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Mechanisms of Ventricular Arrhythmias and Implications for Catheter Ablation **547**

Daniele Muser, Pasquale Santangeli, and Jackson J. Liang

Ventricular arrhythmias present with a wide spectrum of clinical manifestations, from mildly symptomatic frequent premature ventricular contractions to life-threatening events. Pathophysiologically, idiopathic ventricular arrhythmias occur in the absence of structural heart disease or ion channelopathies. Ventricular arrhythmias in the context of structural heart disease are usually determined by scar-related reentry and are associated with increased mortality. Catheter ablation is safe and highly effective in treating ventricular arrhythmias. The proper characterization of the arrhythmogenic substrate is essential for accurate procedural planning. We provide an overview on the main mechanisms of ventricular arrhythmias and their implications for catheter ablation.

Intracardiac Electrogram Targets for Ventricular Tachycardia Ablation **559**

Sachin Nayyar

The pathogenesis of ventricular tachycardia (VT) in most patients with a prior myocardial scarring is reentry involving compartmentalized muscle fibers protected within the scar. Often the 12-lead ECG morphology of the VT itself is not available when treated with a defibrillator. Consequently, VT ablation takes on an interesting challenge of finding critical targets in sinus rhythm. High-density recordings are essential to evaluate a substrate based on whole electrogram voltage and activation delay, supplemented with substrate perturbation through alternate site pacing or introducing an extra stimulation. In this article, we discuss contemporary intracardiac electrogram targets for VT ablation, with explanation on each of their specific fundamental physiology.

Best Practices for the Catheter Ablation of Ventricular Arrhythmias **571**

Auras R. Atreya, Sachin D. Yalagudri, Muthiah Subramanian, Vickram Vignesh Rangaswamy, Daljeet Kaur Saggu, and Calambur Narasimhan

Techniques for catheter ablation have evolved to effectively treat a range of ventricular arrhythmias. Pre-operative electrocardiographic and cardiac imaging data are very useful in understanding the arrhythmogenic substrate and can guide mapping and ablation. In this review, we focus on best practices for catheter ablation, with emphasis on tailoring ablation strategies, based on the presence or absence of structural heart disease, underlying clinical status, and hemodynamic stability of the ventricular arrhythmia. We discuss steps to make ablation safe and prevent complications, and techniques to improve the efficacy of ablation, including optimal use of electroanatomical mapping algorithms, energy delivery, intracardiac echocardiography, and selective use of mechanical circulatory support.

Improving Outcomes in Ventricular Tachycardia Ablation Using Imaging to Identify Arrhythmic Substrates 609

Michael Ghannam and Frank Bogun

Ventricular tachycardia (VT) ablation is limited by modest acute and long-term success rates, in part due to the challenges in accurately identifying the arrhythmogenic substrate. The combination of multimodality imaging along with information from electroanatomic mapping allows for a more comprehensive assessment of the arrhythmogenic substrate which facilitates VT ablation, and the use of preprocedural imaging has been shown to improve long-term ablation outcomes. Beyond regional recognition of the arrhythmogenic substrate, advanced imaging techniques can be used to create tailored ablation strategies preprocedurally. This review will focus on how imaging can be used to guide ablation planning and execution with a focus on clinical applications aimed at improving the outcome of VT ablation procedures.

Techniques for Catheter Ablation of Idiopathic Ventricular Arrhythmias Originating from the Outflow Tract and Left Ventricular Summit 621

Takumi Yamada

Idiopathic ventricular arrhythmias (VAs) most commonly originate from the ventricular outflow tracts. Because the anatomy of this region is complex and some of those VA origins are intramural and epicardial, it may sometimes be difficult to locate the site of the VA origin. Meticulous mapping in multiple different locations such as the right and left ventricular outflow tracts, endocardial and epicardial sites, and above and below the aortic and pulmonic valves may be required to achieve successful catheter ablation of those VAs. Special ablation techniques may be considered to improve the outcome of catheter ablation of intramural and epicardial VAs.

Catheter Ablation for Ventricular Tachycardia Involving the His-Purkinje System: Fascicular and Bundle Branch Reentrant Ventricular Tachycardia 633

Akihiko Nogami, Wipat Phanthawimol, and Tetsuya Haruna

Video content accompanies this article at http://www.cardiacep.theclinics.com

The Purkinje system has been found to mediate several monomorphic ventricular tachycardias (VTs). These include fascicular VTs and bundle branch reentrant (BBR) VTs. Previous studies have revealed that VTs involving the His-Purkinje system are composed of multiple discrete subtypes that are best differentiated by their mechanism, drug effect, VT morphology, and successful ablation site. Recognition of the heterogeneity of these VTs and their unique characteristics should facilitate the appropriate diagnosis and therapy and help guide catheter ablation therapy. In this article, we focus on the latest updates of the mechanisms underlying left ventricle fascicular VTs and BBR-VTs as well as the latest catheter ablation techniques.

Patient Selection, Techniques, and Complication Mitigation for Epicardial Ventricular Tachycardia Ablation 657

Timothy Maher, John-Ross Clarke, Zain Virk, and Andre d'Avila

Percutaneous epicardial ventricular tachycardia ablation can decrease implanted cardioverter defibrillator shocks and hospitalizations; proper patient selection and procedural technique are imperative to maximize the benefit–risk ratio. The best candidates for epicardial ventricular tachycardia will depend on history of prior

ablation, type of cardiomyopathy, and specific electrocardiogram and cardiac imaging findings. Complications include hemopericardium, hemoperitoneum, coronary vessel injury, and phrenic nerve injury. Modern epicardial mapping techniques provide new understandings of the 3-dimensional nature of reentrant ventricular tachycardia circuits across cardiomyopathy etiologies. Where epicardial access is not feasible, alternative techniques to reach epicardial ventricular tachycardia sources may be necessary.

Catheter Ablation of Ventricular Tachycardia in Arrhythmogenic Right Ventricular Cardiomyopathy **679**

Alessio Gasperetti and Harikrishna Tandri

Arrhythmogenic right ventricular cardiomyopathy is an inherited desmosomal myopathy characterized by progressive fibrofatty replacement of the myocardium, right ventricular enlargement, and malignant ventricular arrhythmias. Ventricular tachycardias is one of the most common initial presentation of ARVC. This manuscript addresses invasive VT ablation options for the managmenet of VT in patients with ARVC.

Advances in Ventricular Arrhythmia Ablation for Brugada Syndrome **685**

Ronpichai Chokesuwattanaskul and Koonlawee Nademanee

Video content accompanies this article at http://www.cardiacep.theclinics.com

Three decades have passed since the Brugada syndrome (BrS) clinical entity was introduced in the early 1990s. During the first 2 decades, treatment of patients with BrS was challenging because there were limited treatment options, and an implantable cardioverter-defibrillator was the only choice for high-risk patients with BrS, that is, those who had aborted sudden cardiac death or had previous ventricular fibrillation episodes. In this article, the authors focus on these advances and how to treat patients with BrS with catheter ablation.

Catheter Ablation for Ventricular Arrhythmias in Hypertrophic Cardiomyopathy **693**

Muthiah Subramanian, Auras R. Atreya, Sachin D. Yalagudri, P. Vijay Shekar, Daljeet Kaur Saggu, and Calambur Narasimhan

Implantable cardioverter-defibrillators are the mainstay of therapy for prevention of sudden cardiac death in high-risk patients with hypertrophic cardiomyopathy (HCM). Catheter ablation is a useful option for patients with recurrent, drug refractory monomorphic ventricular tachycardia (VT), and device therapy. Compared with other nonischemic substrates, there are limited data on the role and outcomes of catheter ablation in HCM. The challenges of VT ablation in HCM patients include deep intramural and epicardial substrates, suboptimal power delivery, and higher recurrence due to progression of disease. Patient selection, using cardiac MRI scar localization, and optimizing ablation techniques can improve outcomes in these patients.

Ventricular Tachycardia in Granulomatous Myocarditis: Role of Catheter Ablation **701**

Daljeet Kaur Saggu, Sachin D. Yalagudri, Muthiah Subramanian, Auras R. Atreya, and Calambur Narasimhan

Granulomatous myocarditis is an inflammatory disease of the myocardium, characterized by lymphocytic infiltration with characteristic granuloma formation. Although a host of disease processes can elicit myocardial granulomas, two common entities are cardiac sarcoidosis and cardiac tuberculosis. Cardiac arrhythmias in this

condition are frequent and management of ventricular arrhythmias can be challenging, especially in those with drug-refractory ventricular tachycardia and electrical storm. In this review, we highlight the role of catheter ablation for ventricular tachycardia and optimal patient selection for catheter ablation, based on cardiac imaging.

Ventricular Tachycardia Ablation in Adult Congenital Heart Disease **709**

Justin Wallet, Yoshitaka Kimura, and Katja Zeppenfeld

Patients with congenital heart disease (CHD) are at risk for late ventricular tachycardia (VT) and sudden cardiac death. Slow conducting anatomical isthmuses, bordered by unexcitable tissue created by valve annuli, ventricular incisions, and prosthetic material are the dominant substrate for macroreentrant monomorphic VTs in repaired CHD. These well-defined substrates allow for catheter or surgical transection with clear endpoints. This review elaborates on VT substrates in various CHD, and evolving mapping and ablation approaches. Because most research is conducted in patients with repaired tetralogy of Fallot, this malformation will serve as a paradigm.

Catheter Ablation of Ventricular Fibrillation **729**

Fatima M. Ezzeddine, Ashley M. Darlington, Christopher V. DeSimone, and Samuel J. Asirvatham

Ventricular fibrillation (VF) is a common cause of sudden cardiac death (SCD) and is unfortunately without a cure. Current therapies focus on prevention of SCD, such as implantable cardioverter-defibrillator (ICD) implantation and anti-arrhythmic agents. Significant progress has been made in improving our understanding and ability to target the triggers of VF, via advanced mapping and ablation techniques, as well as with autonomic modulation. However, the critical substrate for VF maintenance remains incompletely defined. In this review, we discuss the evidence behind the basic mechanisms of VF and review the current role of catheter ablation in patients with VF.

Chemical Ablation of Ventricular Tachycardia Using Coronary Arterial and Venous Systems **743**

Thomas Flautt and Miguel Valderrábano

Radiofrequency catheter ablation (RFCA) is the first-line therapy for treatment of drug refractory ventricular arrhythmias (VAs), however, creating a safe, transmural lesion can be difficult. Ethanol in the arterial system has been used as an adjunctive therapy to RFCA since 1986, but with limited use due to technical and efficacy limitations. Venous ethanol is emerging as powerful alternative.

Improvement in Lesion Formation with Radiofrequency Energy and Utilization of Alternate Energy Sources (Cryoablation and Pulsed Field Ablation) for Ventricular Arrhythmia Ablation **757**

Hiroshi Nakagawa, Atsushi Ikeda, Katsuaki Yokoyama, Yoshimori An, Ayman A. Hussein, Walid I. Saliba, Oussama M. Wazni, and Quim Castellvi

Current ablation systems rely on thermal energy to produce ablation lesions (heating: RF, laser and ultrasound, and cooling: cryo-thermia). While thermal ablation has been proven to be effective, there are several limitations: 1) relatively long procedural times; 2) high recurrence rate of ventricular arrhythmias; and 3) excessive heating potentially leading to serious complications, including steam pop (perforation), coronary arterial injury and thrombo-embolism. Pulsed field ablation (PFA)/irreversible electroporation (IRE) offers a unique non-thermal ablation strategy which

has the potential to overcome these limitations. Recent pre-clinical studies suggest that PFA/IRE might be effective and safe for the treatment of cardiac arrhythmias.

Adjunctive Therapies for Ventricular Arrhythmia Management: Autonomic Neuromodulation—Established and Emerging Therapies **769**

Justin Hayase and Jason S. Bradfield

The autonomic nervous system plays an integral role in the pathophysiology of ventricular arrhythmias. In the modern era, several therapeutic interventions are available to the clinician for bedside and procedural/surgical management, and there are many ways in which modulation of the autonomic nervous system can provide life-saving benefit. This review discusses some of the current treatment options, the supporting evidence, and also introduce some of the emerging therapies in this expanding field of electrophysiology.

Stereotactic Radiotherapy in the Management of Ventricular Tachycardias: More Questions than Answers? **779**

Jana Haskova, Marek Sramko, Jakub Cvek, and Josef Kautzner

Stereotactic body radiotherapy is a recent promising therapeutic alternative in cases of failed catheter ablation for recurrent ventricular tachycardias (VTs) in patients with structural heart disease. Initial clinical experience with a single radiation dose of 25 Gy shows reasonable efficacy in the reduction of VT recurrences with acceptable acute toxicity. Many unanswered questions remain, including unknown mechanism of action, variable time to effect, optimal method of substrate targeting, long-term safety, and definition of an optimal candidate for this treatment.

Surgical Ablation of Ventricular Tachycardia **793**

Takashi Nitta

Surgery for ventricular tachycardia (VT) is indicated in patients in whom pharmacotherapy or catheter ablation is ineffective or frequent VT attacks are not suppressed or with frequent activation of implantable cardioverter defibrillator. In ischemic VT, resection of fibrous endocardium combined with encircling cryothermia at the border between the infarcted and normal myocardium is performed. In surgery for VT associated with cardiomyopathy, close collaboration between the physician and surgeon is important and intraoperative mapping using electro-anatomic mapping system is helpful. In VT associated with cardiac tumors, cryothermia of the thinned subepicardial myocardium at the edge of the tumor is recommended in addition to resection of tumors.