Management of supraventricular tachycardia in children (medication - ablation)

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Scientific Associate 1st Cardiology Dpt Evangelismos Hospital Athens Greece
SVT: Types

Atrial tachycardias
- Ectopic atrial tachycardia
- Atrial flutter
- Atrial fibrillation

AV node dependent tachycardias
- AV nodal reentrant tachycardia
- AV reentrant tachycardia (AP mediated), including atriofascicular and nodofascicular tachycardia
- Junctional ectopic
Most common forms of SVT

AVRT
AVNRT
EAT
JET
## Atrial tachycardias

<table>
<thead>
<tr>
<th>Location</th>
<th>Mechanism</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrial</td>
<td>Re-entrant</td>
<td>Automatic</td>
</tr>
<tr>
<td>Atrial flutter</td>
<td>Automatic atrial tachycardia</td>
<td></td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>Chaotic atrial tachycardia</td>
<td></td>
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<tr>
<td>AV node re-entry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WPW</td>
<td></td>
<td></td>
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<tr>
<td>Concealed AP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PJRT</td>
<td></td>
<td></td>
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<tr>
<td>Mahaim</td>
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</tbody>
</table>
**Atrial flutter-fibrillation**

Atrial flutter, or macro reentrant AT in the absence of CHD is uncommon in children and most commonly occurs in neonates.

Often initiated by either AVRT or AVNRT

Tachycardia that responds to adenosine that is not consistent with AVRT or AVNRT labeled “non-automatic focal atrial tachycardia” or NAFAT

Ablating within a pulmonary vein or its orifice, there are no reports in the pediatric literature of pulmonary vein stenosis.
Ectopic atrial tachycardia
Ectopic atrial tachycardia

Arises from a focus other than the sinus node (right and left atrial appendages, pulmonary vein ostia and crista terminalis), with heart rates faster than expected from the current autonomic state.

Rates may vary between 90-350 bpm.

Often incessant.

Tachycardia was present 100% of the time in 76% of the patients, 50-99% in 13% and 10-19% in 11% of the patients.

Clinical course of atrial ectopic tachycardia in children < 3 or ≥ 3 years of age.

68 children with EAT (<3 years n=22 and ≥3 years n=46)

Control of EAT with AAD achieved in 91% of children <3 yrs but only 37% of children ≥3 years (p < 0.001)

Higher rate of spontaneous resolution in the younger group (78%) compared with the older group (16%) (p < 0.001)

Radiofrequency ablation was performed in 35 of the older children, with ultimate success in 74%. Surgical intervention was required for six children

Atrial tachycardias

Inappropriate sinus tachycardia (IST) is a rare form of AT is Class IIb for ablation.

Ablation is not recommended for sinus tachycardia related to postural ortho-static tachycardia syndrome or other autonomic conditions.

<table>
<thead>
<tr>
<th>COR</th>
<th>LOE</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>C-LD</td>
<td>1. Evaluation for and treatment of reversible causes are recommended in patients with suspected IST.(^{160,185})</td>
</tr>
</tbody>
</table>

It is important to distinguish IST from physiological sinus tachycardia or focal AT from the high right atrium, which can have P-wave morphology similar to the sinus P wave. A careful history and physical examination, with further laboratory and imaging studies, are necessary to determine reversible causes of tachycardia, such as exogenous substances and drugs, infection, anemia, and hyperthyroidism. A focal AT would have sudden onset and termination, which would not be the case for IST.
AV nodal reentrant tachycardia
AVNRT in children

Most common mechanism when tachycardia appears for the first time after 10 yrs of age

Common experience is that once episodes start, they continue throughout most adult life

Typical AVNRT (slow-fast) is by far the most common form in pediatrics, with atypical AVNRT (fast-slow and slow slow) accounting for less than 10% of cases.

Catheter ablation either RF or cryo, treatment of choice in older children (>10 yrs) with success rates >95% and very low risk for AV block (1-2% with RF, probably 0 with cryo)
AVNRT: Intracardiac study
AVNRT: Intracardiac study

The classical definition of dual AV node physiology (an atrio-His [AH] jump greater than 50 ms with a 10-ms decrement in the A1A2) is only met in approximately half of pediatric patients with AVNRT.

Although a PR interval greater than or equal to RR was observed in only 60% of pediatric AVNRT patients, it was far more frequent in the AVNRT patients compared with the controls (13%, P 0.001).
Atrioventricular Nodal Reentrant Tachycardia in Patients With Congenital Heart Disease: Outcome After Catheter Ablation

John Papagiannis, MD; Daniel Joseph Beissel, MD; Ulrich Krause, MD; Michel Cabrera, MD, PhD; Marta Telishevskaya, MD; Stephen Seslar, MD, PhD; Christopher Johnsrude, MD; Charles Anderson, MD; Svjetlana Tisma-Dupanovic, MD; Diana Connelly, CCRC; Dimosthenis Avramidis, MD; Christopher Carter, MD; Laszlo Kornyei, MD; Ian Law, MD; Nicholas Von Bergen, MD; Jan Janusek, MD; Jennifer Silva, MD; Eric Rosenthal, MD; Mark Wilcox, MD; Peter Kubus, MD; Gabriele Hessling, MD; Thomas Paul, MD; for the Pediatric and Congenital Electrophysiology Society

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Group A (%)</th>
<th>Group B (%)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute success</td>
<td>82%</td>
<td>97%</td>
<td>0.04</td>
</tr>
<tr>
<td>AVNRT documented and reablated in repeat procedure</td>
<td>9 (18%)</td>
<td>6 (10%)</td>
<td>0.27</td>
</tr>
<tr>
<td>Final success</td>
<td>86%</td>
<td>100%</td>
<td>0.004</td>
</tr>
<tr>
<td>Atrioventricular block of any degree</td>
<td>14%</td>
<td>0%</td>
<td>0.004</td>
</tr>
<tr>
<td>Need for chronic pacing</td>
<td>10%</td>
<td>0%</td>
<td>0.008</td>
</tr>
</tbody>
</table>

AVNRT indicates atrioventricular nodal reentrant tachycardia.

WHAT THE STUDY ADDS

- AVNRT can complicate the course of patients with congenital heart disease, especially in patients with right heart pressure or volume overload.
- The outcome of catheter ablation is favorable in patients with simple congenital heart disease, but patients with complex congenital heart disease have increased risk of procedural failure and atrioventricular block.
- Advanced methods of mapping and cryoablation should be considered when the exact anatomy of the atrioventricular node cannot be precisely defined.
Orthodromic reciprocating tachycardia
Natural history of SVT due to accessory pathways in children

In infants with WPW, preexcitation disappears in 2/3 of pts during the first year of life


140 patients with Wolff-Parkinson-White syndrome who had their initial episode of supraventricular tachycardia before 18 months

If tachycardia began at age 0 to 2 months, it disappeared in 93% but it reappeared in 31% at an average age of 8 years

If tachycardia was present after age 5 years, it was persistent in 78% at a mean follow-up period of 7 years

Perry J, Garson A, JACC 1990;16(5):1215-20
Is it possible to predict the recurrence of infant SVT with transesophageal EPS?

42 pts presented with SVT at median age of 4 (0-300) days

**TEEPS** performed at median 13 (9-22) months of age

SVT was inducible in 27/42: 8 AVNRT and 19 AVRT

All pts with positive TEEPS were treated and none had recurrence after medical therapy or ablation at median f/u of 27 (6-37) mo

Of 15 not inducible at TEEPS, none had known SVT recurrence off medications at median follow-up of 25 months (3-97 months)

Among patients having SVT in early infancy:
  
  ◦ (1) TEEPS results are not associated with clinical variables
  ◦ (2) noninducibility is a good indicator of lack of clinical recurrence at intermediate follow-up
  ◦ (3) AVNRT may be more prevalent in infancy than previously reported

*Blaufax AD et al, Pediatr Cardiol 2011;32(8):1110-4*
WPW syndrome: A Wolf(f) in sheep’s clothing?
Ventricular fibrillation during AVRT
Aborted sudden death in the Wolff-Parkinson-White syndrome

15/690 (2.2%) pts with WPW had aborted cardiac arrest

VF was the first manifestation of the WPW syndrome in 8 patients

Ten of the 15 patients were exercising or under emotional stress at the time of aborted sudden death

Septal APs in 11/15 ACA pts

Timmermans et al, AJC 1995;76(7):492-4

Developed in partnership between the Pediatric and Congenital Electrophysiology Society (PACES) and the Heart Rhythm Society (HRS). Endorsed by the governing bodies of PACES, HRS, the American College of Cardiology Foundation (ACCF), the American Heart Association (AHA), the American Academy of Pediatrics (AAP), and the Canadian Heart Rhythm Society (CHRS)

WRITING COMMITTEE MEMBERS

Task Force Chair
Mitchell I. Cohen, MD, FACC, FHRS¹‡

In large-scale general population studies involving children and adults, the prevalence of WPW is estimated to be 1–3 in 1000 individuals.⁷–¹³ Familial studies have shown an incidence of 5.5 in 1000 among first-degree relatives following an index case of WPW.¹⁴ Identification of the truly asymptomatic patient with WPW is difficult, as these individuals are by definition without palpitations, syncope, or other symptoms secondary to ventricular preexcitation. At

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Mitchell I. Cohen, MD, FACC, FHRSM

<table>
<thead>
<tr>
<th>Author</th>
<th>Patients</th>
<th>Years studied</th>
<th>Age</th>
<th>Follow-up (y)</th>
<th>Died</th>
<th>SCD per patient-year</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berkman (1968)</td>
<td>128</td>
<td>1933–1968</td>
<td>21</td>
<td>20</td>
<td>3</td>
<td>0.0039</td>
<td></td>
</tr>
<tr>
<td>Leitch (1990)</td>
<td>75</td>
<td>1980–1988</td>
<td>34 ± 13</td>
<td>4.3</td>
<td>0</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>Klein (1989)</td>
<td>27</td>
<td>1981–1989</td>
<td>45</td>
<td>4.5</td>
<td>0</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>Munger (1993)</td>
<td>113*</td>
<td>1953–1989</td>
<td>33 ± 16</td>
<td>12</td>
<td>2</td>
<td>0.0015</td>
<td>Both SCD patients were symptomatic</td>
</tr>
<tr>
<td>Inoue (2000)</td>
<td>57</td>
<td>1985–1993</td>
<td>10.2</td>
<td>8</td>
<td>0</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>Goudevenos (2000)</td>
<td>157</td>
<td>1990–1997</td>
<td>20</td>
<td>4.6</td>
<td>0</td>
<td>0.0000</td>
<td></td>
</tr>
<tr>
<td>Fitzsimmons (2001)</td>
<td>238*</td>
<td>1955–1999</td>
<td>34.3</td>
<td>21.8</td>
<td>1</td>
<td>0.0002</td>
<td>SCD patient had SVT and atrial fibrillation</td>
</tr>
<tr>
<td>Sarubbi (2003)</td>
<td>98</td>
<td>1985–2001</td>
<td>5.4</td>
<td>4</td>
<td>1</td>
<td>0.0019</td>
<td>2 patients had VF and were resuscitated</td>
</tr>
<tr>
<td>Pappone (2003)</td>
<td>212</td>
<td>1993–1996</td>
<td>36 ± 21</td>
<td>3.2</td>
<td>1</td>
<td>0.0150</td>
<td>3 patients had VF and were resuscitated</td>
</tr>
<tr>
<td>Santinelli (2009)</td>
<td>184</td>
<td>1995–2005</td>
<td>10</td>
<td>4.6</td>
<td>0</td>
<td>0.0000</td>
<td></td>
</tr>
</tbody>
</table>

An incidence of 4.5 episodes of sudden death, including resuscitated SCD, per 1000 patient-years was recently reported in a prospective study of asymptomatic adults with WPW followed for a mean of 38 months. Furthermore,
Current strategy for treatment of patients with Wolff–Parkinson–White syndrome and asymptomatic preexcitation in Europe: European Heart Rhythm Association survey

Jesper Hastrup Svendsen1,2*, Nikolaos Dagres3, Dan Dobreanu4, Maria Grazia Bongiorni5, Germanas Marinskis6, and Carina Blomström-Lundqvist7 conducted by the Scientific Initiatives Committee, European Heart Rhythm Association

Table 1 Anticipated treatment strategy for a child presenting at your emergency department with overt WPW (pre-excitation) and symptomatic orthodromic AV-reentry tachycardia

<table>
<thead>
<tr>
<th>Score 1 (fully disagree)</th>
<th>Score 2</th>
<th>Score 3</th>
<th>Score 4</th>
<th>Score 5 (fully agree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only ablation if severely symptomatic (%)</td>
<td>15.7</td>
<td>13.7</td>
<td>17.6</td>
<td>27.5</td>
</tr>
<tr>
<td>Only ablation if severely symptomatic despite medical therapy (%)</td>
<td>18.0</td>
<td>20.0</td>
<td>8.0</td>
<td>22.0</td>
</tr>
<tr>
<td>Only ablation if patient weighs &gt;15 kg (%)</td>
<td>14.0</td>
<td>10.0</td>
<td>14.0</td>
<td>38.0</td>
</tr>
<tr>
<td>Only ablation if parents have a strong wish for cure (%)</td>
<td>16.0</td>
<td>14.0</td>
<td>24.0</td>
<td>32.0</td>
</tr>
<tr>
<td>I will wait with ablation until the child can make its own decision (ideally &gt;18 years) (%)</td>
<td>37.4</td>
<td>17.6</td>
<td>13.7</td>
<td>13.7</td>
</tr>
</tbody>
</table>

In their answer to the question the responders should indicate to what degree they would agree with a statement. Score 1 indicates that the responder fully disagree with the statement, whereas score 5 indicates that the responder fully agrees with the statement.
PACES/HRS Expert Consensus Statement on the Management of the Asymptomatic Young Patient with WPW Pattern

Baseline Electrocardiogram

- Persistent manifest pre excitation
  - Exercise Stress Test*
    - Persistent or uncertain loss of manifest pre excitation
    - Abrupt and clear loss of manifest pre excitation
      - Diagnostic transesophageal or intracardiac electrophysiology study**
        - SPERRI in atrial fibrillation > 250 msec and absence of inducible SVT††
          - Follow in cardiology with counseling regarding symptom awareness (Class IIA)
        - SPERRI in atrial fibrillation ≤ 250†
          - May consider ablation based on pathway location and/or patient characteristics (Class IIB)
        - Inducible SVT
          - Discuss risk/benefits of ablation (Class IIA)
          - Discuss risk/benefits of ablation (Class IIB)
How are arrhythmias managed in the paediatric population in Europe? Results of the European Heart Rhythm survey

Antonio Hernández-Madrid1, Mélèze Hocini2, Jian Chen3, Tatjana Potpara4, Laurent Pison5, and Carina Blomström-Lundqvist6, conducted by the Scientific Initiative Committee, European Heart Rhythm Association

- Patients with congenital heart disease
- Left-sided accessory pathways were ablated using a retrograde approach
- Small percentage of centres used electroanatomic mapping
- Cryoablation appears to be underutilized in the survey
Catheter ablation of LLAP
Permanent junctional reciprocating tachycardia (PIRT)
PJRT in children: Clinical profile and outcome

85 pts, age at diagnosis 0-20 yrs (median 3 mo)
57/85 presented before 1 yr (19 in utero, 3 hydrops)
Follow-up 0.1-26 yrs

28% had CHF at presentation which resolved with treatment in all

CHF more common in infants vs older pts (37% vs 11%)

Vaksmann G et al, Heart 2006;92(1): 101-104
PJRT in children: response to medical therapy
PJRT due to LPAP
PJRT stops during RFA at LP paraseptal site
Junctional ectopic tachycardia

Postoperative form
Congenital form
Adult onset form
Congenital JET
Congenital JET

Typically not associated with CHD

Often incessant

Positive family history in as many as 50% of cases

Associated with maternal SSA and SSB antibodies in some cases

*Dubin AM et al, Heart Rhythm 2005;2:313-15*
Congenital JET: Natural history

Often resistant to multiple AADs

May spontaneously resolve over months to years

*Villain E et al, Circulation 1990;81:1544-49*

May result in complete heart block

*Dubin AM et al, Heart Rhythm 2005;2:313-15*
Antiarrhythmic medications for SVT

Not a cure

May allow time for either spontaneous resolution (Infants with AVRT, EAT and JET) or for somatic growth to perform safe ablation

Proarrhythmia (Class IC, class III)

Multiple organ side effects (amiodarone)

Psychological and compliance issues
Adverse Effects of Radiation

- **Deterministic Effects**
- Skin injury and epilation (hair loss)
- Eyes (cataracts)
- Other organs (e.g. parotiditis)
  - Thresholds
  - Dose-response relationships
- **Stochastic Effects**
- Neoplasms
- Heritable genetic effects
  - Linear, no threshold model (LNT)
  - Latent periods

49-year-old woman with 8-year history of refractory supraventricular tachycardia.
Sharply demarcated ulceration above elbow 5 months after radiofrequency cardiac catheter ablation.

Skin wound caused by an estimated 2 hours of fluoroscope time during coronary angioplasty.
The first symptoms appeared six to eight weeks after the procedure. The wound appeared to heal spontaneously and then reappeared. This photograph was taken 18 to 24 months following the procedure.
Catheter placement with fluoroscopic vs non-fluoroscopic methods
Radiofrequency Ablation of Accessory Pathways in Children and Congenital Heart Disease Patients: Impact of a Nonfluoroscopic Navigation System

JOHN PAPAGIANNIS M.D., DIMOSTHENIS AVRAMIDIS M.D., CHRYSANTHOS ALEXOPOULOS M.D., GEORGE KIRVASSILIS M.D.


John Papagiannis, M.D., Division of Pediatric Cardiology, Mitera Children’s Hospital, 6 Erythrou Stavrou Street, 15123 Maroussi, Greece. Fax: 0030-210-6899405; e-mail: jpapagiannis@mitera.gr

Results: The two groups were comparable in terms of age, AP location, and presence of CHD. The mean age was 11.34 ± 4.65 years in group A versus 10.91 ± 3.68 years in group B. The procedure duration was significantly shorter in group B than in group A (177.06 ± 62.18 vs 242.45 ± 99.07) (P < 0.001). There was a significant reduction in the fluoroscopy time in group B compared to group A (8.27 ± 8.23 vs 39.77 ± 32.65 minutes) (P < 0.001). The difference between the two groups was statistically significant in all categories of APs. The success rate was 97.4% in group A and 96.6% in group B. There were no complications directly related to the use of the nonfluoroscopic system. There was no difference in the recurrence rate.

Conclusions: The use of a nonfluoroscopic system for catheter navigation resulted in significant reduction of total procedure and fluoroscopy time during catheter ablation of APs in pediatric and CHD patients, regardless of the location of the pathway, without a compromise in safety and efficacy. (PACE 2011; 34:1288-1296)
Διάρκεια επεμβάσεως: 1 ώρα και 30 λεπτά.
Χρόνος ακτινοσκόπησης: 25 δευτερόλεπτα.

ΣΥΜΠΕΡΑΣΜΑ: Δεν υπάρχει καμία περιοριστική περίοδος σε χρονικές υπηρεσίες αποκολλήσεων και προκεκλητική καλτοπλακατής σαμπλερία εποπτεύσεων.

Επιπλέον κατάληψη με ρεύμα ακτινοσκόπησης.

ΣΥΣΤΑΣΕΙΣ: Παρακολούθηση για 24 ώρες και επανέλεγχος με ΗΚΓ. Επανεξέταση σε 2 μήνες.

Οι Ιατροί

I. Παπαγάνης
Δ. Αβραμίδης
Επιστημονικός Υπεύθυνος
Επιμελητής
Παιδιατρική Ελεγκτική Κλινικής

Επιπλοκές δεν παρατηρήθηκαν. Η σεβαστής ανένήμηση από την ανασκόπηση και οδηγήθηκε στο θάλαμο της σε καλή κατάσταση.

Διάρκεια επεμβάσεως: 1 ώρα.
Χρόνος ακτινοσκόπησης: 0 λεπτά.
Αριθμός εφαρμογών ακτινοσκόπησης: 1.

ΣΥΜΠΕΡΑΣΜΑ: Δεν υπάρχει οποιοσδήποτε περιορισμός σε διεξαγωγή επιπλοκών καταληφθέν με ρεύμα ακτινοσκόπησης χωρίς επιπλοκές.

Οι Ιατροί
For women and children, the conversion factor is higher since they have a higher risk of cancer development by radiation. The proposed estimates for different age groups are:

- 3.7 ± 0.2 mSv in neonates
- 1.9 ± 0.2 mSv above 1 year
- **1.0 ± 0.1 mSv above 5 years**
- 0.6 ± 0.1 mSv above 10 years
- 0.4 ± 0.1 mSv between 15 and 20 years
159x1,1x1,09x10-4 = 0,019

**Risk Calculator**

<table>
<thead>
<tr>
<th>Plain Films (x-rays)</th>
<th>Chest x-ray (2 views)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest x-ray (2 views)</td>
<td></td>
</tr>
<tr>
<td>Abdomen x-rays</td>
<td></td>
</tr>
<tr>
<td>Pelvis x-rays</td>
<td></td>
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<tr>
<td>Hip x-rays (unilateral)</td>
<td></td>
</tr>
<tr>
<td>Neck x-rays</td>
<td></td>
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<tr>
<td>Upper Back x-rays</td>
<td></td>
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<tr>
<td>Lower Back x-rays</td>
<td></td>
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<tr>
<td>Extremity x-rays (Hands, Feet, etc)</td>
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<tr>
<td>Mammogram (unilateral)</td>
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<tr>
<td>Dental x-ray (panoramic)</td>
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<tr>
<td>Dental x-ray (4 intraoral bitewings)</td>
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<tr>
<td>Skull x-rays</td>
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<tr>
<td>DEXA Scan (Bone Density)</td>
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</table>

Dose is based on multiple views

<table>
<thead>
<tr>
<th>Study:</th>
<th>Chest x-ray (2 views):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender:</td>
<td></td>
</tr>
<tr>
<td>Male ○ Female ✗</td>
<td></td>
</tr>
<tr>
<td>Age at Time of Study:</td>
<td></td>
</tr>
<tr>
<td>Number of Exams:</td>
<td></td>
</tr>
<tr>
<td>Average Dose:</td>
<td></td>
</tr>
<tr>
<td>DLP (Optional for CT):</td>
<td></td>
</tr>
</tbody>
</table>

| Total Effective Dose:       | 0.1 (mSv)                                                  |
| Additional Cancer Risk:     | 0.00200 (%) [1 in 49850]                                   |
| Baseline Cancer Risk:       | 37.5 (%)                                                   |
| Baseline + Additional Risk: | 37.5020 (%)                                               |

To learn more about how these calculations are made, see the About page.
Pediatric ablation for SVT: safety issues

Vascular damage (2%), usually transient, occasional need for surgery (AV fistula, pseudoaneurysm)

Valvular and myocardial damage (small but well known risk)

AV block, risk ~1.2%, mostly septal APs (10%), AVNRT (1.6%)


Coronary artery damage, <1% (true incidence unknown)

Death: 10 of 4,651 cases (0.22%) reported to the Pediatric RFCA Registry (0.12%, ages 0.1 to 13.3 years with structurally normal hearts)

Schaffer MS, Am J Cardiol 2000;86(6):639-43
Enlargement of Catheter Ablation Lesions in Infant Hearts With Cryothermal Versus Radiofrequency Energy
An Animal Study

Paul Khairy, MD, PhD; Peter G. Guerra, MD; Lena Rivard, MD; Jean-François Tanguay, MD; Evelyn Landry, AHT; Marie-Claude Guertin, PhD; Laurent Macle, MD; Bernard Thibault, MD; Jean-Claude Tardif, MD; Mario Talajic, MD; Denis Roy, MD; Marc Dubuc, MD

Figure 2. Epicardial surface 1 year after ablation. Gross appearance of ventricular lesions 1 year after endocardial cryothermal (A) and radiofrequency (B) catheter ablation are shown. Note the large, pale, white lesions on the epicardial surface of the left ventricles. In addition, a pearly white transmural lesion produced in the left atrium by radiofrequency energy may be seen in panel B.

Figure 3. Histological characteristics of cryothermal and radiofrequency ablation lesions. Typical histological characteristics 1 month (A) and 1 year (B) after radiofrequency ablation are shown. Lesions at 1 month (C) and 1 year (D) after cryothermal ablation are shown. All displayed lesions were created in the right ventricle, stained with Masson trichrome, and magnified 16-fold for visual comparison. At 1 month, thrombus is noted on the surface of the radiofrequency (A) but not cryothermal (C) ablation lesion. Twelve-month lesions are devoid of surface thrombosis (B and D). Multiple extensions of fibrous and elastic tissue were observed as early as 1 month after ablation. Note the much larger lesion volumes at 12 months (B and D) compared with 1 month (A and C).

Conclusion
As the immature myocardium grows, atrial and ventricular lesions produced by cryothermal and radiofrequency ablation enlarge to a similar degree, refuting the notion that cryoablation should be favored on the basis of lesion expansion. In contrast, AV groove lesion volumes do not increase significantly with either energy modality. Further studies are required to elucidate the pathogenesis of ablation lesion growth in immature myocardium, identify potential therapeutic targets to limit lesion expansion, and assess the efficacy of preventive approaches.
Pharmacological and non-pharmacological therapy for arrhythmias in the pediatric population: EHRA and AEPC-Arrhythmia Working Group joint consensus statement

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Table 1  Recommendations for acute treatment of haemodynamically stable regular narrow QRS tachycardia in infants and children

<table>
<thead>
<tr>
<th>Drug/intervention</th>
<th>Dosage (iv)</th>
<th>Class</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vagal manoeuvres</td>
<td>Ice immersion, gastric tube insertion in infants, Valsalva, and head stand in older children</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Transoesophageal atrial overdrive pacing³</td>
<td>Rapid bolus starting dosages: For infants: 0.15 mg/kg. For &gt;1 year of age: 0.1 mg/kg Increasing dosage up to 0.3 mg/kg</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Adenosine</td>
<td></td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Verapamil b,c</td>
<td>0.1 mg/kg slowly over 2 min</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Flecaïnide b</td>
<td>1.5–2 mg/kg over 5 min</td>
<td>IIA</td>
<td>B</td>
</tr>
<tr>
<td>Propafenone b</td>
<td>Loading: 2 mg/kg over 2 h Maintenance: 4–7 μg/kg/min</td>
<td>IIA</td>
<td>B</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>Loading: 5–10 mg/kg over 60 min Maintenance infusion:5–15 μg/kg/min</td>
<td>IIb</td>
<td>B</td>
</tr>
</tbody>
</table>

iv, intravenously; Class, recommendation class; Level, level of evidence.
³Most effective if AV reentrant tachycardias or atrial flutter.
⁴Myocardial depressant effect.
⁵Contraindicated in infants <1 year of age.
Pharmacological and non-pharmacological therapy for arrhythmias in the pediatric population: EHRA and AEPC-Arrhythmia Working Group joint consensus statement

Table 3  Suggested doses and main side effects/precautions for commonly used oral prophylactic antiarrhythmic drugs for SVT and VT in infants and children

<table>
<thead>
<tr>
<th>Drug</th>
<th>Total daily dosage per body weight divided in × doses</th>
<th>Main contraindications and precautions</th>
<th>Features prompting lower dose or discontinuation</th>
<th>AV nodal slowing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digoxine</td>
<td>1–3 mg/kg in 3 × daily</td>
<td>Asthma bronchiale</td>
<td>Bradycardia</td>
<td>Moderate</td>
</tr>
<tr>
<td>Propranolol</td>
<td>0.3–1.3 mg/kg in 1 × daily</td>
<td>Asthma bronchiale</td>
<td>Bradycardia</td>
<td>Moderate</td>
</tr>
<tr>
<td>Atenolol</td>
<td>4–8 mg/kg in 3 × daily</td>
<td>Myocardial depressant effect</td>
<td>Bradycardia</td>
<td>Moderate</td>
</tr>
<tr>
<td>Verapamil</td>
<td>2–7 mg/kg in 2 × daily</td>
<td>Contraindicated if creatinine clearance &lt; 50 mg/mL or reduced LVEF. Caution if conduction system disease.</td>
<td>QRS duration increase &gt; 25% above baseline</td>
<td>None</td>
</tr>
<tr>
<td>Flecaïnide</td>
<td>200–600 mg/m² or 10–15 mg/kg in 3 × daily</td>
<td>Contraindicated if reduced LVEF. Caution if conduction system disease and renal impairment.</td>
<td>QRS duration increase &gt; 25% above baseline</td>
<td>Slight</td>
</tr>
<tr>
<td>Propafenone</td>
<td>2–8 mg/kg in 2 × daily</td>
<td>Contraindicated if significant LV hypertrophy, systolic HF, pre-existing QT prolongation, hypokalaemia, creatinine clearance &lt; 50 mg/mL and asthma bronchiale. Moderate renal dysfunction requires careful adaptation of dose</td>
<td>QT interval &gt; 500 ms</td>
<td>Similar to high-dose beta-blockers</td>
</tr>
<tr>
<td>Sotalol</td>
<td>Loading: 10 mg/kg for 10 days. Maintenance: 5 mg/kg in 1 × daily</td>
<td>Caution when using concomitant therapy with QT-prolonging drugs, HF. Dose of vitamin K antagonists and of digitoxin/digoxin should be reduced.</td>
<td>QT interval &gt; 500 ms</td>
<td>Slight</td>
</tr>
</tbody>
</table>

LVEF, left ventricular ejection fraction; HF, heart failure.
<table>
<thead>
<tr>
<th>Clinical situation</th>
<th>Recommendation</th>
<th>Class</th>
<th>Level</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>WPW syndrome and episode of aborted SCD</td>
<td>Catheter ablation</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>WPW syndrome and syncope combined with preexcited RR interval during AF &lt;250 ms or antegrade AERP during PES &lt;250 ms</td>
<td>Catheter ablation</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Incessant or recurrent SVT associated with ventricular dysfunction</td>
<td>Catheter ablation</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Recurrent monomorphic VT with haemodynamic compromise and amenable to catheter ablation</td>
<td>Catheter ablation</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>WPW syndrome and recurrent and/or symptomatic SVT and age &gt;5 years</td>
<td>Catheter ablation, Flecaïnine, propafenone, Sotalol, Amiodarone</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>WPW syndrome and recurrent and/or symptomatic SVT and age &lt;5 years</td>
<td>Flecaïnine, propafenone, Sotalol, Amiodarone</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>WPW syndrome and palpitations with inducible sustained SVT during EP test, age &gt;5 years</td>
<td>Catheter ablation, Flecaïnine, propafenone, Sotalol, Amiodarone</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Single or infrequent SVT (no pre-excitation), age &gt;5 years</td>
<td>None</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Valsalva maneuver <em>Pill-in-Pocket</em>:a</td>
<td>Ila</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flecaïnine (3 mg/kg), Diltiazem (120 mg) + Propranolol (80 mg)</td>
<td>Sotalol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beta-blocking agents</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catheter ablation</td>
<td>Ila</td>
<td></td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Catheter ablation, Any AA drug</td>
<td>III</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asymptomatic preexcitation, age &gt;5 years, no recognized tachycardia, risks and benefits of procedure and arrhythmia clearly explained</td>
<td>Catheter ablation</td>
<td>III</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Asymptomatic preexcitation, age &lt;5 years</td>
<td>Catheter ablation</td>
<td>III</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>SVT controlled with conventional AA medications, age &lt;5 years</td>
<td>Catheter ablation</td>
<td>III</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Idiopathic monomorphic ventricular tachycardia</td>
<td>Propranolol, Sotalol, Flecaïnine, propafenone, Verapamil, Procainamida, Amiodarone</td>
<td>III</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

WPW, Wolff–Parkinson–White; SVT, supraventricular tachycardia; LV, left ventricular; SCD, sudden cardiac death; AF, atrial fibrillation; AERP, accessory pathway effective refractory period; PES, programmed electrical stimulation; EP, electrophysiological; AA, antiarrhythmic; level, level of Evidence; Class, recommendation classification.

*Patients should be free of significant LV dysfunction, sinus bradycardia, or pre-excitation.
Prospective Assessment with Catheter Ablation (PAPCA) study for SVT

Overall success rate: 96%

Recurrence rate at 1 yr: 11% (mostly in the 1\textsuperscript{st} 2 months)
  - Lowest recurrence in the left lateral category
  - Highest in right lateral and septal

Presence of CHD and multiple APs associated with lower success rates

Van Hare GF et al, J Card Electrophysiol 2004;15:759-770
PACES/HRS expert consensus statement on the use of catheter ablation in children and patients with congenital heart disease

Developed in partnership with the Pediatric and Congenital Electrophysiology Society (PACES) and the Heart Rhythm Society (HRS). Endorsed by the governing bodies of PACES, HRS, the American Academy of Pediatrics (AAP), the American Heart Association (AHA), and the Association for European Pediatric and Congenital Cardiology (AEPC)

TASK FORCE CO-CHAIRS

J. Philip Saul, MD, FHRS, FACC, FAHA, FAAP, Ronald J. Kanter, MD, FHRS, FACC,

In the twelve years since publication of the last ablation guidelines for children and for all patients with CHD, advancements in imaging technologies and ablation energy sources have dominated the field and disproportionately influenced clinical practice. The general availability of EAM systems has led to a reduction in reliance on ionizing radiation for catheter manipulation and has helped refine the identification of arrhythmia substrates in abnormal anatomies. More robust use of higher-energy RF sources now results in greater ablation efficacy in patients with CHD; and, conversely, ablation using cryoenergy permits safer ablation of substrates in the most vulnerable parts of the heart. Together, these experiences have helped inform the recommendations in this document. In the coming years, it is expected that recently initiated registry-based projects will enable benchmarking of outcomes that will inspire the next iteration of guidelines.