Is programmed electrical stimulation mandatory for recognition of ventricular arrhythmogenicity in heart failure?

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Abstract

Ischemic cardiomyopathy often presents with advanced heart failure necessitating an intensive multidisciplinary approach to management. These patients constitute a very difficult population presenting with angina and ventricular tachyarrhythmias sometimes presenting as sudden cardiac death. In those patients presenting with spontaneous ventricular tachyarrhythmias, treatment with automated intracardiac defibrillator implantation has a significant mortality benefit. In patients with significant left ventricular (LV) dilatation and a left ventricular ejection fraction $\leq 30\%$, guidelines state that device implantation should be preceded by programmed electrical stimulation, which demonstrates inducible ventricular tachyarrhythmia. The treatment options for patients with moderate LV dilatation and ejection fraction $\geq 30\%$ is individualized. Devices have their associated problems. Radiofrequency ablation has mixed results. Surgical cryoablation when performed concomitantly with surgical ventricular restoration has shown promising results. But, this option remains isolated to patients eligible for surgical ventricular restoration. Programmed electrical stimulation for inducibility of ventricular tachyarrhythmias in these patients also has a questionable role. The need for programmed electrical stimulation prior to cryoablation also seems highly individualized. In this review, we discuss the mechanisms of ischemic ventricular tachyarrhythmias and treatment options in heart failure. The mechanisms of ventricular arrhythmogenesis in ischemic cardiomyopathy help in formulating novel technical modifications for cryoablation when performed concomitantly with surgical ventricular restoration.

Keywords Ventricular tachyarrhythmias · Cryoablation · Surgical ventricular restoration

Introduction

Ischemic cardiomyopathy requires a careful and multidisciplinary approach due to the conundrum of complex clinical issues. These patients with advanced heart failure also have angina and malignant ventricular tachyarrhythmias, with some patients presenting with syncope and even aborted sudden cardiac death. These arrhythmias often constitute ventricular tachyarrhythmias which can be very difficult to control despite implantation of an automated implantable cardioverter defibrillator (AICD). It has been well documented in the STICH trial that the addition of coronary artery bypass graft (CABG) to medical therapy reduced

the most common modes of death in ischemic cardiomyopathy, namely sudden death and fatal pump failure events. These beneficial effects were seen only after 2 years. Although the post-procedure deaths were increased in patients randomized to CABG, myocardial infarction deaths decreased, demonstrating the benefits of revascularization in these patients [1]. In some patients, the problem of ventricular tachyarrhythmias persisted even after CABG which increased mortality and impacted quality of life significantly.

AICD for treatment of ventricular tachyarrhythmias in heart failure

The MADIT I and MADIT II trials have shown promise in defining criteria for eligibility for AICD and treatment guidelines for eligible patients. In the MADIT I and MADIT II trials [2], patients underwent device implantation without prior programmed electrical stimulation. The results of these landmark trials were encouraging with a 45% reduction in post-trial

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mortality. However, the benefit of the ICD is attenuated among patients who develop symptomatic heart failure after device implantation. The 45% mortality benefit was seen in only those patients who did not develop symptomatic heart failure. In the MUSTT study, all patients underwent programmed electrical stimulation (PES) and were randomized to either AICD or no arrhythmia treatment [3]. Electrophysiologically guided antiarrhythmic therapy with implantable defibrillators, but not with antiarrhythmic drugs, reduced the risk of sudden death. The role of AICD in preventing sudden cardiac death in heart failure has been established by these studies, but they did not elaborate on the requirement of PES in patients with heart failure receiving AICD. The 2017 AHA/ACC/HRS guideline for management of patients with ventricular arrhythmias and prevention of sudden cardiac death clearly states that PES is recommended only for patients with heart failure who do not satisfy the criteria for AICD implantation [4].

All AICDs have their inherent challenges of inappropriate discharges and need for frequent pulse generator replacements. These undesirable effects of AICD are often called device-associated syndrome which not only impact quality of life but also constitute a disease entity in itself.

Radiofrequency ablation has been tried for ischemic ventricular tachyarrhythmias, but has variable results with a high rate of recurrence due to the presence of multiple reentry circuits. These circuits are often present at the border zone between scar tissue and contractile myocardium. In patients with large scar burden, these reentry circuits are often multiple and are responsible for recurrence of ventricular tachyarrhythmias.

Surgical cryoablation

While surgical cryoablation for ventricular tachyarrhythmias has shown better results, the requirement of ventriculotomy precludes its routine use. Cryoablation has been successfully performed concomitantly with surgical ventricular restoration (SVR). These patients underwent unguided subtotal endocardectomy in the septum and anterior wall of the left ventricle. Cryoablation was performed linearly at the edge of endocardial resection. Freedom from post-operative spontaneous ventricular arrhythmias (VT) was 90%. The success rate in patients with pre-operative inducible VT on PES was 89% [5]. Patients with post-operative spontaneous VT and inducible VT (35.8%) required ICD. There are many lessons to be learned from this surgical procedure with reference to its experience concomitant with SVR.

SVR has been successful in post-myocardial LV aneurysms with an end-systolic volume (ESVI) of 60 ml. It has not been successful in patients with advanced ventricular remodeling (LVESVI > 70 ml) and in those with right heart failure and pulmonary hypertension [6]. Therefore, SVR, even when performed alone, qualifies for stringent eligibility criteria.

Role of PES while performing concomitant cryoablation with SVR

With overt baseline tachyarrhythmias, there is no doubt of adding cryoablation during SVR, but in its absence, the indications for electrophysiological testing (EP) presently are solely based on clinical judgment [6].

It has been seen that in some patients with pre-operative non-inducibility, there was occurrence of new post-operative inducible ventricular tachycardia [7]. Sudden death was seen more commonly as a cause of mortality (16%) in patients with baseline non-inducible arrhythmias than in patients with inducible VT and subsequent concomitant arrhythmic surgery (8%). This finding led to many surgeons questioning the role of routine pre-operative PES before SVR. The occurrence of post-operative VT in these patients throws light on yet another mechanism of ventricular tachyarrhythmia, other than reentry. SVR excludes scar with an endoventricular Dacron patch sutured at the border zone. Some SVR techniques also plicate the border zone with a Fontan suture prior to suturing the patch. The exclusion of scar should ideally abolish reentry at the border zone. The occurrence of post-operative ventricular arrhythmias theoretically negates the reentry mechanism as its etiology. The second theory for VT in heart failure is the presence of ventricular stretch.

It was noted that spontaneous arrhythmias were greatest in the most dilated hearts (LVESVI > 120 ml/m²), inducible arrhythmias more frequent with lesser dilation (LVESVI between 100 and 120 ml/m²), and absent in smaller (LVESVI < 100 ml/m²) hearts [6].

Following SVR, there is an immediate decrease in ESVI. Most studies have demonstrated a continued decrease in ESVI at mid-term. Some patients demonstrate LV re-dilatation at mid-term which impacts survival due to recurrence of heart failure.

Pocar et al. [8] studied 31 patients with ESVI 96 ± 36 ml, and the LV contours in systole and diastole on the cineangiogram have a smooth flattened border without presence of a true aneurysm. These patients constitute a subgroup for whom the outcomes of SVR are suboptimal with greater mortality. All these patients were followed up until 43.6 ± 25.6 months.

Recurrence of LV re-modeling or re-dilatation was considered with an occurrence of a 25% increase of ESVI or of an ESVI ≥ 50 ml/m² after SVR. Patients with baseline sphericity index (SI) < 0.75 showed a much lower probability of late LV re-modeling and never showed a late ESVI ≥ 50 ml/m². The increased risk of re-dilatation in case of a more spherical LV before SVR is not surprising because a higher SI is per se an expression of a more remodeled LV, particularly in the setting of type III post-infarction remodeling.

There was a need for ICD implantation for spontaneous VT in 12.9% of patients who presented with late re-modeling. This lends credence to the theory of ventricular stretch being responsible for VT; as in all patients, the infarcted area was excluded from contractile muscle by the intra-ventricular patch.

Impact of technique of SVR on outcomes

Although heart failure is reversed by the Dor procedure, it produces a less elliptical neo-LV compared with its modified approaches aimed at the creation of a longer and more conical LV cavity, with or without implantation of a patch [8]. The benefits of surgical techniques aimed at rebuilding a more conical LV cavity may be more evident in the setting of advanced LV remodeling. Patients ($n=102$) with an ESVI of 95.1 ± 26.1 ml were subjected to SVR with an emphasis on restoration of LV shape by eliminating the Fontan suture at the border zone and excluding the infarct with a rectangular patch. The ESVI decreased to 66 ± 21.7 ml immediately and to 54.2 ± 16.4 ml after 2 years [9]. The sphericity index also improved from pre-operative values immediately post-surgery and further improved at 2 years (0.9 ± 0.02 , 0.79 ± 0.04 , 0.62 ± 0.09 at three respective time points ($p < 0.001$). None of these patients were subjected to pre-operative PES, 6 patients who had spontaneous VT were subjected to concomitant cryoablation. None of them developed post-operative VT.

Taxis et al. compared 38 patients who underwent SVR and encircling cryoablation with inducible VT on PES with 39 patients subjected to SVR only who did not have spontaneous VT, or pre-operative PES designated as controls [5]. During follow-up, 28 (36%) patients experienced more than one VT. About 25% of patients from both groups received ICD (implantable cardiac defibrillator) for VT, although there was no difference in the 5-year survival between them. The need for PES before SVR still remains unresolved.

The recurrence of VT following SVR with encircling cryoablation prompts a re-thinking of the cryoablation technique as well, as ventricular stretch cannot be the underlying mechanism here as none of these patients had re-modeling after SVR as defined by Pocar et al. [8].

Adaptation of cryoablation technique concomitant with SVR

Radiofrequency ablation studies have demonstrated that reentry circuits for ischemic VT exist in a narrow isthmus

of viable tissue and slow conduction that forms a critical part of the VT reentrant circuit and is bound by infarcted tissue or anatomic barriers, such as the mitral valve annulus. Radiofrequency ablation is targeted at ablating this isthmus to abolish the reentrant mechanism of ventricular tachyarrhythmia. This procedure is usually performed after mapping the isthmus by three-dimensional cartography. Surgical mapping of the reentrant circuit is cumbersome, and we have modeled the cryoablation technique from available data on the anatomic location of the isthmus [9]. A linear cryoablation starting from the posterior mitral annulus and extending to the inferior aspect of the apical scar has been done concomitantly with SVR using the LV shape restoration technique. These patients underwent PES at 6 weeks to 6 months after SVR, and none demonstrated inducibility of VT. There was freedom from VT at 5 years.

Summary

There are several mechanisms proposed for ischemic VT in heart failure. When there is overt VT, there is no doubt regarding the need for arrhythmia therapy in terms of AICD or cryoablation concomitant with SVR. AICD has its own device-related issues. Radiofrequency ablation has major limitations in establishing VT cessation. Surgical cryoablation concomitant with SVR in patients eligible for SVR has greater success, suggesting that ischemic VT may have other mechanisms in addition to reentry. The need for PES in heart-failure patients without spontaneous VT is still dependent on individual clinical discretion. To establish the necessity of PES in heart failure patients without spontaneous VT, randomized controlled studies may be needed.

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Compliance with ethical standards Ethics clearance, patient consent, and animal studies are not required as this is a review article.

Conflict of interest No

References

1. Velazquez EJ, Lee KL, Deja MA, et al. Coronary-artery bypass surgery in patients with left ventricular dysfunction. *N Engl J Med*. 2011;364:1607–16.
2. Goldenberg I, Gillespie J, Moss AJ, et al. Long-Term benefit of primary prevention with an implantable cardioverter-defibrillator an extended 8-year follow-up study of the multicenter automatic defibrillator implantation trial II. *circulation*. 2010;122:1265–1271.

3. Buxton A E , Lee KL , Fisher JD, Josephson ME , Prystowsky E N, Hafley G. A randomized study of the prevention of sudden death in patients with coronary artery disease. Multicenter unsustained tachycardia trial investigators. *N Engl J Med* 1999;341:1882–90.
4. Al-Khatib S M, Stevenson WG, Ackerman MJ, et al. 2017 AHA/ACC/HRS guideline for management of patients with ventricular arrhythmias and the prevention of sudden cardiac death. *circulation*. 2018;138:e272–e391.
5. van Huls van Taxis CF, Wijnmaalen AP, Klein P, et al. Programmed electrical stimulation-guided encircling cryoablation concomitant to surgical ventricular reconstruction for primary prevention of ventricular arrhythmias. *Eur J Cardiothorac Surg*. 2018; 54: 98–105.
6. Athanasuleas C L, Buckberg G D, Stanley A W, et al. Surgical ventricular restoration in the treatment of congestive heart failure due to post-infarction ventricular dilation. *J Am Coll Cardiol*. 2004;44:1439–45.
7. Di Donato M, Sabatier M, Dor V, Buckberg G, and the RESTORE Group. Ventricular arrhythmias after LV remodelling: surgical ventricular restoration or ICD? *Heart Fail Rev*. 2004;9:299–306.
8. Pocar M, Di Mauro A, Passolunghi D, et al. Predictors of adverse events after surgical ventricular restoration for advanced ischaemic cardiomyopathy. *Eur J Cardiothorac Surg*. 2010;37:1093–100.
9. Parachuri VR, Adhyapak SM. Surgical cryoablation for ventricular tachyarrhythmia in patients undergoing surgical ventricular restoration: lessons learned from radiofrequency ablation. *J Thorac Cardiovasc Surg*. 2012;144:724–6.

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