty of femoropopliteal stenosis is still hampered by a high percentage of restenosis [1, 2]. To improve the results new techniques, such as directional atherectomy (DA), were introduced in which atherosclerotic material could be removed instead of being pushed aside [3, 4].

Although the theoretical mechanism of DA is simple and the complication rate is low, little is known about the in vivo mechanism [5, 6]. Effects ascribed to DA include “ploughing” caused by the stiff and relatively large device itself, “dilatation” caused by the one-sided low-pressure balloon, and “shaving” caused by the rotating cutter [7]. It has not been established whether an initial passage into a vessel is equally effective as subsequent passages in debulking the atheromatous plaque. Up to now arteriography has been the

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method of choice to assess the results of percutaneous intervention. However, because arteriography visualizes the inner contours of the lumen only as a two-dimensional silhouette, the mechanism of DA is not precisely known. Although there are some insights into the mechanism of DA [8–11] most of these studies have dealt with coronary DA.

With the introduction of angioscopy and intravascular ultrasound (IVUS) it is now possible to understand the underlying mechanism of endovascular interventions. Angioscopy is an efficient technique for studying the vessel lumen in real-time, but lacks visualization of the vessel wall structures [12]. IVUS is a reliable method for investigating the different aspects of an atheromatous vessel wall both before and after vascular intervention [8, 13, 14]. The aim of this study was to investigate the mechanism of DA by IVUS and to evaluate the effect of additional DA passages on lumen enlargement.

Materials and Methods

Patients

Fifteen patients (age range 58–81 years, mean 70.5 years) with intermittent claudication due to one or two stenoses in the femoropopliteal artery were studied with IVUS and arteriography before and after consecutive DA passages. All patients were informed of the potential risks and benefits and had given consent for participation in the study.

Pre-intervention assessment included aortic and iliac arteriography using conventional screen film combined with digital arteriography studies of the femoropopliteal segment. The stenosis was imaged in two orthogonal directions and the diameter reduction (DR) was calculated using minimal lumen diameter, compared with the diameter of a nearby angiographically normal segment. The degree of stenosis was calculated from these measurements using the equation: % stenosis = 100 × [1 – (minimal diameter of diseased segment/nominal diameter of this vessel)]. Stenoses before intervention ranged from 65% to 90% DR, ranging in length from 0.5 to 2.0 cm. The patients were treated with 80 mg aspirin daily, started the day before intervention and continuing indefinitely. During the intervention each patient received 5000 IU of heparin intraarterially.

Equipment

DA was performed via a 7, 8 or 9 Fr sheath, advancing the atherectomy catheter under fluoroscopic guidance. The maximum working diameter of the AtheroCath (Peripheral System Group, Mountain View, CA, USA) or the over-the-wire guided version, AtheroTrack (Peripheral System Group), ranged from 5.3 to 6.7 mm. All atherectomy catheters consisted of an extended collection chamber.

IVUS was performed using a commercially available ultrasound system (CVIS Inc., Sunnyvale, CA, USA). Peripheral imaging was performed using a 5 Fr, 30-MHz (radial penetration 7 mm) CVIS catheter. The mechanically driven mirror rotates with a speed of up to 30 frames per second. The IVUS catheter was advanced distally into the artery and images were recorded during manual pull-back of the catheter. The position of the ultrasound catheter tip within the artery was documented by a digital vascular mapping technique and compared with a radiopaque ruler. The IVUS and radiographic images were stored on an s-VHS video recorder for off-line analysis.

Technique of Intervention

After an antegrade puncture and introduction of a standard 7 Fr sheath (Terumo, Laméris Medical Products, Utrecht, The Netherlands; or Cordis, Rhoden, The Netherlands) into the common femoral artery, an arteriogram was made. The site of maximum stenosis was measured in different projections. By IVUS the working size of the DA catheter was chosen according to the mean diameter of the most normal segment nearby, proximal to the stenosis (reference segment, RF). When necessary an appropriate sheath (8 or 9 Fr) was positioned in the femoral artery to guide the DA catheter. Each DA passage consisted of rotating the catheter 8 to 10 times in the vessel lumen, or until the collection chamber was filled with plaque debris. This latter was noticed when the cutter could not be fully advanced distally, which could easily be seen with fluoroscopy.

IVUS was performed for the second time when the residual stenosis was ≥ 50% DR angiographically. If atheromatous plaque was still detected on IVUS, additional DA passage(s) was performed. After each additional passage arteriography and subsequently IVUS was applied. The radiopaque ruler and anatomical markers such as side-branches were used to identify the position of the previous stenosis. In eccentric lesions special attention was focused on the eccentric location of atheromatous tissue, by guiding the rectangular window against the plaque using a digital vascular mapping technique.

Procedural endpoints were defined when a residual stenosis ≥ 30% DR was achieved as monitored by IVUS, or when the removal of atherosclerotic material by additional DA proved impossible. This latter was noticed when the collection chamber of the DA device remained empty following subsequent DA passages. DR was calculated using the minimal lumen diameter (measured with IVUS) compared with the minimal lumen diameter of a nearby segment with the smallest plaque burden.

Definitions: Before Intervention

Free lumen area (FLA): Area bordered by the inner surface of the vessel lumen.

Media-bounded area (MBA): Area bordered by the inner side of the hypoechoic layer representing the media. The total vessel area is bordered by the adventitial layer of the vessel wall. The MBA is strongly related to the total vessel area, because the thickness of the media is small and the adventitia consists mainly of connective tissue [14].

Plaque area (PLA): Plaque area calculated by subtracting the free lumen area from the media-bounded area.

Soft lesion: A lesion having a homogenous echo structure without shadowing (thickness exceeds 0.5 mm).

Hard lesion: A lesion having a bright echo structure casting peripheral shadowing, representing a calcified lesion.

Eccentric and concentric lesion: The thinnest and thickest segment of the vessel wall was identified at the site of the maximum stenosis [15]. The ratio of these two measurements ≥ 2 defined an eccentric location of the plaque.

Definitions: After Intervention

Plaque rupture: Small echolucent separation of the intimal plaque not extending into the media.

Dissection: Echolucent space behind the surface of the plaque whose thickness was more than 0.5 mm, or if movement was seen as the plaque wavered in the flow of blood behind it [15].

Media rupture: Interruption in the internal elastic membrane and media that exposes the hyperechoic adventitia to the lumen.

Qualitative and Quantitative Analysis

Analysis was performed by two independent observers experienced in IVUS, without knowledge of the angiographic findings. The ref-