Acute Termination of Supraventricular Tachyarrhythmias in Children by Transesophageal Atrial Pacing

MACDONALD DICK II, MD
WILLIAM A. SCOTT, MD
GERALD S. SERWER, MD
BURT I. BROMBERG, MD
ROBERT H. BEEKMAN, MD
ALBERT P. ROCCHINI, MD
A. REBECCA SNIDER, MD
DENNIS C. CROWLEY, MD
AMNON ROSENTHAL, MD

Supraventricular tachyarrhythmia, in contrast to arrhythmias in adults, is the most common abnormal tachycardia in infants and children.[1] When the tachyarrhythmia is reentrant, conversion by physiologic, pharmacologic or electrical interruption of conduction within a limb of the circuit is highly probable. Manipulation of physiologic vagal tone, the obviously preferred mode, is not successful or feasible in a number of patients. Pharmacologic manipulation has been the most commonly used; however, digoxin and propranolol may require several hours for conversion. Intravenous administration of verapamil offers prompt termination[2,3]; however, in newborns it may be unsuccessful and carries the risk of hypotension, bradycardia, apnea and negative inotropy, especially in patients with coexisting congestive heart failure.[4] Electrical conversion by transvenous atrial pacing or by direct current cardioversion requires invasive entry for 1 technique and frequently general anesthesia for the other. Recent reports from our institution[5-7] as well as from others[8,9] have demonstrated the usefulness, simplicity and safety of transesophageal atrial burst pacing for conversion of reentrant tachyarrhythmias in infants and children. The technique, however, has not been included among the recent recommendations of several authorities.[10-12] Our purpose, therefore, is to report our experience with transesophageal pacing in infants and children so that the technique may be more widely known.

Between April 15, 1983, and December 31, 1986, 43 children (25 boys and 18 girls) seen at our institution experienced 73 episodes of supraventricular tachyarrhythmia. Three of these children were less than 1 week of age; 7 children were 1 to 4 weeks of age; 9 were 1 to 12 months of age; 13 were 1 to 10 years of age; and 11 were 10 years of age at the time of their initial episode. Among the 43 patients, 25 had no structural heart disease; 18 had associated postoperative heart disease (9 transposition of the great arteries, 3 univentricular heart and 1 each of 6 different lesions). The older children were symptomatic with palpitations and the infants were symptomatic with tachypnea; 1 infant had hydrops. Twenty-six children had supraventricular tachycardia (SVT) and 17 had atrial flutter. For the purposes of this study, SVT was defined as narrow QRS tachycardia (except in patients in whom preexisting bundle branch block was known), and by history or observation of abrupt initiation and termination and retrograde P waves with short RP intervals.

Atrial flutter was defined by typical sawtooth-pattern P waves and variable atrioventricular block (leads II, III, aVF, V_1) on the electrocardiogram. Following the Mustard or Fontan operation, because of slow intraatrial conduction, the typical pattern is frequently absent in such patients. Atrial flutter in this group of patients was considered present if variable atrioventricular block was observed during the tachycardia and history or observation of abrupt initiation and termination was present. Of the 26 children with SVT, only 2 had associated structural heart disease; in contrast, 14 of the 17 children with atrial flutter had structural heart disease. Among the 25 children with SVT, 10 had preexcitation. Four patients, including 2 infants, were converted from 6 different episodes as outpatients, avoiding hospitalization. In addition 4 patients were converted after surgery while still in the intensive care unit.

To begin transesophageal pacing the patient is first connected to a 3-lead standard electrogram. An intravenous line is not routinely placed. The choice of the electrode catheter depends on the patient's age and size. In infants and small children up to 2 to 3 years of

TABLE I Clinical and Electrophysiologic Data

	No.	Mean ± SD	Range
Age (yr)			
Initial episode	43	5 ± 6	1 day–19 yr
Weight (kg)	43	—	2–77
Height (cm)	43	—	46–170
Arrhythmia (episode)			
Cycle length (ms)			
Supraventricular tachycardia	43	236 ± 46	140–333
Atrial flutter	27	241 ± 51	160–350
Pacing cycle at converison length (ms)			
Supraventricular tachycardia (episodes)	44	188 ± 36	100–300
Atrial flutter (episodes)	26	170 ± 34	110–220
Pacing stimulus strength at threshold (capture)			
Supraventricular tachycardia			
Amplitude (mA)	43	14 ± 4	8–20
Pulse duration (ms)	43	5 ± 2	3–10
Atrial flutter			
Amplitude (mA)	26	16 ± 3	10–20
Pulse duration (ms)	26	6 ± 2	4–10

The descrepancy in numbers between the arrhythmia and the pacing cycle length is related to incomplete data in a few patients.

From the Division of Pediatric Cardiology, C.S. Mott Children's Hospital, and the Department of Pediatrics, University of Michigan, Ann Arbor, Michigan. Manuscript received October 15, 1987; revised manuscript received and accepted December 11, 1987.

age, a 4Fr bipolar (10 mm interelectrode distance) catheter is used (n = 49 episodes). For children 3 to 8 years of age, a 6Fr endocardial pacing catheter (interelectrode distance 2.9 cm) is used (n = 13). Children 8 years and older are asked to swallow an electrode "pill" (n = 11). The 2 electrodes of the bipolar catheter are then connected to a recording amplifier and strip chart recorder. The electrodes are positioned close to the atrium by identifying the maximal atrial electrogram, thus enhancing the atrial signal, which may be small or within the QRS complex on the electrocardiogram. The battery powered stimulator provides constant current pulses from 1 to 40 mA and 1 to 10 ms in impulse amplitude and duration, respectively (Arzco Inc.). However, because of the experience in adults of excessive esophageal discomfort at stimulus strengths of >20 mA current and >10 ms pulse duration, no attempt to pace patients at outputs in excess of those values is made. The threshold is measured at the minimal current and pulse duration required for constant atrial capture (Table I). Pacing is delivered in bursts of 3 to 10 seconds at 90% of the tachyarrhythmia cycle length, reducing the cycle length of each burst by 10 ms until either the arrhythmia is converted or refractoriness of the atria is reached. Details of the technique have been published previously.[5-7] Other than one 18-month-old infant, no children under 2 years of age received sedation. Children aged 2 to 12 years often expressed apprehension regarding passage of the electrode catheter. In the 10 patients with continuing apprehension, sedation was accomplished with 75 to 100 mg/kg of chloral hydrate by mouth, an intramuscular injection (1 patient) of meperidine (1 mg/kg), phenergan (0.5 mg/kg) and thorazine (0.5 mg/kg), or diazepam (1 to 5 mg) administered intravenously. Because swallowing the pill electrode requires an awake, cooperative state, the 11 children using the pill did not receive (or request) sedation.

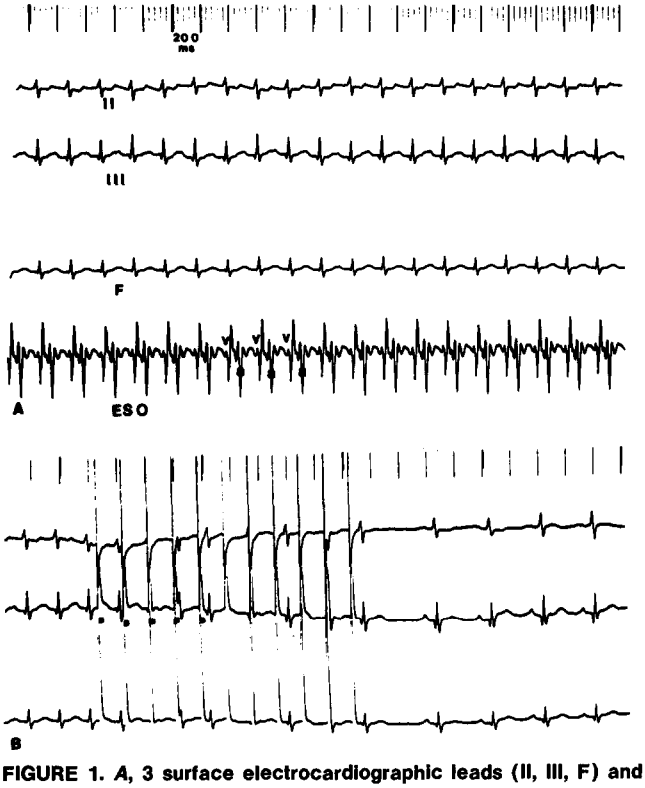

FIGURE 1. *A*, 3 surface electrocardiographic leads (II, III, F) and simultaneous esophageal lead (ESO) demonstrating tachycardia at a heart rate of 273 beats/min (cycle length 220 ms) in a 1-month-old infant. Note the narrow QRS and the large atrial (a) electrogram equal to the ventricular (v) electrogram. *B*, pacing stimuli (s) are delivered at a cyclic length of 170 ms (353 beats/min) for 1.7 seconds. Normal sinus rhythm appears after termination of pacing.

The threshold could be determined in each patient before conversion. Ninety-one percent (42/46) of episodes of supraventricular tachycardia were successfully converted using this technique (Figure 1). In contrast 74% (20/27) of episodes of atrial flutter were successfully converted to sinus rhythm ($p = 0.06$). Reasons for failure in the SVT group include failure to achieve capture in one 13-year-old patient dispite maximal 20 mA and 10 ms stimulus strength, depleted stimulator battery in 2 infants with SVT and insufficient shortening of the pacing cycle length in the fourth. All these failures occurred early in our experience (within the first 25 trials) and most likely can be avoided by improved attention to technique. Reason for failure of conversion of atrial flutter by this technique has been reviewed previously.[6] Conversion of SVT was achieved with pacing cycle length of 78% of the SVT cycle length. The pacing cycle length required to convert the patients with atrial flutter was slightly shorter at 71% of the atrial flutter cycle length. The threshold for capture was not related to the patients' age or size, the catheter used or the tachyarrhythmia converted, and did not differ between 2 separate episodes of tachyarrhythmia within a single patient with multiple episodes. Likewise, successful conversion was not related to the presence or absence of heart disease either as a whole or within either tachyarrhythmia groups[5-7] or to the presnce or absence of concurrent digoxin therapy.

All verbally expressive children stated, when asked, that they felt a sensation of "heartburn" (substernal discomfort) with each pacing discharge.[5-7] In no patient did this sensation require termination of the procedure. No complications were noted in the infants and children in whom the 4Fr soft bipolar electrode catheter was used. Passage of the catheter into the trachea occurred in a 13-year-old girl at which point the catheter was withdrawn and correctly placed with successful conversion. One 15-year-old girl bit through the fine wire of the pill electrode resulting in inadvertent pacing of her tongue. The pill was withdrawn, and exchanged for an endocardial pacing catheter with successful conversion. The next day she required repeat conversion and the pill was used successfully. One 19-year-old girl with a dual chamber pacemaker required programming of the pacemaker to the asynchronous (fixed rate) ventricular mode during conversion of atrial flutter to avoid inhibition of the pacemaker and ventricular asystole. One 5-year-old boy experienced inadvertent intermittent ventricular pacing during an unsuccessful at-

tempt in converting atrial flutter; no adverse effect was noted. Two 17-year-old boys immediately regurgitated the pill electrode after swallowing (they are not included in the 43 study patients).

Arrhythmias generated as a result of the technique occurred in 8 patients, all with atrial flutter. Three patients (2 with transposition/Mustard) were converted from atrial flutter to atrial fibrillation; the fibrillation persisted from 30 seconds to 45 minutes before self-extinguishing into sinus or a stable junctional rhythm. Three patients, all with transposition/Mustard, were converted from atrial flutter to atrial fibrillation or a faster flutter; these patients then received transthoracic direct current cardioversion under general anesthesia. No patient experienced hemodynamic deterioration or a ventricular response during atrial fibrillation faster than that observed during the original 2:1 atrioventricular block of atrial flutter. One patient with preexcitation but in atrial flutter was converted to SVT; the latter tachycardia was immediately converted to sinus rhythm. The final patient is the one with inadvertent ventricular pacing; no sustained arrhythmia was initiated. Thus, in none of the patients did an adverse arrhythmia develop and, importantly, in 3 patients conversion to a stable rhythm was achieved by a transition through a period of nonsustained atrial fibrillation.

These data indicate that transesophageal atrial pacing easily, predictably and safely converts reentrant supraventricular tachyarrhythmias to normal sinus rhythm. Although we and others have reported similar pediatric experience previously,[5-9] this more comprehensive serial study underscores the usefulness and safety of this technique especially in infants. Many authorities suggest that the first-line therapy for supraventricular tachycardia in infants and children is digoxin, and that if the patient is hemodynamically impaired, transthoracic direct current cardioversion.[10-12] Our data indicate that the delay inherent in digoxin or propranolol therapy, the risk of intravenous verapamil therapy and the transthoracic electrical discharge often requiring general anesthesia can frequently be avoided by transesophageal atrial pacing.

Our experience outlines several special applications of this technique in the young. First, although the time required to achieve access to the atria through the transesophageal route was not recorded, passage of the nasoesophageal catheter appeared to be quicker, simpler and less traumatic in an infant than establishing an intravenous route for pharmacologic agents. This difference in access is heightened by the potentially deleterious response to intravenous verapamil in the infant. Second, the use of a pill electrode requires, and may even encourage, a cooperative, participatory attitude in a reluctant older child or adolescent. The youngest patient to swallow the pill, which was used in all patients older than 10 years, was 8 years old. Third, the successful conversion of 74% of atrial flutter episodes suggests that this technique—perhaps because of the theoretical advantage of overdrive pacing for intraatrial reentrant arrhythmias when compared with most antiarrhythmic agents, and the smaller atrial size of young subjects—may be particularly suitable for children with atrial flutter.[6] Finally these data address the role of transesophageal atrial pacing in conversion of repeated episodes of either supraventricular tachycardia or atrial flutter in a single patient. Clearly, burst pacing through any route is an acute therapeutic technique and not a prophylactic one. Yet only 1 infant and two 8-year-old girls who were easily converted by transesophageal pacing immediately (within seconds) resumed the tachycardia. On the other hand, 19 of the 43 children required 1 or more repeat conversions at an interval of several hours to 3 years. Importantly, 4 of the 10 infants required repeat converison during their initial hospitalization while drug treatment was under evaluation. Although this study did not randomly assign to the patient episode or type of SVT transesophageal atrial pacing, drug trials or direct current cardioversion, it is nonetheless clear that atrial pacing through the esophagus offers at least equally prompt and safe therapy compared with the other forms of converison, especially in the infant.

1. Campbell RM, Dick M, Rosenthal A. *Cardiac arrhythmias in children. Ann Rev Med 1984;35:397-410.*

2. Soler-Soler J, Sagrista-Sauleda J, Cabrera A, Sauleda-Pares J, Iglesias-Berengue J, Permanyer-Miralda G, Roca-Llop J. *Effect of verapamil in infants with paroxysmal supraventricular tachycardia. Circulation 1979;59:876-878.*

3. Porter CJ, Garson A Jr, Gillette PC. *Verapamil: an effective blocking agent for pediatric patients. Pediatrics 1983;71:748-755.*

4. Epstein ML, Kiel EA, Victoria BE. *Cardiac decompensation following verapamil therapy in infants with supraventricular tachycardia. Pediatrics 1985; 75:737-740.*

5. Dick M, Campbell RM, Jenkins JM. *Thresholds for transesophageal atrial pacing. Cathet Cardiovasc Diagn 1984;10:507-513.*

6. Campbell RM, Dick M, Jenkins JM, Spicer RL, Rocchini AP, Crowley DC, Snider AR, Stern AM, Rosenthal A. *Atrial overdrive pacing in conversion of atrial flutter in children. Pediatrics 1985;75:730-740.*

7. Crawford TM, Dick M, Bank E, Jenkins JM. *Transesophageal atrial pacing: importance of the atrial-esophageal relationship. Med Instrument 1985;20: 40-44.*

8. Benson DW Jr, Dunnigan A, Sterba R, Benditt DG. *Atrial pacing from the esophagus in the diagnosis and management of tachycardia and management of tachycardia and palpitations. J Pediatr 1983;102:40-46.*

9. Benson DW Jr, Dunnigan A, Benditt DG, Prizker MR. *Transesophageal study of infant supraventricular tachycardia: Electrophysiologic characteristics. Am J Cardiol 1983;52:1102-1106.*

10. Garson A Jr. *Medicolegal problems in the management of cardiac arrhythmias in children. Pediatrics 1987;79:84-88.*

11. Silver HK, Kemp CH, Bruyn HB, Fulginitti VA. *Handbook of Pediatrics. Englewood Cliffs, New Jersey: Appleton and Lange, Prentice Hall, 1987:306.*

12. Newburger JW. *Cardiac Disorders. In: Graef JW, Cone TE Jr, eds. Manual of Pediatric Therapeutics. Boston: Little Brown and Co., 1985:243.*