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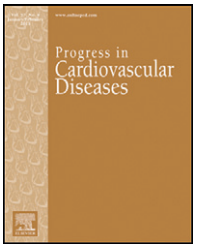

The Role of Left Atrial Imaging in the Management of Atrial Fibrillation

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ABSTRACT

Atrial fibrillation (AF) is the most commonly encountered sustained cardiac rhythm disorder, is an independent risk factor for stroke, heart failure and death, and its development is promoted by a range of common cardiovascular pathologies. The management of AF is directed at these predisposing conditions, at reducing the risk of systemic thromboembolism, and towards rate or rhythm control of the arrhythmia. Guidelines increasingly support the use of catheter ablation (CA) as an early management strategy, with the efficacy of CA crucially dependent on the extent of left atrial (LA) structural remodeling; LA imaging plays a central role in each of identifying comorbidities, risk stratification for stroke, and identification of suitable candidates for CA. An understanding of the strengths and limitations of various echocardiographic modalities, of cardiac computed tomography and of cardiac magnetic resonance imaging is therefore an increasingly important part of the armory of the electrophysiologist. In particular, individualized use of imaging to select patients more likely to benefit from CA of AF is important, and post-procedural imaging to evaluate the extent of reverse LA remodeling after CA is critical to appropriate decisions regarding ongoing anti-arrhythmic therapy and long-term anticoagulation.

As the most frequently encountered sustained cardiac arrhythmia,[1] atrial fibrillation (AF) imposes a major public health burden. In addition to the imposition of often debilitating cardiac symptoms, AF is an independent risk factor for stroke, heart failure (HF) and death.[2–4] The development of AF is promoted by a range of common cardiovascular (CV) pathologies such as systemic hypertension (HTN), diabetes mellitus (DM), obesity and obstructive sleep apnea (OSA), many of which enhance the risk of stroke in the setting of AF through a presumed effect on left atrial (LA) mechanical function but likely also thorough more widespread vascular effects. The management of AF is therefore directed at identifying and ameliorating predisposing conditions, at quantifying and reducing the risk of stroke and systemic thromboembolism (STE), and at either rate or rhythm control of the arrhythmia itself. Guidelines increasingly support the use of catheter ablation (CA) of AF as an early management strategy, particularly for symptomatic paroxysmal AF.[5] The efficacy of CA appears crucially dependent on the extent of remodeling of the LA substrate, most obviously manifest in the size of the chamber. LA imaging plays a central role in all of these management priorities: in identifying comorbidities,

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Abbreviations and Acronyms

2D = 2-dimensional

3D = 3-dimensional

AF = Atrial fibrillation

CA = Catheter ablation

CCT = Cardiac computed tomography

CMR = Cardiac magnetic resonance

DM = Diabetes mellitus

HF = Heart failure

HTN = Hypertension

ICE = Intra-cardiac echo

LGE = Late gadolinium enhancement

LA = Left atrium/atrial

LAA = Left atrial appendage

LV = Left ventricle

MDCT = Multi-detector row CT

NSR = Normal sinus rhythm

OSA = Obstructive sleep apnea

PV = Pulmonary vein

PVI = Pulmonary vein isolation

TDI = Tissue Doppler imaging

LV = Left ventricle

STE = Systemic thromboembolic/ thromboembolism

TEE = Transesophageal echocardiogram

TTE = Transthoracic echocardiogram

in risk stratifying for stroke and in identifying suitable candidates for CA.

Imaging modalities: Echocardiography, cardiac computed tomography and cardiac magnetic resonance

Non-invasive cardiac imaging with echocardiography, cardiac computed tomography (CCT) and/or cardiac magnetic resonance (CMR) imaging can assess LA morphology and pulmonary vein (PV) anatomy (Table 1). These imaging modalities also provide additional information regarding cardiac structure and function that may be of direct relevance to AF management. Generally, echocardiography is performed in the first instance, with further testing guided by a patient's specific clinical situation and with consideration of potential adverse effects, contraindications and availability.

Echocardiography

Echocardiography is the most widely available and established means of assessing cardiac structure and function. Piezoelectric crystals within echocardiographic transducers propagate and receive high frequency sound waves. These ultrasound beams travel straight within homogenous tissue, but are reflected within heterogeneous tissue and at tissue interfaces.[6,7] Motion (M-mode) and 2-dimensional (2D) echocardiographic images are generated in real time by interpreting these reflected ultrasound waves. Doppler echocardiography, which can be color-encoded, evaluates cardiac blood flow by using the ultrasound beam to detect changes in the frequency of the backscatter signal from moving red blood cells. In tissue Doppler imaging (TDI), lower velocity frequency shifts are analyzed to calculate the velocity of myocardial movement.

The reproducibility of volumetric measurements by echocardiography is inherently limited because estimates of volumes derived from 2D images are subject to variability and error imposed by reduced image quality, selection of the imaging plane, difficulties in identifying the endocardium-blood interface, geometric assumptions underlying the volumetric calculations, and beat-to-beat variations in volume and function. With the advent of 3-dimensional (3D) echocardiography, a more accurate and reproducible technique than 2D imaging, echocardiographic assessments of chamber size and cardiac function now correlate more closely with the gold standard, CMR.[8–10]

Cardiac computed tomography

A common indication for CCT is the assessment of coronary arteries for the presence of luminal plaque, but CCT can also accurately measure atrial dimensions[11] and PV anatomy.[12] Multi-detector row scanners (MDCT) acquire between 64 and 320 slices (0.6mm slice thickness) of cardiac tissue within a single gantry rotation. The timing of image acquisition following intravenous administration of iodinated contrast is determined to enable optimal opacification of the cardiac structure of interest. Image quality can be impaired with heart rates greater than 60 beats per minute and by irregular heart rhythms such as AF. Also of potential concern, CCT is associated with a small dose of radiation exposure[13,14] and may be contra-indicated in patients with allergies to iodinated contrast or significant renal impairment.

Cardiac magnetic resonance imaging

Over recent years CMR has been used in clinical and research settings to provide gold standard volumetric assessments of chamber structure and function, and to characterize cardiac tissue. The high spatial and temporal resolution capabilities of CMR provide several advantages over other imaging modalities. Furthermore, contrast-enhanced CMR with gadolinium-based agents has revolutionized the non-invasive assessment of cardiac fibrosis. However CMR remains relatively expensive, is limited in its availability in many health care systems, and some patients cannot be scanned due to claustrophobia. The presence of implanted cardiac devices or metallic foreign bodies has also been regarded as a contra-indication, although this is changing with the development of MRI-conditional devices.[15,16] In patients with significant renal dysfunction, administration of gadolinium contrast may lead to nephrogenic systemic fibrosis.[17]

CMR images are generated using the magnetization attributes of cardiac tissue. During CMR scanning, hydrogen protons are tilted off the longitudinal (z) axis of the scanner into the transverse plane (x and y axes) by applied pulse sequences. Following restoration of longitudinal magnetization of the protons, tissue-specific T_1 and T_2 relaxation properties can be determined.[18,19] The T_1 relaxation time reflects the time decay constant for 63% recovery of the longitudinal magnetization equilibrium value of a proton,