INTRODUCTION

The intravascular ultrasound (IVUS) is an invasive access technique that allows the dynamic acquisition of tomographic imaging *in vivo* of the vascular lumen and wall, being considered one of the best invasive imaging methods for the analysis of characteristics (qualitative and quantitative) of coronary atherosclerosis[1].

In theory, the use of IVUS could improve the long-term results of angioplasty with stent implantation. These better results derive from at least three factors: the confirmation that there is no significant residual stenosis or that artery dissection did not occur; definite identification and removal of the calcified plaque that limits stent expansion; visualization of an optimal luminal gain[2].

Percutaneous coronary intervention (PCI) remains challenging for high-risk patient groups, especially those with type C lesions, and their outcomes are often compromised[3–5]. It is further known that IVUS guidance of stent implantation may result in more effective stent expansion as compared to angiographic guidance alone[6]. Thus, it is plausible that IVUS guidance may improve short- and long-term outcomes of patients undergoing stent implantation. However, previous trials comparing IVUS guidance to angiographic guidance alone have provided conflicting results. Importantly, these studies have examined the results in unselected populations or have reported on predominantly noncomplex target lesions[7–9]. Thus, it can be argued that the impact of IVUS use on the outcome of patients with complex lesions in which the efficacy of IVUS-guided stent placement might be most effective has not been examined in detail.

An American College of Cardiology/American Heart Association (ACC/AHA) classification was applied to differentiate between the complexities of the target lesions for PCI and to suggest that more complex lesions are associated with lower procedural success rates and poorer late outcomes. Class C lesions are considered to have the highest degree of lesion complexity[10]. Percutaneous coronary intervention (PCI) of complex lesions (i.e., American College of Cardiology/ American Heart Association class type C) remains challenging and the outcome may be compromised. The use of intravascular ultrasound (IVUS) to guide PCI was suggested to improve outcome[11].

AIM OF THE WORK

The study aims to compare intravascular ultrasound-guided and angiography-guided Intervention for Type C coronary lesions regarding major adverse cardiac events (MACE).

Chapter (1)
INTRAVASCULAR ULTRASOUND

Introduction:

Coronary angiography is the principal imaging modality used to assess coronary vessel anatomy and morphology. However, despite the broad implementation and the unanimous acceptance of this technique for the evaluation of the extent and severity of coronary artery disease, it is well known that it has limited ability in assessing the atherosclerotic disease process as the obtained two-dimensional images cannot accurately depict the complex three-dimensional anatomy of the vessel and cannot give any information regarding the type of the plaque and its burden[12].

To address these limitations, Intravascular Ultrasound (IVUS) was introduced that provides high resolution cross-sectional imaging of the vessel, which permits identification of the lumen, the plaque and the outer vessel wall and accurate evaluation of the plaque burden. Several studies have confirmed that IVUS is safe and thus today it is often used in clinical practice as a complementary to coronary angiography tool[13,14]. IVUS appears to be useful in assessing the severity of ambiguous lesions and guiding complex percutaneous coronary interventions (PCIs). In addition, is it also valuable in research and has been implemented in a number of studies that examined the impact of several interventional and non-interventional treatments on the evolution of the atherosclerotic process[15].

IVUS has become indispensable in everyday clinical practice. The supplementary information provided has rendered it valuable in guiding complex percutaneous coronary interventions and its use has significantly limited intervention-related complications. In addition, its increased radial resolution has rendered it a useful research tool that allows accurate evaluation of the plaque burden and estimation of the atherosclerotic evolution.

The physical principles:

As with other imaging techniques that use ultrasound, an electrical current is passed through a piezoelectric crystalline material. This material produces sound waves by expanding and contracting after electrical stimulation. Sound waves reflect from various tissue planes and are received by the transducer. The image is constructed from the electrical impulse created by the transducer. Ultrasound frequencies of 20-50 MHz are used in IVUS imaging[12].

The necessary hardware:

Catheter and transducer: Catheter sizes range between 2.6 and 3.5 French (F), compatible with a 6F guiding catheter. Two different transducer systems are available.

Mechanical systems include a single rotating transducer that is mounted on a cable. The rotating transducer can be freely moved inside an echolucent sheath at the distal tip of the IVUS catheter[12].

Phased array systems include multiple imaging elements that are sequentially activated in a circular way to obtain images[12].

Pullback device: The transducer can be advanced or pulled back manually. Alternatively, an automatic motorized pullback device that draws the catheter at a fixed speed can be used for more precise measurements. The speed of the automatic pullback ranges between 0.25 and 1.0 mm/s[12,13].

Console: It is composed of a hardware and software for image reconstruction, recording devices and a monitor. For storage, videotapes or CD-ROMs are used.

The examination technique:

Following anticoagulation with intravenous heparin (5000 to 10000 units), 100 to 300 µg of intracoronary nitroglycerin is given to maximally dilate the arteries and to prevent spasm. A 0.014 inch guide-wire is placed into the target artery. Then IVUS catheter is placed distal to the area of interest or as distal as safely possible. Motorized transducer pullback allows steady withdrawal of the catheter, providing equidistant images for volumetric calculations. It is particularly important in serial studies because obtained images are reproducible, thus allowing comparative volumetric calculations[16].

Manual transducer pullback allows pausing the catheter at specific locations. This gives an advantage of focusing for a long time on specific lesion characteristics.

However, pulling the transducer rapidly or irregularly may result in missing an important pathology[16].

Safety of Coronary Ultrasound:

The safety of intracoronary ultrasound is well documented. Studies report complication rates varying from 1% to 3%; the complication most frequently reported is transient spasm, which responds rapidly to intracoronary nitroglycerin. The major complication rate (dissection or vessel closure) is <0.5%. Nearly all major complications occur in patients undergoing intervention rather than diagnostic imaging. Examination of vessels previously imaged by IVUS compared with non-instrumented vessels shows no accelerated progression of atheroma at 1 year of follow-up. Despite the favorable safety profile, subselective coronary instrumentation always carries a potential risk of vessel injury. Accordingly, only operators experienced in intracoronary catheter manipulation should perform intravascular imaging[14].

The display modes:

With 2-dimensional IVUS imaging, only cross-sectional images of the coronary artery are displayed. However, information about length and distribution of the lesions cannot be obtained with this display method. Alternatively, in L (longitudinal)-mode imaging, longitudinal appearance of the artery along a single cut plane is displayed by image reconstruction techniques[12].

The vessel size changes with each cardiac cycle and this causes a characteristic 'sawtooth' appearance.

By advanced computer techniques, three-dimensional imaging can also be performed[17,18]. Since tissue interfaces may be located arbitrarily by current systems, there may be errors in the determination of the real boundaries[19,20].

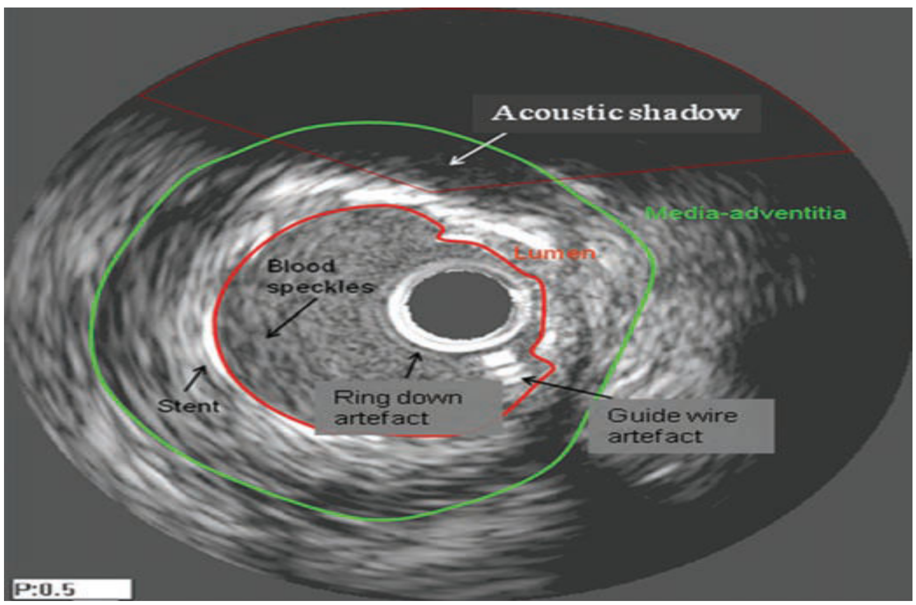

Figure (1): Structures and artefacts seen in IVUS images[21]

Normal Arterial Anatomy:

In a normal coronary artery, the following structures are identified: the vessel lumen (blood), the vessel wall and the adjacent structures[12,15]. The Lumen At frequencies >20 MHz, flowing blood presents a specific echogenic pattern called speckle. The blood speckle may be described as finely textured echoes moving in a swirling pattern in video loops/sequences. The blood speckle can provide valuable help in image interpretation as its typical morphology may facilitate differentiation between lumen and vessel wall and identification of vessel dissection, which appears as a communication between the lumen and the dissected vascular wall. However, problems may arise in a substantial proportion of cases and diagnosis may elude. Blood speckle can be much more prominent in higher imaging frequencies and might interfere with the delineation of the wall tissue rendering image interpretation a demanding process. Interrogating video sequences rather than frozen images and flushing the vessel with saline or contrast medium during IVUS imaging may help this differentiation, especially in cases of dissections.

The Vessel Wall:

Previous IVUS studies performed on pressure distended coronary arteries have provided the characteristic appearance of normal coronary arteries [15,22,23] (Figure 2). There are two distinct changes in acoustic impedance as ultrasound waves are reflected on vessel wall tissues. The first is created at the border between blood and the leading edge of the vessel intima and this trailing edge can be used reliably for measurements. The second is sited at the external elastic membrane (EEM) that is located at the media-adventitia interface. The outer border of the adventitia cannot be easily differentiated from the surrounding tissue. In high-quality images, the tunica media can be possibly visualized as an echolucent, lower density, layer. In young healthy subjects the intima thickness is normally reported to be 0.15±0.07 mm, while a thickness of 0.25-0.50 mm is usually considered as the upper reference limit for intima[15].

The Adjacent Structures:

Arterial side branches, cardiac veins and the pericardium constitute the adjacent structures that can be recognized during pull-back of the IVUS catheter. Vessel bifurcations are frequently identified as the sites of early and eccentric plaque development which is due to the unique hemodynamic patterns seen in these areas. As the IVUS catheter is withdrawn, the arterial side branches appear at the peripheral parts of the screen and gradually join the main vessel. In most cases, IVUS imaging allows partial assessment of the ostium of the branch. However, a complete evaluation of the proximal segment is often not feasible as the IVUS catheter is moving at an angle compared to the side branch axis. Cardiac veins are typically seen as vessels which run parallel or cross the coronary artery and can be recognized by their characteristic compression during systole. Arterial side branches and cardiac veins are frequently used as landmarks to match coronary arterial segments interrogated in serial examinations.

Coronary Venous Grafts:

The wall morphology of venous bypass grafts is different from the native coronaries. The venous grafts have no surrounding tissue, no side branches and no EEM. The outer echolucent zone surrounding the intima corresponds to the 'EEM area' of the venous graft. Venous grafts gradually undergo characteristic morphological changes: intimal fibrous thickening, medial hypertrophy and lipid deposition that represent a distinct process leading to 'arterialization' of the grafts. The plaque burden and atheroma characterization are assessed in a similar to native coronary arteries manner.

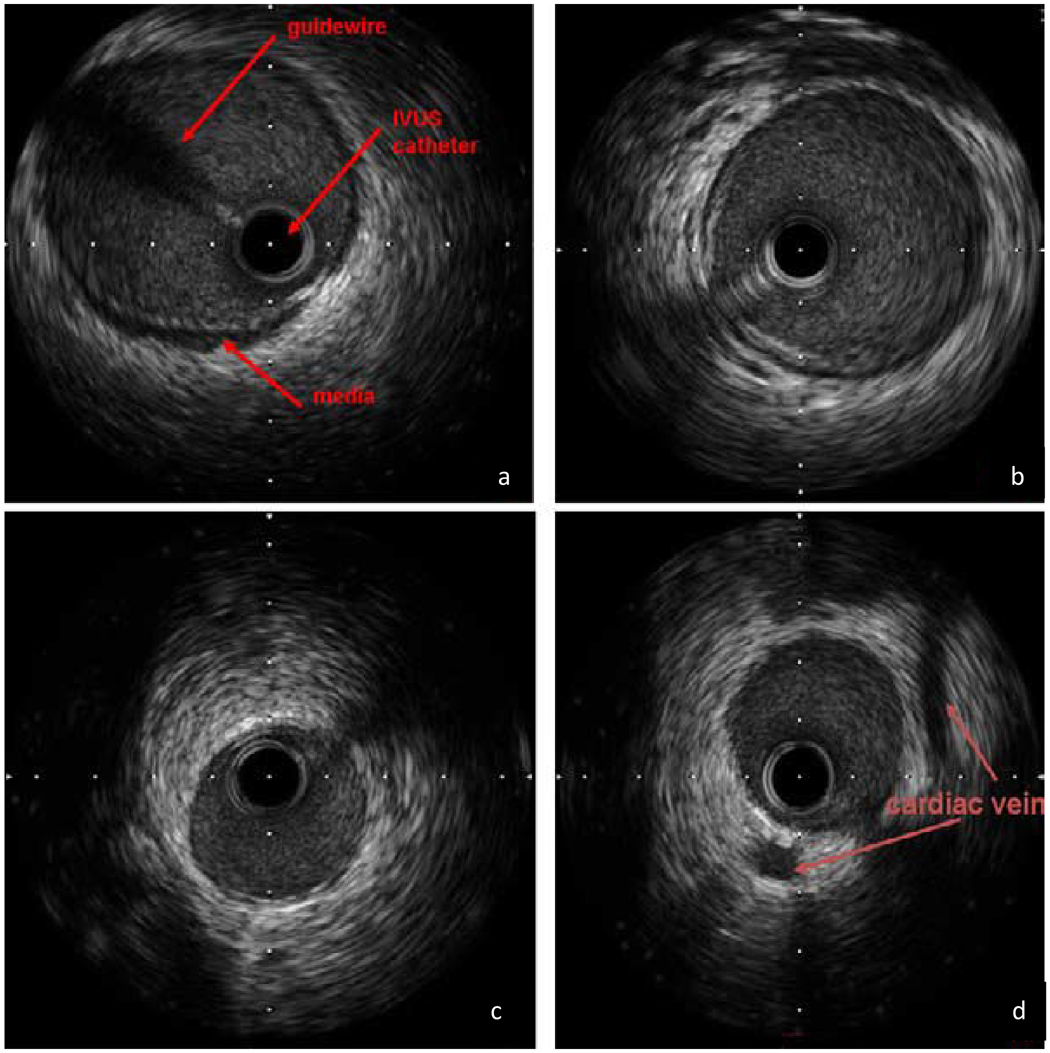

Figure (2): a) Normal coronary artery (the echolucent round zone is the media, the black circle inside the lumen is the IVUS catheter, the shadow inside the lumen is due to the guidewire – obvious in most of the figures); b) Minimal intimal thickening (from 6 to 10 o' clock); c) Normal coronary artery (distal part of the vessel). Note that the media is not very obvious here; d) Normal coronary artery. Note the veins outside the adventitia[21].

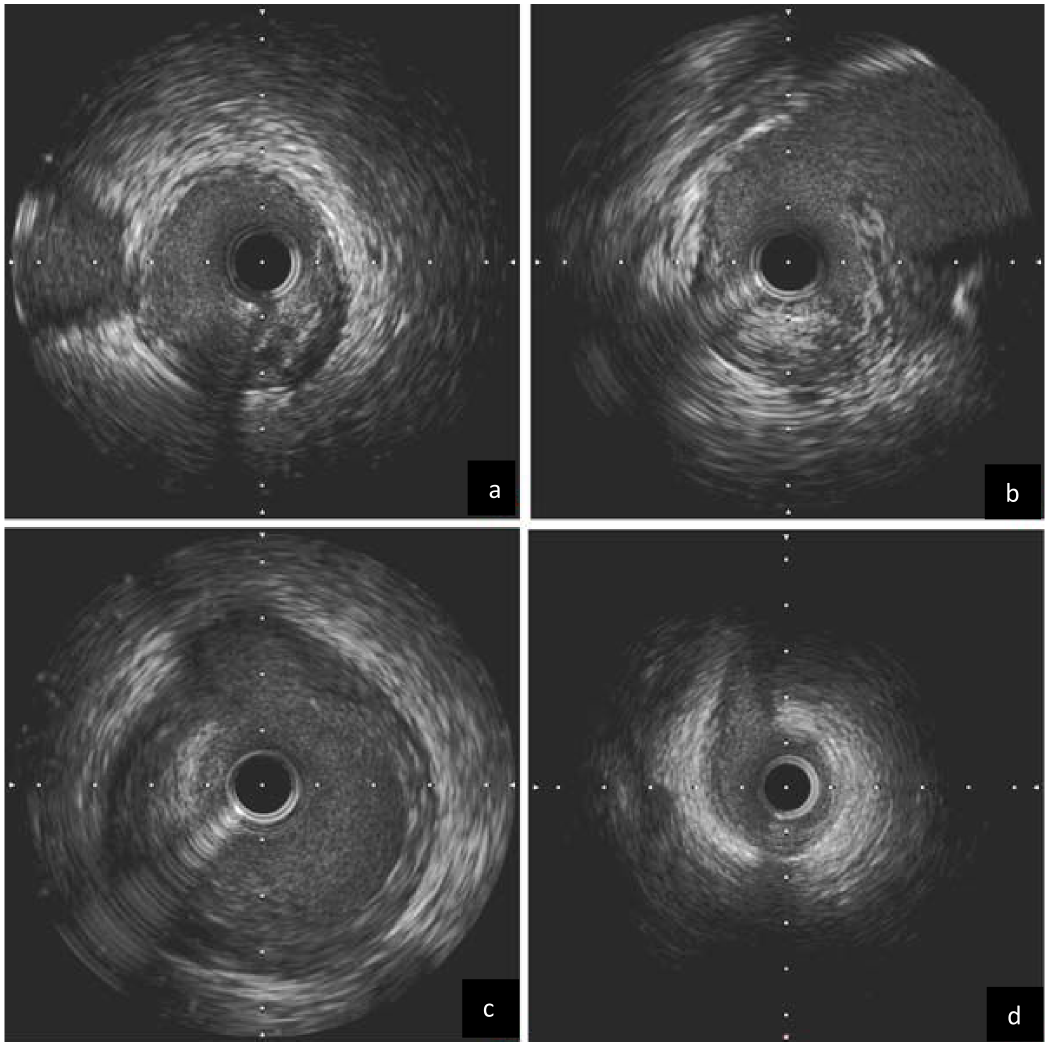

Figure (3): a) Eccentric fibrofatty plaque (extending from 3 to 8 o' clock). Side-branch about to enter the main vessel at 9 o'clock; b) Eccentric fibrofatty plaque (extending from 3 to 9 o' clock). Large side branch entering the vessel from 12 to 2 o' clock. The site of entry could be confused with plaque rupture in this frozen image; c) Concentric fibrous plaque. Side branch at 12 o' clock; d) Side branch at 11-12 o' clock[21].

Image Artifacts

Several artifacts often seen in IVUS can impair the quality of the acquired images[12,15]. Some of them depends on the catheter design (mechanical or solid state transducer) while others are seen in IVUS images regardless of the catheter that was used for image acquisition.

Guidewire-Artifact:

When monorail catheter technology is used, the guidewire is situated outside the transducer and produces a “linear” or narrow-angled artifact that disturbs visualization behind its shadow. Nevertheless, retraction of the guidewire is generally not recommended so that a secure access to the coronary vessel may be preserved.

Non-Uniform Rotational Distortion:

Non-uniform rotational distortion (NURD) may be observed only when mechanical transducers are used. This artefact is caused by an uneven drag of the drive cable of the mechanical catheter. This results to cyclic oscillations that are observed as a severe distortion of the image. This particular artifact appears in several occasions such as acute bends of the coronary artery, tortuous guide catheter shape or small lumen of the guide catheter, excessive tightening of the hemostatic valve, variance in manufacturing the driveshaft, or kinking of the image sheath[21].

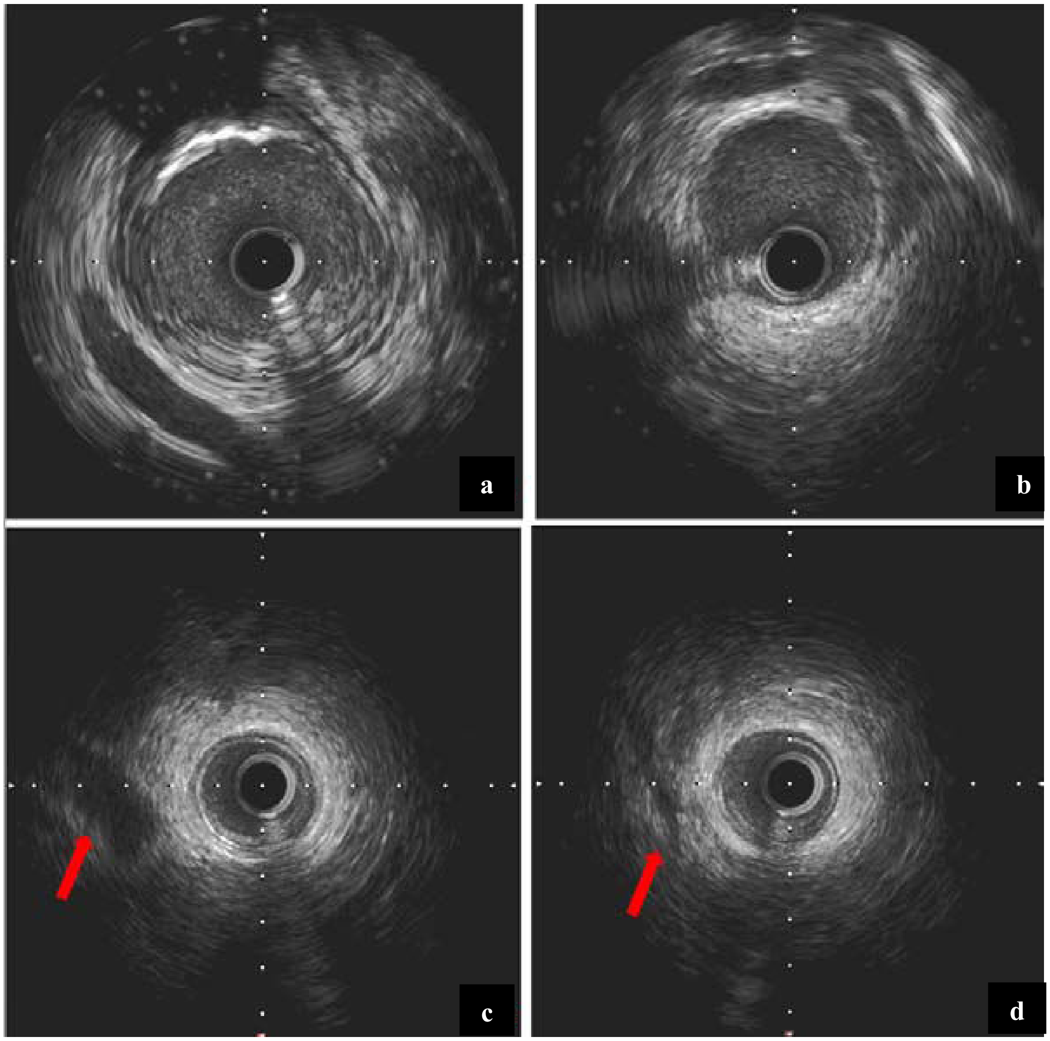

Figure (4): a) Concentric fibrous plaque with a 45 degrees arc of superficial calcium (10-12 o' clock).Outside the artery, note the longitudinal view of a vein extending from 5 to 8 o' clock; b) Normal coronary artery. Outside the artery note the large cardiac vein with branches extending from 11 to 3 o' clock; C) Cardiac vein 8-9 o' clock uncompressed - during diastole (arrow); d) Same cardiac vein as in Figure 3c compressed – during systole (arrow)[21].