Origin of the Atrial Electrogram Recorded from the Esophagus

ERIC N. PRYSTOWSKY, M.D., EDWARD L.C. PRITCHETT, M.D., AND JOHN J. GALLAGHER, M.D.

SUMMARY The purpose of this study was to ascertain the origin of the atrial electrogram recorded on the esophageal lead. The atria and esophagus were mapped during reciprocating tachycardia in 11 patients with the Wolff-Parkinson-White syndrome and one patient with atrioventricular nodal reentry, and during right ventricular pacing in four additional patients. The esophagus was mapped by recording atrial electrograms at 1-cm intervals throughout the esophagus beginning at the most distal area where atrial depolarization was seen. The retrograde atrial activation time recorded on the esophageal lead in its distal position occurred at the same time as atrial septal depolarization in all patients. In 14 of 16 patients, the distal esophageal ventriculoatrial (VA) conduction time was also the shortest esophageal VA conduction time recorded. In two of five patients with left lateral accessory pathways, the shortest esophageal VA conduction time was noted during pullback of the lead from the esophagus instead of at the most distal area. The most likely explanation for this was an unusual anatomic relationship between the esophagus and left atrium in these two patients.

We conclude that 1) the most distal esophageal atrial electrogram probably records posterior paraseptal atrial depolarization; 2) it is unusual to record clearly identifiable left atrial activation in the esophagus; and 3) the esophageal lead is not useful in locating left-sided accessory pathways.

THE ESOPHAGEAL LEAD has been used to record atrial activity since 1906. Because the esophagus is adjacent to part of the left atrium, investigators have assumed that atrial activity recorded on an esophageal lead originates in the left atrium. Thus, the esophageal lead has been used in conjunction with a right atrial endocardial lead to measure interatrial conduction time, identify dissimilar atrial arrhythmias and study patients with the Wolff-Parkinson-White (WPW) syndrome. Because the esophagus is closer to the interatrial septum than to the left atrium through most of its intrathoracic course, the assumption that atrial activity recorded on an esophageal lead is from the left atrium may not be valid and needs to be tested.

Patients with the WPW syndrome have accessory pathways at different sites along the atrioventricular (AV) ring. In these patients, conduction in the retrograde direction during reciprocating tachycardia usually occurs over the accessory pathway, which can be located by endocardial mapping. After mapping, the earliest site of atrial activation is known, and these patients provide an excellent opportunity to compare activation sequences recorded on atrial and esophageal leads. The purpose of this paper was to analyze the origin of the atrial electrogram recorded on the esophageal lead during known different atrial activation sequences in patients with the WPW syndrome. The use of the esophageal lead in identifying left-sided accessory pathways was also investigated.

Methods

Studies were performed between January and June 1978 in 16 patients. Eleven patients were studied during reentrant tachycardia using an accessory pathway. One patient was studied during tachycardia due to reentry within the AV node. Four patients were studied during right ventricular pacing.

The sequence of atrial activation was recorded during endocardial mapping. In brief, during reciprocating tachycardia or right ventricular pacing, ventriculoatrial conduction times were recorded from known sites on the left AV groove with a modified Brockenbrough catheter in the coronary sinus and on the right AV groove. Ventriculoatrial conduction times were measured from the earliest recorded ventricular activity on either standard electrocardiographic or endocardial leads to the first rapid deflection of the atrial electrogram recorded at each site. The atrial septum was recorded with the Brockenbrough catheter in the foramen, medial right atrium (RA), and posteromedial RA positions. Atrial septal activity was also recorded from the His-bundle catheter.

Esophageal electrograms were recorded with a filtered Medtronic (Model #6904) bipolar endocardial lead. Simultaneous bipolar and unipolar recordings were obtained and there were no significant differences in ventriculoatrial conduction times between recording modes. The distal tip was inserted through the nares and positioned below the diaphragm using fluoroscopy. The lead was withdrawn at 1-cm intervals until atrial activity was first recorded; this distance from the nares to the distal tip was defined as the most distal atrial electrogram. As the esophageal lead was withdrawn, ventriculoatrial conduction times were recorded at 1-cm intervals until no further atrial ac-

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tivity was seen. All data were simultaneously recorded on tape at 3 1/4 inches/sec (Ampex PR2200) and directly written out at 250 mm/sec (Siemens-Elema Mingograf 1605).

**Results**

The endocardial mapping data are presented in table 1, together with the shortest ventriculoatrial conduction time recorded from the esophageal lead. Patient 1 had a left accessory pathway and his data are typical of this group of patients. Figure 1A shows ventriculoatrial conduction times during reciprocating tachycardia recorded during his electrophysiologic study. The earliest conduction time is 115 m sec and occurs at the lateral left atrium. The site of his pathway was confirmed at surgery during an epicardial map (fig. 1B).

Figure 2 shows the relationship of the esophageal lead to the left atrium in patient 1. The shortest ventriculoatrial conduction time on the esophageal lead was 160 m sec, recorded 43 cm from the nares. This conduction time occurred at the same time as activation of the atrial septum (fig. 1A).

**Esophageal Mapping Data**

Data from the esophageal recordings are shown in table 2. The most distal atrial electrograms were recorded 40-51 cm from the nares (mean 46 cm), and the location of the shortest ventriculoatrial conduction time was within 2 cm of the most distal electrogram in all patients except patients 2 and 7. Except for these two patients, the shortest esophageal ventriculoatrial conduction times occurred simultaneously with atrial septal activation.

Esophageal atrial electrograms were recorded for a distance of 7-17 cm (mean 12 cm). The site of the "best" atrial electrograms (those with the largest amplitude) varied considerably among patients (table 2). In most patients, excellent recordings could be obtained 37-41 cm from the nares. Figure 3 shows recordings from the esophagus during reciprocating tachycardia in a patient with a septal accessory pathway. Atrial potentials were recorded over a 16-cm distance beginning 40 cm from the nares. The best atrial electrograms were seen 26-32 cm from the nares. There was no increase in ventriculoatrial conduction time until the esophageal lead, as noted by fluoroscopy, was above the level of the heart (28 cm).

**Esophageal Map During Eccentric Atrial Activation**

Ventriculoatrial conduction time during esophageal mapping was plotted as a function of the distance of the esophageal lead from the nares (fig. 4). The graphs from patients with left-sided pathways are shown in
TABLE 1.  (Continued)

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180 220 210 220 210 220 220 — —

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200 200 180 160 160 140 120 120 120

140 140 140 140 140 140 140 — —

160 160 160 160 160 160 160 — —

170 170 170 170 170 170 170 — —

180 180 180 180 180 180 180 — —

190 190 190 190 190 190 190 — —

Graphs from patients without left-sided pathways are shown in figure 4B. The variability in these curves is similar to that seen in figure 4A. However, no patient had a large decrease in ventriculoatrial conduction time during pullback of the esophageal lead.

TABLE 2.  Location and Range of Esophageal Recordings

<table>
<thead>
<tr>
<th>Pt</th>
<th>Most distal atrial electrogram (cm)</th>
<th>Range of atrial recordings (cm)</th>
<th>Range of best atrial electrogram* (cm)</th>
<th>Location of earliest ventriculoatrial conduction time (cm)</th>
<th>Range of ventriculoatrial conduction time (msec)</th>
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Mean ± SD 46 ± 4 12 ± 3 37 ± 6-41 ± 4

*Atrial electrograms with the greatest amplitude.
FIGURE 1. Retrograde atrial map during reciprocating tachycardia in patient 1. The earliest ventriculoatrial conduction times recorded during the electrophysiology study (115 msec) (panel A) and at surgery (141 msec) (panel B) were at the lateral left atrium. At surgery, the left ventricle was paced and the external aspects of the atria were mapped, accounting for the differences in ventriculoatrial conduction times obtained in the laboratory and at surgery.

FIGURE 2. Relationship of the esophageal lead to the left atrium in patient 1. The lateral (panel A) and the right anterior oblique chest x-rays (panel B) are shown. The quadripolar catheter is in the coronary sinus, with the distal pair of electrodes at the approximate site of the accessory pathway. The bipolar catheter is in the esophagus, with the distal electrode 45 cm from the nares, where the most distal atrial electrogram was recorded.
Inability of Esophageal Lead
To Localize Left-sided Pathways

The interatrial septum is the earliest right-sided structure activated during reciprocating tachycardia in a patient using a left accessory pathway for conduction in the retrograde direction. Therefore, ventriculoatrial conduction time recorded on the esophageal lead would have to be significantly shorter than that recorded on the septum to identify the presence of a left-sided accessory pathway. This occurred only in patients 2 and 7 (table 3 and figure 5). The ability of the esophageal lead to identify these pathways was not dependent on a more lateral location of the pathway or on the atrial conduction time from the pathway to the septum. For example, patients 2 and 6 had left lateral pathways, and though atrial conduction time to the septum was longer in patient 6, the esophageal lead identified the pathway only in patient 2.

Discussion

Patients with the WPW syndrome who have reentry using an accessory pathway provide a means to study different sequences of atrial activation. The site of retrograde atrial activation during tachycardia can be determined accurately, and the pattern of atrial depolarization is not subject to minor variations in rate as is antegrade atrial depolarization during sinus rhythm. During reciprocating tachycardia, the origin of the esophageal atrial electrogram can be analyzed by comparing ventriculoatrial conduction times recorded on the intra-atrial leads with those recorded on the esophageal lead.

In all patients, the most distal esophageal atrial

<table>
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<tr>
<th>Pt</th>
<th>Left atrium</th>
<th>Septal area</th>
<th>Esophagus</th>
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Values are in milliseconds.
Figu re 5. Ventriculoatrial (VA) conduction intervals during reciprocating tachycardia in patient 2. The proximal coronary sinus (PCS) electrogram was recorded at the site of the accessory pathway and the distal coronary sinus (DCS) electrogram was lateral to this area. The earliest VA conduction time recorded on the esophageal lead (ESOPH) was shorter than the VA conduction time recorded at the septum (HBE). Lat RA = lateral right atrium.

electrogram probably recorded posterior paraseptal atrial depolarization, although the distance at which this recording was obtained was quite variable. As the esophageal lead was withdrawn, ventriculoatrial conduction-time curves were made. The shape of these curves varied and was not related to the site of the pathway, except for patients 2 and 7, in whom a significant decrease in conduction time was recorded as the catheter was withdrawn.

Retrograde atrial activation beginning in the lateral left atrium proceeds with wave fronts along the inferior and superior left atrial surface. As activation continues, the wave front of depolarization becomes complex. If recordings are obtained from a lead on the myocardium, accurate times of activation can be measured. As the lead is moved even small distances away from the heart, the recorded electrogram becomes a composite of multiple excitation waves. The esophageal maps of the patients with left-sided accessory pathways reflect these complexities of atrial activation.

At some point during pullback of the esophageal lead, the electrode will approach the left atrial wall near the interatrial septum. During reciprocating tachycardia with conduction in the retrograde direction over a left-sided accessory pathway, if the esophageal atrial electrogram originated from the left atrium, one would expect to see a curve like the one recorded in patients 2 and 7 (fig. 4). In these patients, there was a dip in the ventriculoatrial conduction-time curve as the esophageal lead was withdrawn. The dip resulted from a decrease in the ventriculoatrial conduction time from the value recorded at the septum (most distal atrial electrogram) to the value recorded with the esophageal lead at a more proximal position. The shorter ventriculoatrial conduction time occurred because the esophageal lead recorded left atrial activity in the more proximal position. In fact, only two of seven patients with a left-sided pathway had a dip in their curve. The reason for the dip seen in these patients could be: 1) location of the accessory pathway, 2) slower conduction to the atrial septum, or 3) more lateral relation of the esophagus to the left atrium.

The dip in the esophageal curve was seen only in patients with a lateral pathway, but three of five patients did not have this phenomenon. Atrial conduction time did not appear to be a major factor, for similar conduction times from the pathway to the interatrial septum were seen in patients with and without the dip in their curve. This factor cannot be excluded, for the mapping procedure cannot detect subtle local conduction differences. The most likely explanation for the curves in patients 2 and 7 is an unusual anatomic relation between the esophagus and left atrium.

Clinical Implications

Excellent atrial electrograms were recorded on the esophageal lead, which remains a valuable tool in the analysis of arrhythmias. The esophageal atrial electrogram should not be used in place of a coronary sinus electrogram when left atrial potentials need to be recorded. Although undoubtedly the esophageal electrode records left atrial potentials at some point in its withdrawal, it also records potentials from other areas of the atria and the resultant electrogram is a combination of this asynchronous conduction.

To ascertain the location of an accessory pathway, the most important data are the ventriculoatrial conduction times recorded at the atrioventricular ring. Because the esophageal atrial electrogram at this level appears to record posterior paraseptal atrial depolarization, it is not useful in localizing the site of a left atrial pathway. However, if the earliest ventriculoatrial conduction time recorded on the esophageal lead is significantly shorter than the earliest septal conduction time, the presence of a left-sided pathway is suggested.
Acknowledgment

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