

## Value of Transition Zone during Right Ventricular Entrainment in Determining Site of Accessory Pathway in Orthodromic Reentrant Tachycardia

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### Abstract

**Background:** RV entrainment is very important pacing maneuver during EP study. Resetting during the transition zone (TZ) of QRS fusion occur in orthodromic reentrant tachycardia (ORT) and after the TZ in atrioventricular nodal reentrant tachycardia (AVNRT) and this represents a simple diagnostic maneuver to differentiate the two tachycardia mechanisms.

**Objective:** The purpose of this study was to determine whether the number of beats with reset in the TZ predicts accessory pathway (AP) location in ORT and if value of PPI-TCL can help in localization of AP.

**Methods:** We prospectively and retrospectively reviewed 34 patients with ORT (18 left-sided AP, 10 septal AP, and 6 right-sided AP) out of 75 patients presented to EP lab with narrow complex tachycardia. In ORT patients we analyzed the number of beats with reset during the TZ, demonstrated by fixed ventricular stimulus-atrial (SA) interval during VOP and calculate PPI-TCL.

**Results:** In our study we found that total number of QRS complexes within TZ in AVRT group was (5.1 ± 2.3). The mean number of QRS with fixed SA interval within TZ was 2.2 ± 1.1 for left AP, 3.9 ± 1.1 for septal AP, 3.4 ± 0.9 for right AP. Using Cutoff point < 2 for left side AP Versus right and septal AP. Also, we found that value of PPI-TCL can help in detecting site of accessory pathway using cutoff point > 92ms with left AP and cutoff point ≤ 61 ms with right AP.

**Conclusion:** Assessing the number of beats in the TZ with fixed SA interval during VOP helps to determine AP location in ORT. Also PPI-TCL value help in localization of AP.

**Keywords:** Transition Zone (TZ); Orthodromic Reentrant Tachycardia (ORT); Atrioventricular Nodal Reentrant Tachycardia (AVNRT); Supraventricular Tachycardia (SVT)

### Introduction

Observations during tachycardia and sinus rhythm as well as several pacing maneuvers have been described in order to aid in the diagnosis of supraventricular tachycardia (SVT) and ultimately guide ablation strategy [1-6]. For example, a septal ventriculoatrial (VA) interval of < 70 ms is diagnostic of atrioventricular nodal reentrant tachycardia (AVNRT) [4].

Once an atrial tachycardia has been ruled out, an increase of > 35 ms in the VA interval during tachycardia with the development of a bundle branch block (BBB) indicates orthodromic reentrant tachycardia (ORT) through an accessory pathway (AP) ipsilateral to the BBB [1] and a corrected postpacing interval minus tachycardia cycle length (TCL) of < 110 ms [5] with stable fusion of the QRS complexes is highly specific for ORT.

During recent years studies have analyzed resetting during, or after the transition zone (TZ) of ventricular overdrive pacing (VOP) in order to rapidly distinguish ORT from AVNRT [7-9]. The TZ begins with progressive fusion beats between the paced and tachycardia wavefronts and ends with the first beat of stable QRS morphology, the latter representing constant fusion in the case of ORT and a fully paced QRS morphology in patients with AVNRT.

With few exceptions [10] resetting of ORT takes place during the TZ, given that ventricular activation is an obligatory part of the circuit, and after the TZ in AVNRT since the paced wavefront needs to progress beyond the His bundle and lower common pathway before entering the tachycardia circuit [7-9].

We hypothesized that the number of reset beats in the TZ during VOP would help determine AP location, due to the difference in proximity of the pacing catheter to the tachycardia circuit, so that ORT through a right-sided AP would produce reset before a left-sided AP, thus adding valuable information to an established diagnostic pacing maneuver. Also the difference between the postpacing interval (PPI) and tachycardia cycle length (TCL) was shown to be helpful in assessing the proximity of the pacing site to the reentry circuit [1] and differentiating atypical atrioventricular (AV) nodal reentrant tachycardia (AVNRT) from ortho-dromic reciprocating tachycardia (ORT) using a septal accessory pathway (AP) [2].

Subsequent study showed that the PPI-TCL that was subtracted by the induced delay in AV nodal conduction time from the PPI (corrected PPI-TCL) < 110 ms was useful to differentiate ORT from AVNRT [3]. Although ORT using a left-sided AP can easily be recognized by an eccentric retrograde atrial activation pattern in the left atrium, it requires a catheter placement in the coronary sinus (CS).

A simple diagnostic maneuver that can determine the site of the AP in ORT before placing the CS catheter or in case CS cannulation is difficult would be helpful. Because the right ventricular (RV) pacing site is closer to the reentry circuit of the ORT using a right-sided AP than a left-sided AP, the corrected PPI-TCL should be shorter in the ORT using a right-sided AP.

## **Patients and Methods**

### **Study design**

We performed a retrospective and prospective study to evaluate the electrophysiologic response of various SVT mechanisms to RV pacing delivered for the purpose of tachycardia entrainment.

### **Inclusion criteria**

All patient with documented narrow complex supraventricular tachycardia presented to electrophysiology lab including all age and sex groups (in Assiut university cath. lab and Cairo university cath. lab) during the period between April 2015 and April 2016. The study included 75 patients. The study protocol was approved by the Ethical Committee of Assiut Faculty of medicine.

### **Exclusion criteria:**

1. Atrial flutter.
2. Atrial fibrillation.
3. Manifest preexcitation on surface ECG.

All patients were subjected to:

1. Written informed consent.
2. Complete history and examination.
3. Twelve leads ECG during rest and another one with documented possible SVT.
4. The baseline electrophysiological study was performed after antiarrhythmic drugs had been discontinued for at least 5 half-lives.

The study included patients who presented with supraventricular tachyarrhythmia (AVNRT, AVRT, AT).

### **Electrophysiological procedure**

The study was done under local anesthesia and mild sedation. Quadripolar electrode catheters were inserted via the femoral vein and positioned in the high right atrium, right ventricular (RV) apex and the anteroseptal tricuspid valve (His bundle recording).

A deflectable decapolar catheter was inserted into the femoral vein and positioned in the coronary sinus (CS). All 12 ECG leads and intracardiac electrograms were recorded and stored on a digital recording system. Bipolar intracardiac electrograms were filtered between 30 and 500 kHz and recorded from the proximal electrode pair of quadripolar catheters and all pairs of decapolar catheters at speeds of 100 to 200 mm/s.

Bipolar pacing was performed from the distal electrode pair using a programmable stimulator (EP mate stimulator). The onset of RVP was timed to begin on the basis of sensing from the RV catheter so the coupling interval between the last sensed RV signal and the first paced beat approximated the pacing cycle length.

### **SVT diagnosis**

The diagnosis of typical AVNRT was made when the VA interval in the earliest intracardiac atrial recording was < 70 ms and 1 or more of the following criteria were satisfied:

1. Presence of anterograde functional dual AV nodal pathways;
2. A concentric midline atrial activation sequence during SVT that matched that during RV pacing;
3. AV block coincident with tachycardia termination; and
4. An "AV" response after entrainment with RVP and PPI-TCL > 115 ms and SA-VA > 85 ms.

The diagnosis of atypical AVNRT was made when earliest VA interval was > 70 ms and 1 or more of the following criteria were satisfied:

1. Concentric atrial activation pattern;
2. An "AV" response after entrainment with RVP and a PPI-TCL > 115 ms.

The diagnosis of orthodromic reciprocating tachycardia (ORT) was made when the earliest VA interval was > 70 ms and 1 or more of the following criteria were satisfied:

1. Eccentric atrial activation pattern.
2. An "AV" response after entrainment with RVP with a PPI-TCL < 115 ms and SA-VA < 85 ms.
3. Atrial timing was advanced and tachycardia reset, atrial timing delayed or tachycardia terminated without depolarizing the atrium associated with a scanned single premature ventricular extrastimulus that occurred when the His bundle was refractory (His synchronous single ventricular extrastimulus).
4. The VA interval during tachycardia increased by > 20 ms with the development of ipsilateral bundle-branch block.

Atrial tachycardia was diagnosed by the presence of an "AAV" response after RVP, absence of VA linking (i.e. variable AH and VA intervals), changes in H-H or V-V intervals that were preceded by changes in A-A intervals, or AV dissociation with rapid RVP at a cycle length between 200 and 250 ms during tachycardia

### **Characteristics of RV pacing trains and definitions**

RVP was attempted from the RV apex. Entrainment was confirmed when the atrial cycle length accelerated to the pacing cycle length (PCL) and the tachycardia resumed after pacing was discontinued.

Typically, RV Pacing results in overdrive suppression when the atrial cycle length is accelerated to the paced cycle length in patients with focal atrial tachycardia, but we defined this as "entrainment" in this study.

We reviewed the surface ECG for all patients included in this study. RVP trains were included in the analysis regardless of entrainment success if:

1. PCL was 10 to 40 ms shorter than the TCL; and
2. the maximum spontaneous oscillation in TCL within 3 cycles before the RVP train was < 10 ms.

The transition zone (TZ) of RVP was defined as the region that contains paced complexes showing progressive QRS fusion and the first paced complex showing a stable QRS morphology. The end of the TZ, therefore, usually is a fully paced complex, but this complex may represent constant fusion in some patients with ORT.

All 12 ECG leads were inspected (by at least 2 independant observers) to determine the beginning and the end of the TZ in all patients.

Resetting during VOP was defined as a fixed stimulus-atrial (SA) interval (variation < 10 ms), measured between the ventricular pacing stimulus to the earliest atrial activation.

The SA interval was measured at the end of the TZ, from the first paced complex showing a stable QRS morphology and for each subsequent QRS complex until pacing terminated or VA block occurred. When tachycardia resetting occurred during the TZ the number of beats with fixed SA interval was recorded and in the case of tachycardia resetting after the TZ, the number of beats outside the TZ until the establishment of a fixed SA interval was noted.

For the purpose of measuring SA intervals, an RVP train that resulted in termination of tachycardia was included if:

1. No change in atrial activation sequence was noted before SVT termination and
2. There were at least 3 paced QRS complexes with a stable morphology and VA conduction. When fusion beats resulted in termination of tachycardia during RVP train SA interval was measured during other RVP trains in the same patient.

**Tachycardia induction**

If tachycardia is not induced in the baseline state, atropine or dobutamine was infused to facilitate its induction.

**Results**

**Baseline characteristics**

A total number of 75 patients with history of paroxysmal SVT were included in study. There were 36 patients with typical AVNRT, 34 patients with ORT and 5 patient with AT. In AVRT group 18 patient (of 34) had left lateral accessory pathways, 10 patients had septal accessory pathways and 6 patient had right lateral accessory pathways. Baseline patient characteristics are shown in table 1.

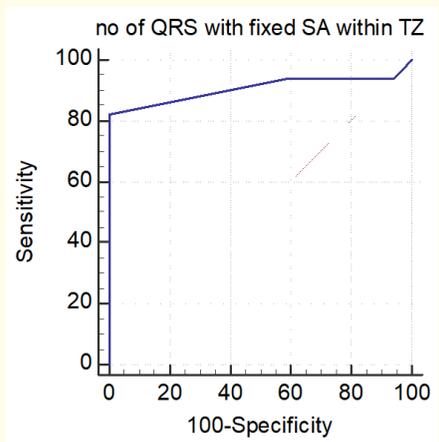
| Type of tachycardia |                     | No.          | %     |    |       |    |          |        |
|---------------------|---------------------|--------------|-------|----|-------|----|----------|--------|
| AT                  |                     | 5            | 6.6   |    |       |    |          |        |
| AVNRT               |                     | 36           | 48    |    |       |    |          |        |
| AVRT                |                     | 34           | 45.3  |    |       |    |          |        |
| Range               |                     | 260 - 460    |       |    |       |    |          |        |
| Mean ± SD           |                     | 332.1 ± 42.6 |       |    |       |    |          |        |
|                     | Type of tachycardia |              |       |    |       |    | P. value |        |
|                     | AT                  |              | AVNRT |    | AVRT  |    |          |        |
|                     | No.                 | %            | No.   | %  | No.   | %  |          |        |
| <b>Age</b>          |                     |              |       |    |       |    |          |        |
| < 20 years          |                     | 2            | 40.0  | 2  | 5.6   | 9  | 26.4     | 0.020* |
| 20 - 40 years       |                     | 1            | 20.0  | 11 | 30.6  | 19 | 55.8     |        |
| 40 - 60 years       |                     | 2            | 40.0  | 22 | 61.1  | 6  | 17.6     |        |
| > 60 years          |                     | 0            | 0.0   | 1  | 2.8   | 0  | 0.0      |        |
| <b>Sex</b>          |                     |              |       |    |       |    |          |        |
| Male                |                     | 2            | 40.0  | 16 | 44.4  | 14 | 41.1     | 0.830  |
| Female              |                     | 3            | 60.0  | 20 | 55.6  | 20 | 58.8     |        |
| RV entrainment      |                     | 2            | 40.0  | 36 | 100.0 | 34 | 100.0    | 0.000  |
| AV dissociation     |                     | 3            | 60.0  | 0  | 0.0   | 0  | 0.0      |        |

**Table 1:** Baseline characteristics of study subjects.

**Number of QRS complexes with fixed SA within TZ**

In our study we found that mean number of QRS with fixed SA interval within TZ was  $2.2 \pm 1.1$  for left AP,  $3.9 \pm 1.1$  for septal AP,  $3.4 \pm 0.9$  for right AP.

From ROC curve analysis cutoff point for number of QRS with fixed SA interval within TZ was  $\leq 2$  for left AP versus right and septal AP.



**Figure 1:** NO of QRS within TZ with fixed SA interval ...cutoff point of LT lateral AP vs RT AP. LT lateral AP vs. RT AP. Cutoff  $< 2 \rightarrow$  left.

|                                   | Septal AP     | Left lateral AP | Right AP      | P. value |
|-----------------------------------|---------------|-----------------|---------------|----------|
| No of QRS within TZ with fixed SA | $3.9 \pm 1.1$ | $2 \pm 1.1$     | $3.4 \pm 0.9$ | 0.001**  |

**Table 2:** No of QRS complexes within TZ with fixed SA interval in different accessory pathways. TZ: Transition Zone; AP: Accessory Pathway; SA: Stimulus Atrial.



**Figure 2:** Case 1: case of AVRT in which VOP showed 2 QRS with fixed SA interval within TZ. This patient has left lateral AP.

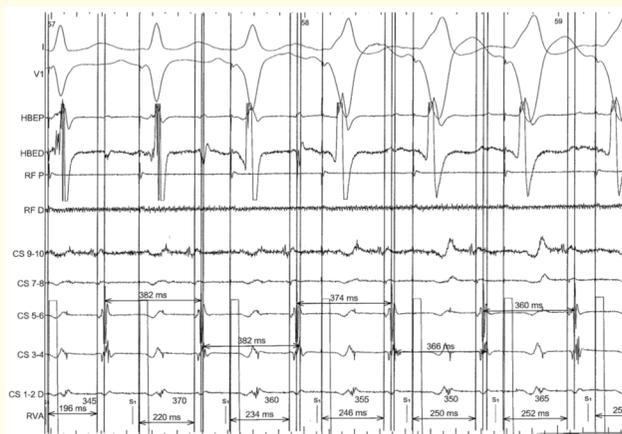


Figure 3: Case 2: AVRT with septal AP in which VOP showed 3 QRS with fixed SA interval within TZ.

|                                   | AUC   | Cutoff | Sensitivity | Specificity | PPV | NPV  | Accuracy |
|-----------------------------------|-------|--------|-------------|-------------|-----|------|----------|
| For left (QRS)Vs RT and septal AP | 0.908 | ≤2     | 82.4        | 100         | 100 | 85   | 91.2     |
| For right (QRS)Vs septal AP       | 0.642 | ≤3     | 80          | 50          | 40  | 85.7 | 65       |

Table 3: Sensitivity, specificity, PPV and NPV of no of QRS within TZ with fixed SA interval in different types of accessory pathways.

NPV: Negative Predictive Value; PPV: Positive Predictive Value; AP: Accessory Pathway.

From table above we found that there was low sensitivity and high specificity for number of QRS with fixed SA interval within TZ in discriminating left AP versus RT and septal AP. However, had low sensitivity and specificity in differentiating right versus septal AP.

**Value of PPI-TCL in determining site of accessory pathway in AVRT group**

In our study we found that value of PPI-TCL can help in detecting site of accessory pathway.

From analysis of ROC curve we found that cutoff point > 92 ms with left AP and cutoff point ≤ 61 ms with right AP.

|                               | Sensitivity | Specificity | PPV   | NPV  | Accuracy |
|-------------------------------|-------------|-------------|-------|------|----------|
| LT lateral AP vs. rt and sept | 72.7        | 100.0       | 100.0 | 78.6 | 86.4     |
| RT lateral AP vs. sept        | 100.0       | 87.5        | 75    | 100  | 93.7     |

Table 4: Sensitivity, specificity, PPV and NPV of PPI-TCL interval in different types of accessory pathways.

NPV: Negative Predictive Value; PPV: Positive Predictive Value; AP: Accessory Pathway.

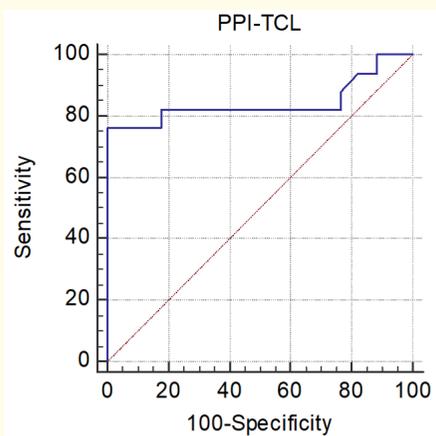


Figure 4: Roc curve to predict the cutoff value of PPI-TCL for left vs. right and septal AP.

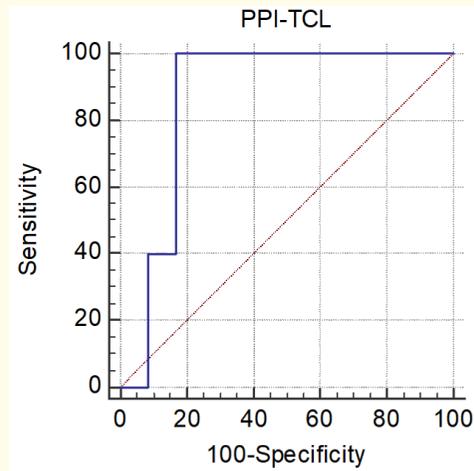


Figure 5: Roc curve to predict the cutoff value of PPI-TCL for right Vs. septal AP.

## Discussion and Conclusion

This study sought to evaluate whether the number of reset beats, defined as fixed SA interval, in the TZ during VOP from RV apex of ORT depend on the proximity of the AP to the pacing catheter, thereby predicting AP location.

In our study the mean number of beats in the TZ with fixed SA interval was  $2.7 \pm 1.0$  for the whole ORT group,  $2 \pm 0.6$  for left-sided AP,  $3.5 \pm 0.8$  for septal AP and  $3.4 \pm 0.9$  for right-sided AP ( $P < 0.001$ ). Using a cutoff  $< 2$  beats distinguished left versus right-sided and septal AP in all cases.

Akerstrom, *et al.* [11] assessed the number of beats in the TZ with fixed SA interval during apical right VOP helps to determine AP location in ORT, the mean number of beats in the TZ with fixed SA interval was  $2.5 \pm 1.4$  for the whole ORT group,  $1.1 \pm 0.4$  for left-sided AP (range 1 - 2),  $2.8 \pm 0.9$  for septal AP and  $4.0 \pm 0.9$  for right-sided AP ( $P < 0.001$ ). Using a cutoff  $> 2$  beats distinguished right- versus left-sided AP in all cases.

Miles, *et al.* [12] studied the preexcitation index (PI;  $V1V1 - V1V2$ ) derived from ventricular-induced atrial preexcitation during AVNRT or ORT and found that the further the pacing catheter is from the tachycardia circuit, the more premature the ventricular extrasystole has to be in order to penetrate the AP and preexcite the atrium.

As expected, left-sided AP required a significantly longer PI when compared with septal AP to produce atrial preexcitation ( $PI \geq 75$  and  $< 45$  ms occurred only in left-sided and septal AP, respectively).

Our observation that the prematurity of resetting of ORT during VOP depends on the location of the AP is thus analogous to that of the preexcitation index, i.e. the proximity of the pacing catheter to the tachycardia circuit dictates the degree of readiness to produce atrial preexcitation and reset by “getting ahead” of the retrograde limb of the tachycardia circuit, either by a single ventricular extrastimulus or by continuous advancements of the VOP orthodromic wavefront [13].

### The number of beats with stable morphology required to accelerate the tachycardia to the pacing rate in AVNRT group

In our study we found that in AVNRT total number of pacing beats with stable morphology required to reset tachycardia was  $3.6 \pm 0.9$  while in AVRT it was  $1.0 \pm 0$ .

Dandamudi, *et al.* [8] found that the number of beats (having a stable paced morphology) required to accelerate the tachycardia to the pacing rate in AVNRT was  $3.7 \pm 1.1$  while in AVRT it was  $1.0 \pm 0$ . The authors used a cut off of 1.0 which had a 100% positive and a negative predictive value for AVNRT over AVRT.

This maneuver is based on a simple principle that it is easier to entrain and reset AVRT during ventricular entrainment as the ventricular pacing site is close to the tachycardia circuit when compared with AVNRT. Also, the AVRT circuit is larger than AVNRT circuit with a large excitable gap.

Rosman, *et al.* [9] found that advancement during the TZ or after  $1 \pm 0$  stable paced QRS was consistent with AVRT, whereas  $4 \pm 1$  stable paced QRS complexes were needed to advance atrial activation during AVNRT.

#### **Value of PPI-TCL in determining site of accessory pathway in AVRT group**

In our study we found that value of PPI-TCL can help in detecting site of accessory pathway.

Cutoff point  $> 92$  with left AP and cutoff point  $\leq 54$  with right AP.

Boonyapisit, *et al.* [14] found that the mean corrected PPI-TCL was  $83 \pm 20$  ms in patients with ORT using a left-sided AP and  $27 \pm 19$  ms in patients with a right-sided AP. All patients with ORT using a left-sided AP except three patients with left septal AP and none of the patients with ORT using a right-sided AP had a corrected PPI-TCL  $> 55$  ms.

Gonzalez-Torrecilla, *et al.* [15] also found that the corrected postpaced interval tachycardia cycle length (PPI-TCL) was significantly shorter for septal APs when compared to free-wall APs, and one patient with a free-wall AP presented a corrected PPI-TCL long enough to be incorrectly classified as AVNRT.

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