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Original Article

Role of Programmed Ventricular Extrastimulation in Differentiating Atrioventricular Nodal Re-entrant and Atrioventricular Re-entrant Tachycardias in Supraventricular Tachycardias

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ABSTRACT

Objective: To evaluate the diagnostic effectiveness of Programmed Ventricular Extrastimulus (PVE) during supraventricular tachycardia (SVT) in differentiating atrioventricular nodal re-entrant tachycardia (AVNRT) from atrioventricular re-entrant tachycardia (AVRT).

Study Design: Analytical Cross-Sectional Study

Place and Duration of Study: Electrophysiology Department, Armed Institute of Cardiology/National Institute of Heart Disease, Rawalpindi, Pakistan, from Mar to Aug 2025

Methodology: A total of 180 adult patients (aged ≥18 years) of either gender with suspected or documented supraventricular tachycardia (SVT) or inducible tachycardia during an electrophysiology (EPS) study were enrolled. Both ventricular entrainment and PVE (V2) pacing techniques were applied to record electrophysiological parameters, including stimulus-to-atrial minus ventriculoatrial (SA-VA) time and post-pacing interval minus tachycardia cycle length (PPI–TCL). Based on EPS findings, patients were classified into two groups: AVNRT (n=90) and AVRT (n=90).

Results: Among 180 patients, the AVNRT group included 53 males (58.9%), and the AVRT group had 64 males (71.1%). The mean age was 45.50 ± 15.31 years in the AVNRT group and 34.29 ± 11.78 years in the AVRT group (p<0.001). AVNRT patients exhibited significantly longer PR intervals (168.59 ± 9.81 ms) and shorter VA intervals during SVT (53.47 ± 7.94 ms) compared to AVRT patients (145.33 ± 12.58 ms and 166.1 ± 9.91 ms, respectively; p<0.001). Using the V2 technique, an SA–VA interval cutoff of 92.00 ms achieved 100% sensitivity and specificity for differentiating AVNRT from AVRT, with an AUC of 1.00 (95% CI: 1.00–1.00, p<0.001), indicating perfect diagnostic performance.

Conclusion: PVE from the right ventricle (V2) shows excellent diagnostic accuracy in differentiating AVNRT from AVRT involving septal or right-sided accessory pathways.

Keywords: Atrioventricular Nodal Re-entry. Re-entrant, Sensitivity and Specificity, Stimulus, Supraventricular tachycardia

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INTRODUCTION

Paroxysmal supraventricular tachycardias (PSVTs) are common arrhythmias, with a prevalence of one in 300 in the United States, although data from Pakistan and South Asia are limited.[1,2] The overall incidence is approximately 36 per 100,000 people. Atrial fibrillation is the most common arrhythmia, affecting 3 million persons in the United States, with a 0.4-1% incidence.[3] Radiofrequency catheter ablation is commonly accepted as a final treatment for most SVTs, but its effectiveness is heavily dependent on a correct diagnosis.[4] The three most prevalent forms of SVTs are atrioventricular nodal tachycardias (AVNRT), atrial tachycardia, and atrioventricular re-entry tachycardias (AVRT). Electrophysiological studies of these arrhythmias use a variety of diagnostic manoeuvres to identify their precise source and ablation target.[2] Differentiating between AVNRT and accessory pathway-mediated AVRT is difficult, even during electrophysiological studies, and becomes important when the arrhythmia is resistant to treatment and catheter ablation is typically being considered.[5] Ventricular entrainment is one of the most useful manoeuvres to distinguish AVNRT from AVRT, as it can be done by comparing the stimulus atrial (SA) interval after ventricular entrainment to the ventriculoatrial (VA) interval during tachycardia or by comparing the post-pacing interval (PPI) and tachycardia cycle length (TCL).[5] However, this manoeuvre frequently results in AV dissociation, which has been found to occur in 5% to 65% of patients.[6]

SA−VA after resetting with ventricular extrastimulus (V2) can differentiate AVNRT from AVRT. However, this characteristic overlaps between

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AVNRT and AVRT with a left/free wall accessory pathway.[7] Although several moves have been described to distinguish AVNRT from AVRT, each has limitations.[8,9] However, analysing the beginning of ventricular entrainment efficiently distinguishes AVRT from AVNRT instances, with a high positive predictive value.[10]

There is minimal but promising global research on the use of programmed ventricular extrastimulus (PVE) to distinguish AVNRT from AVRT, with methodology variations leading to contradictory results. The purpose of this study is to determine if RV extrastimulus resetting is comparable or superior to ventricular entrainment in distinguishing various arrhythmias, as well as to investigate the diagnostic value of early coupling intervals through analysis of VA intervals and tachycardia cycle duration. The purpose is to improve diagnostic techniques for SVTs and support clinical decision-making in AVNRT and AVRT treatment.

METHODOLOGY

Present study was an analytical cross-sectional study conducted at the Electrophysiology Department, Armed Forces Institute of Cardiology & National Institute of Heart Diseases, Rawalpindi, from March 2025 to August 2025, following approval from the Institutional Ethical Review Board (IERB) (ltr#9/2/R&D/2025/342). The data was acquired using non-probability sequential sampling.

The WHO calculator was used to calculate the sample size, which was 180 patients, based on the 0.38 and 0.62 proportions of AVRT and AVNRT patients found with PVE5, respectively. The computation was performed with 95% confidence, 80% power, and a 5% margin of error. The study included 90 individuals with AVNRT and 90 patients with AVRT.

Inclusion Criteria: Patients aged ≥18 years, irrespective of gender, with suspected or documented PSVT and inducible tachycardia during EPS were enrolled.

Exclusion Criteria: Patients < 18 years and adults with structural heart disease, significant ventricular dysfunction, or other arrhythmias were excluded from the study.

Patients who presented to the electrophysiology unit with symptoms suggestive of SVT, such as palpitations, dizziness, or syncope, were initially assessed by the clinical team. Upon confirmation of eligibility, written informed consent was obtained, ensuring each participant clearly understood the study objectives, procedures, and potential risks. Baseline demographic and clinical details were recorded. Subsequently, electrophysiological studies (EPS) were conducted under local anesthesia and conscious sedation. Intracardiac electrograms were acquired by introducing catheters through femoral venous access into the right atrium, right ventricle, coronary sinus, and His bundle. These recordings were used to evaluate baseline conduction properties and the underlying mechanisms of tachycardia.

Tachycardia was then induced using programmed atrial or ventricular stimulation. In cases where SVT could not be induced at baseline, isoproterenol infusion was administered to increase the sinus rate (>20% or >100 bpm), followed by repeated stimulation attempts. Once a sustained tachycardia was achieved, the tachycardia cycle length (TCL) was measured and documented. PVE was performed using a catheter placed in the right ventricular cavity. Premature ventricular contractions (PVCs) were delivered at progressively shorter coupling intervals (CIs), starting from a value 10 ms shorter than the TCL. These intervals were decreased in 10-ms steps until resetting occurred, or the ventricular effective refractory period was reached. Resetting was confirmed when atrial depolarisation following the PVC was advanced or delayed by at least 10 ms without terminating the tachycardia. The shortest CI that resulted in resetting was recorded.

Tachycardia response to PVE was categorised into three patterns: termination of tachycardia, resetting of tachycardia, or no measurable effect. VA intervals and early CIs were measured during this manoeuvre to assist in the differentiation of AVNRT (typically associated with shorter VA intervals) from AVRT (characterised by longer VA intervals due to retrograde conduction via accessory pathways). After diagnosis, 90 patients with AVNRT and 90 patients with AVRT were recruited in this study. RV entrainment testing was also conducted using pacing at a cycle length 10–30 ms shorter than the TCL. Entrainment was considered successful when the atrial cycle length matched the pacing cycle and maintained the same activation sequence, with tachycardia resuming post-pacing. The V2 technique was repeated in this phase as well to reconfirm resetting behaviour. Post-procedure, patients were monitored in the recovery unit for immediate complications such as arrhythmias or hemodynamic

instability. A follow-up ECG was performed two weeks later to assess for arrhythmia recurrence or delayed procedural effects.

After data collection, the data were analyzed using statistical software (SPSS version 23.0). Normality was tested through Shapiro Wilk, and the data were found to be normally distributed. Mean and standard deviation were reported for continuous variables and compared by independent samples t test, while frequency and precentage were reported for categorical variables and compared using chi-square or Fisher's exact tests, as appropriate. The sensitivity, specificity, area under the curve (AUC), and diagnostic accuracy of SA–VA intervals were calculated to assess its utility in differentiating AVNRT from AVRT, with a *p*-value of <0.05 considered statistically significant

RESULTS

One hundred eighty patients were recruited in this study. The mean age of AVNRT patients was 45.50±15.31 years, significantly higher than that of AVRT patients, who had a mean age of 34.29±11.78 years (p<0.001). Gender distribution showed 53(58.9%) males in the AVNRT group and 64(71.1%) in the AVRT group, with no statistically significant difference (p=0.118). Ejection fraction was comparable between groups (58.16±2.74% in AVNRT vs. 58.72±2.19% in AVRT, p=0.136). Hypertension and diabetes mellitus were significantly more common in the AVNRT group [27(30%) and 20(22.2%), respectively] compared to the AVRT group [4(4.4%) and 3(3.3%), respectively], with p<0.001 for both as depicted in Table-I.

AVNRT patients had significantly longer PR intervals (168.59±9.81 ms vs. 145.33±12.58 ms), TCL (357.31 ± 23.11 ms vs. 345.56±15.65 ms), SA-VA during entrainment (129.57±12.44 ms vs. 52.67±4.01 ms), and PPI-TCL (159.52±9.32 ms vs. 84.76±4.39 ms). In contrast, the VA interval during SVT (53.47±7.94 ms vs. 166.1±9.91 ms) and CI/TCL ratio (62.91±3.13% vs. 68.16±1.72%) were significantly lower in AVNRT. These values underscore the diagnostic utility of these parameters in distinguishing between AVNRT and AVRT, as shown in Table II.

AVNRT cases predominantly fall above 100 ms, with SA-VA intervals mostly ranging between 120 and 140 ms. Conversely, AVRT cases are clustered below this threshold, generally between 50 and 70 ms. Although some overlap is seen in the CI/TCL ratio values, the SA-VA interval shows a clear diagnostic distinction between AVNRT and AVRT. The horizontal line at 92ms appears to serve as a cutoff point, emphasising the potential utility of the SA-VA interval as a reliable parameter in differentiating these two types of arrhythmias as shown in figure 1.

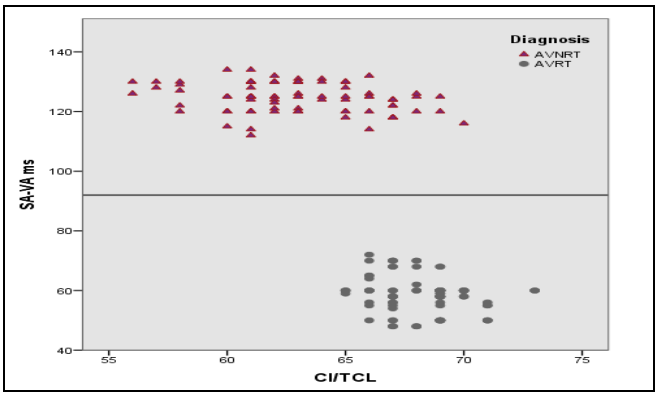

Figure-1: Scatterplot showing AVNRT and AVRT differentiation by SA-VA interval and CI/TCL ratio.

Using the V2 technique, a cut-off value of 92.00 ms for the SA–VA interval yielded both a sensitivity and specificity of 100% in distinguishing AVNRT from AVRT. The receiver operating characteristic (ROC) curve analysis demonstrated an AUC of 1.00, with a 95% confidence interval of 1.00–1.00 (p<0.001), indicating perfect diagnostic accuracy (Figure-2)

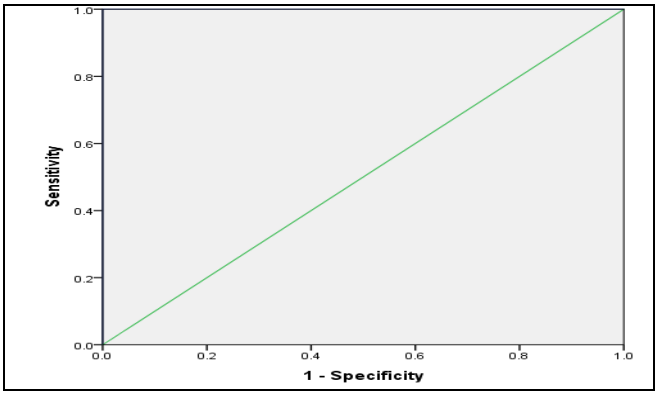

Figure-2: ROC Curve Analysis to Discriminate AVNRT from AVRT Using the ΔSA-VA (V2)

DISCUSSION

In the current investigation, PVE administered from the right ventricle via the V2 method revealed remarkable diagnostic accuracy in distinguishing AVNRT from AVRT, especially in cases involving septal or right-sided accessory routes. By analysing the response to V2, the SA-VA interval and the CI/TCL ratio revealed unique electrophysiological patterns that reliably discriminated between both arrhythmias,

demonstrating PVE's clinical value as a useful tool in SVT subtype classification.

Table-I: Baseline characteristics of Participants (n=180)

Variables		AVNRT (n=90)	AVRT (n=90)
Age (years)		Mean± SD	
		45.50±15.30	34.29±11.78
Frequency (%)			
Gender	Male	53(58.9%)	64(71.1%)
	Female	37(41.1%)	26(28.9%)
Mean± SD			
Ejection Fraction, (%)		58.16±2.74	58.72±2.19
Comorbid		Frequency (%)	
CAD	No	88(97.8%)	90(100%)
	Yes	2(2.2%)	0
AF	No	87(96.7%)	90(100%)
	Yes	3(3.3%)	0
HTN	No	63(70%)	86(95.6%)
	Yes	27(30%)	4(4.4%)
DM	No	70(77.8%)	87(96.7%)
	Yes	20(22.2%)	3(3.3%)

HTN=Hypertension; DM=Diabetes Mellitus; CAD=coronary artery disease; AF=Atrial Fibrillation.

Table-II: Electrophysiological Values and Results of Diagnostic Manoeuvres (n=190)

Variables	AVNRT (n=90)	AVRT (n=90)	*p*-value
	Mean± SD		
PR during SR(ms)	168.59±9.81	145.33±12.58	<0.001
QRS during SR (ms)	90.10±4.064	88.57±5.10	0.27
TCL(ms)	357.31±23.11	345.56±15.65	<0.001
VA interval during SVT (ms)	53.47±7.944	166.1±9.91	<0.001
V2 technique	Mean± SD		
Coupling interval (ms)	226.56±10.93	237.56±11.04	<0.001
CI/TCL ratio	62.91±3.13	68.16±1.72	<0.001
SA - VA (V2) (ms)	124.59±4.91	58.29±6.11	<0.001
PPI - TCL (V 2) (ms)	138.84±10.20	92.04±4.85	<0.001
Ventricular entrainment	Mean± SD		
SA - VA (ms)	129.57±12.44	52.67±4.008	<0.001
PPI - TCL(ms)	159.52±9.32	84.76±4.39	<0.001

PR=PR interval of ECG; SR=Sinus Rhythm; QRS=Width of QRS interval in ECG; TCL=Tachycardia Cycle Length; VA=Ventriculoatrial interval; CI/TCL=Coupling interval ÷ Tachycardia Cycle Length; SA-VA=Stimulus to atrial time – Ventriculoatrial time; PPI – TCL = Post pacing Interval – Tachycardia Cycle Length

Accurate separation of AVNRT from AVRT with a right-sided or septal auxiliary route is crucial for guiding suitable ablation therapy. This study found that when PVE (V2) is performed, the SA-VA interval can accurately and consistently distinguish between both types of PSVT. The manoeuvre successfully advanced or delayed atrial electrograms without inducing tachycardia termination, allowing for accurate SA-VA measurement.[11] Compared to the earlier work conducted by Ito et al., the V2 method parameters in our dataset demonstrated a more obvious difference between AVNRT and AVRT.[12] In AVNRT, the coupling interval was substantially shorter (226.56±10.93 ms vs. 237.56±11.04 ms, p<0.001) compared to the prior study (240 ± 51 ms vs. 237 ± 49 ms, p=0.694). The CI/TCL ratio in AVNRT was lower in both investigations (62.91±3.13% vs. 68.16±1.72% in the present and 61±7.4% vs. 71 ± 8.3% in the prior; p < 0.001). In the current investigation, the SA-VA interval and PPI-TCL difference consistently favor AVNRT diagnosis, with more precise measurements (SA-VA: 124.59±4.91 ms vs. 58.29±6.11 ms; PPI-TCL: 138.84±10.20 ms vs. 92.04 ± 4.85 ms; all p<0.001).

While conventional ventricular entrainment showed substantial changes in SA-VA and PPI-TCL values, it is associated with a higher risk of AV dissociation and tachycardia termination. In contrast, Avila et al., concluded that the PVE (V2) approach has various advantages, including a lower risk of tachycardia termination, easier interpretation, and less reliance on operator experience.[13] Additionally, McGarry et al., examined simple criteria classify patients as having a high or low probability of SVT induction and ablation at EPS. They can be used as a guide for clinical decision-making when considering invasive testing for patients with symptoms of tachycardia.[14] Research by Bennett *et al.,* concluded that slowly conducting accessory pathways frequently yield RV entrainment criteria traditionally attributable to AV node re-entry.[15]

Fernendez *et al.,* validated the diagnostic yield of cPPI-TCL and SA-VA measurements after resetting and determined the proportion of AVNRT and ORT that can be entrained and/or reset from the right ventricular apex (RVA). The study focused on the impact of extrastimulus in PSVT distinction utilizing metrics such as the pre-excitation index and reset patterns.[16] However, our research found that the V2 procedure outperforms other diagnostic methods while also being simpler and more consistent. Current findings support the accuracy of V2-derived metrics in distinguishing AVNRT from AVRT.

Furthermore, Kanjwal *et al.,* have shown that SA-VA and PPI-TCL periods following ventricular entrainment are beneficial in arrhythmia differentiation independent of AP location.[17] Consistent with this, a high diagnostic yield occurred

when ventricular entrainment occurred without tachycardia termination or AV separation. In accordance with findings examined by Zohu *et al.*, our investigation found that a single premature ventricular extrastimulus administered via the V2 approach efficiently reset the atrial electrogram without affecting ventricular activation or terminating tachycardia.[18] This atrial resetting pattern has also been confirmed by Ali et al., that the presence of an auxiliary circuit helps rule out normal AVNRT, highlighting the diagnostic value of ventricular extrastimulus in determining the underlying tachycardia mechanism.[19] Kupó *et al.,* demonstrated that, while traditional ventricular pacing procedures are specific, they may lack sensitivity and have poor interobserver reproducibility, particularly when qualitative markers such as fusion patterns are used.[20] These constraints emphasize the need for more objective and reproducible procedures. In our study, the V2 method addressed these problems by giving clear, quantifiable metrics such as the SA-VA interval and the PPI-TCL difference, which had great diagnostic accuracy in separating AVNRT from AVRT. Given the excellent diagnostic performance exhibited by the ROC curve in our investigation, the PVE (V2) method should be considered the first-line procedure in PSVT diagnosis. It is especially useful in resource-constrained environments or when hemodynamic instability prevents the use of more complicated procedures.

Furthermore, it can provide a quick and dependable alternative when tachycardia is inducible but not sustained. Higuchi *et al.,* found an AUC of 0.988 for the SA-VA interval at a cut-off of ≥85 ms, resulting in 97% sensitivity and 96% specificity.10 Our investigation found that a higher cut-off of 92.00 ms had 100% sensitivity and specificity, with an AUC of 1.00 (95% CI: 1.00-1.00; p<0.001), indicating the parameter's significant discriminative significance and clinical application in our population.

The current investigation supports the clinical efficacy of the V2 approach in consistently distinguishing AVNRT from AVRT with high precision. Its ease of use, repeatability, and diagnostic accuracy make it an important first-line tool for electrophysiological evaluation and ablation planning, particularly in difficult clinical situations.

LIMITATION OF STUDY

Our study was conducted in a single tertiary Electrophysiology centre over five months, with non-probability consecutive recruitment, which curtails its generalisability to broader SVT cohorts. We excluded patients with structural heart disease, significant ventricular dysfunction, and left-sided accessory pathways, which substantially narrowed the patient mix and may have inflated the accuracy. The 92ms SA-VA cutoff and the perfect AUC were both tested on the same set in the same group, so external validation is required. The AVNRT group was significantly older and had more diabetes and hypertension than the AVRT group, and we did not adjust for these differences. Also, in each Electrophysiology study, different protocols were used for pacing sequences, sedation depth, and dose of isoproterenol (if used), which could have affected the measurement of critical intervals.

CONCLUSION

Programmed ventricular extrastimulus from the right ventricle (V2) demonstrates exceptional diagnostic accuracy in distinguishing between AVNRT and AVRT using a septal or right-sided accessory pathway. The PVE (V2) approach is more straightforward to perform than entrainment using VOP, is less likely to terminate the PSVT, and may be extremely useful when the tachycardia is challenging to sustain.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

MN & MS: Data acquisition, data analysis, critical review, approval of the final version to be published.

QHK & AR: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

WUR: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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