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Bipolar, high-voltage, long-duration pulsed radiofrequency ablation of the Gasserian ganglion for the treatment of trigeminal neuralgia in a patient with a cardiac implantable electronic device: illustrative case

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BACKGROUND One of the common methods of treating trigeminal neuralgia (TN) nowadays is radiofrequency therapy. However, it has serious limitations in patients with a cardiac pacemaker because of electromagnetic interference. Therefore, it is crucial to select optimal radiofrequency ablation parameters to make this procedure safe with favorable outcomes for such patients.

OBSERVATIONS In this study, the authors present a case of a 70-year-old man with a history of cardiac pacemaker dependency and previous microvascular decompression with complaints of severe, constant facial pain. After reprogramming the cardiac implantable electronic device (CIED), the authors performed bipolar, high-voltage, long-duration pulsed radiofrequency therapy (PRFT) of the Gasserian ganglion under electrocardiography and pulse rate control in the pre-, intra-, and postoperative periods. There were no cardiovascular or neurological complications after PRFT. The patient reported relief of pain after the procedure, and at the 9-month follow-up, he was pain-free.

LESSONS This clinical case demonstrates that the use of bipolar, high-voltage PRFT for TN treatment in patients with a CIED can be safe and effective, provided that the rules and pacemaker instructions are followed. It is necessary to use ablative treatment with caution and to guide the patient in collaboration with a cardiac surgeon and an anesthesiologist resuscitator.

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KEYWORDS trigeminal neuralgia; high-voltage; long-duration pulsed radiofrequency therapy; Gasserian ganglion

Patients with drug-resistant forms of trigeminal neuralgia (TN) are usually subjected to interventional neurosurgical procedures.[1] Despite the gold-standard treatment of microvascular decompression (MVD), a great deal of attention is given to percutaneous procedures.[2–5] Nowadays, an alternative percutaneous treatment for TN gaining scientific support is high-voltage, long-duration pulsed radiofrequency therapy (PRFT) of the Gasserian ganglion (GG) because of its neuromodulation effect with minimal risk of thermal neuronal damage.[6]

PRFT is a novel and safe technique using electromagnetic energy and attaining satisfactory pain relief. The key is the minimal heat destructive effect in alternating current of 20 ms with 480-ms intervals, where the heat caused by output voltage dissipates during

ABBREVIATIONS 3D = three-dimensional; AV = atrioventricular; BNI = Barrow Neurological Institute; CIED = cardiac implantable electronic device; CT = computed tomography; ECG = electrocardiogram; EMI = electromagnetic interaction; FO = foramen ovale; GG = Gasserian ganglion; MVD = microvascular decompression; PRFT = pulsed radiofrequency therapy; RFT = radiofrequency therapy; RFTC = radiofrequency thermal coagulation therapy; TN = trigeminal neuralgia; VAS = visual analog scale.

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the interval, and the temperature of the electrode tip did not exceed 42°C.[7]

PRFT has not only an analgesic effect but also a neuromodulatory effect caused by the reduction of proinflammatory cytokines and increment of endogenous opioid precursor messenger, enhancement of the noradrenergic and serotonergic descending pain inhibitory pathway, and suppression of the excitation of C-afferent fibers and by the microscopic damage of nociceptive C- and A-delta fibers.[8]

A safe strategy of PRFT with minimal risk of thermal neuronal damage in comparison with that in radiofrequency thermal coagulation therapy (RFTC) has aroused great interest in using this method in comorbid elderly patients in whom conventional treatment has failed. However, at present, the question of performing radiofrequency therapy (RFT) in patients with implanted pacemakers remains open. The concurrent use of traditional monopolar RFT and a cardiac implantable electronic device (CIED) is potentially concerning because of electromagnetic interaction (EMI).[9]

With the potential catastrophic consequence of monopolar RFT, we present a clinical case in which bipolar, high-voltage, long-duration PRFT was used in a patient with a CIED and TN. The use of bipolar PRFT is safe because the movement of current occurs between two needles. The current passes from the active electrode to the dissipative electrode. A regional electromagnetic field of low intensity occurs in the zone of direct intervention in the area of the GG and does not involve the CIED zone.[10] Therefore, the theoretical EMI risk associated with bipolar RFT is significantly less than with monopolar PRFT.

Illustrative Case

The patient had presented with a known history of cardiac ischemia, atherosclerotic cardiosclerosis, atrioventricular (AV) blockade of the third degree, and cardiac pacemaker dependency. He also had a history of MVD 4 years earlier for microvascular conflict; however, he had drug-resistant pain recurrence after 2 years (administration of 1000 mg of carbamazepine did not produce any positive effect). The patient presented with a complaint of severe constant facial pain for more than 2 years. The pain syndrome had spread to the second and third branches of the trigeminal nerve. The severity of the pain syndrome on a visual analog scale (VAS) was 8/10, and the Barrow Neurological Institute (BNI) Pain Intensity Scale score was IV. Facial hypoesthesia according to the BNI facial hypoesthesia scale was II. Computed tomography (CT) cisternography did not reveal data for neurovascular conflict.

Taking into account no obvious neurovascular conflict on imaging, together with the drug-resistant neuropathic pain and comorbidity of the patient, it was decided to use a transcutaneous method of treatment. Given the presence of a pacemaker, PRFT of the GG was performed according to CIED requirements to avoid malfunction or damage to the device. Reprogramming of the CIED Adapta DR (stimulation threshold 0.50/0.75 V at duration 0.40/0.40 ms; Medtronic) was performed to the asynchronous mode DOO with a heart rate of 80 beats/min. The electrocardiogram (ECG) showed a pacemaker rhythm at a rate of 80 beats/min, and the pulse oximeter showed the same rate (Fig. 1A).

During PRFT, the patient was supine with slight cervical extension. Before the puncture, the patient underwent intraoperative CT (Cios C-Arm; Siemens) with further three-dimensional (3D) reconstruction. After clear visualization of the foramen ovale (FO), the operating field was prepared with antiseptic solutions and infiltration anesthesia of the skin.

The first 22-gauge, 10-cm radiofrequency treatment trocar with a 10-mm active tip was inserted into the FO according to the standard Hartel technique under 3D fluoroscopic guidance. Correct positioning of the trocar was monitored using 3D CT in the lateral projection, where the tip should be located in the area of the petroclival joint, about 14.50 mm below the bottom of the sella turcica. The second trocar was placed parallel to the previous needle in the area of the entrance to the FO (Fig. 2). The correct position was confirmed on a 3D CT lateral projection (Fig. 3).

After stylets were removed, the cables were connected to the generator for sensory and motor testing for regulating the depth and direction of the needle to ensure correct positioning according to the patient's feelings. We used the Cosman G4 generator radiofrequency equipment. Sensory electrical stimulation on each needle with a frequency of 50 Hz causes tingling in the area of the passage of the third branch of the trigeminal nerve at a voltage of 0.1–0.3 V. Motor stimulation with a frequency of 2 Hz causes mandibular movement at a voltage of 0.1–0.3 V. Before starting the main stage of the procedure, the intravenous injection of 0.005% (2 ml) fentanyl was administered. When an analgesic effect was achieved, high-voltage, long-duration PRFT (output voltage 85 V, temperature 42°C, pulse frequency 2 Hz, 14 minutes) of the GG was performed (Fig. 2A).

During the stimulation and the PRFT, ECG showed no critical change in cardiac electrical conduction; the heart rate was stable according to the pulse oximeter; and pacemaker output remained continuous (Fig. 1B).

The patient was taken to the recovery room for 2 hours for monitoring of vital functions. No cardiovascular or neurological pathologies were observed. In the postoperative period, the patient noted a decrease in his pain syndrome (VAS score 2, BNI score up to 1 point). The severity of numbness was 1 on the BNI scale. Three hours after PRFT, the ECG parameters and heart rate according to the pulse oximeter were stable, without any pathological changes (Fig. 1C).

Postoperatively, the pacemaker was evaluated, showing no change in its variables, and was reprogrammed to its original settings. After the surgery, the CIED Adapta DR was transferred to the DDD mode.

The patient was discharged on the second day after the operation. He reported complete relief of pain after the procedure, and at the 9-month follow-up, he was pain-free.

Patient Informed Consent

The necessary patient informed consent was obtained in this study.

Discussion

Observations

TN is a highly disabling disorder usually characterized by facial pain in the distribution of branches of the fifth cranial nerve.[11,12] With the acceleration of aging of the global population, the prevalence of TN in elderly comorbid patients with severe heart disease is increasing; therefore, the need to study and explore minimally invasive methods for TN treatment is growing.[13] Nowadays, according to research, the most useful procedures for TN among minimally invasive options is percutaneous RFT in different modes. However, the known risk of EMI is a limitation of the use of RFT in patients with severe heart diseases requiring pacemaker support.[14,15]

Our clinical case demonstrates the successful and safe use of RFT in a patient with TN and CIED. The use of RFT with an implanted pacemaker became possible by using a bipolar mode, whereas a monopolar mode could create interference with an automated implantable

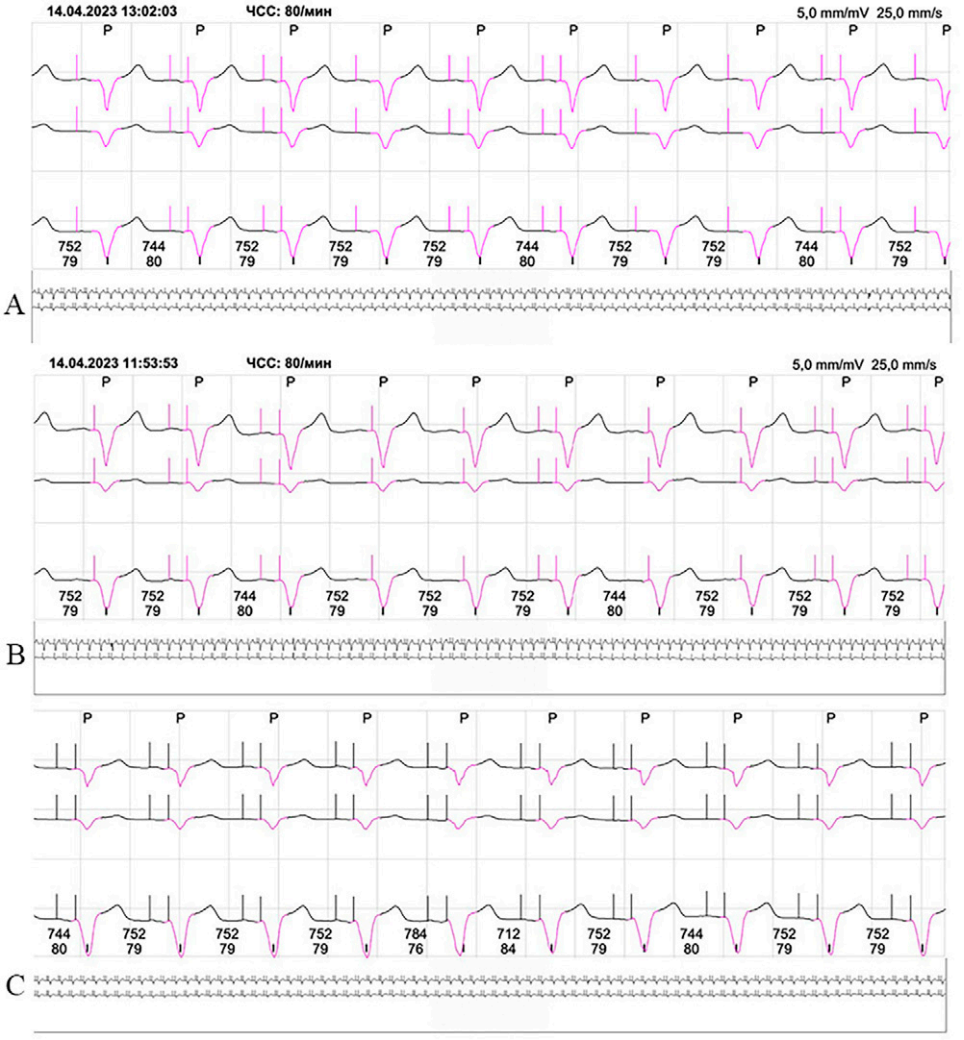

FIG. 1. A: The ECG before the operation in a patient with a CIED Adapta DR (two-chamber) in the asynchronous mode with a heart rate of 80 beats/min. **B:** The ECG during the operation. **C:** The ECG 3 hours after operation.

cardioverter defibrillator function due to the mechanism of the monopolar regimen.

Monopolar RF current flows into the patient's body from an active electrode. The high-frequency electric current generated by the radiofrequency generator passes from the active electrode to the scattering grounding electrode through the whole patient's body. This current can form an arc in the air toward the device and demodulate the electronic signal. Such a signal may be overly perceived by the implantable cardioverter defibrillator (ICD), which will lead to an inappropriate discharge.[9,15]

EMI is a key problem of using RFT in patients with an ICD. EMI that occurs from the resulting arc of the current can interfere with ICD sensing, which may result in erroneous detection of a ventricular arrhythmia (oversensing) and delivery of a defibrillator shock.[9,15,16]

The relative safety of using a bipolar mode in our clinical case lies in the mechanism of its action. The high-frequency current does not pass through the patient's body but passes from one RFT probe electrode to the other RFT probe electrode. The current is localized directly at the point of application and does not spread to the surrounding tissues. Therefore, the theoretical risk of EMI associated with bipolar RFT is substantially less than with monopolar RFT.[17]

We studied several works that reported on the safety and efficacy of RFT for TN in patients with CIEDs.[10,18,19] Hanna et al.[10] emphasized the safety of bipolar radiofrequency ablation in patients with chronic pain and implantable cardiac rhythm devices. Their study emphasizes that the technique is considered safe and effective for managing chronic pain in patients with these devices, and it did not mention any complications.[10] A study by Huerta et al.[19] reported that RFT was safe and effective in treating TN in patients with implanted pacemakers, with no significant changes in cardiac device parameters observed after the procedure.

In our clinical case, RFT was performed according to the requirements of the CIED, which contributed to the prevention of malfunction or damage to the device.

The risks were minimized by means of the following. 1) We reprogrammed the CIED Adapta DR (stimulation threshold 0.50/0.75 V

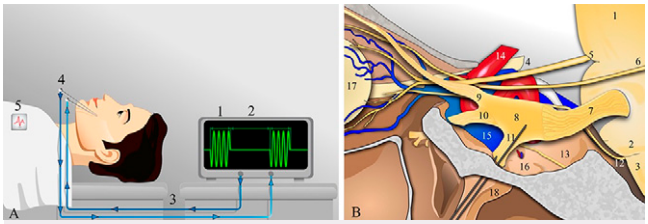

FIG. 2. Schematic representation of the GG PRFT procedure. **A:** Schematic representation of current direction in bipolar radiofrequency ablation: 1, alternating current with 20 ms heat caused by output voltage; 2, alternating current with 480-ms intervals; 3, direction in bipolar radiofrequency ablation where the path of the current does not run through the device and the electrode system; 4, positioning of two needles for radiofrequency ablation of the GG; 5, the CIED. **B:** Anatomy and topography of the GG: 1, midbrain; 2, pons; 3, medulla; 4, optic nerve; 5, oculomotor nerve; 6, trochlear nerve; 7, root of trigeminal nerve; 8, GG; 9, ophthalmic nerve (first branch of trigeminal nerve); 10, maxillary nerve (second branch of trigeminal nerve); 11, mandibular nerve (third branch of trigeminal nerve); 12, abducens nerve; 13, greater superficial petrosal nerve; 14, internal carotid artery; 15, cavernous sinus; 16, meningeal artery and vein; 17, eye; 18, positioning of two needles for radiofrequency ablation of the GG (the first active tip in the GG; the second active tip in the area of the entrance to the FO).

at duration 0.40/0.40 ms) to the asynchronous mode DOO with a heart rate of 80 beats/min. This was done because working in this mode, the stimulator does not perceive any signals during the entire base interval, resulting in constant AV stimulation at the base rate. 2) We performed the PRFT in a bipolar pulse mode because the path of the electric current does not run through the device and the electrode system. 3) We avoided direct contact between the ablative catheter and implanted system. 4) We monitored the blood pressure, heart rate, pulse blood oxygen saturation, and ECG during the surgical treatment. 5) We prepared the equipment for temporary pacing and defibrillation before the surgery.

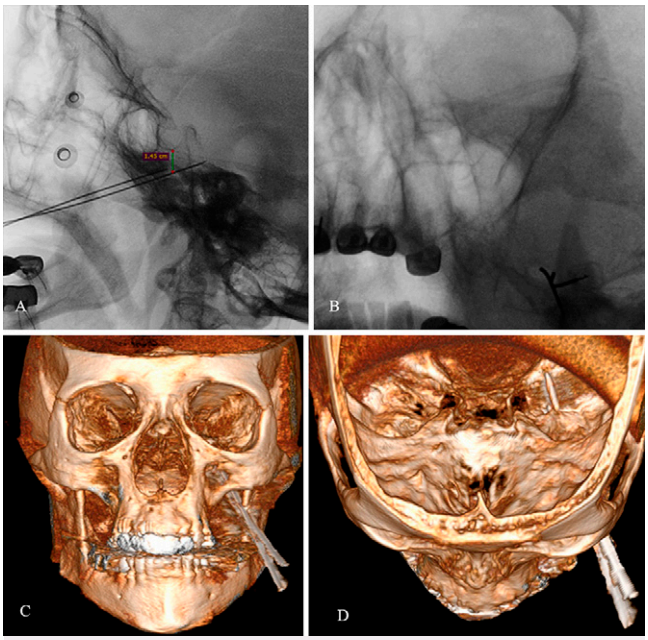

FIG. 3. Real-time CT fluoroscopy. **A:** Sagittal projection. **B:** Frontal projection. **C:** 3D CT reconstruction of the needle positioning in the frontal projection. **D:** 3D CT reconstruction of the needle tip positions.

The bipolar mode in TN treatment was described in the work of Huang et al.,[20] who demonstrated bipolar RFTC with a lower incidence of residual and recurrent pain, although they noticed a higher incidence of conventional complications (e.g., masseter muscle atonia and strong numbness), which significantly influenced patient quality of life. The high frequency of complications lies in the mechanism of RFTC, which exposes the target nerves to high temperature through a continuous electrical stimulation, thereby causing nerve destruction and pain relief.[21] Despite the different sensitivities to heat between unmyelinated nociceptive fibers and myelinated sensory fibers, the probability of developing severe facial numbness and other side effects after RFTC, considering the individual characteristics of the patient, is unpredictable.

To avoid the above complications, we used PRFT in our clinical case.[22] PRFT was introduced by Sluijter in 1998. Since that time, PRFT has been widely used for various types of pain.[23,24] PRFT delivers a low-energy electrical field in target nervous tissue and associated microglia by placing a long resting period between brief electrical stimulations.[25] Compared with RFTC, PRFT is not an ablative but rather a neuromodulating procedure.[7] In their work, Cosman et al.[26] suggested that the low frequency of pulses during PRFT and the high voltages cause long-term suppression of synaptic transmission, subsequently preventing the transfer of noxious signals to the brain. Neuromodulation is performed by different pathways involved in long-term depression of nociceptive signaling, reducing the expression of proinflammatory cytokines and decreasing the expression of tumor necrosis factor-α, one of the major players in the development and maintenance of neuropathic pain at the molecular level.[8] Moreover, PRFT can change neuronal activity of the pain inhibitory mechanism by the enhancement of the noradrenergic and serotonergic descending pain inhibitory pathway.[25]

In the literature, considering the high efficiency of PRFT neuromodulation in pain syndromes, with less risk of thermal neuronal damage in comparison with RFTC, there are a lot of articles describing different modes and parameters of PRFT. Teixeira and Sluijter[6] first reported that monopolar high voltage (60 V) used for pain treatment attained satisfactory efficacy. In their study in 2014, Fang et al.[27] discovered the significant improvement in pain relief in the cases using monopolar high voltage and a large pulse width compared with the standard-voltage group. The same result was demonstrated in the Wan et al. report.[13] A study of the bipolar mode was conducted in the work by Silva et al.[28] in two clinical cases of high-voltage PRFT, in which they noticed an absence of characteristic side effects after the procedure with a good postoperative result. Wan et al.[29] conducted a randomized, double-blind, controlled trial in which they confirmed that bipolar, high-voltage, long-duration PRFT is a safe and effective treatment.

On the basis of our literature review, to achieve a good effect with minimal complications in our clinical case, we used high-voltage, long-duration PRFT of the GG with the output voltage of 85 V, temperature of 42°C, and pulse frequency of 2 Hz for 14 minutes. During the PRFT ECG, no critical change in cardiac electrical conduction was detected, the heart rate was stable, and the pacemaker output remained continuous. In the postoperative period, the patient noted a decrease in his pain syndrome: VAS score 2, BNI scale up to 1 point.

The severity of numbness was 1 on the BNI scale. Three hours after PRFT, the ECG and the heart rate according to the pulse oximeter were stable, without any pathological changes.

Postoperatively, the pacemaker was evaluated, showing no changes in its variables, and was reprogrammed to its original settings. After surgery, the CIED Adapta DR was transferred to the DDD mode because that mode is the most functional of all the modes supported by the stimulator. In the absence of intrinsic activity in the DDD mode, sequential stimulation of the atria and ventricles occurs with a set AV delay and base pacing rate.[30–32] In the case in which one's own atrial rhythm has a frequency above the baseline, the atrial channel is inhibited, and the detected P-waves are carried out to the ventricles with a given AV delay. In the case in which one's own atrial rhythm and AV conduction are less time than the programmed AV delay, both channels are inhibited, and the stimulator simply tracks the patient's own rhythm.[33,16]

Our clinical case demonstrates the use of a bipolar regimen without significant changes on the ECG and without any pathological changes in the neurological and cardiovascular systems of the organism.

Lessons

Bipolar high-voltage PRFT is reported to be a safe and effective percutaneous method of treatment in age-related patients with TN, and our case is among those to support this opinion. However, despite the relative safety of this method of treatment in patients with an implanted pacemaker, it is necessary to use it with caution, to carefully study the instructions of the pacemaker, and to guide the patient together with a cardiac surgeon and an anesthesiologist resuscitator. The pacemaker should be checked before and after the procedure, and the peripheral pulse should be monitored throughout the whole procedure.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: AA Sufianov, Garifullina, Shapkin, Markin, Baldoncini. Acquisition of data: Garifullina, Shapkin, Markin, RA Sufianov. Analysis and interpretation of data: Garifullina, Shapkin, Markin, Encarnacion Ramirez, RA Sufianov. Drafting the article: Garifullina, Shapkin, Markin, Baldoncini, RA Sufianov. Critically revising the article: AA Sufianov, RA Sufianov. Reviewed submitted version of manuscript: AA Sufianov, Garifullina. Approved the final version of the manuscript on behalf of all authors: AA Sufianov. Statistical analysis: Garifullina, Encarnacion Ramirez. Administrative/technical/material support: AA Sufianov. Study supervision: AA Sufianov, Borba, RA Sufianov.

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