Use of Transesophageal Atrial Pacing for Documentation of Arrhythmias Suspected in Infants and Children

Jae Kon Ko,1 MD, Su Jeong Ryu,1 MD, Ji Eun Ban,1 MD, Young Huwe Kim,1 MD, and In Sook Park,1 MD

SUMMARY

Transesophageal atrial pacing study was used to document arrhythmias in 67 infants and children age 2 months to 16 years (mean, 8.3 years), who had palpitations or symptoms suggesting tachyarrhythmias but had no electrocardiographic documentation of cardiac dysrhythmias. The transesophageal pacing and medical records were reviewed retrospectively.

In 47 of 67 (70%) of the infants and children with suspected tachyarrhythmias, transesophageal atrial pacing induced various tachycardias, which may be the cause of symptoms. In 10 of 67 patients, tachycardia was induced during infusion of isoproterenol. During the study, tachycardia was initiated in 14 of 15 patients less than < 6 years-old and in 33 of 52 patients ≥ 6 years-old (P < 0.05). Of these induced tachycardias, 25 of 47 were atrioventricular reciprocating tachycardia, 16 atrioventricular nodal reentrant tachycardia, and 6 idiopathic left ventricular tachycardia. Both transesophageal study and invasive electrophysiologic study were performed in 10 patients. The mechanisms of tachycardia in the invasive study and transesophageal study were identical except for one patient.

In conclusion, transesophageal atrial pacing and recording was less invasive, safe and useful for documenting arrhythmias in infants and children who had symptoms suggesting tachyarrhythmias, especially in patients < 6 years of age. Evaluation of the mechanism of induced tachycardia provided useful information regarding the prognosis and therapeutic options in infants and children. (Jpn Heart J 2004; 45: 63-72)

Keywords: Children, Tachycardia, Transesophageal atrial pacing

PALPITATION is an unpleasant awareness of a rapid heart beat and may be a terrifying event for children. Sometimes, in infants and young children, parents notice a paroxysmal rapid pulse by observing fluttering in the neck or pounding in the chest of their children. These symptoms often have been ascribed to a variety of cardiac rhythm disturbances and electrocardiographic documentation during episodes is the initial goal in the evaluation of patients with suspected
tachyarrhythmias. However, routine methods often fail to document episodic arrhythmia because the episodes may be brief, infrequent, or both.\textsuperscript{1-4)}

Transesophageal study is a minimally invasive procedure and atrial stimulation from the esophagus can initiate and terminate tachycardia.\textsuperscript{5)} The inducibility and causative mechanism of the tachycardia induced by transesophageal atrial pacing has shown an excellent correlation to findings at a subsequent invasive electrophysiologic study.\textsuperscript{6-10)} Information about the causative mechanism of the tachycardia provides a basis for determining whether therapy for tachycardia is indicated, and in some instances provides an opportunity for patient education to permit self-termination without medication.

The purpose of this study was to review the efficacy of transesophageal atrial pacing study for the documentation of arrhythmias in infants and children with symptoms suggesting tachyarrhythmias.

**METHODS**

**Patients:** Transesophageal electrophysiologic study was conducted between January 1998 and December 2001 on 69 infants and children with a history of at least 2 episodes of palpitations or symptoms suggesting tachyarrhythmias which were detected by parent's observation of paroxysmal rapid pulse, fluttering in the neck, or pounding in the chest. Medical and electrophysiologic study records were reviewed retrospectively. Transesophageal electrophysiologic study was completed in all but 2 girls who could not endure the chest discomfort. All infants and children had no evidence of other heart disease based on medical history, physical examination, chest roentgenogram, and/or echocardiographic examination. All patients underwent a standard electrocardiogram (ECG) and there was no evidence of preexcitation. Until transesophageal electrophysiologic study, no arrhythmic event was documented on the surface electrocardiograms. There were 32 female patients and 35 male patients. The patients were 2 months to 16 years old (mean, 8.3 years), and 11 of 67 were < 2 years old.

In 10 patients, a subsequent invasive electrophysiologic study for radiofrequency catheter ablation was performed.

**Transesophageal electrophysiologic study:** Transesophageal studies were performed in the fasting state on an outpatient basis after obtaining consent from the parents. Midazolam (0.1 mg/kg) was administered as needed through a venous line. A bipolar electrode was positioned in the esophagus at the appropriate depth according to the patient height. A pill electrode was used in older patients, and in younger patients a transesophageal electrode (Arzco 4 Fr) or a bipolar silicon electrode (Daig pacel 401673) with an interelectrode distance of 10 mm was inserted through the nares. When necessary, adjustments to the electrode position
were made in order to obtain the minimal pacing threshold. The bipolar esophageal ECG was filtered at 20-160 Hz and preamplified using an Arzco preamplifier, while the unipolar ECGs were connected directly to the ECG recorder (Marquette Mac VU) with a bandpass of 30 to 500 Hz and paper speeds of 25 and 50 mm/sec. Atrial stimulation was done with a pulse generator (Arzco model 7A) using a fixed pulse duration of 10 ms and a stimulus amplitude slightly in excess of that resulting in consistent atrial capture (10-20 mA). Atrial extrastimuli could not be introduced using an Arzco model 7A pulse generator so since 2000 we have been using a programmable stimulator (Medtronic 5328) connected to an Arzco model 7A pulse generator. Single extrastimuli at progressively closer coupling intervals were introduced at least 2 drive cycle lengths until the atrioventricular (AV) effective refractory period was reached. Incremental pacing to the point of second degree AV block and burst pacing at cycle lengths similar to those producing second degree AV block were performed. If sustained tachycardia was not induced under basal conditions, we repeated the pacing protocol after isoproterenol (0.05-0.1 µg/kg/min) infusion. The induced tachycardias were terminated by atrial overdrive pacing. The endpoint of the procedure was either an induction of tachycardia or completion of the protocol.

**Mechanisms of tachycardia:** Orthodromic reciprocating tachycardia was presumed to be present under the condition of regular rhythm, no evidence of AV dissociation, and the ventriculoatrial (VA) interval (onset of ventricular depolarization to rapid atrial deflection on the esophageal waveform) ≥ 70 ms (Figure 1). AV nodal reentrant tachycardia was presumed to be present under the condition of regular rhythm, there was no evidence of AV dissociation and the VA interval was < 70 ms (Figure 2). Ventricular tachycardia was diagnosed if tachycardia had a wide QRS morphology, and there was AV dissociation with a rapid ventricular rate. Idiopathic left ventricular tachycardia was presumed if ventricular tachycardia had a right bundle branch block morphology with a superior QRS axis and tachycardia was terminated by verapamil infusion.

**Statistical methods:** The statistical significance was tested between the patients with and without inducible tachycardia as a function of age by Fisher's exact test. A $P < 0.05$ was presumed to be significant.

**Results**

The onset age of palpitations or symptoms was 1 month to 14 years (mean, 6.6 years). In infants and young children, symptoms such as a rapid pulse, fluttering in the neck, or pounding in the chest, suggesting tachyarrhythmias were mainly detected by a parent. The duration of the symptoms was an average of 19 months (1 month to 10 years) before the study.
Figure 1. Atrioventricular reciprocating tachycardia.
A: Atrioventricular reciprocating tachycardia was induced by transesophageal atrial extrastimulus.
B: Measured ventriculoatrial interval was 100 ms in transesophageal electrocardiogram (Eso).
VA = ventriculoatrial interval; ESO = esophageal lead; v = ventricular deflection; a = atrial deflection.

Figure 2. Atrioventricular nodal reentrant tachycardia.
A: Atrioventricular nodal reentrant tachycardia was induced by transesophageal atrial extrastimulus.
Tachycardia was induced with atrioventricular conduction delay.
B: Measured ventriculoatrial interval was 50 ms in transesophageal electrocardiogram (Eso).
VA = ventriculoatrial interval; ESO = esophageal lead; v = ventricular deflection; a = atrial deflection.
In 47 of 67 patients (70%) who had completed the procedure, sustained tachycardia was induced during transesophageal study. In 10 patients, tachycardia was induced only during isoproterenol infusion, while in 37 patients, tachycardia was initiated in the basal state.

Table. Tachycardia Induction by Transesophageal Atrial Pacing

<table>
<thead>
<tr>
<th>Tachycardia induction</th>
<th>&lt; 6 Years old (n = 15)</th>
<th>≤ 6 Years old (n = 52)</th>
<th>Total (n = 67)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVRT</td>
<td>14 (93%)</td>
<td>20 (38%)</td>
<td>34 (51%)</td>
</tr>
<tr>
<td>AVNRT</td>
<td>5</td>
<td>11</td>
<td>16 (24%)</td>
</tr>
<tr>
<td>VT</td>
<td>4</td>
<td>2</td>
<td>6 (9%)</td>
</tr>
</tbody>
</table>

AVRT = atrioventricular reciprocating tachycardia; AVNRT = atrioventricular nodal reentrant tachycardia; VT = idiopathic LV tachycardia.

Figure 3. Idiopathic left ventricular tachycardia.
A: Tachycardia with wide QRS morphology was induced by burst transesophageal pacing.
B: Ventriculoatrial dissociation is clearly visible in the transesophageal electrocardiogram (Eso).
VA = ventriculoatrial interval; ESO = esophageal lead; v = ventricular deflection; a = atrial deflection.
Tachycardia was induced in 14 of 15 (93%) patients < 6 years old, whereas in patients ≥ 6 years old, 33 of 52 (63%) patients had inducible tachycardia (P < 0.05) (Table).

AV nodal reentrant tachycardia was induced in 16 (34%) patients and orthodromic reciprocating tachycardia was initiated in 25 (53%). The other 6 (13%) patients had idiopathic left ventricular tachycardia. In these 6 patients, wide QRS tachycardia was induced by burst atrial pacing and terminated by rapid overdrive atrial pacing. Wide QRS tachycardia had a right bundle branch block morphology with a superior QRS axis and AV dissociation was evident in the esophageal ECG (Figure 3). The ventricular tachycardia was also terminated in all 6 patients by verapamil infusion. Among these 6 patients, the youngest patient was 2 months old.

In 10 patients who had undergone both transesophageal study and invasive electrophysiologic study, the mechanisms of inducible tachycardia between 2 studies were identical, except for one patient. In this 14 year old female patient, regular narrow QRS tachycardia was induced and the VA interval was measured as 60 ms. This tachycardia was presumed to be tachycardia due to reentry within the AV node, but in the invasive electrophysiologic study, she had orthodromic
reciprocating tachycardia using the right posteroseptal accessory pathway (Figure 4).

No major complications occurred during or after transesophageal study.

**DISCUSSION**

The present study shows that in infants and children with a history of palpitations or symptoms suggesting tachyarrhythmias, transesophageal atrial pacing frequently (70%) induces various tachycardias, which may be the cause of the symptoms. In these patients, induction of tachycardia was more successful in infants and younger children than in older children. The mechanisms of induced tachycardias by transesophageal study showed good correlation with those by invasive electrophysiologic study.

Palpitations may be a terrifying event for children and their parents, and pose diagnostic problems for pediatric cardiologists. ECG documentation during episodes is important in the evaluation of the patients who have symptoms suggesting arrhythmias, but this can be a difficult task. The available noninvasive methods often fail to document episodic arrhythmia because the episodes may be brief, infrequent, or both.

In patients with symptoms due to suspected arrhythmias, Holter monitoring may allow assessment of the relationship between symptoms and dysrhythmias. Holter monitoring is widely used in arrhythmic disorders in adult patients. However, studies in the pediatric age group are limited and the diagnostic yield is low with arrhythmic symptoms.1-4)

The event recorder is complementary to Holter monitoring in the investigation of possible arrhythmias and is particularly suitable for patients with infrequent symptoms.11) A patient-activated ambulatory electrocardiogram device is not suitable for infants and young children because they can not activate the device appropriately and they can not acknowledge their symptoms. An automatic event recorder may be useful but practical experience is limited in the pediatric age group.12)

The provocation of tachycardia during exercise stress testing is rarely accomplished except in cases in which the symptoms are known to be precipitated by exercise.3,4)

Transesophageal atrial pacing study is a minimally invasive procedure, applicable to even young infants without major complications, and can be performed on an outpatient basis.5)

As demonstrated by the patients we studied, transesophageal atrial pacing study can be successfully used to elucidate a cause of symptoms in most infants and children. The results of this study demonstrate that in most infants and chil-
In young patients (70%) with suspected tachyarrhythmias, it is possible to initiate tachycardia and paroxysmal tachycardia is likely to be the cause of the symptoms in young patients without other evidence of heart disease. This result is comparable with that reported by Pongiglione, et al.\textsuperscript{13}) In their study induction of tachycardia was successful in 20 (71\%) of 28 patients, and 5 of the 28 patients had demonstrated ventricular preexcitation or a short PR interval which may lead one to suspect that the tachycardia was the probable cause of the symptoms. In their patients with palpitations, success in initiating tachycardia appears to be greater in adolescents than in younger children. However, in this study induction of tachycardia was more successful in infants and younger children than in older children. This difference seems to be due to the difference in the age of the patients between the two studies. In the study of Pongiglione, et al\textsuperscript{13}) there were no patients younger than 3 years, while in the present study, 11 of 67 patients were less than 2 years old and tachycardia was induced in all these patients.

Transesophageal stimulation infrequently results in ventricular pacing and therefore may be of limited value in the investigation of patients with paroxysmal ventricular tachycardia. In this study, ventricular tachycardia was induced by transesophageal atrial pacing in 6 patients and the youngest patient with ventricular tachycardia was 2 months old. Induced ventricular tachycardias were all idiopathic left ventricular tachycardia and all responded to verapamil. Idiopathic left ventricular tachycardia is known as it occurs primarily in young adults, and reports in pediatric age groups are limited.\textsuperscript{14-16}) Moreover, the occurrence of idiopathic left ventricular tachycardia in infancy seems to be infrequent and the natural course is unknown.\textsuperscript{15}) In 2 of 6 patients, this ventricular tachycardia was resolved spontaneously during follow-up without any medication.

By elucidating the cause of the symptoms and evaluation of the mechanism of induced tachycardia in young patients who have symptoms suggesting tachyarrhythmias, transesophageal study provided useful information for patient and parent education regarding prognosis and therapeutic options. In infants and young children, differentiation between AV nodal reentrant tachycardia and an accessory pathway related tachycardia is useful for both the patient and the pediatric cardiologist. AV nodal reentrant tachycardia may prefer to delay the invasive procedure in face of the known risk for damage to the normal conduction system during an ablation procedure in small children.\textsuperscript{17})

**Limitations of this study:** The mechanism of tachycardia evaluated in transesophageal study may not correlate with that of invasive intracardiac study. In this study, an incorrect diagnosis was made in one of 10 patients who underwent both transesophageal and invasive studies. In this patient the VA interval was measured to be 60 ms. The ventriculoatrial conduction intervals measured in transesophageal study can be a reliable marker with which to differentiate between AV
ESOPHAGEAL PACING FOR ARRHYTHMIA DOCUMENTATION

The causes of palpitations or symptoms suggesting tachyarrhythmias in infants and children, especially in patients less than 6 years of age, and evaluation of the mechanism of induced tachycardia provided useful information regarding the prognosis and therapeutic options in infants and children.

REFERENCES


