

Experience on the Invasive Treatment of Supraventricular Tachycardia and Accessory Pathways in Pediatric Patients

Experiencia en el abordaje invasivo de las taquicardias supraventriculares y vías accesorias en pediatría

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ABSTRACT

Background: Supraventricular tachycardia secondary to accessory pathways is the most prevalent symptomatic tachyarrhythmia in pediatric patients and its invasive approach is consistently growing.

Objectives: The aim of this study was to evaluate the experience of surgical treatment of supraventricular tachycardia in pediatric patients.

Methods: This was a retrospective cohort study including patients below 18 years of age undergoing electrophysiological study and radiofrequency ablation of supraventricular tachycardia and accessory pathways. Types of substrate, accessory pathway location, presence of congenital heart disease, results, procedure complications and recurrence during follow-up were analyzed.

Results: A total of 416 patients were identified. Average age was 13 years (range 2-18) and 275 were male patients (67%). Twenty patients (5%) had congenital heart disease, 286 (69%) accessory pathways and 130 (31%) other mechanisms of supraventricular tachycardia, including double nodal physiology in 109 patients (26%), ectopic atrial tachycardia in 14 (3%) and atrial flutter in 7 (2%). The efficacy in accessory pathway ablation was 94.7%. Six patients (1.4%) presented with complications: one had a stroke, one complete atrioventricular block, one femoral artery thrombosis and 3 mild pericardial effusion. Accessory pathways recurred in 26 patients (9.8%). One hundred percent efficacy was observed in double nodal physiology with recurrence in 2 patients. (3.2%) Efficacy in atrial tachycardia treatment was 86% and recurrence occurred in 2 patients (14.2%) without complications. Atrial flutter ablation was successful and without complications. No recurrences were observed during an average 67-month follow-up period (range 2-114).

Conclusions: Surgical treatment of supraventricular tachycardia in pediatric patients is an effective and safe therapeutic tool with a low rate of complications and recurrence during follow-up.

Key words: Tachycardia, Supraventricular - Catheter Ablation - Accessory Atrioventricular Bundle.

RESUMEN

Introducción: La taquicardia supraventricular, secundaria a la presencia de vías accesorias, es la taquiarritmia sintomática más frecuente en pediatría. Su abordaje invasivo en pediatría está en creciente desarrollo.

Objetivos: Evaluar la experiencia en el tratamiento invasivo de las taquicardias supraventriculares en pacientes pediátricos.

Materiales y métodos: Estudio retrospectivo de cohortes que incluyó pacientes menores de 18 años, sometidos a un estudio electrofisiológico y ablación por radiofrecuencia de taquicardias supraventriculares y vías accesorias. Se analizaron los tipos de sustrato, la localización de las vías accesorias, la presencia de cardiopatía congénita, los resultados, las complicaciones del procedimiento y la recurrencia en el seguimiento.

Resultados: Se identificaron 416 pacientes. La edad promedio fue 13 años (rango 2-18), 275 fueron varones (67%). Hubo 20 pacientes (5%) con cardiopatía congénita. Tuvieron vías accesorias 286 pacientes (69%) y 130 pacientes (31%) otros mecanismos de taquicardia supraventricular que incluyeron: doble fisiología nodal, 109 pacientes (26%); taquicardia auricular ectópica, 14 pacientes (3%); y aleteo auricular, 7 pacientes (2%). En las vías accesorias la eficacia fue del 94,7%. En 6 pacientes (1,4%) hubo complicaciones: uno presentó un accidente cerebro-vascular; otro, bloqueo AV completo; otro, trombosis en la arteria femoral; y 3 pacientes, derrame pericárdico leve. Presentaron recurrencia 26 pacientes con vías accesorias (9,8%). Observamos el 100% de eficacia en doble fisiología nodal con recurrencia de 2 pacientes (3,2%). En taquicardias auriculares la eficacia fue del 86%, y recurrieron 2 pacientes (14,2%) y no hubo complicaciones. Los aleteos auriculares fueron ablacionados eficazmente sin complicaciones. Ninguno recurrió durante un seguimiento promedio de 67 meses (rango 2-114).

Conclusiones: El tratamiento invasivo de las taquicardias supraventriculares en pediatría constituye una herramienta terapéutica eficaz y segura, con una baja tasa de complicaciones y recurrencia en el seguimiento.

Palabras clave: Taquicardia supraventricular - Ablación por radiofrecuencia - Fascículo Atrioventricular Accesorio

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Abbreviations

AP	Accessory pathways	EPS/RFA	Electrophysiological study and radiofrequency ablation
ASA	Acetyl salicylic acid	SVT	Supraventricular tachycardia
CAVB	Complete atrioventricular block	WPW	Wolff-Parkinson-White
CHD	Congenital heart disease		

INTRODUCTION

Supraventricular tachycardia (SVT) is the most prevalent symptomatic tachyarrhythmia in pediatric patients. (1) Accessory pathway-mediated reentry, including manifest anterograde conduction pathways, as Wolff-Parkinson-White (WPW) syndrome, is the most common mechanism. Among the different therapeutic options, transcatheter ablation is the procedure of choice for the definitive invasive treatment of SVT and accessory pathways (AP) in the pediatric population. (2)

The aim of this study was to evaluate the experience in the invasive treatment of SVT in pediatric patients, reporting the acute success rates, efficacy of post-ablation recurrence and the presence of complications associated with the procedure.

METHODS

This was a retrospective cohort study of a pediatric electrophysiological team database, including patients below 18 years of age undergoing electrophysiological study and radiofrequency ablation (EPS/RFA) between June 2004 and May 2015. Demographic data, presence of congenital heart disease (CHD), AP mechanisms and location, success and recurrence rates and presence of complications were analyzed. Patients underwent clinical examination, 12-lead ECG in sinus rhythm and during SVT (in those in whom it was possible to document it), 24-hour Holter monitoring, 12-lead exercise-stress test (according to age) and color Doppler echocardiogram at the time of diagnosis and indication of EPS/RFA.

The EPS/RFA was indicated based on the presence of SVT symptoms under pharmacological treatment and/or in patients with WPW syndrome with clinical criteria of invasive stratification for risk of sudden death, or the patient's family choice.

The procedure was performed under general anesthesia in most patients, except in some patients >15 years where it was conducted under conscious sedation. Access routes were either the femoral vein and/or artery. Three catheters were used in most cases; in some smaller patients or with limitations due to their anatomy, only two catheters were employed. The radioscopy system was monoplanar. The three-dimensional (3D) navigation system which allows the construction of the heart anatomy in three dimensions and the development of activation maps of the arrhythmic circuits marking the points of interest for ablation, was used in patients with CHD, in recurrences and in atrial tachycardia and atypical atrial flutters.

Baseline and pre- and post RFA conduction intervals were measured during EPS/RFA. Atrial and ventricular asynchronous train pulse stimulation protocols and train pulses plus extra stimuli were performed to obtain the refractory period of the specific conduction tissue and AP, and to induce tachycardia. Previously described maneuvers were

used for the differential diagnosis of the tachycardia mechanism induced during the study. When the 3D navigation system was used, cardiac chambers of interest were generated in three dimensions and activation maps were obtained.

Mapping and radiofrequency applications were performed with a 6, 7 or 8 Fr 4 mm- or 8 mm-tip electrode radiofrequency ablation catheter according to the identified substrate. In the case of AP, the local atrial or ventricular electrocardiogram during mapping was sought to occur before the onset of the earliest delta wave in the surface QRS or the earliest intracardiac electrogram, as well as the presence of a continuous atrial and ventricular electrogram. Activation maps for atrial tachycardia were made with the 3D system to identify the arrhythmogenic focus and in atrial flutters critical areas of the circuit were identified to perform the applications.

Ablations were conducted with temperature and power control. In the case of AP, internodal or atrial tachycardia, once the site of interest was found, a test application, lasting not more than 10 seconds, was performed in all cases. If this was unsuccessful, it was interrupted and mapping was resumed. When it was successful, temperatures above 50°C were selected with 60-second applications per lesion. One or two safety lesions were performed according to the operator's criterion.

Whenever necessary, the left atrium was accessed by transeptal puncture through the foramen ovale when present or by retrograde aortic pathway. Patients undergoing EPS/RFA of left substrates or presenting right to left short-circuits were anticoagulated with sodium heparin during the procedure and after the procedure received antiplatelet therapy with 100 mg/day acetyl salicylic acid (ASA) for six weeks.

All patients were evaluated by a pediatric electrophysiologist. Controls at one, 6, 12 and 24 months after the EPS/RFA procedure were done with clinical examination, medical interrogation and ECG. Holter monitoring and exercise stress test were performed at the specialists' criterion.

Measurements were expressed as percentages and averages with their range of values.

Ethical Considerations

In all cases, families were explained the nature of the procedure, its benefits and potential complications, and an informed consent was obtained.

RESULTS

A total of 416 patients undergoing EPS/RFA for SVT and AP were identified. Average age was 13 years (range 2-28) and 275 patients (67%) were male. The heart was structurally normal in 396 patients (95%) and 20 (5%) had CHD (five Ebstein's anomaly, three L-transposition of the great arteries, three ostium secundum atrial septal defect, one single ventricle heart defect, one scimitar syndrome, one mitral valve stenosis and ventricular septal defect (VSD), two hyper-

trophic cardiomyopathy, one with aortic valve stenosis, one with pulmonary valve stenosis and VSD, one with VSD, and one with persistent ductus arteriosus). Mean weight was 47 kg (range 16-78). They were all followed-up for at least 2 months with an average of 67 months (range 2-114).

Among the total number of patients, 286 (69%) presented with AP and 130 (31%) other mechanisms of SVT, including nodal physiology in 109 (26%), ectopic atrial tachycardia in 14 (3%) and atrial flutter in 7 (2%).

Among the 286 patients with AP, 154 (54%) had right- and 132 (46%) left-sided pathways. In all those with left AP, the left heart was accessed through trans-septal puncture or through the foramen ovale, except in 4 patients in whom the aortic retrograde pathway was used. In 28 patients (9.7%), multiple AP were found.

Two hundred and thirteen patients (74.5%) with AP had anterograde conduction (ventricular preexcitation); in 117 (55%) no specific tachycardia was induced during the procedure and in 96 (45%) AP-mediated tachycardia was generated. Associated double

nodal physiology was found 10 patients (4.6%) and in 2 (1%) of them tachycardia was induced by nodal reentry. Figure 1 shows a diagram representing AP location.

Retrograde (occult) conduction AP was diagnosed in 73 patients (25.5%). In 39 of these patients (53.4%) AP-mediated SVT was induced during the procedure and in 34 (46.6%) tachycardia was not triggered.

Radiofrequency ablation was efficient in 94.7% of patients with AP (Figure 2), without the inclusion of those with para-Hisian location, in whom radiofrequency was not applied due to the risk of AV block.

Six patients presented with complications associated with the procedure during AP ablation (1.4%): one had stroke, one complete AV block (CAVB), one a thrombus in the femoral artery and three mild pericardial effusion, which resolved spontaneously.

An 18-year old patient with WPW syndrome and SVT which was successfully ablated had a stroke, which was completely resolved during the patients's evolution.

Complete AV block occurred during ablation of an occult left posteroseptal AP by aortic retrograde

Fig. 1. Diagram showing accessory pathway location on left anterior oblique radiological position, with both tricuspid and mitral valve annuli. The area of His is marked. Right accessory pathways were: 1. posteroseptal (42%), 2. anteroseptal (14%), 3. anterolateral (11%), 4. posterolateral (11%), 5. lateral (5.3%), 6. parahisian (9.7%), 7. anterior (4%) and 8. posterior (3.5%). Left accessory pathways were: 9. posterolateral (30%), 10. lateral (30%), 11. posteroseptal (17.5%), 12. posterior (12%) and 13. anterior (1%).

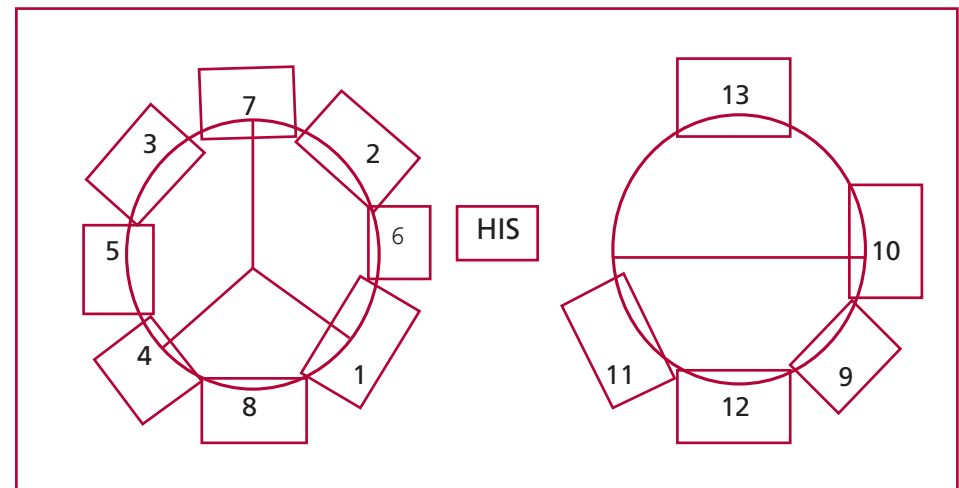


Fig. 2. Early ventricular electrogram in the first intracardiac channel (in white), initiating before the delta wave in the surface electrocardiogram indicates adequate position of the mapping-ablation catheter. The first three channels correspond to aVF, V1 and V6 electrocardiographic leads, and the following 4 channels are intracardiac electrograms (in green) from the catheter placed in the coronary sinus and in magenta from the catheter situated in the apex of the right ventricle.



access pathway in a 13-year-old patient with hypertrophic cardiomyopathy and SVT refractory to medical treatment. Normal conduction system mapping was performed as in all cases, positioning a diagnostic deflectable tip catheter in the bundle of His region. It is worth mentioning that it was difficult to obtain a bundle of His electrogram in the usual location in this patient. The patient presented nodal rhythm a few seconds after applying radiofrequency in the left posteroseptal region. Despite the immediate interruption of the application, he presented with CAVB requiring definitive dual chamber pacemaker implantation. The AP conduction was also eliminated during radiofrequency application.

A 10-year-old girl presented with femoral artery thrombus after ablation of a left AP. The aortic retrograde access was used due to a thick, compliant interatrial septum that precluded transeptal puncture. Five days after the intervention, despite receiving ASA, she manifested mild functional impairment and pain in the affected limb. A 3 mm non-occlusive thrombus was documented, attached to the wall of the femoral artery. Anticoagulant therapy was initiated with low molecular weight heparin and ASA, with symptom reversal and satisfactory posterior outcome.

Mild pericardial effusion was documented in 3 patients with left AP, with no hemodynamic involvement and spontaneous resolution.

All patients were followed-up for at least 2 months with an average of 67 months (range 2-114). Twenty-six patients (9.8%) with AP presented with recurrence and in 24 (99.3%) a second procedure was curative. Only 2 patients (0.7%) required a third therapeutic procedure to achieve definitive resolution.

Regarding other mechanisms of SVT, 109 patients (26%) exhibited double nodal physiology and in 74 (67.7%) tachycardia was induced by nodal reentry. Slow nodal pathway modulation (modification of the

conduction characteristics to avoid tachycardia generation) was performed in 59 patients (54.2%) and slow nodal pathway ablation in 50 (45.8%). No complications were recorded during the procedure. During an average 67-month-follow-up period (range 6-109) only 2 patients (3.2%) recurred. One of these patients presented an episode of tachycardia documented at 6 months of ablation, receiving medical treatment.

Fourteen patients had atrial tachycardia; 11 were right-sided (78.6%) and 3 left-sided (21.4%). Tachycardia could not be induced in 2 patients (14.2%). No complications were registered during the procedure and 2 patients (14.2%) recurred during follow-up.

Seven patients presented atrial flutter, 3 associated with the cavotricuspid isthmus and 4 were atypical. Five patients (71.4%) had associated CHD. They were all reproducible and efficiently ablated without complications (Figure 3) and with no recurrence during follow-up.

DISCUSSION

The first case of refractory atrial tachycardia curative treatment in a child was reported in 1969 (3) and the first AP surgical ablation was published on the same year. (4) During the 80's, the percutaneous treatment of SVT started to emerge and since 1990 percutaneous RFA became an alternative treatment of SVT and AP in pediatric patients, (5) with reported elevated efficiency and safety rates comparable to those of adults. (2)

There are some exclusive aspects of the pediatric population, including patient age and size, the natural history of SVT and the response to medical treatment. The response to pharmacological therapy and the high spontaneous resolution in patients presenting their first episode in the first year of life, approximately 70%, generally makes surgical treatment unnecessary in this age group. (6)

This is added to the high rate of severe complica-

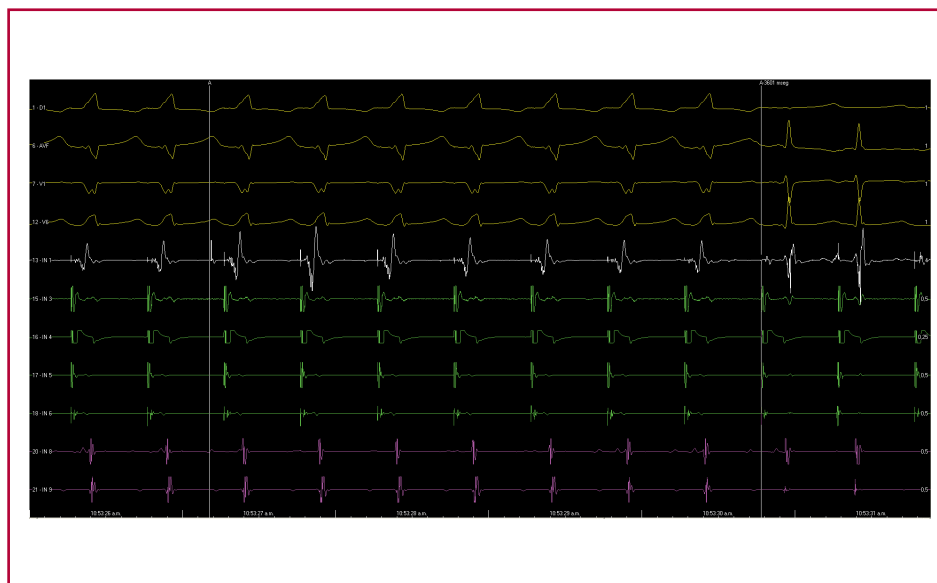


Fig. 3 and 4. Disappearance of ventricular preexcitation with PR prolongation and QRS narrowing in the seventh beat (arrow), a few seconds after initiation of radiofrequency application during atrial stimulation (the stimulation artifact is observed during the entire tracing). Tracing velocity is 100 mm/s. The first four channels correspond to L1, aVF, V1 and V6 electrocardiographic leads of the surface electrocardiogram and the following seven are intracardiac electrograms. Channel 1 (IN 1) represents the distal dipole of the mapping-ablation catheter placed on the ablation target (earlier ventricular activity with respect to the delta wave; see Figure 2).

tions associated with the procedure in infants. Studies report the growth of radiofrequency scars in the myocardium of immature hearts, with its potential deleterious effect. (7)

The situation is different in older patients. A recent publication showed that SVT has a highly negative impact in the quality of life of affected patients, equivalent to suffering from a complex congenital cardiomyopathy. This psychosocial aspect is a substantial issue at the moment of indicating this treatment in an entity such as SVT or WPW syndrome, that even in asymptomatic patients impose limitations in sports and physical activities. Therefore, the possibility of an early intervention should be evaluated as contemplated in the current recommendations. (8) Furthermore, the high efficiency and safety of the procedure should be considered at the moment of deciding the indication.

The efficacy and safety results observed in this series of patients agree with published series from electrophysiology referral centers. The rate of complications was not above 1.4% of the total number of patients. Two patients presented severe complications (a CAVB and a stroke). Restitution was complete and without neurological sequelae in the case of the patient with stroke.

In the case of CAVB, this occurred in a patient with left posteroseptal AP. In a publication of the previously called Pediatric Electrophysiology Society, the incidence of AV block as complication of radiofrequency ablation was 1.2%. (9) This value, which is significantly higher than the one reported in the present series, can be explained by the less aggressive conduct adopted for high septal AP. Complete atrioventricular block in left posteroseptal pathways is not common,

but the patient presented hypertrophic cardiomyopathy, which does not allow ruling out the possibility of less frequent anatomical variants in the arrangement of the conduction system. The patient required a definitive pacemaker and did not have further episodes of SVT.

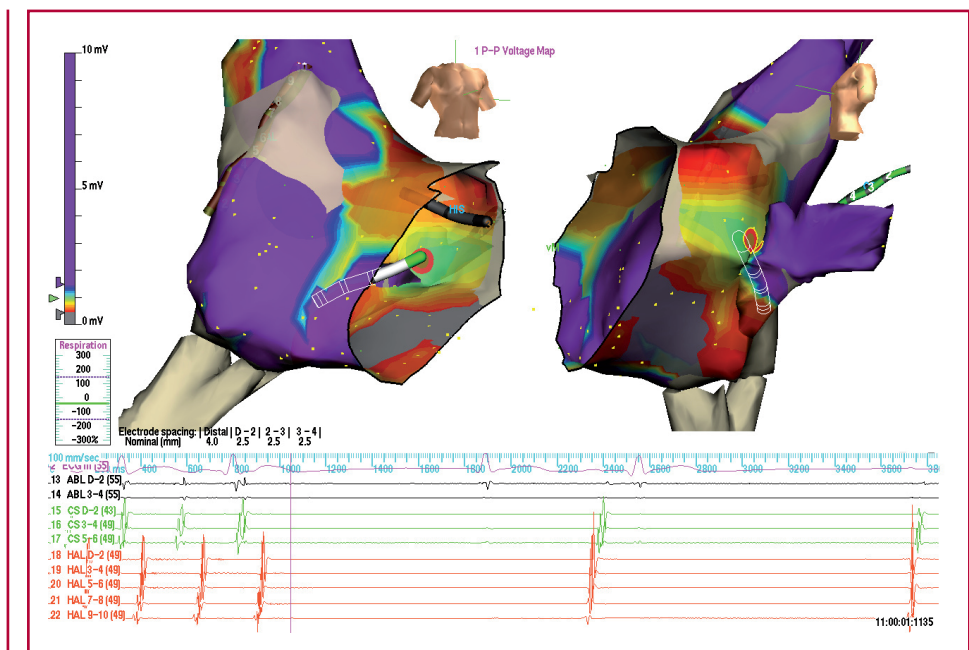
The rate of efficacy in the subgroup of patients with CHD reported in different referral centers' publications is lower and with greater rate of recurrence compared with patients without structural heart disease. (10, 11) In this series of patients, the success rate in patients with heart disease and simple substrates, as AP and nodal reentrant tachycardia, is also somewhat lower, being efficient in 85% of patients, versus the general efficacy rates of approximately 95%. In turn, the rate of recurrence was higher.

In complex substrates, the rate of success was greater than that reported in previous publications. A 100% efficacy was achieved in atrial flutters (isthmic and atypical) with no recurrence during follow-up. The systematic use of navigation systems and the lower age of our population might explain this efficiency rate, due to the proarrhythmic effect of residual anatomical lesions of previous surgeries and older age. (11-14)

CONCLUSIONS

Surgical treatment of SVT and AP in pediatric patients is an efficient and safe therapeutic tool, even in patients with CHD. The positive impact on the quality of life of patients who do not need prolonged drug treatment and are neither restricted in their sporting activities, places surgical therapy as a first line treatment tool in selected patients and in centers with experience in this type of procedure.

Fig. 4. Atypical right atrial flutter interruption during radiofrequency applied in the fifth beat (arrow). Tracing velocity is 100 mm/s. The first channel corresponds to a surface electrocardiographic lead, and the next 10 to intracardiac electrograms of the ablation catheter, one catheter placed on the coronary sinus (green) and a multipolar catheter placed in the right atrium. Note the three-dimensional reconstruction of the right atrium and the position of the ablation catheter at the moment of flutter interruption. (red arrow).



Conflicts of interest

None declared.

(See authors' conflicts of interest forms on the website/ Supplementary material)

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