CT-Guided Cardiac Electrophysiology

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Introduction

Catheter-based ablation has revolutionized the management of patients with tachyarrhythmias and has become the first-choice therapy for many tachyarrhythmias. Radiofrequency (RF) ablation for atrioventricular (AV) node reentry, isthmus-dependent atrial flutter (AFL), and paroxysmal atrial fibrillation (AF) is performed almost entirely as an anatomy-based ablation in many centers [1,2]. RF current is the energy source of choice in the destruction of minute arrhythmogenic myocardial tissue to control or cure arrhythmias. Percutaneous transvenous endocardial catheter ablation, which delivers treatment to the inside of the heart, is usually the preferred approach for the treatment of several types of arrhythmias. Transthoracic epicardial catheter ablation, through a subxiphoid needle placed in the pericardial sac, delivers RF energy to the outer surface of the heart and is an alternative approach for patients who failed endocardial ablation or in whom endocardial ablation is contraindicated [3]. In select cases, ablations can be performed through the coronary sinus conduit [4].

Multidetector CT (MDCT) allows comprehensive study of the heart in less than a few seconds and provides accurate anatomic information. This technique not only nicely depicts the coronary vessels but also visualizes the cardiac chambers, including their important anatomic landmarks, with spatial resolution of less than 1 mm. At the same time, functional assessment of the heart chambers, anatomic variants, and congenital malformations can be easily performed. Given its capacity to perform noninvasive “virtual dissection” of the heart in a three-dimensional fashion, registered images of MDCT will allow faster and more accurate placement of intracardiac electrode catheters and pacemaker leads, thus optimizing results as well as minimizing complications.

In this review, we focus on the latest developments in the application of MDCT for electrophysiologic interventions. We provide background on the cardiac anatomy as well as anatomic landmarks of interest to electrophysiologists, their relationships with other structures, and their anatomic variants. We also discuss the anatomic barriers in transcutaneous interventions, potential complications of transcatheter ablation procedures and other interventions, and future directions of CT cardiac imaging.

CT for Assessment of Anatomic Barriers in Transcutaneous Interventions

Although fluoroscopy is frequently used to localize anatomic landmarks for ablation, MDCT can depict various cardiac structures that are difficult to visualize at fluoroscopy (e.g., oval fossa, intra-atrial webs, Eustachian ridge, anatomic variants of the coronary sinus, and oblique vein of Marshall) [5••]. The improved temporal and spatial resolution of MDCT provides anatomic data for easier placement of intracardiac catheters and can facilitate complex ablation strategies [6]. Clarification of potential anatomic barriers is important to decrease potential complications.

Peripheral venous occlusion, superior vena cava stenosis (post-thrombosis, fibrosis, lipomatosis), and inferior vena cava interruption (thrombosis, azygous continuation)

It is crucial to know the patency and any anomalies of the central and peripheral venous systems prior to performing an electrophysiology study (Fig. 1). Contrast-enhanced imaging...
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CT scan can rapidly and accurately define the site and nature of the obstruction as well as any anomalies of the venous system [7]. This will help the electrophysiologist in selecting an appropriate entry point to perform the study and avoid complications such as dislodging a thrombus or rupturing a tight stenosis.

Transseptal interventions (size of fossa ovale, presence or absence of patent foramen ovale, atrial septal defect, and lipomatosis of the septum)

Occasionally, a transseptal approach is used if access to the left side of the heart is mandated. In some cases, percutaneous puncture of the interatrial septum for the left heart catheterization can be difficult and may result in life-threatening complications, particularly in patients with atypical anatomy or a small fossa ovalis [8]. Given that a major portion of the atrial septation is formed by infoldings of walls (interatrial grooves), puncture outside the limited margins of the fossa ovalis during transseptal interventions will perforate the heart [9]. Patent foramen ovale (PFO) is formed by failure of fusion of the antral margins of the septum primum with the septum secundum [10]. MDCT may be useful in planning transatrial interventions by identifying the anatomy of the interatrial septum and demonstrating the precise morphology of the PFO, as well as identifying the presence of atrial septal defect [8,9].

MDCT can also be used to make the diagnosis of lipomatous hypertrophy of the interatrial septum (LHIS), which is characterized by accumulation and deposition of fat in the interatrial septum. LHIS commonly occurs in older, obese women. It remains asymptomatic in most cases, but it can cause atrial arrhythmias or obstructive flow symptoms. Surgical intervention is reserved only for cases of severe superior vena cava (SVC) obstruction or intractable rhythm disturbance [11].

Intra-atrial obstacles: large Eustachian valve/Chiari network, valve of Thebesian, valve of Vieuxsens, ligament of Marshall, and intraluminal membrane

The Eustachian valve locates in the superior portion of the inferior vena cava (IVC) to direct blood from the IVC toward the foramen ovale, thereby bypassing the pulmonary circulation during fetal life. The Eustachian valve/ridge may be large and muscular in some cases, posing an obstacle to catheter passage [12]. A Chiari network is a web-like structure with a variable number of thread-like components in the right atrium connected to the Eustachian valve [13]. Although this nonpathological embryonic remnant has no known purpose, entrapment of right cardiac catheters has been reported.

A prominent Thebesian valve can impede an endocardial approach to left ventricular pacing. The coronary sinus and cardiac veins are useful conduits for catheter treatment of arrhythmias as well as left ventricular pacing. A potential technical difficulty to these procedures is obstruction to passage of a catheter, and the most frequent cause is the valve of Vieussens (Fig. 2). Prevalence of the Vieussens valve, which is the ostial valve of the great cardiac vein located near the beginning of the coronary sinus, is reported to vary from 65% to 87% [14].

The ligament or oblique vein of Marshall is a possible origin of electrical ectopic activity in nonpulmonary vein paroxysmal AF [15] and can cause blockage of the coronary sinus catheterization (Fig 2). This ligament is an embryonic remnant of the left SVC. It runs between the left pulmonary veins (PVs) and the left atrial appendage (LAA) and joins the coronary sinus approximately 3 cm from its ostium [16]. Detection of intra-atrial membranous web is another challenging issue in cardiac CT studies [17]. Although the classic cor triatriatum is rare, incidental finding of a small incomplete membrane is not.