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Interventional Echocardiography

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ABSTRACT

Echocardiography guidance for interventions in the catheterization laboratory allows for reduction in radiation exposure from fluoroscopy as well as superior anatomic definition and visualization. The additional information provided over fluoroscopy has translated into an increasing use during interventional procedures. Procedures such as transeptal puncture, percutaneous valvular interventions, myocardial biopsy, echo-guided pericardiocentesis and other interventions have evolved to a complexity level that requires combined echocardiographic and fluoroscopic guidance. Different imaging modalities are utilized in the catheterization laboratory including intracardiac echocardiography, two-dimensional (2D) or three-dimensional (3D) transthoracic echocardiography, and 2D or 3D transesophageal echocardiography. This review is intended to provide an overall summary of the impact echocardiography has had in the catheterization laboratory. We will describe how echocardiography is utilized to guide a diverse array of interventional procedures, emphasizing specific practical issues with respect to echocardiographic guidance of interventional procedures and also pointing out the limitations of echocardiography.

Historically, cardiovascular interventions in the catheterization laboratory were guided by fluoroscopy and angiography. However, increasingly complex procedures such as transeptal puncture, percutaneous valve interventions, pericardiocentesis, have evolved to a complexity that now most often require echocardiographic guidance. Different imaging modalities are utilized in the catheterization lab including intracardiac echocardiography (ICE), two-dimensional (2D) or three-dimensional (3D) transthoracic echocardiography (TTE), and 2D or 3D transesophageal echocardiography (TEE). This manuscript will describe how echocardiography is utilized to guide a diverse array of interventional procedures. We will review the specific key imaging issues with respect to echocardiographic guidance and also point out the limitations of echocardiography and when a complimentary approach incorporating fluoroscopy is also necessary. This review is intended to provide an overall summary of the impact echocardiography has had in the catheterization lab.

Echocardiographic guidance of transseptal puncture

Transseptal puncture is traditionally performed under direct fluoroscopy, but 2D echocardiographic guidance was described already 30 years ago.[1] As interventional mitral valve (MV) procedures requiring echocardiographic guidance have become more common, the echocardiographer has increasingly been involved by assisting with imaging at the time of septal

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Abbreviations and Acronyms

ICE = intracardiac echocardiography

2D = two dimensional

3D = three dimensional

TTE = transthoracic echocardiography

TEE = transesophageal echocardiography

MV = mitral valve

MR = mitral regurgitation

RA = right atria or atrial

LA = left atria or atrial

ABV = aortic balloon valvuloplasty

AR = aortic regurgitation

AS = aortic stenosis

LV = left ventricle or ventricular

RV = right ventricle or ventricular

LVOT = left ventricular outflow tract

LAA = left atrial appendage

TAVR = transcatheter aortic valve replacement

PISA = proximal isovelocity surface area

EMB = endomyocardial biopsy

PBMV = percutaneous balloon mitral valvuloplasty

ASD = atrial septal defect

PFO = patent foramen ovale

HOCM = hypertrophic obstructive cardiomyopathy

MI = myocardial infarction

SAM = systolic anterior motion

puncture. Indeed, TEE is critical in MV interventions in general,[2] and confers the benefit of excellent visualization of the interatrial septum. Accurate guidance to cross the interatrial septum at a specific location is particularly important in percutaneous treatment of mitral regurgitation (MR) with the MitraClip system.[3]

Proper understanding of the septal anatomy is vital in assisting the intervention. The target area for safe septal puncture is the floor of the fossa ovalis and its immediate rim.[4] Imaging can be performed in either single or biplane plane 2D, or more recently in live 3D imaging[4]; biplane or 3D imaging is the preferred modality. We usually start with the bi-caval view (90–100° rotation), as this will show both fossa ovalis and the inferior aspect of the right atrium (RA), allowing imaging of the septal puncture system once advanced from the inferior vena cava (Fig 1). The needle is gently advanced on the membrane of the fossa ovalis, and direct contact is confirmed by observing slight tenting. Before performing the septal puncture we recommend rapid verification of the needle position in an orthogonal plane usually at ~30–60° as this will identify the needle position relative to the aortic root. Thus, biplane imaging is more convenient, and easier to implement. Simultaneous visualization at bi-caval and short axis view (30–60°) reproduces monoplane imaging without the need for angle rotation. Notably, the relative angle between the imaging planes can be adjusted to adapt better to the specific patient anatomy. Once position is confirmed, the needle can be advanced safely. Left atrial position is confirmed echocardiographically as well as by fluoroscopy with radiographic contrast injection; due to formation of microbubbles by mixture of contrast and saline in the catheter system, this injection will also be well-visualized on echocardiography.

3D-guidance of the septal puncture is gaining momentum. As with any other 3D technique there is a learning curve in understanding the 3D appearance of atrial structures; for the initial experience we suggest displaying both 3D and orthogonal (biplane) 2D images. The major advantage of live 3D imaging is the ability to identify the position of the needle tip in relationship with surrounding structures in real time, avoiding the limitations of single-plane 2D imaging when only a portion of the hardware is visualized. When performing 3D imaging of the septum, it is easier to start with the bicaval view, then go to 3D zoom and select the widest possible area, but a narrow sector depth to exclude RA and left atrial (LA) lateral walls. Current scanners allow 3D display of both right and left sides of the atrial septum, as well as simultaneous display of 2D X-plane (biplane) and live 3D images.

Echocardiographic guidance in aortic valve interventions

Transcatheter Aortic Valve Replacement (TAVR) is increasingly performed in patients at high risk for open surgical replacement, as well as in multiple on-going clinical trials. In parallel with development of TAVR, use of aortic balloon valvuloplasty (ABV) has increased, either as a bridge to TAVR, or as a diagnostic and therapeutic tool in differentiating valvular from non-valvular causes of dyspnea in patients with multiple comorbidities.[5] In addition, percutaneous closure of periprosthetic aortic valve regurgitation (AR) and of pseudoaneurysms of the intervalvular fibrosa and aortic root are increasingly being performed. Echocardiographic imaging of the stenotic aortic valve in the catheterization laboratory can be challenging due to both acoustic shadowing by the heavily calcified aortic valve, and from supine positioning of the patient which can significantly reduce the number and quality of acoustic windows.

Aortic balloon valvuloplasty

We usually guide ABV with TTE, although TEE may be needed when image quality is poor. As with any interventional technique, we start by confirming the diagnosis (in this case aortic stenosis/AS), and perform a pre-procedural screen of left ventricular (LV) and right ventricular (RV) function, other valvular conditions, and presence or absence of pericardial effusion. We carefully measure the LV outflow tract (LVOT) antero-posterior diameter on long axis parasternal image; this should be performed in early systole, at the insertion point of aortic leaflets.[2] Increasingly, we are also estimating the transverse diameter of the LVOT, although this is more challenging with TTE. Orthogonal biplane imaging may help, but for true "alignment" with the aortic valve annular plane, 3D imaging is required (Fig 2). Particular attention must be given to assessment of AR at baseline, as moderate or more AR is a contraindication to ARV. We then obtain a transvalvular gradient, usually only from TTE apical position. This will