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EP & Arrhythmia

Acute Outcomes for Cryoablation in Pediatric Patients with Perinodal Tachyarrhythmia: Single Center Report

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Background: Cryoablation is an alternative treatment for atrioventricular nodal reentrant tachycardia (AVNRT) and right anteroseptal and midseptal accessory pathways (APs) with a low complication rate. A high recurrence rate is still a concern in pediatric patients.

Methods: From February 2015 to March 2017, all consecutive patients who underwent cryoablation for supraventricular tachycardia were included in this study. The demographic and clinical data of the patients were reviewed.

Results: Fifty-two patients (AVNRT 43, anteroseptal and midseptal AP 9) were enrolled, including 24 males and 28 females. The median age at the time of the procedure was 15.6 years. For patients with AVNRT, 34 (79.1%) had the typical form, 5 had the atypical form (11.6%), and another 4 had both forms. For AP, four patients had right midseptal and 5 had right anteroseptal APs. The median total procedure time was 114 min (range 69-331 min), and the median fluoroscopy time was 25.9 min (range 9.2-99.6 min). After a median 6 attempts of cryomapping and 3 of cryoablation, the arrhythmia substrate was successfully ablated in 51 of 52 patients (98.1%). Ten developed transient second degree atrioventricular (AV) block and one developed transient third degree AV block, but none had permanent AV block or other complications. After a mean follow-up of 1.95 $\pm$ 0.54 years (range 1.1-2.86 years), there were three cases of recurrence (5.9%). The mean number of cryoablations decreased from 6.6 $\pm$ 6.4 (early group) to 3.1 $\pm$ 2.6 (late group) (p = 0.01) after a 1-year learning period.

Conclusions: Cryoablation for AVNRT and anteroseptal and midseptal APs in pediatric and adolescent patients is safe and effective.

Key Words: Atrioventricular nodal reentry tachycardia • Cryoablation • Learning curve • Perinodal accessory pathway • Wolff-Parkinson-White syndrome

INTRODUCTION

Over the last two decades, radiofrequency catheter ablation (RFCA) has become the mainstay therapy for supraventricular tachycardia, and the success rates are high even in young children.[1-3] However, for atrioventricular nodal reentry tachycardia (AVNRT), anteroseptal and midseptal accessory pathway (AP)-related atrioventricular reentry tachycardia (AVRT), a small but definite risk of damage to the atrioventricular (AV) node has been described with an incidence of permanent AV block of about 1-10%.[4,5] In children, because the size of Koch's triangle is small, the risk of AV nodal injury is even higher. Cryoenergy has been available as an alternative source of energy to RFCA for catheter ablations since 2003.[6,7] Cryoablation can overcome this complication due to the characteristics of the reversibility of tissue damage after

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energy withdrawal. Recent studies have reported a success rate of 76-100% without complications of permanent AV block. However, the recurrence rate of cryoablation has consistently been reported to be higher than that of RFCA.[6-16] Considering the age-related differences in the dimension and vicinity of perinodal structures, cryoablation appears to be a safer and more suitable alternative treatment for AVNRT, anteroseptal and midseptal APs than RFCA in children.

In Taiwan, RFCA is still the mainstay treatment modality for AVNRT, anteroseptal and midseptal APs, however there are currently no reports about cryoablation. This study presents our initial results of cryoablation in pediatric patients.

METHODS

Patient population

All patients who underwent cryoablation for AVNRT, anteroseptal and midseptal APs in the pediatric department of National Taiwan University Children's Hospital from February 2015 to March 2017 were enrolled. The study was approved by the Institutional Review Board of our hospital, and the requirement for informed consent was waived. The demographic and clinical data of the patients were reviewed. In this study, we also reviewed our learning curve for cryoablation of AVNRT over a 25-month period. The early group was defined as the first 12 months of procedures (February 2015-January 2016, n = 26) and the late group thereafter (February 2016-March 2017, n = 26).

Basic electrophysiological study

Written informed consents were obtained from the patients or parents before all procedures. All antiarrhythmic agents were discontinued for 3 days, except for beta-blockers. Intravenous sedation with propofol (Recofol®, Bayer Schering, Finland) was given during the electrophysiological study (EPS) and ablation procedure, and blood pressure was monitored from the femoral artery. In the mapping procedure, one quadripolar fixed catheter (Inquiry™ 4 F or 5 F Fixed Diagnostic Catheter, Irvine Biomedical Inc., St Jude Medical Co.) was placed in the high right atrium, and one steerable decapolar mapping catheter (Livewire™ Steerable Catheters, Irvine Biomedical Inc., St Jude Medical Co. or Epstar CS-Low steerable type, Japan Lifeline Co. Ltd) was placed into the coronary sinus. A 4 or 5 F multipolar catheter (EPstar His-RV Fixed, Japan Lifeline Co. Ltd or Inquiry™ Steerable Diagnostic Catheter, Irvine Biomedical Inc., St Jude Medical Co.) was placed into the right ventricle and recorded both the His bundle and the right ventricle apex signals (Figure 1). An EPS was performed to test for AVRT and AVNRT induction in each patient. Standard protocols for atrial and ventricular extrastimulus testing including single, double and triple were performed. If reentrant tachycardia was not induced in the baseline state, an infusion of isoproterenol (0.005 to 0.02 g/kg/min) was used. Standard protocols were applied. The mechanism of the tachycardia and the ablation target site were confirmed using standard burst pacing or extrastimulation pacing maneuver and via standard atrioventricular ring mapping techniques in all patients. The diagnoses of AVNRT, anteroseptal and midseptal Aps were made using standard criteria.[1-3,7]

Cryoablation

After confirming the diagnosis and determining the inducibility of AVNRT or AVRT, a 4-mm, 6-mm or 8-mm cryoablation catheter (CryoConsole, Freezor, Freezor Xtra, Freezor Max CryoCath Technologies Inc., Montreal, Canada) was inserted from the femoral vein through a 7-, 8- or 10-Fr short sheath. For AVNRT, the initial application site was identified using an anatomical-based approach. The target site was the slow pathway, and the tip of the cryoablation catheter was placed in the lower third of Koch's triangle using fluoroscopic guidance. The AV junction of the septal cusp, extending from the coronary sinus ostium to the most proximal His bundle recording site, was divided into posterior, middle and anterior regions according to the study by Jazayeri and colleagus.[16] For anteroseptal or midseptal AP, sites for cryoablation were identified using established methods for localizing atrial and ventricular insertions.[18]

AVNRT ablation

We used a posterior approach first during the initial cryomapping. Cryomapping was carried out at any potential ablation site to test the electrophysiological effect using programmed electrical stimulation to see if dual AV nodal physiology persisted and AVNRT was still

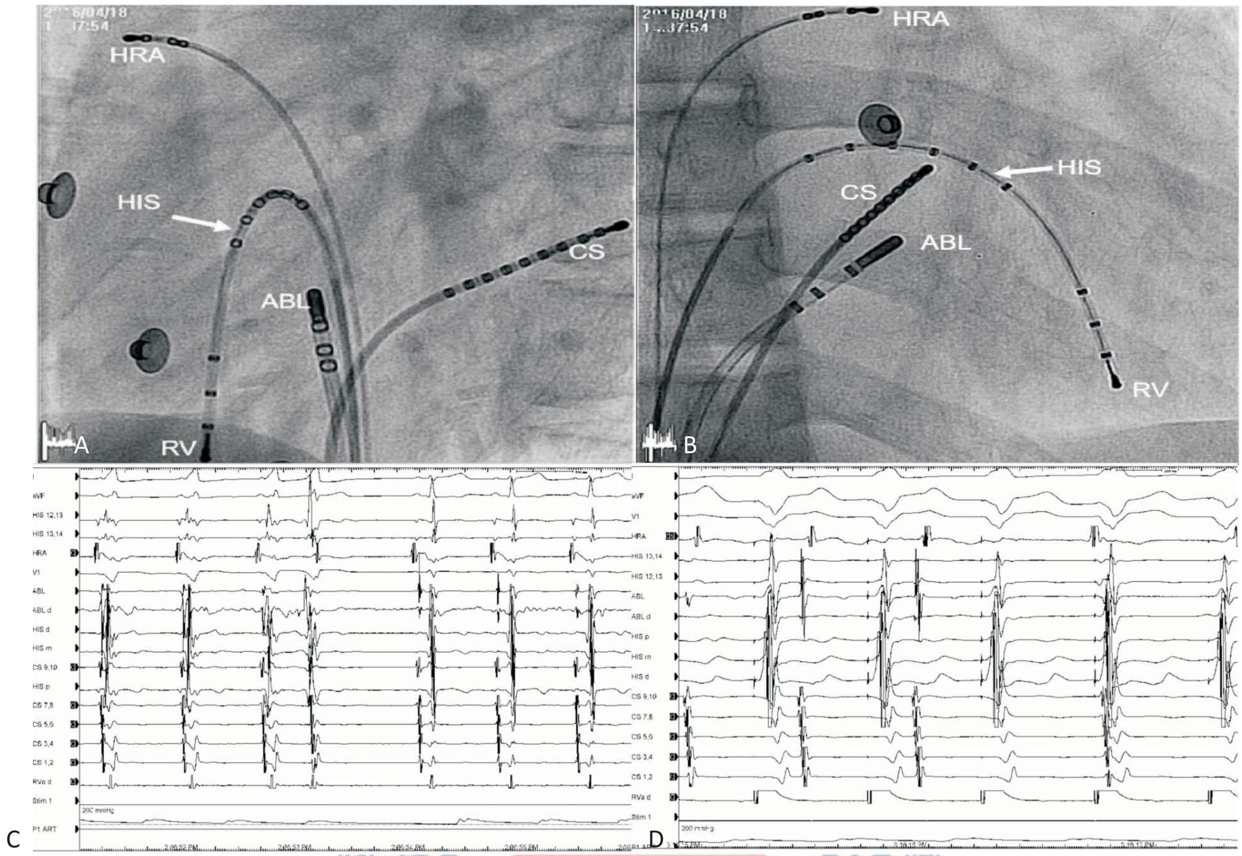

Figure 1. *Fluoroscopic images in the left anterior oblique view (A) and in the right anterior oblique view (B) in a 16-year-old patient with WPW syndrome with right mid-septal accessory pathway. The RV-His catheter showed the His signal was most prominent at the arrowhead site. We mapped the right atrioventricular ring and showed the AV and VA fusion at the right mid-septal area site as A&B. After cryomapping (-30 °C) on for 5 seconds, the accessory pathway disappeared (C). RV pacing revealed VA block after cryoablation (D). ABL, cryoablation catheter; AV, atrioventricular; CS, coronary sinus; HIS, his bundle; HRA, high right atrium; LAO, left anterior oblique; RAO, right anterior oblique; RV, right ventricle; VA, ventriculoatrial.*

inducible. The temperature of cryomapping was set at -30 °C to -40 °C when using a 4-mm or 6-mm-tip catheter. If no effect was noted within 30~45 seconds, cryomapping was discontinued, and we tried another target. If an 8-mm-tip catheter was used, we used short duration cryoablation as the cryomapping mode.[19] We also identified whether there was any evidence of fast pathway damage as AV block or prolongation of the AV interval through continually monitoring the atrial-His (AH) interval. If AV block or significant prolongation of AH interval was demonstrated, the ablation was immediately stopped. If the target slow pathway was successfully eliminated without fast AV nodal pathway damage, we then shifted to cryoablation with freezing at -70 °C to -80 °C for 4 minutes. The cryoablation technique with a "freeze-thaw-freeze" approach was performed. If the target slow pathway still existed, we tried a more anterior site. Booster cryoablation lesions were positioned in a linear fashion at the same level.

Anteroseptal or midseptal AVRT ablation

We mapped the tricuspid ring and observed the AV or ventriculoatrial (VA) fusion during sinus rhythm or right ventricle pacing. For the manifest accessory pathway, we monitored the subsidence of the delta wave at sinus rhythm during cryomapping (Figure 2). If the delta wave was successfully eliminated during cryomapping, we then shifted to cryoablation with freezing at -70 °C to -80 °C for 4 minutes. Booster cryoablation lesions were positioned at the same site. If the delta wave still existed, we then remapped the tricuspid ring to see if there was another site with better AV fusion or VA fusion by right ventricle pacing. For the concealed AP, we monitored the subsidence of AP retrograde conduction

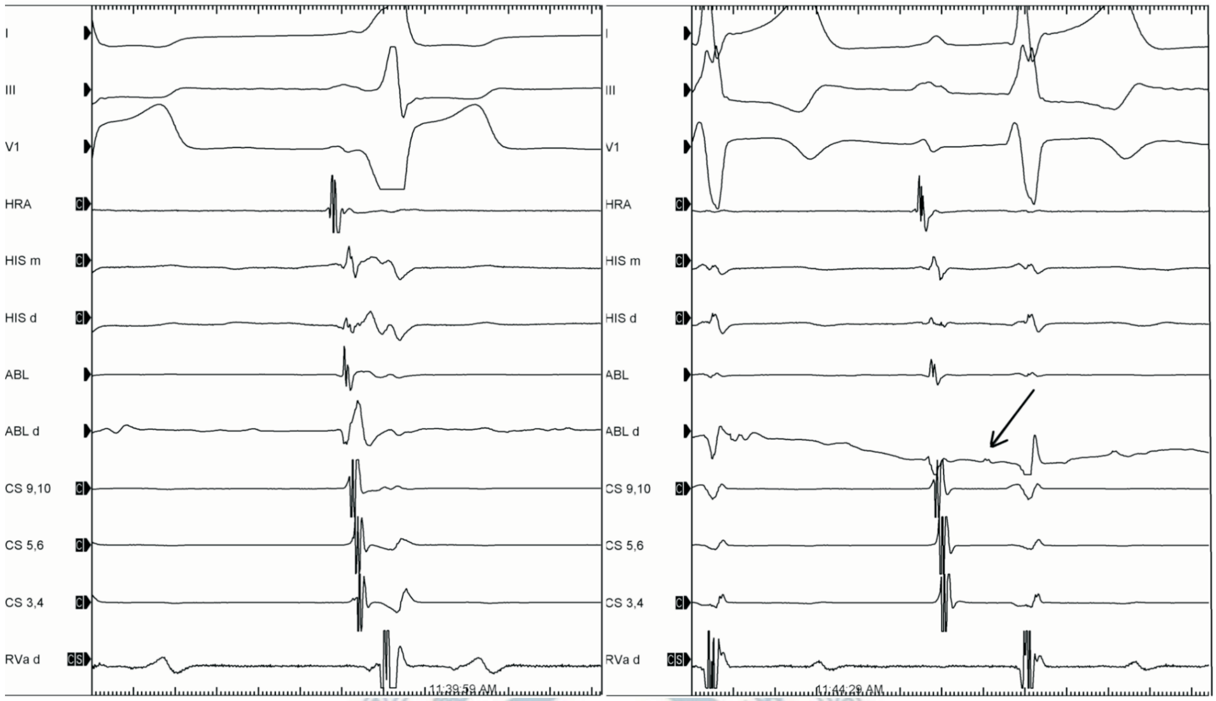

Figure 2. *A 15-year-old male patient had WPW syndrome with right anterior septal accessory pathway. Before cryoablation, atrioventricular fusion signal was recorded at left panel. After successful cryoablation, delta wave disappeared with His potential signal recorded at right panel. (The arrow point).*

via right ventricle pacing during cryomapping. If the AP was successfully eliminated, we then stopped pacing, checked for any evidence of AV node damage, and shifted to cryoablation with freezing at -70 °C to -80 °C for 4 minutes. Booster cryoablation lesions were also positioned at the same site.

Procedural success

After successful cryoablation, a repeated EPS was performed, both at baseline and during isoproterenol infusion, after a waiting period of 30 minutes. Procedural success or an acceptable endpoint was defined as a lack of tachycardia induction. For AVNRT, elimination of the slow pathway (SP) without AVN echo beat was regarded as procedural success. However, if repeated ablation failed to eliminate SP but was associated with repeated transient AV block during ablation or after a prolonged procedure of more than 6 hours, residual SP with single AVN echo was regarded to be an acceptable endpoint. For AVRT, procedural success was defined as the loss of AP conduction, both antegrade and retrograde. We routinely used the adenosine test (rapidly administer 2 mg/kg of adenosine intravenously) to document successful delta wave ablation in the EP laboratory. The type of AV block, related to either catheter trauma or a cryoablation lesion, length of time to resolution, and any therapies utilized were recorded.

Statistical analysis

For comparative analysis, considering the small number of cases, non-parametric statistics were used. Categorical variables were compared using the chi-square test, and the Mann-Whitney U test was used for continuous data. Clinical significance was defined as $p < 0.05$. Descriptive data are presented as mean ± SD or median (range). Statistical analysis was performed using commercially available software (SPSS Version 12).

RESULTS

Basic demographic and electrophysiological data

Fifty-two patients (median age: 15.6 years) were enrolled. All patients had symptomatic supraventricular (SVT) clinically. Twenty-four (46.2 %) of the patients had received EPS before for AVNRT, anteroseptal and midseptal APs, but only one patient had undergone prior ablation in consideration of the risk of AV block. The basic demographic data are shown in Table 1. Three patients (5.8%) had concomitant congenital heart disease: one had a small ventricular septal defect (unrepaired) and the other two had a small ostium secundum type atrial septal defect (unrepaired).

Forty-three patients had AVNRT [one had concomitant Wolff-Parkinson-White Syndrome (WPW) with right lateral AP, and the other had concealed left lateral AP], and 9 had anteroseptal or midseptal AP-related AVRT. During the EPS, SVT was inducible at baseline in 26 (50%) patients, and after isoproterenol infusion in another 19 (36.5%) patients, which was sustained in 42 patients (80.8%) and not sustained in 3. No SVT was induced in 7 patients [but 5 patients with AVNRT had documented SVT in surface electrocardiography (ECG) with a slow pathway identified during EPS, and another 2 had WPW in surface ECG with previously documented SVT]. With regards to AVNRT, 34 (79.1%) had the typical form, 5 (11.6%) had the atypical form, and another 4 (9.3%) had a combination of both forms. Typical AVNRT with 2:1 AV conduction was demonstrated in 4 (9.3%) of these 43 patients. Among the patients with anteroseptal or midseptal AP-related AVRT, manifest AP presented in 4 patients and concealed AP was noted in 5. All inducible tachyarrhythmias were orthodromic AVRT.

The median fluoroscopy time was 25.9 minutes, and the median total procedure time was 114 minutes. The cryocatheter tip size was 4 mm in 3 patients, 6 mm in 32 patients, and 8 mm in 17 patients. The median number of cryoablation lesions was 3 (1-21), and the median number of cryomapping lesions was 6 (1-38). The median number of cryoablations was 1 in the anteroseptal or midseptal AP group, which was significantly lower than that in the AVNRT group (p = 0.01). The procedure time in the anteroseptal or midseptal AP group was also significantly lower than that in the AVNRT group (p = 0.032).

Procedural success was achieved in 51 of the 52 (98.1%) patients. For the 42 patients with AVNRT procedural success, a complete loss of slow pathway conduction without AVNRT was identified in 35 patients. AH jump without an AVN echo beat was observed in 3 patients, and AH jump with a single AVN echo beat was induced in the post-ablation EPS in 4 patients. The successful ablation sites of SP in 42 patients included posterior regions in 13 patients, medial regions in 27 patients, and anterior regions in 2 patients according to Jazayeri MR Classification.[16] For septal AP, the successful ablation sites of AP were right anteroseptal in 5 and right midseptal in 4.

Table 1. Comparison of basic clinical characteristic between early group (n = 26) and late group (n = 26) of patients receiving cryoablation

	Early group (n = 26)	Late group (n = 26)	p value
Mean age (years)	16.8 ± 6.3	15.2 ± 4.2	0.31
Female, n (%)	14 (53.8)	14 (53.8)	1
Mean weight (kg)	55.79 ± 14.2	53.6 ± 14.5	0.58
CHD, n (%)	2 (7.7)	1 (0.8)	0.55
Pre-AAD, n (%)	18 (69.2)	18 (69.2)	1
pre-EPS, n (%)	14	10	0.27
AVNRT, n (%)	22 (84.6)	21 (80.8)	0.71
AP, n (%)	4 (15.4)	5 (19.2)	0.71

AP, accessory pathway; AVNRT, atrioventricular nodal reentry tachycardia; CHD, congenital heart disease; n, patient number; Pre-AAD, previous antiarrhythmic; Pre-EPS, previous electrophysiological study.

The only patients who failed the procedure was a 19-year-old male with initial atypical AVNRT (fast-slow) induced by atrial and ventricular extrastimulation. After a prolonged procedure (345 minutes) with 9 cryoablations, sustained SVT was no longer induced. However, another non-sustained tachycardia (slow-fast AVNRT) was induced during isoproterenol infusion. He was subsequently scheduled to receive further ablation.

Complications

No patients had permanent complications during or after the procedure. Twelve patients had transient impairment of AV conduction (23.1%). One patient had first degree AV block, 10 had second degree AV block, and the other patient with right mid-septal AP had transient third degree AV block during cryoablation (Figure 3). All of these AV blocks resolved within 10 seconds after the cessation of ablation with normal AV conduction thereafter. None of them had permanent AV block or other complications. In the 12 patients with transient AV block, 2 had AP-related AVRT (both in the right midseptal area) and 10 had AVNRT (anterior regions in one, medial regions in 4, and posterior regions in 5). No th-

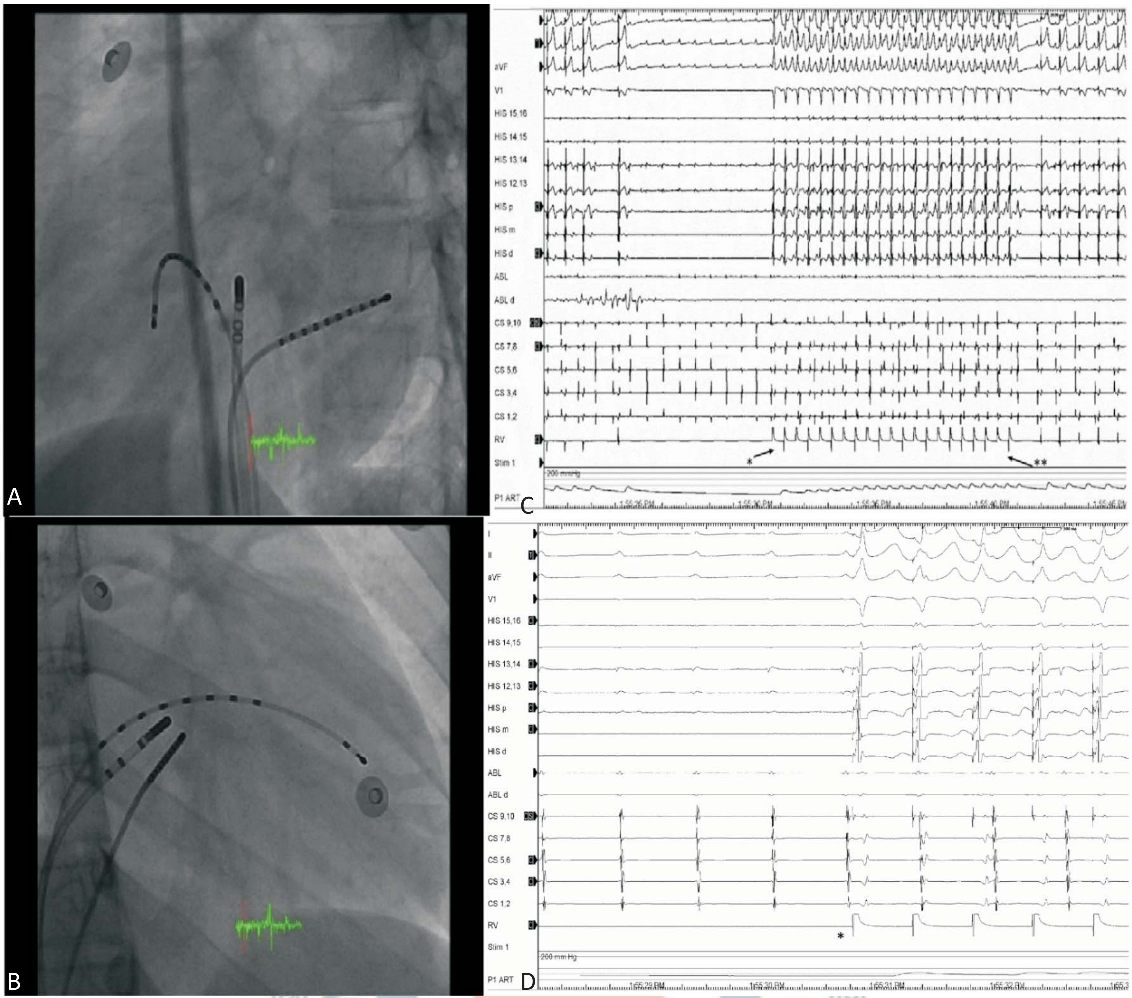

Figure 3. *Transient complete atrioventricular block occurred in cryoablation. Fluoroscopic images in the left anterior oblique view (A) and in the right anterior oblique view (B) in a 13-year-old patient with WPW syndrome with right midseptal accessory pathway. We mapped the right atrioventricular ring and showed the AV and VA fusion at the right midseptal area site as A&B. After cryoablation, the AP was successfully eliminated. However, when we booster cryoenergy at the same location, transient complete atrioventricular block occurred and recovered to sinus rhythm 10 seconds later (C). A bigger size which clearly presented the complete atrioventricular block and right ventricular pacing with ventriculoatrial dissociation (D). (* Right ventricle apex pacing began, ** Termination of right ventricle pacing and recovery to sinus rhythm).*

romboembolic events, cardiac perforation, or coronary artery injuries were recorded.

Recurrence

After a mean follow-up of 1.95 $\pm$ 0.54 years (range 1.1-2.86 years), three patients had SVT recurrences (5.9%). The first patient was an 18-year-old male patient with both the slow-fast and fast-slow forms of AVNRT. The successful ablation site of the slow pathway was a medial region. After ablation, no AVNRT was induced, but there was residual AH jump without an AV nodal echo beat. SVT recurred presenting as palpitation 1 month after ablation. He is currently receiving oral medications for SVT control. The second patient was a 12-year-old female. The successful ablation site of the slow pathway was a posterior region. After ablation, AVNRT was not induced, but there was neither residual AH jump nor echo beat. SVT recurred also presenting as palpitation 1 month after ablation. She underwent a second cryoablation procedure which successfully eliminated the slow pathway three months later. The third patient was a 13-year-old female with WPW and a midseptal accessory pathway. Cryoablation was successful in the first few seconds, and we completed cryoablation for 4 minutes.

However, after giving booster energy in the same location, transient complete AV block occurred (Figure 3C). We terminated the procedure immediately, and no delta wave resumed. Unfortunately, a delta wave was recorded in surface electrography 1 year later, although no supraventricular tachycardia was documented. We performed another EPS and only antegrade recurrence was found. We performed another cryoablation successfully.

Learning curve analysis

There were no significant differences in demographic data including gender, age and body weight between the early and late groups (Table 1). Acute success was achieved in 96.1% of the early group and 100% of the late group. The mean number of cryoablations decreased from 6.6 ± 6.4 (early group) to 3.1 ± 2.6 (late group). The mean fluoroscopy time also decreased from 32.7 ± 21.4 minutes to 24.5 ± 13.2 minutes. The fluoroscopy time, procedure time, transient AV block and mean number of cryomapping procedures all reduced in the late group, but only the number of cryoablations reached statistical significance (p = 0.01). The recurrence rate was similar between the early and late groups, with 2 in early and 1 in late group (Table 2).

The successful region of cryoablation notably differed between the early and late groups in our study. With regards to radiofrequency ablation, the initial target site often began from the posterior region of the triangle of Koch and progressed anteriorly. We also started the cryomapping point from the posterior region initially. Our data showed that 57.1% of the initial cryomapping points were in posterior regions, and 42.3% were in medial regions in the early group (Table 3). The strategy of cryomapping points was modified in the late group, and only 9.5% of the initial cryomapping points were in posterior regions and 71.4% were started at medial regions in the late group (p = 0.003). Overall, 10 patients (47.6%) in the early group and 4 patients (19%) in the late group had to change the ablation region in order to achieve successful ablation. The most successful site was located in medial regions in both groups (Table 3). This finding is discussed further in the discussion section.

DISCUSSION

Cryoablation outcomes

The initial outcome of our study for cryoablation of

Table 2. Comparison of early group (n = 26) and late group (n = 26) of patients receiving cryoablation

	Early group (n = 26)	Late group (n = 26)	p value
Fluoroscopy time (minutes)	32.7 ± 21.4	24.5 ± 13.2	0.1
Procedure time (minutes)	160.9 ± 73.1	140.3 ± 66.1	0.29
No of cryomapping	9.9 ± 10.8	8.9 ± 6.3	0.68
No of cryoablation	6.6 ± 6.4	3.1 ± 2.6	0.01
Acute success	25 (96.1)	26 (100)	1
Transient AVB	8 (30.7%)	4 (15.3%)	0.32
First degree AVB	1	0	
Second degree AVB	6	4	
Complete AVB	1	0	
Permanent AVB	0	0	1
Recurrence	2 (8%)	1 (3.84%)	0.61

AVB, atrioventricular block.

Table 3. The initial and successful region of cryomapping for the atrioventricular nodal reentry tachycardia in early and late group

	Early group (N = 21)	Late group (N = 21)	p value
Initial target region			0.003
Posterior region	12 (57.1%)	2 (9.5%)	
Medial region	9 (42.3%)	17 (81%)	
Anterior region	0	2 (9.5%)	
Success site			0.232
Posterior region	9 (42.3%)	4 (19%)	
Medial region	10 (47.6%)	15 (71.4%)	
Anterior region	2 (9.5%)	2 (9.5%)	
Need to change region to achieve successful ablation			0.05
Total	10 (47.6%)	4 (19%)	
Poster region to other region	7 (33.3%)	1 (4.8%)	
Medial region to other region	3 (14.3%)	1 (4.8%)	
Anterior region to other region	0	2 (9.5%)	

AVNRT and anteroseptal or midseptal APs was satisfactory and achieved an acute success rate of 98.1%. In previous reports, the initial procedural success rates of cryoablation for AVRNT and anteroseptal or midseptal AP were 91% (range 83-97%) and 78% (70-87%), which were significantly lower than the results of RFCA.[6-10,17,18,20,21] In the past decade, several methods have been developed to improve the success rate and decrease the recurrence rate of cryoablation. These include increasing the duration of cryoablation, using a large cryocatheter tip size,[15-20] delivering several extra lesions near the successful site (Triple Freeze-Thaw cycles),[11] and the linear lesion method.[21] The success rate and recurrence rate have greatly improved using these new methods, and according to current literature, the acute success rates of cryoablation for AVRNT and anteroseptal or midseptal AP were 95% (range 85-99%) and 90.9% (range 78-98%) respectively, in children and adolescents.[10-21] In the present study, using cryoablation with the freeze-thaw-freeze method (4 minutes for each lesion) and linear lesions, we achieved an acute success rate of 98.1%, which is similar to previous studies, and almost equal to that of using RFCA in our institution.[11-15,17-21] With more experience, the results may improve further.

No patients had permanent complications during or after the procedure in this study. Only one patient had transient third degree AV block which immediately recovered after stopping ablation with normal AV conduction thereafter. Complete AV block is a potentially severe complication while using RFCA for AVNRT or anteroseptal or midseptal AP. The incidence of permanent complete AV block has been reported to be 1-2% in AVNRT and 2-10% in anteroseptal or midseptal AP.[4,5,18] Cryoablation has overcome this problem. The reasons for the low incidence of AV block when using the cryoablation method include reversible lesions during the cryomapping procedure before the production of a permanent lesion, adherence of the cryocatheter tip to the myocardial tissue upon ice formation which avoids movement of the catheter, production of a homogeneous lesion, and increased safety around surrounding vasculatures. To the best of our knowledge after reviewing published studies,[6-21] no case has developed complete AV block requiring pacemaker implantation after cryoablation. In the present study, there were also no cases of permanent AV block after cryoablation. Because of its high safety, cryoablation should be the first choice of treatment for AVNRT and anteroseptal or midseptal AP in children in Taiwan.

Catheter size choice

With regards to the choice of catheter, previous reports have suggested that an 8-mm tip has a lower recurrence rate than 6-mm-tip catheters.[20] Therefore, we used an 8-mm-tip cryocatheter to treat tachyarrhythmia initially. However, the large electrode tips of 8-mm catheters are stiffer than 6-mm catheters, and movement of the catheter to the target site is sometimes limited. Catheter stiffness and “memory” are distinctly associated with cryoablation catheters and the range of catheter selection is limited.[9-13]

Qureshi et al.[11] also described that stiff 8-mm-tip catheters were difficult to manipulate and often needed a long sheath to change catheter direction and operate safely in the triangle of Koch to avoid traumatic injury to the conduction system. Therefore, we used both 6-mm and 8-mm-tip cryocatheters according to the size of the patients. The appropriate choice of catheter size in the cryoablation of children and adolescents may need further study.

Ablation endpoint

Previous studies have reported a recurrence rate of cryoablation of 11% (range 2-19.7%), which is significantly higher than that of RFCA (3% to 5%).[6-15,17-23] The selection of the ablation endpoint may influence the recurrence rate, however the best endpoint is still controversial in cryoablation. Residual AH jump with or without an AVN echo beat has been associated with a high recurrence rate in recent studies, implying that complete elimination of SP conduction is distinctly better.[12,17] However, no randomized controlled studies have compared acute and chronic results and complication rates using different endpoints.[6-15] In our study, we used a stricter endpoint, i.e. elimination of SP completely if no transient AV block or prolonged procedure time was achieved. However, in some cases it was not easy to achieve the goal without damage to the fast pathway even when we ablated different target sites. In our study, residual AH jump could still be induced in 7 patients (16.7%) after cryoablation of AVNRT. Although the follow-up time was not long in this study, only three patients had recurrence (5.8%), one of the two AVNRT patients had residual jump after cryoablation. Another one had incomplete cryoablation for a midseptal accessory pathway, due to transient AV block. Therefore, the proper endpoint for cryoablation needs further evaluation.

Learning curve

The purpose of this study was to define the learning curve for cryoablation. Although the reductions in fluoroscopy time, procedure time, and transient AV block were not clinically significant, we were able to demonstrate a significant reduction in the mean number of cryoablations after the learning curve (p = 0.01). This reduction was related to improvements in manipulating the cryocatheter and averting the possibility of AV block. With more experience, transient AV block, procedure times and fluoroscopy time may be further decreased.

In our hospital, the ablation strategy for cryoablation of AVNRT changed from an initial target site in the posterior region in the early group to the medial region in the late group (Figure 4). In conventional radiofrequency ablation, the initial target site often begins from the posterior region of the triangle of Koch and progresses anteriorly. However, in our initial experience (as seen in the early group), cryoablation of the posterior region had a high failure rate. The most common site of success was in medial regions in both groups, so we changed the initial target site to the medial region (as seen in the late group). After changing policy, the percentage of those needing to change ablation region for successful ablation decreased significantly (from 47.6% to 19%). We think that these steps improved the success rate and shortened the procedure time.

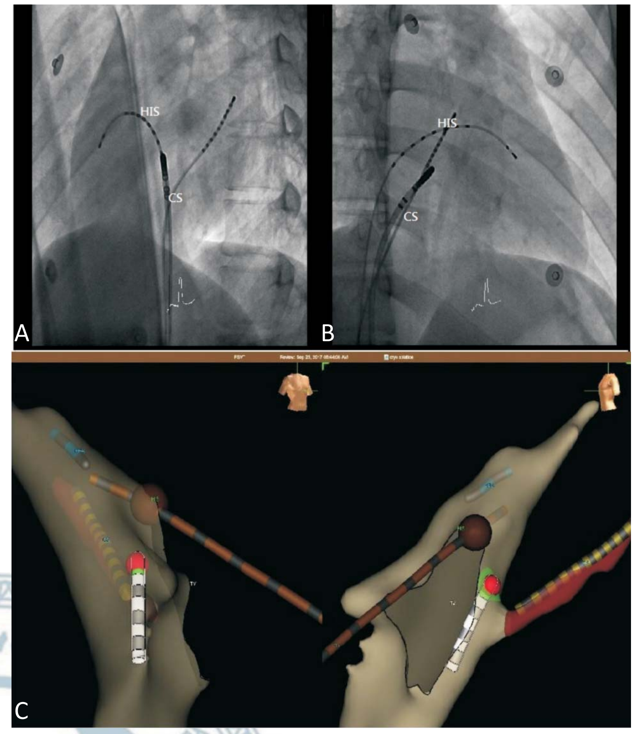

Figure 4. *Fluoroscopic images in LAO 60° (A), in RAO 30° (B), and a single biplane image by EnSiteNavX™ mapping system in RAO 30° and LAO 60° views (C). The anatomical location of the successful site for cryoablation was usual above the level of the roof of the coronary sinus (medial site). The red sphere marks the successful lesion, with the brown spheres marking the location of His bundle. CS, coronary sinus; HIS, His bundle; LAO, left anterior oblique view; RAO, right anterior oblique view.*

Study limitations

A major limitation of this study is the relatively short follow-up period. However, in previous studies, most cases of recurrence developed within 6 months, which is within our follow-up period. Another limitation of the study is the heterogeneity in catheter tip size. A unified protocol with a multicenter study with long-term follow-up is required to elucidate the most suitable size of catheter for Asian children.

CONCLUSIONS

Cryoablation for the treatment for AVNRT and anteroseptal or midseptal AP in pediatric and adolescent patients is safe and efficacious, and should be used as a first-line therapy in these patients.

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DECLARATION OF CONFLICT OF INTEREST

All the authors declare no conflict of interest.

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