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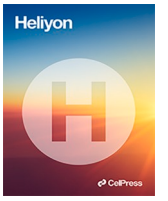

Case report

Stellate ganglion block therapy in management of ventricular electrical storm: A case report

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ABSTRACT

Sympathetic overactivity is a recognized underlying mechanism contributing to the pathogenesis of ventricular electrical storm (VES). The growing body of evidence supports the efficacy of stellate ganglion block (SGB) in attenuating myocardial sympathetic tone, rendering it a valuable adjunctive therapy for managing VES. This case report presents the clinical details of a 60-year-old patient admitted for ventricular tachycardia (VT), necessitating the implantation of an implantable cardioverter defibrillator (ICD) to mitigate the risk of fatal ventricular arrhythmias (VAs). Subsequently, the patient received repeated antitachycardia pacing (ATP) therapy due to persistent symptomatic VT episodes. SGB was contemplated due to the patient's hemodynamic instability during episodes of VT and the ineffectiveness of pharmacotherapy. Initially, complete suppression of VT was achieved for 3 days using local anesthesia, followed by partial suppression via pulsed radiofrequency (PRF), culminating in sustained relief for 3 months following continuous radiofrequency (CRF) therapy. Different methods of SGB elicited varied responses in this patient. CRF appeared to be more effective than PRF and conventional local anesthetics. CRF ablation of the stellate ganglion for refractory VAs offers a potential therapeutic option.

1. Introduction

VES, characterized by repetitive VT or ventricular fibrillation events over a short time interval, is traditionally defined as 3 or more episodes of sustained or treated VAs [1]. Patients with VES are associated with an 8-fold higher risk of mortality [2]. Treatment-refractory VAs are often driven and exacerbated by heightened sympathetic tone. Mounting evidence suggests that SGB can suppress sympathetic overactivity and thus serve as an effective therapy in the management of VES [2–9]. However, local anesthetic agents were utilized in nearly all SGB procedures, resulting in a suppressive effect on VAs lasting for several days. Many patients required repeat SGB until other therapies could be applied [2]. To overcome this limitation, SGB with continuous infusion has been proposed, which has shown to be safe and effective for the acute management of patients with refractory VAs [9,10]. Another potential method is radiofrequency ablation. Although radiofrequency ablation of the stellate ganglion for neuropathic pain has been described [3,11–13], its application for refractory VAs has been scarcely reported. Only two single-case studies [14,15] and a small case series [16] have demonstrated the long-term efficacy of radiofrequency ablation therapy of the stellate ganglion. Herein, we also present a case demonstrating suppression of refractory VAs for 3 months with CRF ablation of the left stellate ganglion. This case is unique as the patient underwent different SGB therapies over a short timeframe, with results indicating that CRF was more effective than PRF and conventional local anesthetics.

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2. Case report

A 60-year-old male patient was admitted to the hospital due to palpitations, accompanied by chest tightness and shortness of breath over the past 10 days. He had experienced intermittent palpitations for six years, during which premature ventricular contractions were detected on electrocardiography; however, these findings were disregarded and not systematically managed. The patient also had a 10-year history of diabetes with well-controlled blood glucose levels maintained on regular metformin therapy, and no other medication history. Upon admission, the patient's physical examination revealed a body temperature of 36.5 °C, a pulse rate of 72 beats per minute, a respiratory rate of 18 beats per minute, and a blood pressure of 104/77 mmHg (1 mmHg = 0.133 kPa). The 24-h Holter monitor revealed frequent ventricular premature contractions, VT, and a complete right bundle branch block (Fig. 1A–C). The VT cycle length was approximately 400 ms, with episodes lasting several hours. Initially, the patient's blood pressure was maintained at 110/80 mmHg, but over time, it gradually decreased to below 90/60 mmHg, accompanied by worsening chest tightness and dyspnea. Synchronized cardioversion was administered to terminate the VT. Echocardiography demonstrated a markedly enlarged left ventricle (68mm) with a significantly reduced left ventricular ejection fraction (38 %), diffuse decreased left ventricular wall motion, and mild regurgitation of the mitral and tricuspid valves. Cardiac magnetic resonance imaging revealed a dilated left ventricle with decreased contractile function, without evident myocardial fibrosis. Coronary angiography showed no significant abnormalities. Serological examinations revealed no obvious abnormalities. The patient was diagnosed with VT, dilated cardiomyopathy, and heart failure with a reduced ejection fraction. Consequently, Oral therapy for heart failure drugs was initiated, including sacubitril-valsartan at a dose of 50mg twice daily, metoprolol succinate at a dose of 47.5mg once daily, spironolactone at a dose of 20mg once daily, dapagliflozin at a dose of 10mg once daily. Concurrently, the patient received oral amiodarone hydrochloride at a dosage of 200mg three times daily. Following successful control of VT, dual-chamber ICD implantation was performed to prevent sudden death. The patient underwent repeated ATP therapy due to symptomatic sustained VT over the following days. Intravenous administration of amiodarone hydrochloride (1 mg/min) combined with esmolol hydrochloride (50–200 μg/kg/min) for 4 days did not result in a significant decrease in VAs. VT could be effectively controlled with mild sedation using intravenous dexmedetomidine hydrochloride (0.2 μg/kg/h) without requiring mechanical ventilation. However, VAs recurred following the cessation of the drug. Due to the patient's hemodynamic instability during episodes of VT and the ineffectiveness of anti-arrhythmic drug treatment, our team recommended, after thorough discussion, initially performing SGB. Endocardial VT ablation was planned after stabilizing the VES. The specific methods of SGB were outlined in Table 1.

Initially, the left stellate ganglion was blocked with local anesthesia under the guidance of an ultrasound. The technical details of ultrasound-guided SGB have been described in previous studies [2,17]. In brief, the puncture needle was visualized by planar continuous ultrasound so that the tip of the needle was at the level of the 6th or 7th cervical vertebra, between the carotid artery and the longus cervicalis. Once the needle was in its final position, 5 ml of a compound solution (4 ml of 2 % lidocaine mixed with saline to make the total volume 8 ml) was slowly injected after ensuring negative aspiration of blood, cerebrospinal fluid, or paresthesias. A successful block was defined by the presence of Horner syndrome and a change in temperature of the upper limb on the blocked side. Complete suppression of VT persisted for 3 days (Fig. 2), providing short-term efficacy.

Then, we attempted to ablate the left stellate ganglion by PRF under the guidance of an ultrasound. The placement of the needle was the same as above. PRF was then applied after the absence of motor activity involving the vocal cords, diaphragm, or brachial plexus using 2 Hz stimulation and sensory perception within target structures using 50 Hz stimulation. Radiofrequency current was applied at 42 °C, using a 2 Hz frequency and a 20 ms pulse width lasting 300 seconds. However, VT was partially suppressed and gradually increased over the following days (Fig. 2).

Finally, CRF was administered to block the left stellate ganglion under the guidance of an ultrasound. The accurate positioning of

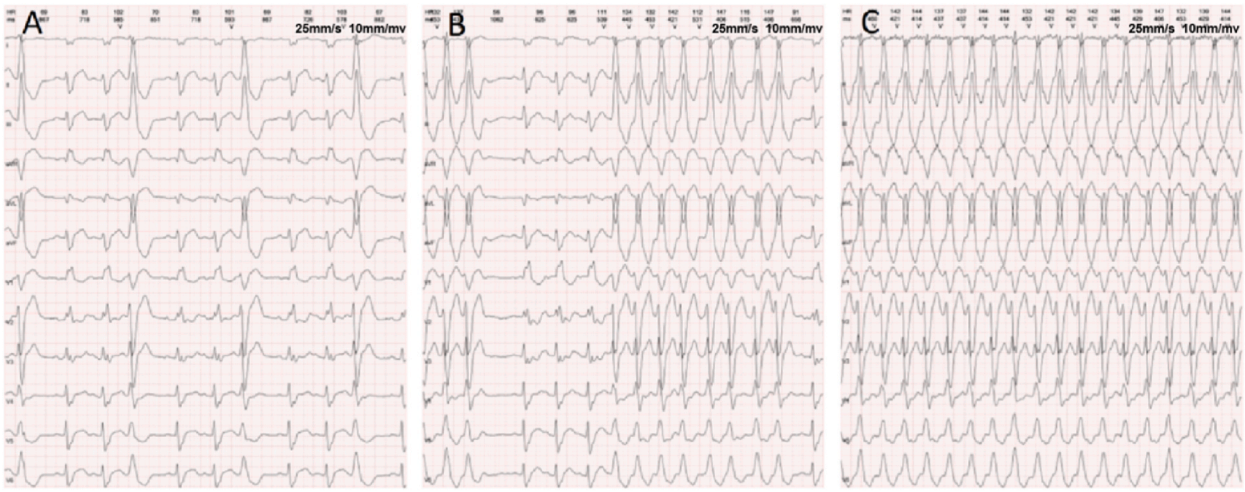

Fig. 1. The 24-h holter showed frequent ventricular premature contractions (A) and ventricular tachycardia (B and C).

Table 1
Detailed methods for SGB.

Time	Therapy	method	Effect	adverse events
Day 0	ICD implantation	–	–	–
Day 5	SGB with local anesthetic	5 ml of a compound solution (4 ml of 2 % lidocaine and saline added to make the total volume 8 ml)	complete suppression VT for 3 days	no
Day 9	SGB with PRF	42 °C, using 2 Hz frequency and 20 ms pulse width and lasting 300 seconds	partial suppression VT	no
Day 15	SGB with CRF	1ml 2 % lidocaine 55 °C and 60 °C for 60 seconds each	complete suppression VT for 3 months	no

CRF, continuous radiofrequency; LA, local anesthetic; PRF, pulsed radiofrequency.

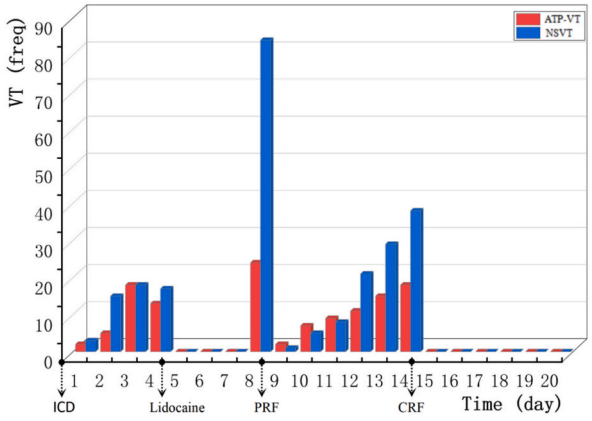

Fig. 2. Interrogation of ICD demonstrated episodes of sustained VT that required ATP therapy, and nonsustained VT during the hospital stay. The X-axis represents time, and the arrows on the coordinates indicate treatments given at different times. The Y-axis represents the frequency of VT episodes. ATP-VT, sustained ventricular tachycardia required antitachycardia pacing; USVT, nonsustained ventricular tachycardia.

the needle tip was the same as PRF. Before starting CRF, we injected 1ml of 2 % lidocaine to prevent irritation and pain that may result from neurolysis at high temperatures. CRF was performed at 55 °C and 60 °C for 60 seconds each, consecutively and without interruption. VT was completely suppressed during the subsequent hospital stay (Fig. 2).

The procedure was well tolerated, with a transient episode of Horner syndrome lasting approximately 1 h, characterized by left-sided partial ptosis, miosis, and conjunctival hyperemia. No other adverse events were noted. After treatment, the patient's condition improved, and he was discharged on the 21st day of admission. The discharge medication regimen included sacubitril-valsartan 50mg twice daily, metoprolol succinate 47.5mg once daily, spironolactone 20mg once daily, dapagliflozin 10mg once daily, and amiodarone hydrochloride 200mg once daily. Throughout the hospital stay, interrogation of ICD demonstrated 124 episodes of sustained VT that required ATP therapy, and 239 episodes of nonsustained VT (Fig. 2). At the three-month follow-up after discharge, the patient had no symptoms of palpitations. And interrogation of the ICD revealed no episodes of VT or device discharges. Echocardiography indicated a LVEF of 40 %, indicating no significant improvement. Given the current effective control of VT, the patient has opted for conservative medical management. Thus, we have advised the patient to maintain the current medication regimen and adhere to regular follow-up appointments. In the event of VT recurrence, consideration will be given to endocardial radiofrequency ablation as a therapeutic option.

3. Discussion

3.1. Mechanisms and treatment of VES

VES is a dire medical emergency linked to adverse prognostic outcomes, including psychological disorders, heart failure exacerbation, and increased mortality [18]. Its clinical spectrum varies, encompassing monomorphic VTs managed with ATP to hemodynamically unstable polymorphic VTs and ventricular fibrillations necessitating ICD shocks. Despite the life-saving potential of ICDs in malignant VAs, both ICD shocks and ATP elevate mortality, with shocks particularly associated with higher mortality [19–21]. VES arises across diverse settings, such as myocardial infarction, ischemic and nonischemic cardiomyopathy, and inherited arrhythmia syndromes [1]. While the precise mechanism remains elusive, it's believed to involve multiple factors. Pathological changes in cardiomyopathy, including fibrosis, fat deposition, and ion channel remodeling, create an electrophysiological substrate for VT [18,22]. Dysregulated calcium handling and protein phosphorylation at the cellular level are also implicated [1,18,23,24]. The autonomic nervous system, especially sympathetic hyperactivity, contributes significantly to VES, making it a crucial therapeutic target. Strategies like thoracic epidural anesthesia [9,25], SGB, and cardiac sympathetic denervation (CSD) [26] are employed to curtail sympathetic tone and mitigate VES. While antiarrhythmic medications form the cornerstone of VES management, their impact on mortality is limited, necessitating alternative approaches like SGB, which can be performed at the bedside using ultrasound guidance. In this context, we delve into SGB.

3.2. Stellate ganglion block

Autonomic neural structures regulate cardiac responses to stimuli, categorized into three main levels: the brainstem and spinal cord, extracardiac-intrathoracic ganglia, and intrinsic cardiac nervous system [27]. Extracardiac-intrathoracic ganglia comprise middle cervical ganglia, stellate ganglia, T2-T4 paravertebral sympathetic chain ganglia, and mediastinal ganglia [27]. The stellate ganglion is located in the lower part of the neck, typically in front of the 7th cervical or 1st thoracic vertebral body [2]. The stellate ganglia are bilateral, with the left contributing more sympathetic tone to the myocardium than the right [28,29]. SGB decreases sympathetically driven cardiac excitability, likely by reducing both efferent sympathetic signals to and afferent signals from the heart

[27,30]. The procedure is typically guided by fluoroscopy or ultrasound [17]. Ultrasound is increasingly used because it allows direct visualization of critical structures near the stellate ganglion, including the carotid and vertebral arteries [2]. Previous studies have demonstrated SGB's efficacy in suppressing EVS [4–6,10,31]. Overall, SGB is safe, convenient, and effective in treating drug-refractory VES; Nevertheless, certain drawbacks arise as many patients necessitate repeated SGB procedures. This problem may be addressed by SGB with continuous infusion, a technique that allows for the continuous infusion of local anesthetics via an epidural catheter. According to findings derived from a case series and systematic review [9], more than half of the cases had a complete VAs suppression and more than 90 % achieved an overall clinical benefit during continuous SGB. Additionally, the authors recommend prioritizing it as the first choice whenever a definitive antiarrhythmic strategy isn't planned within 48 h and/or a clear transient/reversible trigger can't be identified. A study comparing the efficacy and safety of single-injection versus continuous-injection SGB revealed that continuous infusion was correlated with a greater reduction in VAs, while exhibiting similar adverse events [10]. Next, we discuss other promising approaches.

3.3. Promising alternative approaches

SGB is initially an effective means of treating pain, but its effects may be temporary. The same is true for the treatment of VES. Neurolytic procedures may extend these effects in refractory pain phenomena [3]. Despite greater risk, the potential benefits of neurolytic procedures like chemical neurolysis, cryotherapy, and radiofrequency outweigh their risks and are evidenced in pain management [3]. Radiofrequency is increasingly used for sympathetically maintained pains due to its ability to create controlled lesions in discrete anatomic locations [32], with lower complication rates compared to other neurolytic measures [3]. This makes radiofrequency ablation a promising treatment for VES, given its success in pain management. Radiofrequency has two modes: PRF and CRF. PRF delivers short bursts of radiofrequency to a target nerve, maintaining the probe temperature at 42 °C, just below the neurolytic threshold of 45 °C, thus causing reversible damage [3,33]. Studies also demonstrate PRF's reversibility compared to classic CRF [33–36]. The therapeutic effect may arise from electric field generation and modulation of nerve signaling [3]. In contrast to PRF, CRF is a true neurolytic procedure capable of producing destructive thermal leision [11,32,34]. The generated temperature is controlled by adjusting high-frequency current and voltage within the neuro-destructive range of 45–90 °C [3,32]. It produces only very localized effects, and no effect was observed if the distance between the electrode tip and nerve cells was more than 2mm [34].

So far, the application of radiofrequency ablation of the stellate ganglia for the treatment of VES has been documented in two single-case studies [14,15] and one small case series [16]. Hayase et al. [14] presented a case report involving PRF in a patient with refractory VAs. The patient received PRF treatment targeting the left stellate ganglion, with 3 lesions applied for 2 minutes each, at 42 °C, 2-Hz frequency, and 20 ms pulse width, resulting in sustained suppression of arrhythmia for over 12 months without major complications. Rahimzadeh et al. [15] reported a case involving radiofrequency in a patient with VAs sensitive to ICD. The patient underwent high-voltage PRF at 42 °C for 360 seconds, with a 20 ms pulse width and 2-Hz frequency. Then he underwent CRF at 80 °C for 60 s and repeated it four times. Subsequently, there were no ICD activities, shocks, or signs of cardiac tachyarrhythmia recurrence for up to 14 months post-procedure. Rao et al. [16] reported a series of patients with VES who underwent bilateral stellate ganglion ablation by using conventional radiofrequency. Under fluoroscopy guidance, CRF ablation was applied to the left stellate ganglia, targeting three lesions at 50 °C, 55 °C, and 60 °C, respectively, for 90 seconds each. Subsequently, CRF was administered at 70 °C for 60 seconds targeting three lesions. Then, the entire procedure was repeated on the right side. A total of 6 patients underwent the surgical procedure, without any complications. With an average follow-up period of 22 ± 8 months, all were alive free of VES but two patients received appropriate shocks for VT and one patient had VT terminated by ATP.

In our case report, the local anesthetic yielded a short-term effect lasting 3 days, consistent with existing literature. PRF achieved partial suppression, while CRF achieved complete inhibition lasting for 3 months. Despite variations in the choice of unilateral or bilateral ablation and differences in radiofrequency parameters such as temperature, duration, and frequency compared to the above literatures, all demonstrate promising outcomes for the suppression of VAs by radiofrequency ablation and without complications. Notably, in our patient, CRF appeared to be more effective than PRF, suggesting that destructive nerve damage may be more effective, as observed in the studies mentioned above. However, our approach has limitations. Bilateral CSD has been shown to be more beneficial than left CSD alone [16,26], yet we performed only left stellate ganglion ablation. Additionally, the lack of VT recurrences in the weeks after CRF block and discharged could have theoretically also been related to amiodarone's accumulation and increase in plasmatic levels.

4. Conclusions

SGB with CRF presents a promising approach for patients with refractory VAs and might be considered for patients not suitable for CSD. Meanwhile, it's worth noting that it's not an alternative to CSD due to a lesser extent of denervation and the lack of a definitive confirmation of a proper target hitting. The current body of research is limited, highlighting the need for further studies to evaluate its safety, efficacy, durability, radiofrequency modes, and optimal therapeutic parameters for suppressing VAs.

Ethics statement

This study was reviewed and approved by the Review Ethics Committee of the First Bethune Hospital of Jilin University with the approval number: 2024-665, dated March 1, 2024. The patient provided written informed consent to participate in the study and for his data to be published.

Data availability statement

Data sharing was not applicable to this article as all relevant data are included within the manuscript.

CRediT authorship contribution statement

Chaoqun Huang: Writing – original draft. **Shangzhi Shu:** Software, Methodology. **Miaomiao Zhou:** Visualization, Data curation. **Zhenming Sun:** Visualization, Software. **Shuyan Li:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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