CLINICAL RESEARCH

Follow-up of children or teenagers with paroxysmal supraventricular tachycardia, but without pre-excitation syndrome

Suivi d’enfants ou adolescents ayant des tachycardies supraventriculaires paroxystiques mais pas de syndrome de pré-excitation ventriculaire

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KEYWORDS
Supraventricular tachycardia; Children; Follow-up; Ablation

Summary
Background. — Paroxysmal supraventricular tachycardia (SVT) is considered benign in children if the electrocardiogram in sinus rhythm is normal, but causes anxiety in parents, children and doctors.
Aims. — To report on the clinical and electrophysiological data from children with SVT, their follow-up and management.
Methods. — Overall, 188 children/teenagers (mean age 15 ± 2.8 years) with a normal electrocardiogram in sinus rhythm were studied for SVT, and followed for 2.3 ± 4 years.
Results. — SVT was poorly tolerated in 30/188 children (16.0%). SVT was related to atrioventricular nodal reentrant tachycardia (AVNRT) (n = 133) or atrioventricular reentrant tachycardia (AVRT) over a concealed accessory pathway (n = 55; 29.3%). Ablation of the slow pathway (n = 66) or the accessory pathway (n = 43) was performed without general anaesthesia, 2 ± 3 years after initial evaluation. Failure or refusal to continue occurred in 18/109 (16.5%) children: 7/66 with AVNRT (10.6%), 11/43 with AVRT (25.6%) (P < 0.001). Symptoms of SVT recurred in 20/91 children (22.0%) with apparently successful ablation: 6/91 (6.6%) had real SVT recurrence; 14/91 (15.4%)

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had only a sinus tachycardia, more frequent in AVNRT (11/59; 18.6%) than AVRT (3/32; 9.4%) \( (P = 0.05) \). In 13 children treated with an antiarrhythmic drug (AAD), SVT recurred in four; two presented AAD-related syncope. In 66 untreated children, one death was noted after excessive AAD infusion to stop SVT; the others remained asymptomatic or had well-tolerated SVT.

**Conclusions.** — At the time of ablation, SVT management remains difficult in children. Indications for ablation are more common in AVRT than in AVNRT, but failures are frequent; 22.0% remained symptomatic after successful ablation, but false recurrences were frequent (15.4%). Without ablation, one third had a spontaneous favourable evolution.

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### Background

Paroxysmal supraventricular tachycardias (SVTs) are considered benign [1] if the electrocardiogram in sinus rhythm is normal, but their occurrence in children/teenagers is often associated with anxiety in parents, children and their doctors, and sometimes with embarrassing and invalidating symptoms.

Invasive evaluation of tachycardia is rarely indicated in children for several reasons, including misdiagnosis or fear of hospitalization. Frequently, children/teenagers who complain of palpitations or tachycardia are only considered to be anxious, and for several months or years a false diagnosis of sinus tachycardia is given. Our group [2–4] and other authors [5–9] have reported on the benefit of a transoesophageal electrophysiological study (EPS) in children/teenagers complaining of tachycardia. The results suggested that the method is safe, useful and effective for the evaluation of arrhythmia-related symptoms and the SVT mechanism, and can assist with choice of treatment. The method is associated principally with a more comprehensive evaluation in children complaining of tachycardia.

Our aim was to report on the clinical and electrophysiological data from children with SVT, and their follow-up and management.

### Methods

#### Population

This was a retrospective chart review of 188 children and teenagers (99 boys, 89 girls), aged 6–19 years (mean 15 ± 2.8 years), with a normal electrocardiogram in sinus rhythm, and studied for spontaneous SVT from 27 November 1997 to 30 September 2015 (Table 1).
**Methodology**

The study of patients’ files was approved by the *Commission nationale informatique et libertés* (CNIL), in keeping with French law for single-centre usual-care observational studies. Before EPS and ablation, informed consent was obtained for clinical purposes from the children and their parents. The protocol included systematic non-invasive and invasive studies.

The standard package of non-invasive studies included 24-hour Holter monitoring, echocardiography in the case of systolic murmur, bicycle exercise testing if possible and head-up tilt test in children referred for syncope and SVT.

An EPS was performed systematically, either by the transeosophageal route in asymptomatic patients or patients with undocumented tachycardia, or by the conventional intracardiac method. Patients were not sedated. Details of the EPS protocol have been described previously [2–4].

Briefly, atrial pacing and programmed atrial stimulation were performed systematically during sinus rhythm, with atrial pacing conducted at two cycle lengths (600 and 400 ms). Premature stimuli (S2) were delivered after every eighth paced atrial complex, with 10 ms decrements until atrial refractoriness was reached. When an SVT was induced, the protocol was halted. In the absence of tachycardia induction, isoprotrorenol (0.02–1 μg/min) was infused alternatively to increase the sinus rate to at least 130 bpm. Atrial pacing was repeated, and programmed atrial stimulation was performed at a cycle length of 400 ms. Diagnosis of SVT was confirmed by the EPS, and its mechanism was collected.

The SVT was classified as a typical atrioventricular nodal reentrant tachycardia (AVNRT) (slow-fast AVNRT or the common form with atrial activity inside ventriculogram) or an atypical AVNRT (fast-slow AVNRT or the uncommon form with a long R-P interval) or atrioventricular reentrant tachycardia (AVRT) over a concealed accessory pathway (AP).

Atrial vulnerability was defined as the induction of atrial fibrillation or atrial flutter lasting for more than 1 minute during the protocol.

When indicated, ablation was performed by the same senior operator, with different assisting clinical fellows, without general anaesthesia. Ablation of the AP was carried out using a 7F deflectable catheter with a 4-mm electrode, by searching the site where ventriculoatrial conduction was the shortest during SVT and/or ventricular pacing in bipolar and unipolar recording. The left AP ablation procedure was generally performed using a retrograde femoral arterial approach. The radiofrequency current was applied with a power output of 40–50 W and a maximum temperature of 65 °C. Catheters were removed 30 minutes after the disappearance of the anterograde and retrograde conduction in the AP. In the case of slow pathway ablation, identified by a potential slow pathway, radiofrequency ablation was performed with a power output of 30–40 W, a maximum temperature of 65 °C and a 4-mm tip catheter.

Ablation-related complications were defined as major if they were life-threatening and required admission of the patient to the intensive care unit, and as without further consequences if they regressed without the need for monitoring in intensive care.

Complications considered as major were mostly pericardial tamponade requiring emergency drainage, complete atrioventricular block requiring pacemaker implantation and death. Complications considered as without further consequences were local bleeding, vagal syncope at femoral puncture, minor pericardial suffusion, transient traumatic or radiofrequency-related second or complete atrioventricular block and transient sinus bradycardia.

**Follow-up**

Ablation, antiarrhythmic drug (AAD) treatment, or follow-up without treatment was indicated according to the child’s age and the frequency or tolerance of SVT. Ablation was performed either promptly in teenagers after identification of the SVT mechanism during the EPS or during a later second procedure. Children treated by SVT ablation were discharged without an AAD, and were systematically examined by a cardiologist at least 1 month after ablation. As a general rule, children with recurrent tachycardias, aged <10–14 years, who were too small, were incapable of having ablation without general anaesthesia or who refused ablation were discharged with beta-blockers (atenolol).

If beta-blockers were not tolerated, flecaainide was used. No treatment was indicated for one or two episodes of well-tolerated tachycardia; vagal manoeuvres only were explained. These indications are reported in Fig. 1.

The study enabled access to a mean of 2.3 ± 4 years of follow-up performed by the referring cardiologist and/or general practitioner. This follow-up was available from medical correspondence contained in the patient’s medical records. In addition, information was also collected from patient telephone interviews, as part of the usual clinical follow-up after SVT ablation. General practitioners, patients and, occasionally, other hospitals were contacted to identify clinical outcome. Electrocardiography and 24-hour Holter recordings were performed if the patient reported palpitations or symptoms suspected to be the consequence of SVT occurrence/recurrence. Eight children were lost to follow-up.

<table>
<thead>
<tr>
<th>Table 1 Baseline characteristics of the population</th>
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<td>Age (years) (range, 6–19 years)</td>
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<td>Male sex</td>
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<td>SVT-related syncope</td>
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<td>Other SVT-related adverse event</td>
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<td>Familial SVT</td>
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<td>AVNRT total</td>
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<td>Typical AVNRT</td>
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<td>Atypical AVNRT</td>
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<td>AVRT</td>
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</table>

Data are expressed as mean ± standard deviation or number (%). AVNRT: atrioventricular node reentrant tachycardia (atypical and typical); AVRT: atrioventricular reentrant tachycardia over a concealed accessory pathway; SVT: supraventricular tachycardia.
The following data were collected: recurrences defined as documented or induced SVT after ablation, false recurrences defined as palpitations, but negative control EPS, occurrence of atrial fibrillation, stroke, pacemaker implantation and death.

### Statistical analysis

Continuous variables are expressed as means±standard deviations, and were compared using t-tests for independent samples. Differences in proportions were compared using the χ² test.

Logistic regressions were used, with indications for ablation and then the failures of ablation as dependent variables. Continuous values of age, male sex, mechanism of SVT, SVT-related adverse event, heart disease, complications of ablation and presence of atrial vulnerability were entered into a univariate model, and then the significant data were entered into a multivariable model. No selection process was performed within the multivariable model.

A P-value < 0.05 was considered statistically significant. All statistical analyses were performed using the SPSS package for Windows, version 21 (IBM Corp., Armonk, NY, USA).

### Results

#### Clinical data

Only three children had a congenital heart disease (Ebstein’s disease, n = 1; atrial septal defect n = 1; ductus arteriosus, n = 1), one had hypertrophic cardiomyopathy and two had non-cardiac diseases. SVT was poorly tolerated in 30 patients (16.0%); in 28 of them, the event was syncope. Tachycardio-myopathy occurred in one child, and resuscitated ventricular fibrillation in one teenager. For this last teenager, no cause was identified except excessive sporting activity at the time of the event. Electrocardiogram in sinus rhythm and echocardiogram were normal, and a complete EPS was negative. Only genetic evaluation and magnetic resonance imaging were missing. Twelve children (6.4%) had a history of familial SVT.

#### Electrophysiological data

SVT was related to AVNRT in 133 children (70.8%) — typical AVNRT in 119 (63.3%) and atypical AVNRT in 14 (7.5%) — and to AVRT over a concealed AP in 55 children (29.3%). Signs of atrial vulnerability were noted in 14 children (7.5%).

#### Follow-up

Ablation of SVT was proposed in symptomatic children (children with recurrent SVT or rare but poorly tolerated SVT) aged >10–14 years, the age being dependent on the child’s size and desire, and on their parents. When children were <1 m 40 cm in height and weighed < 40 kg, the ablation was only indicated when the SVT was recurrent and AADs were not tolerated or not effective. The parents of these children were consulted, but some declined radiofrequency. Antiarrhythmic therapy with a beta-blocker and/or flecainide was the preferred mode of treatment in small children and when ablation was refused by a child or their parents.

Radiofrequency of the slow pathway (n = 66) (typical AVNRT, n = 59; atypical AVNRT, n = 7) or the AP (n = 43) was performed in the absence of general anaesthesia in 109 patients (58.0%) from 1 month up to 13 years after the initial evaluation (mean 2 ± 3 years). Ablation of the slow pathway was indicated less frequently than ablation of the AP (66/133 [49.6%] vs. 43/55 [78.2%]; P < 0.001). Ablation was not required to be performed in any patient before the age of 12 years, because all the children were correctly treated with low doses of beta-blockers. In six children aged >11 years, controlled by beta-blockers, ablation was indicated for the practice of competitive sport with a contraindication to the drugs.

Failure of ablation (often because of refusal to continue) was frequent, and occurred in 18/109 children (16.5%): 7/66 (10.6%) with AVNRT – 5/59 (8.5%) with typical AVNRT, 2/7 (28.6%) with atypical AVNRT — and 11/43 (25.6%) with AVRT over a concealed AP (P < 0.001). Absence of general anaesthesia was a limiting factor for success in 12 children, with chest pain at the application of radiofrequency energy in the septal region in five children, despite the use of morphine. The procedure was too long for seven children, who became agitated. The last difficulties were mainly observed with AP ablation: the AP was mainly located in the posteroseptal site (n = 9); other locations were parahisian (n = 1) and left lateral (n = 1). In two children, failure was related to the occurrence of irreducible atrial fibrillation. However, it should be noted that the rate of failure was higher before 2000 than after this date (10/33 [30.3%] vs. 8/76 [10.8%]; P < 0.01).

Complications of ablation (second- or third-degree atrioventricular block) occurred in seven patients undergoing slow pathway ablation; in four of them the atrioventricular block was traumatic and quickly reversible; in another it was of vagal origin and was also reversible. In one teenager, the mechanism was unknown, and this patient had recurrences of SVT without residual conduction disturbance. No complications occurred in children with AVRT.
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Recurrence of SVT occurred in 20/91 patients (22.0%) with apparently successful ablation, 6/91 (6.6%) with real recurrence of SVT (3/59 [5.1%] with typical AVNRT; 3/32 [9.4%] with AVRT over a concealed AP; difference not significant) and 14/91 (15.4%) with only sinus tachycardia-related symptoms (one with atypical AVNRT and 10 with typical AVNRT [11/59 with AVNRT; 18.6%]; 3/32 [9.4%] with AVRT over a concealed AP; P < 0.05). One teenager required ablation of paroxysmal atrial fibrillation 11 years later.

In 13 children treated with AADs or beta-blockers, SVT recurred in four children; two children presented sotalol-related syncope. However, in these last children, a change of beta-blocker was associated with improvement in symptoms.

In 66 untreated children, one death was noted after an excessive dose of an AAD was infused to stop SVT. The exact drugs used to stop the SVT in the small regional hospital remain unknown; only a high dose of digoxin was noted after the asystolic-related death of the girl. Other patients (30%) remained asymptomatic or had short and well-tolerated SVT.

### Multivariable analysis

In the multivariable analysis, indications of ablations were independently related to age and to the SVT mechanism (AVRT) (Table 2). Failures of ablation were related only to the SVT mechanism (AVRT), regardless of the child’s age or the events occurring during ablation (Tables 3 and 4).

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**Table 2** Statistical analysis of indications for ablation.

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AVNRT: atrioventricular nodal reentrant tachycardia; AVRT: atrioventricular reentrant tachycardia over a concealed accessory pathway; CI: confidence interval; OR: odds ratio; SVT: supraventricular tachycardia.

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**Table 3** Statistical analysis of failure of ablation.

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<tr>
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AVNRT: atrioventricular nodal reentrant tachycardia; AVRT: atrioventricular reentrant tachycardia over a concealed accessory pathway; CI: confidence interval; OR: odds ratio; SVT: supraventricular tachycardia.
Discussion

Among children with SVT confirmed by EPS, follow-up was variable. Recurrence of symptoms generally led to an indication for SVT ablation after the age of 12 years. In the present study, it was generally not necessary to perform SVT ablation before this age, because drug therapy controlled the symptoms. AVRT over a concealed AP was the most frequent indication for ablation, but also for failure of ablation. However, in children with apparently successful ablation, the recurrence of symptoms was more rarely related to a real recurrence of SVT in children with AVRT over a concealed AP than in children with AVNRT.

These data contrast with other recent studies of SVT ablation in children and teenagers, with a low risk of complications and a high rate of success [10–16], except in children with complex congenital heart disease [12,15], and despite a 1.4% rate of serious complications in a Czech multicentre study [11].

Some explanations are possible: our first attempts at ablation took place some time previously, when we had less experience with the technique. Procedural course is related to the experience of the electrophysiologist team; after an adequate learning curve, the procedure can be performed in a very acceptable amount of time. That was the case in the present study, with a clear decrease in the rate of failures from 30.3% to 10.8% from the year 2000. A significant reduction in procedural and fluoroscopy time over the study period has been reported in different studies [11]. However, the degree of difficulty of SVT ablation remains unpredictable. Relatively old manuscripts [15,17–19] reported complications or failures that seem to have disappeared, despite disparities in the treated children. In the absence of general anaesthesia, it appears difficult to avoid the failures related to the development of permanent atrial fibrillation during the procedure. Mortality associated with paediatric radiofrequency ablation was reported as rare, but was more frequent when there was underlying heart disease, lower patient weight and a greater number of radiofrequency energy applications, and left-sided procedures were a risk factor for failure. Operator experience did not appear to be a factor leading to mortality [15]. Fortunately, no important complications occurred in our population.

Most important was the lack of general anaesthesia in our children; in some cases, the length of the procedure and the agitation of the child was the cause of the interruption to the procedure in most of our failures. Actually, most groups used general anaesthesia in children, limiting the problems of chest pain, anxiety and agitation, as encountered in the present study, and helping ablation to be achieved successfully [12,13,16]. The risks of general anaesthesia were rarely discussed in these studies; anaesthesia-related adverse events were nausea and vomiting in the study by Tomaske et al. [16].

Some discordance with our study remains unexplained: why, in an apparently successful procedure, is the rate of recurrence so low in recent studies, and why do children with successful procedures have no residual symptoms? Recurrence of symptoms after an initially successful ablation occurred frequently in children [20]. True recurrences were less common after AVNRT ablation, and more common after ablation of right-sided pathways [20], except in the present study. However, some recurrences were related to a sinus tachycardia, and the phenomenon was mainly noted after AVNRT ablation. Details of these data were reported recently by our group [21].

Several years ago, beta-blockers were recommended in children with SVT [22]; two children in our group had some adverse effects. However, 13 patients remained free of symptoms, after a change of drugs in six for recurrence or adverse events. Once-a-day oral atenolol as a monotherapy is generally effective and relatively safe for long-term management of SVT during childhood. However, changes in treatment after evaluation were not rare in our population, for several reasons (dyspnoea, dizziness or some other minor effects), and it was not unusual to note other drug-related adverse events.

Actually, in symptomatic children with SVT refractory to vagal manoeuvres, ablation could be discussed with the child and their parents, and compared with the advantages and disadvantages of an AAD. It should be noted that ablation is sometimes only indicated for the practice of sports. However, the risk of malignant events during sporting activity in children without pre-excitation and without heart disease/channelopathy appears negligible.

Poorly tolerated SVT, such as the association of SVT with syncope, was not a reason leading to an indication for ablation in the present study. Several years ago, our group reported that syncope was frequently related to a vagal reaction in children [23]. The mechanism of SVT was the most important indication for ablation. The risks known to be related to slow pathway ablation are probably the cause of the low rate of referral of children for this procedure. In the present study, adverse events occurred only in this indication, but were reversible.

In the recent joint consensus statement from the European Heart Rhythm Association and the Association for European Paediatric and Congenital Cardiology—Arrhythmia Working Group [24], as a general rule, prescription of AADs requires a clear diagnosis, with electrocardiographic documentation of a given arrhythmia. A risk—benefit analysis of drug therapy should be considered when facing an arrhythmia in a child. Prophylactic AAD therapy is given only to protect the child from recurrent SVT during this time-span, until the disease eventually ceases spontaneously. The
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authors believe that, even in young children, procedures can be performed with high success rates and low complication rates, as shown by several retrospective and prospective paediatric multicentre studies. Three-dimensional mapping and non-fluoroscopic navigation techniques and enhanced catheter technology have further improved safety.

In children with rare or well-tolerated SVT, the prognosis is confirmed as excellent [1], and a decision for ablation should not be influenced by the stress of the child or the parents, and should be infrequent.

Study limitations

Our group was relatively small it was a single-centre study, with the advantage of similar management by the same doctors. The symptoms of tachycardia (palpitations) may have been sinus tachycardia, and the inducible arrhythmia could not have been the cause of symptoms. Thus, it is possible that patients were treated for an inducible non-clinical arrhythmia. Advanced mapping systems were not used in this population. It appears that indications for ablation of SVT, which has been considered as a benign condition for many years, depend on the anxiety of child and their parents or, more rarely, of the referring doctor.

Conclusions

Management of SVT in children remains difficult, despite the development of radiofrequency ablation of SVT. Among children with SVT confirmed by an EPS, follow-up was variable. Recurrences of symptoms generally led to an indication for SVT ablation. The age of the child influenced the indications for ablation. AVRT over a concealed AP was another frequent indication for ablation, but also for failure of ablation. However, in children with apparently successful ablation, the recurrences of symptoms were more rarely related to a real recurrence of SVT in children with AVRT over a concealed AP than in children with AVNRT.

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Disclosure of interest

The authors declare that they have no competing interest.

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