Percutaneous catheter cryothermal ablation of atrioventricular nodal reentrant tachycardia: efficacy and safety of a new ablation technique

Riccardo Riccardi*§, Fiorenzo Gaita*§, Domenico Caponi§, Stefano Grossi*, Marco Scaglione§, Enrico Caruzzo*, Paolo Di Donna§, Gianfranco Pistis*, Elena Richiardi*§, Carla Giustetto*, Mario Bocchiardo§

**Division of Cardiology, Mauriziano Hospital, Turin, §Division of Cardiology, Civic Hospital, Asti, Italy*

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Arrhythmia; Atrioventricular node; Catheter ablation; Tachycardia.

Background. **Radiofrequency catheter ablation is nowadays a widely used technique for the treatment of arrhythmias; however, due to the possible complications such as atrioventricular block when radiofrequency is delivered in the septal area, this type of energy is not optimal. In contrast, cryoenergy has several positive features; first of all, it allows for the creation of reversible lesions and hence to test the effects of the ablation while the lesion is still forming thus reducing the number of ineffective and useless lesions. In addition, it also allows for the evaluation of the acute effects on the structures adjacent to the ablation site. The aim of the present study was to analyze the effectiveness and safety of catheter cryoablation in the treatment of atrioventricular nodal reentrant tachycardia (AVNRT).**

Methods. **Thirty-two patients presenting with AVNRT underwent catheter cryoablation using a 7F catheter. When the optimal parameters were recorded, "ice mapping" at -30°C was performed for 80 s to validate the ablation site by means of a reversible lesion. If the expected result was achieved, the cryoablation was carried out lowering the temperature to -75°C for 4 min thus creating a permanent lesion.**

Results. **Slow pathway ablation guided by a slow pathway potential was successfully performed in 31 out of the 32 patients with a mean of 2.6 ± 1.0 cryoapplications. No complications occurred in any patient. Transient AH prolongation was observed in 2 patients in a midseptal site during the ice mapping phase of AVNRT ablation.**

Conclusions. **Cryoablation is a safe and effective technique for AVNRT ablation. It may be useful particularly when the ablation must be performed close to the atrioventricular node or His bundle, due to the possibility of validating the site of ablation by means of ice mapping that creates only a reversible lesion.**

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Address:

Dr. Riccardo Riccardi

Divisione di Cardiologia
Ospedale Mauriziano
Largo Turati, 62
10126 Torino
E-mail:
riccardoric@yahoo.it

Radiofrequency (RF) catheter ablation has been shown to be a safe and effective technique for the treatment of cardiac arrhythmias and in most cases should be considered as first line therapy. However RF, although widely used, is not the optimal source of energy since it still has some disadvantages such as the possible thrombotic effects due to endocardial disruption and the impossibility of predicting the effectiveness of the lesions. In fact, its electrophysiological effect appears while the lesion is still forming. The former effect can lead to thromboembolic complications as seen when extensive linear lesions are made in the left atrium. The latter may be particularly important when the ablation is performed in critical regions such as in the septum close to the atrioventricular (AV) node or His bundle or within vessels (coronary sinus or pulmonary veins). A small but definite risk of complications has been reported in different series of patients undergoing the ablation procedure[1-3]. Besides, even in recently published papers it has been reported that slow pathway ablation is still associated with an incidence of AV block varying from 0.3 to 1.4%[3-6].

Intraoperative cryoenergy has been widely used in the past for the cure of arrhythmias[7-9] and it has recently been shown to be effective in the cure of atrial fibrillation by means of a limited linear ablation performed in the left atrium during heart surgery[10]. Cryoenergy produces a homogeneous and well demarcated lesion with no endocardial disruption. Moreover, using cryoenergy it is possible to predict the acute effectiveness of the lesion thanks to a transient and reversible lesion before additional cooling determines the irreversible one[11]. In addition, during cryoablation the catheter is well adherent to the endocardium; this is due to the presence of an ice ball which surrounds the catheter tip and the myocardial tissue thus favoring the stability of the catheter and consequently a selective lesion. On the basis of these considerations, the use of cryoenergy seems to be particularly advantageous when it is necessary to perform the ablation in critical regions such as in the septum close to the AV node or His bundle.

Recently, a few reports have shown the effectiveness of percutaneous catheter cryoablation for the ablation of the AV node[12] and of a nodal slow pathway[6,13]. However, the use of 9F catheters and the necessity of 10 min applications in each site to obtain the lesion clearly limited its practical use.

The objective of this study was to analyze the feasibility, the effectiveness and the safety of percutaneous cryothermal ablation using shorter application times (4 min) and smaller catheters (7F) for the slow pathway ablation of atrioventricular nodal reentrant tachycardia (AVNRT).

Methods

The present study included 34 patients (19 females, 15 males, mean age 43 ± 18 years) who presented with AVNRT and were referred to our Institution for catheter ablation. No associated heart disease was present in any patient but one who had been previously submitted to implantation of mitral and aortic prostheses. The ablation procedure was performed after informed consent.

Materials. The catheter used for the ablation was a 7F steerable cryocatheter (Freezor, Cryocath Technologies, Inc., Kirkland, Quebec, Canada) with a 4 mm tip electrode. In all cases, the catheter was inserted through the right femoral vein. The cryocatheter consists of a hollow catheter with a closed electrode tip connected to a console (Cryo Console, Cryocath Technologies, Inc.) that delivers the refrigerant fluid (NO_2) under pressure into the inner lumen. A liquid-to-gas phase of the cryogenic fluid while it passes into the tip rapidly reduces the temperature to a preset value, monitored by the presence of a thermocouple sensor at the distal tip. The gas is then conducted away from the tip through a vacuum return lumen. When the temperature reaches the value of about -20°C, an ice ball surrounding the distal tip of the catheter and the myocardial tissue forms with adhesion of the catheter to the tissue. This allows for perfect stability of the catheter throughout the whole phase of freeze. Thus, a pacing protocol for the validation of the effect of mapping or ablation can be performed without the risk of catheter dislodgment.

In all cases the ablation procedure was performed in a stepwise fashion including first the "ice mapping" and then the "cryoablation" itself.

Ice mapping. Ice mapping consists of cooling the tissue at a temperature of -30°C for a maximum time of 80 s. This cooling determines a modification of the electrophysiological features with a transient and reversible loss of the electrical function[11]. A pathological study has shown that when ice mapping is performed at a temperature warmer than -40°C, no gross anatomical and no or only minimal histological damage occurs; this study suggests that the latter seems to be at least partially secondary to the mechanical trauma caused by manipulation of the catheter rather than to a pure effect of the cooling itself[11].

The use of ice mapping at sites localized on the basis of the electrophysiological parameters may allow one to test the real efficacy of the lesion. In case of a positive effect (i.e. the disappearance or modification of conduction through the slow pathway with no reinduction of the AVNRT) the ice mapping was followed by the cryoablation. In case of ineffective results or undesired events (i.e. impairment of the conduction through the AV node), the ice mapping was terminated in order to allow rewarming and consequently the reversibility of the lesion. Mapping was then continued at adjacent sites in order to record better parameters and the ice mapping was again repeated to validate the appropriateness of the ablation site.

Cryoablation. The ablation was then performed at the validated sites by cooling the tissue to a temperature of -75°C for 4 min thus creating a permanent lesion[11,14,15]. During this period the catheter is well adherent to the atrial wall and, as described above, is perfectly stable. For this reason, it is not necessary to have to resort to fluoroscopy to check the catheter position. The surface ECG and endocavitary signals were continuously monitored and in case of undesired effects the cooling was immediately stopped. During the cryoablation, the programmed stimulation was repeated to test the persistence of the electrophysiological effect demonstrated during ice mapping. In case of recurrence of conduction or arrhythmia induction the catheter was repositioned at adjacent sites and the ice mapping was repeated.

Ablation procedure. A standard electrophysiological study to confirm the diagnosis and to test the inducibility of the AVNRT was performed in all the patients during the same session of the ablation. Quadripolar or hexapolar catheters were positioned in the His bundle region and a multipolar catheter was positioned in the coronary sinus through the right femoral vein or the right jugular vein; an additional catheter, inserted through the femoral vein, was generally positioned in the right ventricle or in the right atrium. Only patients with a reproducible inducibility of the AVNRT and/or the presence of dual AV nodal physiology underwent cryoablation. After electrophysiological study, the ablation was then carried out using an electrogram-guided approach, mapping either the slow potential[16] or the sharp potential[17]. Having recorded one of the two potentials, the ice mapping was started. Once a temperature of -20°C or less was reached for at least 20 s, programmed stimulation was performed in order to analyze the effects on the slow pathway conduction properties. Previous reports[6,13] showed that during cryoablation of the slow pathway, no junctional rhythm is observed. For this reason, other parameters must be used to validate the potential appropriateness of the ablation site. This is generally achieved by resorting to various pacing protocols that can be performed during ice mapping. The parameters able to predict the effects on the slow pathway conduction may be one or more of the following: a) the disappearance of the dual AV node physiology (Fig. 1), b) the modification of the slow pathway conduction and the non-inducibility of the AVNRT (Fig. 2), c) the interruption of the AVNRT due to the slowing down followed by the cessation of conduction over the slow pathway. However, in this series only the first two parameters were used. In all patients, the ablation was performed in sinus rhythm in order to validate the technique using the same parameters (i.e. recordings of the slow pathway potentials) that we generally use for ablation achieved by means of RF energy.

If the ice mapping was positive (i.e. abolition or modification of conduction through the slow pathway and no AVNRT induction) the temperature was lowered to achieve irreversible modifications. If the ice mapping was not positive or if any alteration of the antegrade conduction of the AV node was observed, the ice mapping was stopped and prompt rewarming of the tissue was allowed. During both ice mapping and cryoablation, the anterograde conduction was monitored on the surface ECG and on the endocavitary leads both in sinus rhythm and during atrial stimulation. Ventricular stimulation was also performed in order to ensure that no undesired effect on the retrograde conduction through the fast pathway occurred.

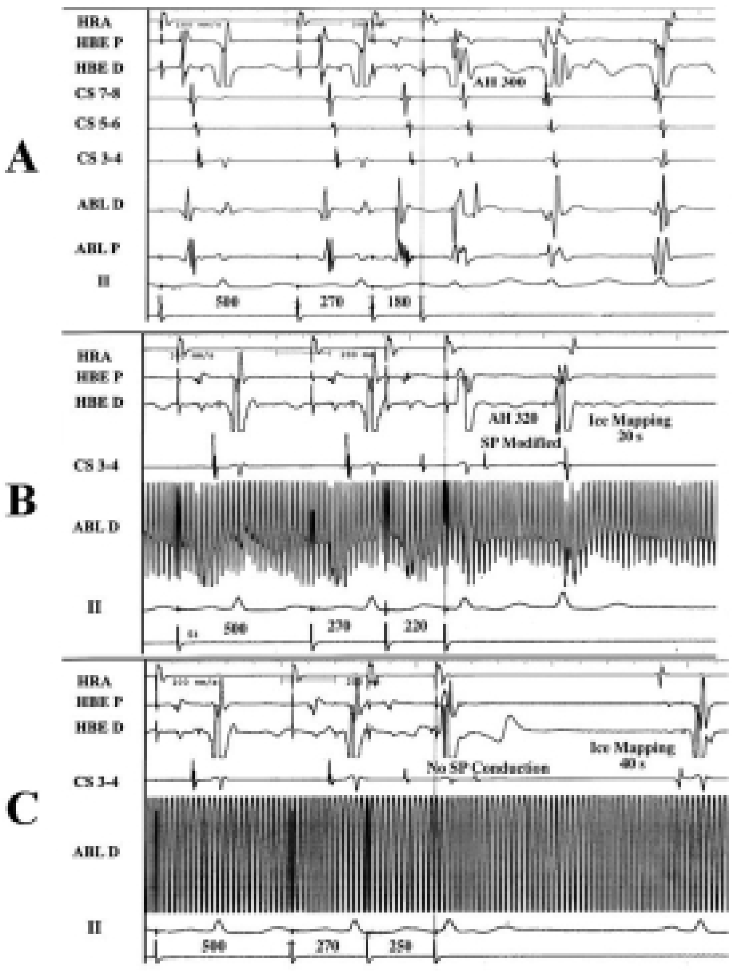

Figure 1. *Slow pathway (SP) ablation.* A: *atrioventricular nodal reentrant tachycardia is induced with two atrial extrastimuli during pre-ablation testing.* B: *after 20 s of ice mapping the conduction through the SP is modified; a less premature extrastimulus is conducted through the SP with a longer AH interval and no atrioventricular nodal reentrant tachycardia is induced.* C: *after 40 s of ice mapping SP conduction is completely abolished even in case of atrial premature beats with a longer cycle length. Measurements are expressed in ms. ABL = ablation catheter distal (D) and proximal (P); CS = coronary sinus proximal (7-8), mid (5-6) and distal (3-4); HBE = His bundle region distal (D) and proximal (P); HRA = high right atrium.*

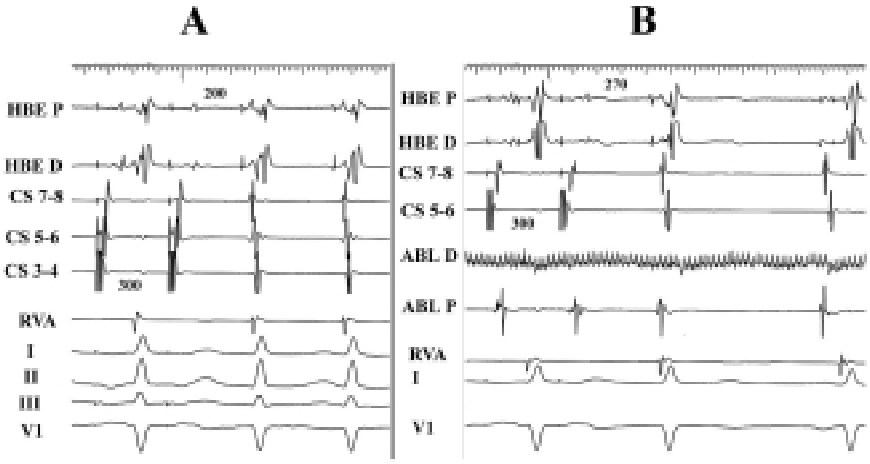

Figure 2. *Slow pathway modulation.* A: *atrial pacing at 600 ms from the coronary sinus. A premature beat with a coupling interval of 300 ms is conducted through the slow pathway with an AH interval of 200 ms and atrioventricular nodal reentrant tachycardia is induced.* B: *during ice mapping the atrial premature beat with a coupling interval of 300 ms is conducted through the slow pathway with a longer AH interval (270 ms). A single echo beat is present but no atrioventricular nodal reentrant tachycardia is induced. ABL = ablation catheter distal (D) and proximal (P); CS = coronary sinus proximal (7-8), mid (5-6) and distal (3-4); HBE = His bundle region distal (D) and proximal (P); RVA = right ventricular apex.*

An electrophysiological study was performed 30 min after the cryoablation in order to check effectiveness of the ablation. The stimulation protocol included one and two atrial extrastimuli, incremental atrial pacing up to 1:1 AV conduction and one ventricular extrastimulus. Isoproterenol infusion was used if, before ablation, the AVNRT was inducible only by means of the drug or in case of the persistence of slow pathway conduction with a single echo beat. This is the standard protocol that we use for AVNRT RF ablation.

Results

In 2 patients, AVNRT was not induced and neither was a clear or reproducible dual AV node physiology observed during the electrophysiological study; in these patients RF ablation was performed. The other 32 patients who underwent cryoablation had a dual AV nodal physiology either with (25 patients) or without (7 patients) AVNRT induction at baseline. In 7 patients, the AVNRT was induced only during isoproterenol infusion. In all cases, ice mapping was performed during atrial extrastimulus testing with a coupling interval critical for AVNRT induction and/or slow pathway conduction. Only in case of the disappearance of the slow pathway conduction or of its modification with no more than single echo beats during ice mapping, cryoablation was then carried out at the same site.

The ablation was successfully performed in 31 cases (97%) with a mean number of cryoablations of 2.6 ± 1.0. In 10 cases, a single cryoablation was performed, in 9 patients two cryoablations were needed and three or more in the others. An early recurrence (i.e. reinduction of the AVNRT within 30 min of the ablation) occurred in the 22 patients in whom more than one cryoablation was necessary. In 18 patients, the recurrence was observed within the first 5 min and only in 2 patients after 20 min. The mean number of ice mappings was 3.3 ± 1.1. In no case did a junctional rhythm develop. The ablation was effective when the slow pathway modification or ablation appeared within the first 40 s of the initiation of ice mapping. When this occurred during the subsequent 40 s, slow pathway conduction reappeared at least partially during the 30 min after the procedure and further cryoablations were needed.

In 2 cases a transient lengthening of the AH interval was observed during ice mapping at a midseptal site (just above the coronary sinus ostium); it occurred 10 and 18 s after a temperature of -20°C was reached. Complete recovery of the AH interval was achieved after rewarming, respectively 40 (Fig. 3) and 15 s after the interruption of ice mapping. No junctional rhythm was observed after rewarming. The cryoablation, preceded by ice mapping, was then successfully performed at adjacent sites located slightly more posteriorly. In no case was any modification of the AH interval observed during the cryoablation phase after noncomplicated ice mapping.

In 18 patients (58%) the ablation was successfully performed with a complete abolition of the slow pathway conduction, while in the other 13 (42%) a modulation of the slow pathway conduction was achieved.

The procedure was unsuccessful in a patient with mitral and aortic prostheses and an almost incessant AVNRT at 150 b/min. After one cryoapplication the slow pathway was modified. After 10 min the tachycardia was still inducible but at a lower heart rate (110 b/min). Two other cryoablations after 6 ice mappings were ineffective; the ablation was then successfully achieved by means of a single RF delivery performed in the same session.

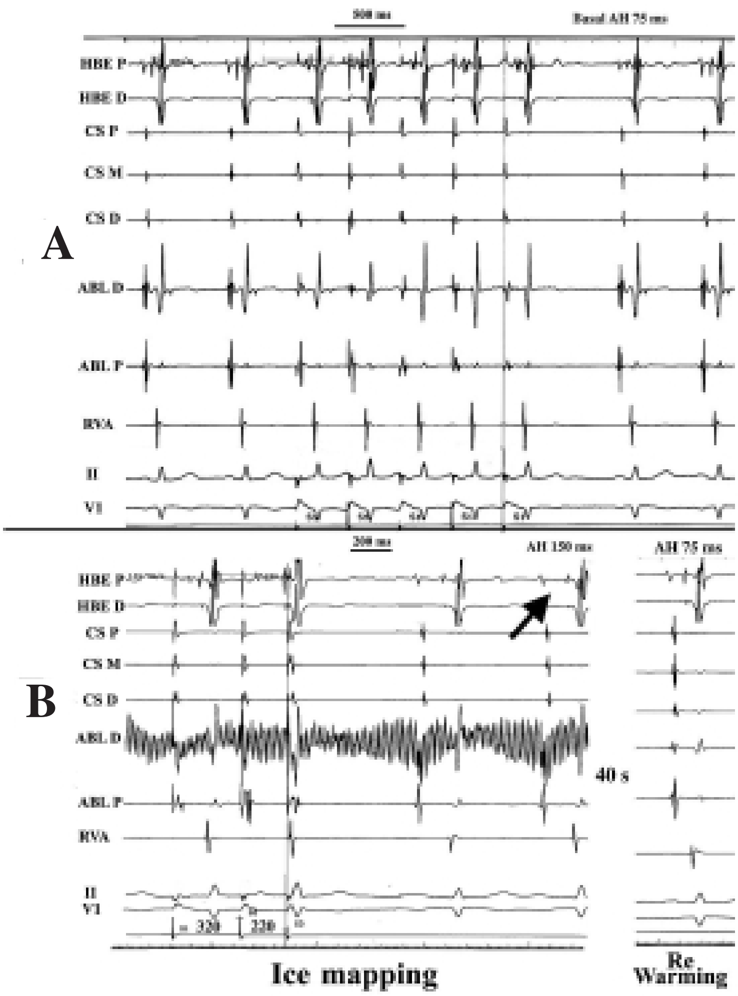

Figure 3. *Reversible electrical effect.* A: *endocardial recording at the ablation site with validation of the slow potential by means of atrial stimulation. The AH interval is 75 ms.* B left: *the second atrial premature beat delivered during ice mapping shows the abolition of the conduction through the slow pathway; however, the AH interval is prolonged to 150 ms due to a concomitant effect on the atrioventricular node* (arrow). B right: *after 40 s of rewarming the AH interval is back at the basal value of 75 ms. ABL = ablation catheter distal (D) and proximal (P); CS = coronary sinus distal (D), mid (M) and proximal (P); HBE = His bundle region distal (D) and proximal (P); RVA = right ventricular apex.*

No significant modification of the AH interval during sinus rhythm, either basal or during isoproterenol infusion, was observed in any patient at the end of the procedure. Similarly, the retrograde conduction through the fast pathway was unchanged after slow pathway ablation. In 2 patients presenting with retrograde dual nodal physiology, the retrograde conduction through the slow pathway as well as the anterograde one were abolished. No complication occurred in any patient; no pericardial effusion was observed at post-ablation echocardiography. No pain or other distress was observed during the cryoapplications.

Follow-up. During a mean follow-up of 10 ± 4 months, 3 patients out of the 31 with an acute successful ablation (9.7%) had an early recurrence of the arrhythmia (1, 6 and 30 days after the procedure). In one patient a complete ablation of the slow pathway was achieved following a single cryoablation, while in the other two, modulation of the slow pathway necessitated 3 and 5 cryoablations respectively. In the latter two, at the end of the procedure slow pathway conduction was still present but modified as demonstrated by the variation of its effective refractory period and by the marked lengthening of the AH interval during atrial extrastimuli conducted through the slow pathway. In these cases the AVNRT, easily inducible before the ablation, was no longer inducible at the end of the procedure even in case of isoproterenol infusion. All the 3 patients underwent a second session and the slow pathway was ablated using RF energy with no further recurrence observed during follow-up; we decided to resort to RF energy in view of the early experimental phase of the cryoablation technique.

No late impairment of the AV nodal conduction occurred in any patient. No significant differences in terms of the number of cryoablations which are related to early recurrences (within 30 min) and the absence or modification of the slow pathway conduction at the end of the procedure were observed between patients with successful ablation and patients with recurrences.

Discussion

Main findings. The main finding of the study is that cryoablation is a safe and effective technique for slow pathway ablation. The acute success rate is similar to the success rate observed following delivery of RF energy.

Radiofrequency and cryoenergy. RF catheter ablation has been developed in the last decade and nowadays it can be considered as the first line therapy for most arrhythmias. However, this type of energy has some limitations and disadvantages. In addition, its efficacy and safety when the ablation requires multiple RF deliveries to create long linear lesions or when RF applications must be performed within a venous structure such as the pulmonary veins or coronary sinus still have to be proven. In the former case the endocardial disruption may favor the occurrence of thromboembolism while in the latter, a risk of stenosis or thrombosis of the venous structure or of injury of the adjacent arterial vessel may be present. Recently, Sun et al.[18] showed that the risk of damaging the coronary arteries during RF ablation within the middle cardiac vein was 64% when the distance between the two structures was < 2 mm, which occurred in 62% of their cases. Moreover, the delivery of RF energy is difficult to titrate and this should be kept in mind when RF energy is applied at the septal region in cases in which it is highly desirable to be as selective as possible on the target site with no damage to the adjacent structures (AV node and His bundle).

Cryoenergy, on the other hand, is a well known source of energy utilized in order to modify the electrical properties of the myocardial structure. It has been widely used in the past for the surgical treatment of arrhythmias. Interest in this technique has recently been revived following the demonstration of the possibility of curing permanent atrial fibrillation in patients with associated valvular heart disease[10].

With cryoenergy the endocardial damage is absent or minimal with a very low thrombogenicity, the potential to create a transmural lesion is high and a perfect contact is not necessary due to the firm adhesion of the catheter tip to the tissue when the ice ball is formed[14]. Moreover, if applied in venous structures such as the coronary sinus, cryoenergy does not damage neither the veins nor the adjacent arterial vessel[19].

The possibility of predicting the acute effect of the ablation with ice mapping and to create a selective, well circumscribed and homogeneous lesion with cryoablation[15], further adds to the several advantages that this source of energy has in the field of ablation.

Ice mapping. The advantages of ice mapping are twofold. First, it allows one to avoid ineffective and useless lesions since ice mapping can guide the ablation only at effective sites, while with RF the lack of effect is evident only several seconds following the delivery when the lesion has been, at least partially, already created. Second, ice mapping allows a precise and definite mapping of the region, testing in advance the predicted effects, both wanted and undesired, of the lesion. This may be useful to further reduce the risk of AV block when the ablation is performed in the septal area. Moreover, the adhesion of the catheter to the tissue prevents any displacement of the catheter during creation of the lesion rendering fluoroscopy unnecessary. Besides, it allows for a more selective lesion than RF and this may be particularly useful in this region. However, although from the electrophysiological point of view the lesion is completely reversible, it cannot be excluded that minimal histological lesions may be related to ice mapping itself[11]. This obviously implies the importance of performing ice mapping in sites where the electrophysiological parameters suggest a positive effect.

Clinical results. Although the risk of AV block during slow pathway ablation is very low, 0.3-1.4% depending on the approach utilized[3-6], the occurrence of this complication may be very frustrating, in view of the young age of the patients and the benignity of the arrhythmia.

In our series slow pathway ablation was accomplished with a mean of about 2.5 freezes in 31 patients. In 2 cases an attempted ablation in a midseptal position of the triangle of Koch led to a transient impairment of the AV conduction during ice mapping. The prompt rewarming allowed a complete recovery of the AV node conduction and the ablation was then performed at an adjacent site after validation by means of ice mapping. In a previous study, using a 9F catheter Skanes et al.[13] reported the development of a junctional block after rewarming in 2 patients with a transient AV block. The reason for this phenomenon is not clear and may be secondary to a non-specific response of the AV node to transient "injury" or to the rewarming-related release of potassium or other substances that may induce the transient enhancement of automaticity in adjacent AV nodal cells[13]. In our experience a junctional rhythm did not develop. A possible explanation of the differences with what observed by Skanes et al.[13] may be a more limited transient damage of the AV node that occurred in our patients. Skanes et al. reported the occurrence of one 2:1 AV block and, in a second patient, a marked prolongation of the AH interval up to 300 ms; on the contrary, in this study we observed only a mild prolongation of the AH interval up to 150 ms (Fig. 3) and 140 ms, suggesting a possible lesser damage of the AV node.

The possibility of testing the potential lesion may be particularly important in case of patients with an abnormal AV nodal anatomy such as a posterior displacement of the fast pathway or of the AV node or a small space in the triangle of Koch between the His bundle region, the compact AV node and the coronary sinus ostium (Fig. 4), when the ablation must be performed in the midseptum or in case of previous ablation attempts or conduction disturbances over the fast pathway. In

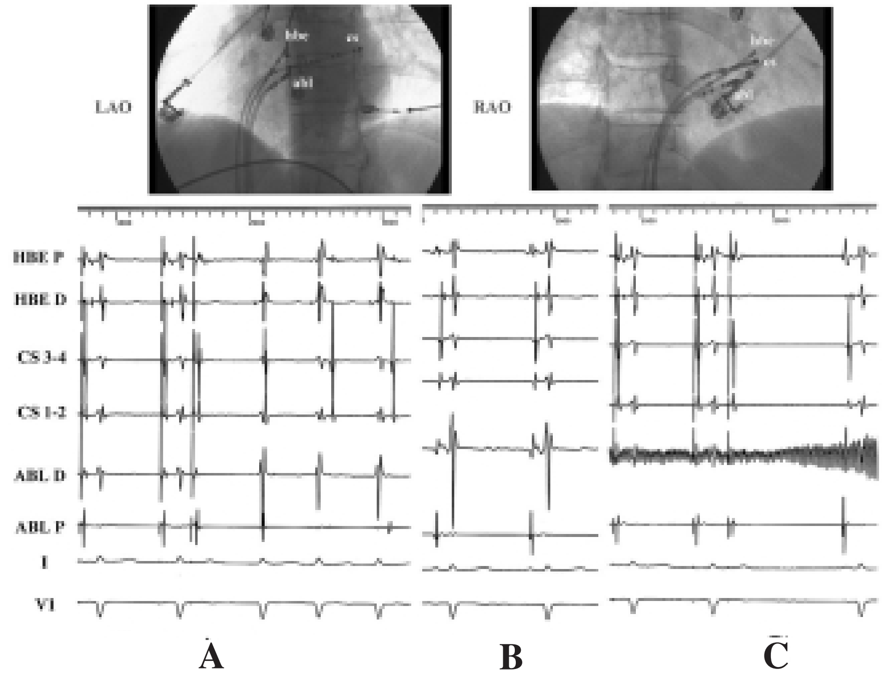

Figure 4. *Slow pathway ablation in a patient with an abnormal atrioventricular junction anatomy.* Top: *the fluoroscopic images in the left anterior (LAO) and right anterior (RAO) oblique views show the small space between the His bundle region and the coronary sinus ostium. The ablation catheter is positioned close to the catheter recording the His bundle.* A: *during coronary sinus pacing at 600 ms an atrial premature beat with a coupling interval of 260 ms is conducted through the slow pathway and it induces the atrioventricular nodal reentrant tachycardia.* B: *recording of the slow potential at the ablation site.* C: *during ice mapping, an atrial premature beat with a coupling interval of 270 ms is not conducted to the ventricle due to the conduction block through the slow pathway. ABL = ablation catheter distal (D) and proximal (P); CS = coronary sinus mid (3-4) and distal (1-2); HBE = His bundle region distal (D) and proximal (P).*

these subgroups of patients the risk of AV block is in fact higher when using RF energy, since the site of ablation is extremely close to the compact AV node. The same holds for an accessory pathway located in the septal region, particularly in the mid or anterior septum[20,21]. Moreover, the ice formation at the catheter tip determines the adhesion of the catheter to the adjacent tissue allowing various pacing maneuvers for the testing of the real electrophysiologic effect of the ablation both on the target as well as on the adjacent structures. Finally the lesion created is smaller and more homogeneous than the one observed following the delivery of RF energy[14,15].

Although no complications occurred in any patient, suggesting the safety of the cryoenergy, the results in terms of the acute success and of recurrences are still slightly inferior to what may be expected for RF energy and to our own results reported in a previous publication[6].

In our study, cryoablation was not effective in curing the AVNRT in one patient. The slow pathway conduction was modified as demonstrated by the variations in the heart rate during reinduction of the AVNRT. The reason for this unsuccessful ablation is unclear especially considering that the ablation was then performed using RF energy. However, it is noteworthy that in this case only 3 cryoablations were performed, with a total of 7 ice mappings (4 of which were ineffective) and even with RF a higher number of deliveries are sometimes necessary, since a larger lesion is needed. It is conceivable that the single RF energy completed the ablation partially achieved by means of cryoenergy and we wonder whether further cryoablations, that create smaller lesions than RF, might have produced the same results. On the other hand, we cannot exclude that the slow pathway region was deeper or that an abnormal anatomy due to atrial dilation or possible fibrosis secondary to the valvulopathy may have prevented us from reaching the selected temperature deep inside the atrial septum.

In 3 of our patients, a recurrence of the arrhythmia occurred. The percentage of recurrence is therefore higher than what is generally reported for slow pathway ablation with RF energy. It is hard to say if the relatively high rate of recurrences in this series may be ascribed to the learning curve phase and the small number of patients or to a possibly more limited lesion created by the cryoenergy that, following tissue healing in the early post-ablation phase, may have been further restricted in size. The lesion achieved by means of cryoenergy is more selective and localized than that achievable by means of RF[15]. Moreover, it must be borne in mind that the permanent lesion is achieved when the intracellular temperature is -21°C or lower[22]. These values are reached close to the tip of the cryocatheter; obviously, as the distance increases the intracellular temperature becomes progressively warmer and in certain areas exceeds -21°C. In these zones the tissue will partially heal; therefore, the effect may be only transient with the reappearance of the electrical function mimicking an ice mapping effect. This may explain the differences observed in the few cases included in the present study between the acute and long-term effects as shown by the number of recurrences.

A possible reduction in the recurrence rate might be achieved by creating a slightly more extensive lesion, more similar in size to those obtainable following the delivery of RF energy. In contrast to the latter, even so doing cryoenergy would still maintain its advantages in terms of safety considering the homogeneity of the lesion and the possibility of testing the acute effect thanks to ice mapping. Larger lesions may be obtained by further decreasing the temperature or by using larger cryocatheters, either in terms of the diameter of the shaft or of the tip (6 or 8 mm).

During RF delivery, the catheter is subject to slight movements (due to the heart beats and respiratory movements) that may increase the extension of the lesion. On the other hand, during cryoablation the catheter is very stable owing to the adhesion of the tip to the tissue. For this reason, the lesion is much more selective. Therefore, the ablation may be slightly more difficult to achieve but this minor disadvantage is compensated by the fact that the possible risk of AV block is reduced owing both to the limited size of the lesion as well as to the prevention of inadvertent catheter displacement.

Limitations of cryoablation. A limitation of cryoablation for the slow pathway ablation is the need of evidence of a dual AV node physiology and/or AVNRT induction during the procedure to test the real effect of both ice mapping and cryoablation. Although these two parameters are usually present in most of the patients with spontaneous episodes of AVNRT, in some cases these may be lacking. On the other hand, in these patients the presence of a junctional rhythm elicited by RF energy during ablation, but not by cryoenergy, cannot predict with certainty the effectiveness of the ablation since it is known that the junctional rhythm is a non-specific sign of thermal irritation of the compact AV node[23] and therefore it may be present even in case of unsuccessful RF ablation.

In conclusion, this study shows that percutaneous catheter ablation by means of cryoenergy is a feasible and effective technique. No complication occurred in this small series of patients. The results in terms of the success rate, considering the early phase of the technique, are good and similar to what reported for the widely used RF energy.

The advantages of cryoenergy, in particular the reversibility of the lesion during ice mapping, may be very useful in case of ablation performed in the septal area and in case of an anomalous anatomy since this technique is associated with a further reduction in the risk of AV block.

Therefore cryoenergy should be considered as a first line energy source in particular cases when a selective lesion is needed and when the risk of AV block is higher. These cases include ablation in children or in young patients and ablation in sites close to the AV node or His bundle such as the midseptum or parahissian accessory pathways. With regard to slow pathway ablation, this technique seems particularly useful in cases of an anomalous anatomy of the AV junction, in case of a small distance between the slow pathway and the fast pathway or a compact AV node and in case of previous unsuccessful ablation attempts or of conduction disturbances of the fast pathway.

Finally, considering the possibility of creating transmural lesions whilst preserving the endocardial integrity, thus reducing the risk of thromboembolism in case of extensive linear lesions in the left atrium and in view of the theoretical absence of the risk of venous stenosis, cryoenergy might have a useful and prominent role in the cure of atrial fibrillation. However, the efficacy and safety of this technique for these purposes are still to be proven.

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