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Published February 4, 2010 as 10.3174/ajnr.A1810

REVIEW ARTICLE

Intravascular Ultrasound: Principles and Cerebrovascular Applications

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SUMMARY: Intravascular sonography is a valuable tool for the morphologic assessment of coronary atherosclerosis and the effect of pharmacologic and nonpharmacologic interventions on the progression or stabilization of atherosclerosis. An analysis of the different modes, applications, and limitations is provided on the basis of review of existing data from multiple clinical case studies, trials, and mechanistic studies. Intravascular sonography has been used to assess the outcomes of different percutaneous interventions, including angioplasty and stent implantation, and to provide detailed characterization of atherosclerotic lesions, aneurysms, and dissections within the cerebrovascular circulation. Evolution of intravascular sonographic technology has led to the development of more sophisticated diagnostic tools such as color-flow, virtual histology, and integrated backscatter intravascular sonography. The technologic advancement in intravascular sonography has the potential of providing more accurate information prior, during, and after a medical or endovascular intervention. Continued assessment of this diagnostic technique in both the intracranial and extracranial circulation will lead to increased use in clinical practice with the intent to improve outcomes.

ABBREVIATIONS: CI = confidence interval; EEL = external elastic lamina; O.D. = outer diameter

Currently there are 3 types of sonography used to assess the extracranial and the intracranial circulation: 1) transcranial Doppler, 2) B-mode sonography, and 3) intravascular sonography (Table). The morphologic appearance of the intra-arterial and intravenous circulation can now be visualized by using intravascular sonography, which has become a commonly used diagnostic technique for randomized clinical trials assessing coronary plaque progression and regression.[1] With excellent resolution, intravascular sonography provides cross-sectional images of both the arterial wall and lumen and identifies intimal flaps and irregularities, and the composition and extent of the atherosclerotic plaque.[2-6] Evolution of the intravascular sonography technology has led to the development of more sophisticated diagnostic tools such as color-flow, virtual histology, and integrated backscatter intravascular sonography.[7] The successful application of conventional (gray-scale) intravascular sonography in the coronary arteries has led to its application within the extracranial and intracranial arteries. Recently, intravascular sonography has also been used to identify and characterize carotid artery aneurysm, dissection, and thrombus.[8]

Intravascular sonography has been used successfully to assist in making measurements before and after percutaneous transluminal balloon angioplasty and stent placement, with emphasis on the identification of stent underexpansion, poor apposition, subacute stent thrombosis, and plaque protrusion.[9,10] Real-time dynamic intravascular sonography of the cervical common carotid artery and internal carotid artery can detect defects that are not readily apparent by conventional angiography, such as residual stenosis, suboptimal plaque coverage, arterial dissection, poor wall apposition of the stent, superficial calcification, atherosclerotic plaque progression or regression, and plaque ulceration.[11-13] The sensitivity and specificity of intravenous sonography is higher than those of angiography and MR imaging for studying the vessel lumen diameter and characteristics.[14,15] High extracranial carotid artery lesions are best evaluated with intravascular sonography because they are not well visualized with conventional noninvasive sonography.[16] The growth of endovascular practices and intravascular sonography capabilities has set the stage for broader use of this technology in neuroendovascular procedures across the United States (Fig 1).

Conventional Gray-Scale Intravascular Sonography

The intensity of reflected signals that are collected by the intravascular sonographic transducer enables the creation of conventional gray-scale images.[7] The elastin and collagen organization within the arterial wall provides the substrate that leads to different sonographic scattering properties between the individual layers. Sonography presents the intima (inner layer) as a white (hyperechoic) signal and the media as a dark (hypoechoic) and echolucent signal. The surrounding adventitia, the outermost layer, produces a white (hyperechoic) signal. The arterial wall of the normal elastic arteries typically has a homogeneous appearance when imaged by intravascular sonography, secondary to the elastin in the media. Hypoechoic (dark) media are seen when muscular arteries are visualized, due to the presence of arterial smooth muscle cells (Fig 2).[17,18] The common carotid artery and the distal internal carotid artery both have a muscular and elastic component. Manninen et al[18] consistently found 3 different circumferential signal-intensity patterns in the distal internal carotid artery segment visualized by intravascular sonography, during life and after death. The common carotid artery typically has a characteristic homogeneous structure.[18] The arterial wall of the internal carotid artery bulb can have marked variation because it is typically a transitional zone. With regard to various parts of the carotid artery wall imaged by intravascular sonography, there appears to be a continuum of findings.[18] Mural thrombus, free-floating clot, and echolucent disease like neointimal hyperplasia

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DOI 10.3174/ajnr.A1810

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