CLINICAL REVIEW

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Ventricular Tachycardia in the Era of Ventricular Assist Devices

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Ventricular Tachycardia in the Era of Ventricular Assist Devices. Sustained ventricular tachycardia (VT) in patients with advanced cardiomyopathy is a potentially life-threatening arrhythmia. Newer treatment strategies have evolved that combine the use of catheter ablation to target the substrate for VT and ventricular assist devices (VADs) to hemodynamically support the failing ventricle. This editorial is targeted to the practicing clinician caring for these difficult patients. The current article reviews the use of percutaneous VADs to support catheter ablation of VT, the use of durable VADs to support the failing heart in patients with recurrent VT, ventricular arrhythmias in patients with durable VADs, and the use of catheter ablation to treat VT in patients with durable VADs. *(J Cardiovasc Electrophysiol, Vol. 22, pp. 359-363, March 2011)*

catheter ablation, congestive heart failure, left ventricular assist device, implantable cardioverter defibrillator, ventricular tachycardia

Sustained ventricular tachycardia (VT) in patients with cardiomyopathy and advanced symptom class heart failure is a potentially life-threatening arrhythmia, especially when it is associated with hemodynamic compromise. In this setting, VT is typically managed with antiarrhythmic drug therapy and placement of an implantable cardioverter-defibrillator (ICD). However, antiarrhythmic drug therapy fails to prevent VT episodes in more than 40% of patients with prior myocardial infarct scars.[1] In recent years, radiofrequency catheter ablation, targeting endocardial left ventricular scar regions critical to the VT circuit, has emerged as a front-line therapy for the treatment of drug-refractory VT.[2-4] Additionally, durable left ventricular assist devices (LVADs) have also been used successfully to support ventricular function in patients with advanced heart failure and hemodynamically unstable VT.[5] These 2 therapeutic options, 1 targeting the VT substrate for elimination of VT and the other supporting the failing ventricle, have expanded the treatment strategies for these patients and each require careful consideration and have distinct advantages and disadvantages associated with their use.

Both durable and percutaneous ventricular assist devices (VADs) have been used to provide hemodynamic support for intractable VT as stand-alone management and to provide hemodynamic support to allow electrophysiologists to safely perform VT catheter ablations. However, the devices themselves can give rise to episodes of VT. Emerging data suggest that new ventricular arrhythmias can arise in VAD recipients as a result of their underlying cardiac pathology and may involve reentry due to the VAD incision or result from a mechanical trigger or "suck down" effect from the VAD flow. It is important that the practicing electrophysiologist employ a multidisciplinary approach in determining when to use a VAD in patients with advanced heart failure and recurrent VT, so as to optimally utilize these devices and appreciate the downstream issues that can arise with their use.

Percutaneous LVADs as Support for VT Ablation

Catheter ablation is being performed with increasing frequency for the treatment of VT, particularly in patients receiving multiple ICD shocks.[2,3] Percutaneous catheter ablation of VT procedures can be challenging in patients with advanced structural heart disease and heart failure. In this setting, ventricular arrhythmias can result in hemodynamic instability that limits detailed mapping and entrainment in VT or when substrate mapping targeting scar areas fails or is not tolerated due to long procedure times. Percutaneous circulatory assist devices have been successfully implanted to provide hemodynamic support during induced VT episodes and have been successfully removed after the procedures.[6-8]

There are presently 2 percutaneous VADs available for clinical use in the United States that can be routinely placed in the cardiac catheterization laboratory without a

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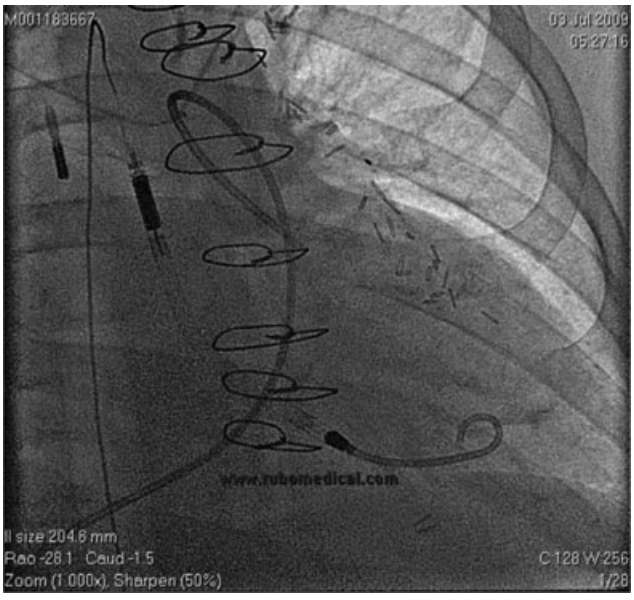

Figure 1. *A fluoroscopic image of an Impella Percutaneous VAD positioned across the aortic valve with the tip in the left ventricular apex.*

cutdown: the TandemHeart (CardiacAssist, Inc., Pittsburgh, PA, USA) and the Impella (Abiomed, Danvers, MA, USA). The TandemHeart provides circulatory support via a left atrial-to-femoral artery bypass system. This system consists of a left atrial inflow cannula, an extracorporeal centrifugal pump, a femoral outflow cannula that extends into the iliac artery, and a microprocessor-based pump controller, and can provide blood flow at rates up to 4 L/min.[9] The Impella device is a catheter-mounted microaxial rotary pump that is retrogradely placed across the aortic valve into the left ventricle (LV) with the pump outlet and motor positioned in the aorta. The Impella system uses a motor-driven microaxial pump placed on the distal end of a flexible catheter to take oxygenated blood from the LV and places it into the ascending aorta. The Impella 2.5 system can provide up to 2.5 L/min forward flow from the LV into the systemic circulation (Fig. 1).[9]

Both the Impella and the TandemHeart percutaneous VADs have advantages and disadvantages. The TandemHeart device offers a higher cardiac output (4 L/min) but requires a transseptal catheterization with placement of a large 14 Fr cannula into the left atrium, thus potentially limiting transseptal access for catheter ablation. The Impella device offers a lower cardiac output (2.5 L) but is placed retrograde across the aortic valve, therefore not limiting transseptal access for the ablation catheter; however, one must be careful to avoid bumping the pump in the LV, which may limit catheter movement within the LV. Both devices can limit catheter mobility within the heart and can limit groin access.

The Impella percutaneous VAD was used for hemodynamic support in 3 patients with unstable VT and allowed successful VT mapping using a combined substrate map, activation map and entrainment, which ultimately led to successful ablation of multiple VTs in these patients.[6] Additionally, the TandemHeart percutaneous VAD was used to support a hypotensive patient allowing endocardial and epicardial mapping of a previously poorly tolerated VT.[7] Although the initial patient experience is small, this series of case reports suggests a promising future for the use of percutaneous VADs in the support of cardiomyopathic patients with hemodynamically unstable ventricular arrhythmias to allow the cardiac electrophysiologists to perform detailed activation and entrainment maps of multiple hemodynamically unstable VTs in these patients.

It is important to recognize that all patients undergoing percutaneous VAD placement may not be able to hemodynamically tolerate removal of the device. On occasion, percutaneous VADs may eventually need to be converted to durable VADs or these patients may need to be evaluated for orthotopic heart transplantation. It is important that the electrophysiologist be aware of this potential issue and involves a heart failure specialist and cardiothoracic surgeon early in these cases, as they should be included in preprocedural discussions with the patient and his or her family.

Durable LVADs to Support the Failing Heart with Recurrent VT

Permanent cure of sustained, recurrent ventricular arrhythmias with catheter ablation in the setting of scar related VTs is difficult to achieve even in the most experienced centers.[10] Recurrent and even intractable ventricular arrhythmias can recur in these patients and are associated with a very poor prognosis. Multiple ICD shocks themselves may further worsen ventricular function and cause psychological distress.[11,12] Durable VADs can provide circulatory support to the failing ventricle in these subjects even if they spend a considerable amount of time in VT. Additionally, surgical implantation of a LVAD has been used to hemodynamically stabilize and potentially prevent recurrent episodes of VT in patients with VT storm and either ischemic or nonischemic cardiomyopathy.[13,14] In these patients, left ventricular assistance by surgically implanted devices prevented further VT episodes and provided a successful bridge to cardiac transplantation. A study by Oz and colleagues demonstrated successful hemodynamic support of 9 patients who underwent LVAD support but continued to have ventricular arrhythmias after LVAD implantation.[15] Furthermore, we have successfully used the axial flow device, the HeartMate II (Thoratec Laboratories Corp., Pleasanton, CA, USA), as a destination device at our center in patients with end-stage ischemic cardiomyopathy and recurrent ventricular arrhythmias not amenable to or failing catheter ablations. In 1 patient with several recurrent reentrant tachycardias around large areas of infarction, both endo- and epicardial cryoablation lesion sets were placed by the cardiothoracic surgeon at the time of LVAD placement (Fig. 2). This strategy resulted in a significant improvement in patient symptoms and has prevented the recurrence of any sustained ventricular arrhythmias to date. Unlike catheter ablation alone, LVAD placement has been shown to result in improved quality of life.[16] Should VT recur after VAD implant, the presence of the VAD will support the ventricle during mapping and catheter ablation. Successful ablation has been reported with durable VAD implanted patients.[17,18]

A subgroup of patients that do not have adequate hemodynamics and flow with univentricular support may require biventricular support when right heart forward flow is significantly reduced secondary to prolonged rapid ventricular arrhythmias (>150 bpm). Farrar and colleagues have successfully demonstrated biventricular support as a bridge to

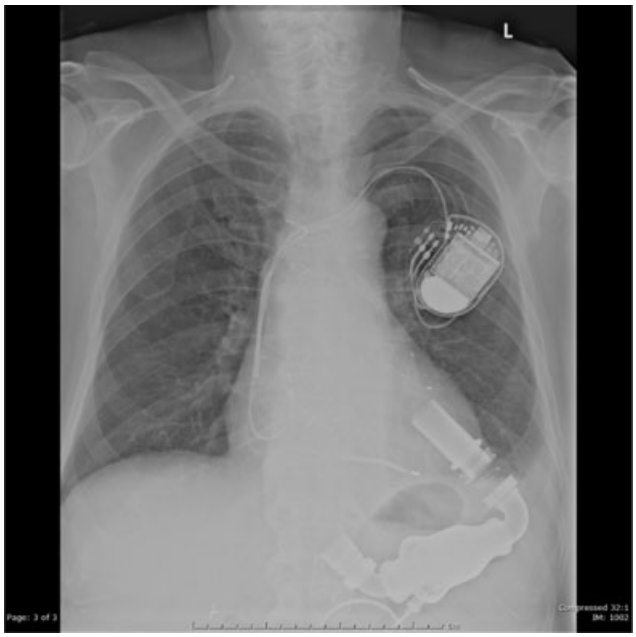

Figure 2. *HeartMateII chest radiograph of a durable VAD in a patient from our center with intractable ventricular tachycardia. The inflow cannula is visible in the left ventricular apex and the outflow cannula in the aorta. A cardiac resynchronization device is also in place. VAD = ventricular assist device.*

cardiac transplantation in a patient with prolonged ventricular fibrillation (VF) and asystole.[19]

Ventricular Arrhythmias in Patients with Ventricular Assist Devices

Durable LVADs have been used as a bridge to cardiac transplantation and, more recently, were approved as destination therapy in patients with severe cardiomyopathy and advanced heart failure.[20] Despite the left ventricular unloading provided by LVADs, a subset of patients implanted with these devices develops significant ventricular arrhythmias that can be associated with worsened outcome.[21] In a large retrospective study, Ziv and colleagues analyzed the pre- and post-LVAD course of 100 consecutive adult patients receiving a HeartMate I LVAD. These investigators noted a significant increase in the episodes of monomorphic VT and a slight reduction in the prevalence of polymorphic VT and VF after LVAD placement compared to pre-VAD placement.[22]

It has been hypothesized that ventricular arrhythmias, which occur in the early postoperative period after LVAD implantation, may result in part from changes in repolarization due to ventricular unloading and remodeling.[23–25] More specifically, it has been shown that early postoperative increases in the QTc interval can occur after ventricular unloading with LVAD placement and may predispose patients to ventricular arrhythmias. Others have theorized that ventricular arrhythmias in patients with LVADs arise related to the presence of an arrhythmogenic substrate associated with the underlying cardiomyopathy as well as conduction block or slowing associated with ventricular resection and incisions related to placement of the left ventricular outflow cannula.[23] Electrolyte abnormalities are also an independent predictor of post-LVAD ventricular arrhythmias in one but not other series.[22] Furthermore, the continuous flow or auxiliary blood pumps used in some current VADs offer only limited load-responsive mechanisms for adjusting pumping performance to venous return and changes in the physiologic requirement for the patient. As a result, excessive ventricular unloading can be observed in situations where venous return is temporarily reduced. These suction events can lead to reduced cardiac output, increased myocardial work and ventricular arrhythmias.[26] An additional issue that should be considered in patients with a history of ventricular arrhythmias undergoing LVAD implantation is the possible interaction between ICDs and the LVAD. One such case has been described, in which LVAD-ICD interactions prevented telemetry communication between the device programmer and the ICD.[27]

Several series analyzing the incidence of ventricular arrhythmias in patients with LVADs have been published to date. These studies have reported that ventricular arrhythmias occur in 22–36% of patients during LVAD support.[21,22,28] Anderson and colleagues' study, which evaluated the incidence of VT and VF in patients on long-term support with a continuous-flow VAD (specifically HeartMate II), demonstrated a 52% incidence of sustained ventricular arrhythmias in this patient population.[29] Of the patients who experienced ventricular arrhythmias, 75% did so within the first 4 weeks after LVAD implantation. None of the patients with arrhythmias in the first 4 weeks postoperatively died of arrhythmia or had worsening of symptoms related to the event; however, early VT/VF was a predictor of recurrent ventricular arrhythmias. In a study by Bedi and colleagues, ventricular arrhythmias, occurring within a week of VAD placement, were associated with worsened outcome and mortality rates as high as 54%.[21]

At least 1 study has suggested that a significant risk factor for ventricular arrhythmias after LVAD implantation has been the non-usage of beta receptor blockers postoperatively.[28] These results suggest that beta receptor blockers should be initiated after VAD placement once patients are off inotropes in an attempt to prevent ventricular arrhythmias. However, in another study evaluating the incidence of ventricular arrhythmias in patients implanted with a continuous flow LVAD (HeartMate II), treatment with beta receptor blockers or amiodarone did not appear to lower the incidence of ventricular arrhythmias.[29]

Catheter Ablation of VT in Patients with Surgically Implanted VADs

In general, most patients with durable VADs tolerate episodes of VT fairly well, and ICD programming can be altered to shock only when episodes are sustained. However, in some cases with malignant recurrent ventricular arrhythmias, hemodynamic stability is not provided with VAD support, threatening RV function. In such patients, catheter ablation therapy may be considered as a treatment option, especially if the only other option is initiating biventricular support. Successful catheter ablation of hemodynamically significant recurrent VT has been described in several patients after VAD implantation.[17,18] In fact, the hemodynamic stability afforded by the VAD may allow for more detailed activation and entrainment mapping of ventricular arrhythmias and lead to increased procedural efficacy. Catheter ablation of VT in patients with VADs, however, can be made more technically difficult by several issues. First, due to ventricular unloading,

left ventricular volumes can be significantly reduced, potentially limiting catheter mobility within the LV. Additionally, one must avoid the ablation catheter becoming entrapped in or damaging the ventricular inflow cannula. Finally, despite the hemodynamic support provided by LVADs, patients with right ventricular (RV) failure may still not tolerate prolonged periods of time in VT, and care must be taken to limit the duration of time in VT in these patients to avoid RV decompensation.[18] Despite these technical difficulties, catheter ablation of VT can be safely and effectively performed in patients with LVADs providing it is done at centers with the requisite equipment and expertise to perform such complex procedures.[18]

Conclusions

Ventricular arrhythmias continue to be a major problem in patients with significant cardiomyopathy and advanced heart failure. Catheter ablation and VADs provide exciting new technologies that can be applied to the treatment of this difficult condition. Percutaneous and surgically implanted durable VADs can provide hemodynamic support to allow for more detailed activation and entrainment mapping of malignant ventricular arrhythmias. Additionally, VADs can be used to provide hemodynamic support and ventricular unloading in patients with recurrent or intractable ventricular arrhythmias. However, VADs have been associated with an increased incidence of monomorphic VT and, at times, these arrhythmias require treatment with catheter ablation. VADs provide mechanical benefits and quality of life improvements that make them an exciting new treatment option for patients with advanced heart failure and arrhythmias.[16] A mulitdisplinary approach to these patients is required with input from the implanting surgeon and heart failure physicians, in addition to the electrophysiologist, to facilitate optimal patient outcomes and understand the implications of each of the therapeutic options.

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