Case reports

Successful treatment of anteroseptal accessory pathways by transvenous cryomapping and cryoablation

Marcelo E. Lanzotti, Roberto De Ponti, Massimo Tritto, Giammario Spadacini, Jorge A. Salerno-Uriarte

University of Insubria-Varese, Department of Cardiovascular Sciences, Ospedale di Circolo e Fondazione Macchi, Varese, Department of Cardiology "Mater Domini", Castellanza (VA), Italy

Key words:
Arrhythmias, supraventricular; Wolff-Parkinson-White syndrome.

Radiofrequency is the most commonly used energy source for the treatment of cardiac arrhythmias. Despite its high success rate, radiofrequency energy may sometimes present limitations, especially in case of anteroseptal atrioventricular accessory pathways. In these patients, inadvertent atrioventricular block may occur during or after the procedure and a high recurrence rate of conduction over the accessory pathway is observed. Since the late 1970s, cryosurgery has been an integral part of the management of cardiac arrhythmias, and recently, animal and clinical studies demonstrated the feasibility and safety of applying percutaneous catheter cryoablation technology. These studies also showed that reversible cryomapping of high-risk arrhythmogenic sites can be performed before creating permanent lesions. In this preliminary report, we describe the successful use of percutaneous cryoablation for the permanent interruption of conduction over anteroseptal accessory pathways.

(Ital Heart J 2002; 3 (2): 128-132)

Dr. Marcelo E. Lanzotti is supported by a grant from Boston Scientific S.p.A.

Received November 6, 2001; revision received January 25, 2002; accepted January 31, 2002.

Address:

Prof. Jorge A. Salerno-Uriarte

Dipartimento di Scienze Cardiovascolari Ospedale di Circolo e Fondazione Macchi Università degli Studi dell'Insubria Viale Borri, 57 21100 Varese E-mail: jorge.salerno@ospedale.varese.it

Introduction

Epicardial cryoablation was introduced in the antiarrhythmic surgical theatre for the ablation of accessory pathways by Klein et al.[1]. As opposed to the endocardial Sealy's surgical technique[2], it had the advantage of allowing continuous monitoring of cardiac electrical activity and proved to be safe and effective[3,4]. A cryothermal lesion is different from hyperthermic injury, since it is associated with the preservation of the underlying tissue architecture with minimal thrombus formation and with histologically uniform and discrete myocardial lesions[5].

Nowadays, catheter ablation has largely supplanted antiarrhythmic surgery and radiofrequency (RF) energy remains the most commonly used energy source for catheter ablation[6]. Nevertheless, in some cases such as anteroseptal accessory pathways RF energy may present limitations[7-13]. In fact, in these patients, the effective ablation site is in close anatomical relationship with the normal conduction pathway and particular care is required to avoid inadvertent atrioventricular (AV) block[14].

In this report, we present our initial experience with the use of a novel percutaneous, catheter-based cryoablation system that allows testing of the effect of cryothermal energy by cooling the target area (cryomapping), before creating a permanent lesion. This system was used in 2 patients to ablate accessory pathways located in critical sites, such as the parahissian and anterior paraseptal areas.

Description of cases

Case 1. A 34-year-old man presenting with postablation recurrences of effort palpitations was admitted to our Institution. Six weeks before, he had undergone a RF catheter ablation procedure at our Institution. The temperature control mode (cut-off temperature 55°C) was used. The short-term outcome was suggestive of successful interruption of a concealed parahissian accessory pathway. After the ablation procedure, the patient received no drugs.

On admission, physical examination, as well as chest X-ray and transthoracic echocardiography, were normal. A 12-lead ECG on sinus rhythm confirmed the absence of ventricular preexcitation. After written informed consent, the patient underwent electrophysiologic study. After having positioned multipolar catheters in the high right atrium, His bundle area and coronary sinus, baseline electrophysiologic testing revealed normal intervals of antegrade AV conduction and resumption of conduction over the concealed parahissian accessory pathway. Programmed atrial stimulation during isoprenaline infusion reproducibly induced a sustained orthodromic AV reentrant tachycardia with a cycle length of 310 ms. In order to perform ablation, a steerable 7F tetrapolar catheter (Freezor™ 3, Cryocath Technologies Inc., Montreal, Canada) was inserted via the inferior vena cava. The cryocatheter has a cooling distal electrode and three proximal ring electrodes that can be used for intracardiac recording or pacing. The temperature is recorded at the tip electrode by using an integrated thermocouple. A computerized console delivers liquid N_2O via an inner lumen of the catheter to a chamber inside the tip electrode. Here, a liquid-to-gas phase change takes place; this causes rapid cooling and heat extraction from the electrode-tissue interface. The delivery system has two algorithms: 1) a cryomapping algorithm, which slowly decreases the temperature at the distal electrode to -30°C (a lower temperature can be obtained by manually changing the parameters on the console) for 80 s; 2) a cryoablation algorithm, which adjusts the N_2O flow to obtain fast cooling at -75°C for a maximum of 240 s. Having gained access to the cardiac chambers via an inferior vena cava approach, the parahissian area was carefully mapped with the cryocathether during orthodromic AV reentrant tachycardia and the site of earliest retrograde atrial activation was localized. An attempt of cryomapping in a suitable site failed because the threshold temperature was not reached. This was probably due to inadequate electrode-tissue contact. Consequently, the cryocatheter was firmly positioned via the superior vena cava in the parahissian region (Fig. 1A) where the shortest ventriculo-atrial interval during tachycardia was recorded (Fig. 1B). As shown in figure 2, cryomapping resulted in interruption of the tachycardia in the retrograde limb at 0°C with no modification of the AV node conduction parameters and no accelerated junctional rhythm; cryoablation at -75°C was then performed for 120 s

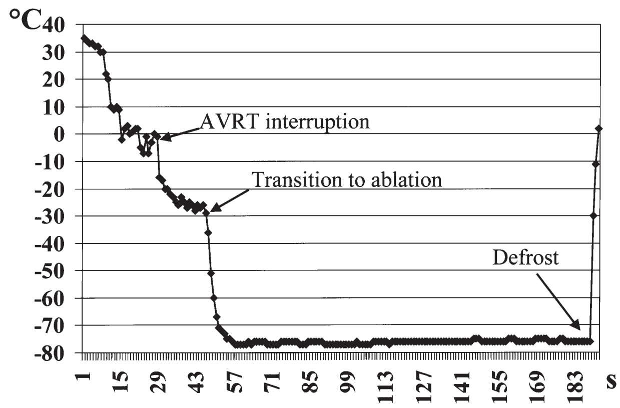

Figure 2. *Diagram showing the temperature over time during cryoablation in case 1. Initially, cryomapping resulted in interruption of the tachycardia at 0°C after about 20 s from the beginning of the application. Upon termination of the tachycardia, a sudden drop in temperature to the lower cryomapping temperature (-30°C) was observed; a few seconds were necessary to check the atrioventricular node conduction and the non inducibility of tachycardia by programmed atrial stimulation. Subsequently, cryoablation was performed at -75°C for 120 s with no modification in the atrioventricular node conduction parameters and no accelerated junctional rhythm. At the end of the application, the defrost phase was very fast. AVRT = atrioventricular reentrant tachycardia.*

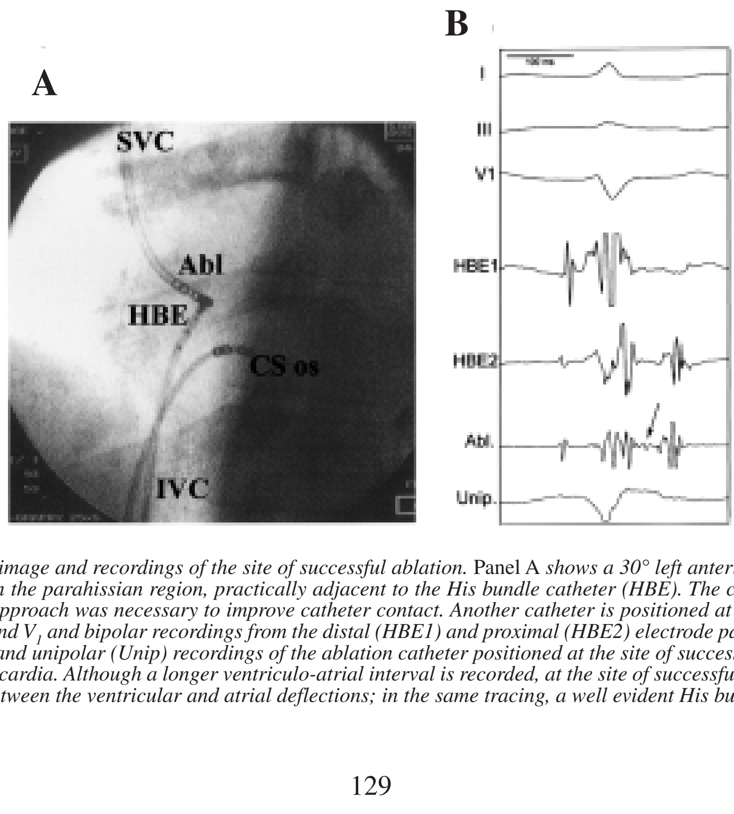

Figure 1. *Case 1: fluoroscopic image and recordings of the site of successful ablation.* Panel A *shows a 30° left anterior oblique view of the cryoablation catheter (Abl) positioned in the parahissian region, practically adjacent to the His bundle catheter (HBE). The change from the inferior (IVC) to the superior vena cava (SVC) approach was necessary to improve catheter contact. Another catheter is positioned at the os of the coronary sinus (CS os).* Panel B *shows leads I, III and* V_1 *and bipolar recordings from the distal (HBE1) and proximal (HBE2) electrode pairs of the His bundle catheter, as well as the distal bipolar (Abl) and unipolar (Unip) recordings of the ablation catheter positioned at the site of successful ablation during orthodromic atrioventricular reentrant tachycardia. Although a longer ventriculo-atrial interval is recorded, at the site of successful ablation a putative Kent bundle potential* (arrow) *is observed between the ventricular and atrial deflections; in the same tracing, a well evident His bundle potential is also recorded.*

with permanent elimination of the conduction through the accessory pathway. In particular, the catheter was not displaced at the end of the tachycardia, and during the application the tight adherence between the tissue and the freezing catheter allowed us to perform programmed atrial stimulation necessary in order to test the tachycardia inducibility (Fig. 3). Subsequently, post-ablation electrophysiological evaluation demonstrated normal AV node conduction parameters, complete and persistent interruption of the conduction over the accessory pathway and no arrhythmia inducibility. No acute or delayed complications occurred. The patient was discharged with no therapy. Palpitations did not recur during the 5-month follow-up period.

Case 2. A 42-year-old man with recurrent episodes of paroxysmal palpitations was admitted to our Institution. A 12-lead ECG recorded on sinus rhythm showed a ventricular preexcitation pattern suggesting the presence of an anteroseptal accessory pathway.

On admission, physical examination as well as chest X-ray and transthoracic echocardiography were normal. After written informed consent, an off-drug electrophysiologic study was performed as described in the previous case. Baseline evaluation confirmed the presence of an unidirectional antegrade anterior paraseptal accessory pathway with an effective refractory period (AP-ERP) of 380 ms. During isoprenaline infusion, 1:1 antegrade conduction over the accessory pathway up to 240 ms in the cycle length was observed.

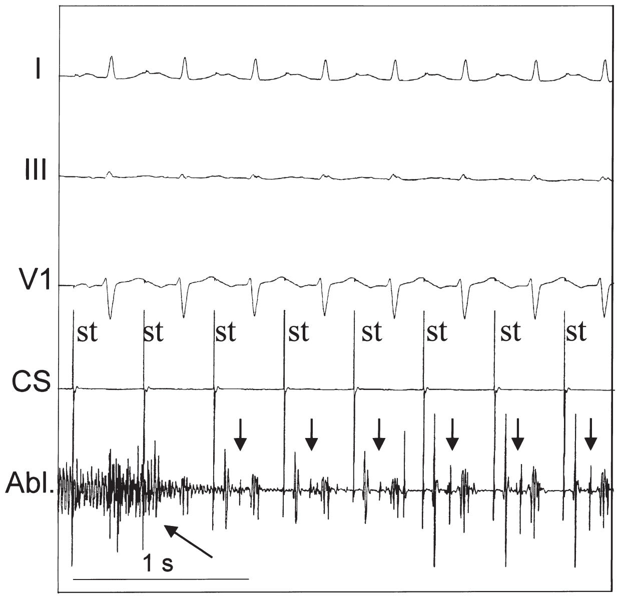

Figure 3. *Recordings during the defrost phase at the end of the application in case 1.* From top to bottom *leads I, III, V_1 are shown together with bipolar recordings from the coronary sinus (CS) and from the ablation (Abl) catheter. Pacing artifacts (st) of atrial stimulation from the coronary sinus catheter are evident. The* oblique arrow *indicates the dissolving artifacts due to cryothermal energy delivery, upon suspension of the application. The* vertical arrows *indicate the His bundle potential recorded from the distal electrode pair of the ablation catheter after successful accessory pathway ablation.*

Programmed atrial stimulation induced preexcited atrial fibrillation with a fast ventricular rate, and programmed ventricular stimulation during isoprenaline infusion documented the reproducible inducibility of an antidromic AV reentrant tachycardia with a 370 ms cycle length. Consequently, accessory pathway ablation was decided and a cryocatheter, similar to the one used in case 1, was inserted through the femoral vein. The anteroseptal region was accurately mapped during sinus rhythm and programmed atrial stimulation at a coupling interval shorter than the AP-ERP to identify the His bundle potential. Again, after having removed the coronary sinus catheter, the cryocatheter was positioned in the anterior paraseptal region via the superior vena cava (Fig. 4A) to obtain a more stable contact. After careful mapping, optimal AV and V-delta intervals were recorded at an estimated distance of a few millimeters from the best His bundle deflection. During cryomapping on sinus rhythm, abolition of ventricular preexcitation was obtained at -30°C (Fig. 4B) and, subsequently, cryoablation at -75°C for 240 s was performed, with no modification of the AV node conduction and no accelerated junctional rhythm. Postablation electrophysiologic evaluation confirmed the successful ablation of the accessory pathway and induced no arrhythmia. No therapy was prescribed at the time of hospital discharge. During the 4-month follow-up period, the patient remained asymptomatic. Surface ECG confirmed the persistent absence of ventricular preexcitation.

No complications occurred and neither patient referred any discomfort whatsoever during the application of cryothermal energy.

Discussion

Recent animal studies demonstrated the feasibility and safety of creating lesions in cardiac tissue by percutaneously applying cryothermal energy and showed that cryomapping can be safely performed before creating permanent lesions[15,16]. Sites of cryothermal ablation are discrete and they are replaced by dense connective tissue with no signs of chronic inflammation[17]. The tissue architecture is preserved[17]. Dubuc et al.[18] previously investigated the feasibility and safety of AV node conduction interruption by percutaneous cryoablation in patients with refractory atrial fibrillation. This technology was also used for slow pathway ablation in patients with AV nodal reentrant tachycardia and permitted the possibility of testing the functionality of specific ablation sites before creating a permanent lesion[19].

Although successful and safe ablation by RF energy has been described in limited series of patients with anteroseptal accessory pathways[7-9], persistent damage to the normal conduction system requiring permanent pacing is a possible complication of an ablation procedure for a parahissian, anterior paraseptal or intermedi-

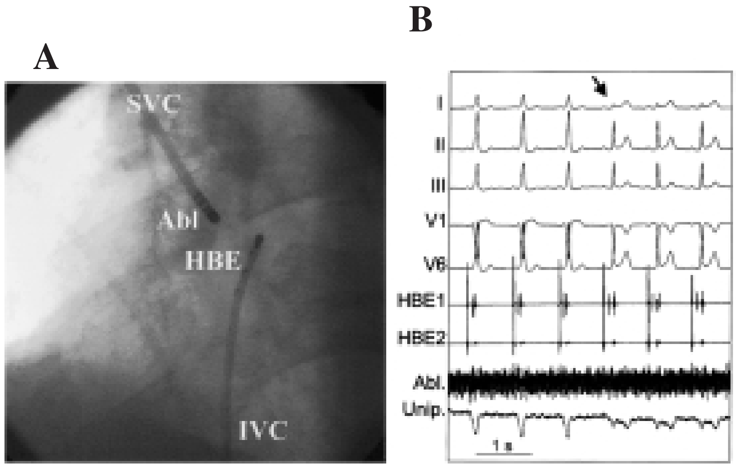

Figure 4. *Case 2: fluoroscopic image and recordings of the site of successful ablation.* Panel A *shows a 30° left anterior oblique view of the cryoablation catheter positioned in the anterior paraseptal region, a few millimeters from where the best His bundle deflection is recorded. Again, the change from the inferior to the superior vena cava approach was necessary to improve catheter contact.* Panel B *shows leads I, II, III, V_1 and V_6 and the bipolar recordings from the distal and proximal electrode pairs of the His bundle catheter, as well as the distal bipolar and unipolar recordings of the ablation catheter. The* arrow *indicates loss of ventricular preexcitation during cryomapping at -30°C. Abbreviations as in figure 1.*

ate septal accessory pathway[10-13]. A "minimally aggressive" approach for these accessory pathways, which relies on accurate mapping, stable catheter positioning and a low power and cut-off temperature, has been previously described[14]. Although this approach is very safe, its main drawback is the increased recurrence rate (up to 26% for parahissian accessory pathways).

In the present paper, a preliminary experience with the cryoablation of anteroseptal accessory pathways is presented. Permanent ablation of a parahissian and of an anterior paraseptal accessory pathway was safely achieved with no modification of the conduction properties of the AV node-His bundle. In these cases, the main advantage of cryothermal technology is that the creation of a permanent lesion can be preceded by test applications (cryomapping) causing only a reversible loss of the functional properties of the tissue. Moreover, the longer estimated time required to create a permanent lesion (240 s) may be useful in trying to better modulate the lesion formation. In fact, this allows timely discontinuation of the cryoablation application as soon as signs of possible initial damage to the normal conduction pathway are observed. These features may be of critical importance to avoid permanent damage to the normal conduction pathway when ablating anteroseptal accessory pathways. Another advantage consists of the fact that cooling causes tight adherence of the catheter tip to the adjacent tissue. Hence, cryoablation can be safely continued even when sudden changes in heart rhythm, that usually displace the ablation catheter, occur. In addition, "cryo-adherence" does not compromise safety since upon discontinuation of the delivery of cryothermic energy, the defrost phase is very fast (within 3 s) and the catheter may be disengaged from the ablation position. An additional advantage is that, in our initial experience, in these as well as in other cases, there were no complaints of any discomfort whatsoever during the application of cryothermal energy, in spite of the fact that the application is long lasting. Although the full explanation of this phenomenon is not completely clear, this characteristic can be particularly useful in young patients.

Some issues regarding this technology require further investigation. Cryoablation might be more sensitive to the blood flow effect with respect to RF ablation since the temperature difference between the blood and the catheter tip is by far greater in the former than in the latter. As shown in figure 2, in the first case, upon termination of the tachycardia by cryomapping a sudden drop in the catheter tip temperature (from 0 to -30°C) was observed. This suggests that the blood flow velocity (higher during tachycardia than during sinus rhythm) may have a warming effect on the catheter tip and, hence, on the application of cryothermal energy to the tissue. This implies that for cryoablation, the achievement of an optimal tissue-electrode contact is mandatory. In fact, in the two presented cases a superior vena cava approach was used to improve contact. Another issue is represented by the fact that the optimal temperature for cryomapping has not been established. Surgical experience previously demonstrated that reversible suppression of electrophysiologic function occurred at 0°C[20]. Animal studies with the current catheter-based system have demonstrated that a tip temperature of -30°C allowed reproducible cryomapping of the AV node[16]. Probably, a lower temperature for cryomapping is required when using percutaneous technology as compared to surgery because of the warming effect of the blood pool. In our initial experience, in these as well as in other cases, the temperature at which conduction through the accessory pathway is interrupted is variable and always ≤ 0°C. In any case, one should bear in mind that the longer the temperature is maintained below 0°C during cryomapping, the higher are the chances of producing an irreversible lesion.

In conclusion, percutaneous cryoablation of anteroseptal accessory pathways is effective and safe and could be the therapeutic option of choice for such conditions. Some features of this new technology are particularly adapt for ablation close to the normal conduction pathway. Further experience is required to confirm our initial experience with this new technology.

Addendum

By the time the paper was accepted, another 3 cases of anteroseptal and 2 cases of intermediate septal accessory pathways have been successfully treated by cryoablation. No acute or late complications were observed.

References

1. Klein GJ, Guiraudon GM, Perkins DG, Jones DL, Yee R, Jarvis E. Surgical correction of the Wolff-Parkinson-White syndrome in the closed heart using cryosurgery: a simplified approach. J Am Coll Cardiol 1984; 3 (Part 1): 405-9.
2. Cobb FR, Blumenschein SD, Sealy WC, Boineau JP, Wagner GS, Wallace AG. Successful surgical interruption of the bundle of Kent in a patient with Wolff-Parkinson-White syndrome. Circulation 1968; 38: 1018-29.
3. Graffigna A, Pagani F, Viganò M. Surgical treatment of Wolff-Parkinson-White syndrome: epicardial approach without the use of cardiopulmonary bypass. J Card Surg 1993; 8: 108-16.
4. Bredikis JJ, Bredikis AJ. Surgery of tachyarrhythmia: intracardiac closed heart cryoablation. Pacing Clin Electrophysiol 1990; 13 (Part 2): 1980-4.
5. Lustgarten LD, Keane D, Ruskin J. Cryothermal ablation: mechanism of tissue injury and current experience in the treatment of tachyarrhythmias. Prog Cardiovasc Dis 1999; 41: 481-98.
6. Calkins H, Yong P, Miller JM. Catheter ablation of accessory pathways, atrioventricular nodal reentrant tachycardia, and the atrioventricular junction: final results of a prospective, multicenter clinical trial. The Atakr Multicenter Investigators Group. Circulation 1999; 99: 262-70.
7. Schlüter M, Kuck KH. Catheter ablation from the right atrium of antero-septal accessory pathways using radiofrequency current. J Am Coll Cardiol 1992; 19: 663-70.
8. Schaffer MS, Silka MJ, Ross BA, Kugler JD. Inadvertent atrioventricular block during radiofrequency catheter ablation. Results of the Pediatric Radiofrequency Ablation Registry. Pediatric Electrophysiology Society. Circulation 1996; 94: 3214-20.
9. Haïssaguerre M, Marcus F, Poquet, Gencel L, Le Metayer P, Clementy J. Electrocardiographic characteristics and catheter ablation of parahissian accessory pathways. Circulation 1994; 90: 1124-8.
10. Yeh SJ, Wang CC, Wen MS, et al. Characteristics and radiofrequency ablation therapy of intermediate septal accessory pathways. Am J Cardiol 1994; 73: 50-6.
11. Xie B, Heald SC, Bashir Y, Camm AJ, Ward DE. Radiofrequency catheter ablation of septal accessory atrioventricular pathways. Br Heart J 1994; 72: 281-4.
12. Brugada J, Puigfel M, Mont L, et al. Radiofrequency ablation of anteroseptal, para-Hisian, and mid-septal accessory pathways using a simplified femoral approach. Pacing Clin Electrophysiol 1998; 21 (Part 1): 735-41.
13. Lin JL, Huang SK, Lai LP, Cheng TF, Tseng YZ, Lien WP. Radiofrequency catheter ablation of septal accessory pathways within the triangle of Koch: importance of energy titration testing other than local electrogram characteristic for identifying the successful target site. Pacing Clin Electrophysiol 1998; 21: 1909-17.
14. De Ponti R, Storti C, Zardini M, et al. Ablation of anteroseptal and intermediate septal accessory pathways: how safe is it? How can one minimize the risk of AV block? In: Raviele A, ed. Cardiac arrhythmias 1999. Milano: Springer-Verlag, 2000: 185-92.
15. Rodriguez LM, Leunissen J, Hoekstra A, et al. Transvenous cold mapping and cryoablation of the AV node in dogs: observations of chronic lesions and comparison to those obtained using radiofrequency ablation. J Cardiovasc Electrophysiol 1998; 9: 1055-61.
16. Dubuc M, Roy D, Thibault B, et al. Transvenous catheter ice mapping and cryoablation of the atrioventricular node in dogs. Pacing Clin Electrophysiol 1999; 22: 1488-98.
17. Fujino H, Thompson RP, Germroth PG, Harold ME, Swindle MM, Gillette PC. Histologic study of chronic catheter cryoablation of atrioventricular conduction in swine. Am Heart J 1993; 125: 1632-7.
18. Dubuc M, Khairy P, Rodriguez-Santiago A, et al. Catheter cryoablation of the atrioventricular node in patients with atrial fibrillation: a novel technology for ablation of cardiac arrhythmias. J Cardiovasc Electrophysiol 2001; 12: 439-44.
19. Skanes AC, Dubuc M, Klein GJ, et al. Cryothermal ablation of the slow pathway for the elimination of atrioventricular nodal reentrant tachycardia. Circulation 2000; 102: 2856-60.
20. Klein GJ, Guiraudon GM, Perkins DG, et al. Controlled cryothermal injury to the AV node: feasibility for AV nodal modification. Pacing Clin Electrophysiol 1985; 8: 630-8.