Classification, Electrophysiological Features and Therapy of Atrioventricular Nodal Reentrant Tachycardia

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Abstract

Atrioventricular nodal reentrant tachycardia (AVNRT) should be classified as typical or atypical. The term 'fast-slow AVNRT' is rather misleading. Retrograde atrial activation during tachycardia should not be relied upon as a diagnostic criterion. Both typical and atypical atrioventricular nodal reentrant tachycardia are compatible with varying retrograde atrial activation patterns. Attempts at establishing the presence of a 'lower common pathway' are probably of no practical significance. When the diagnosis of AVNRT is established, ablation should be only directed towards the anatomic position of the slow pathway. If right septal attempts are unsuccessful, the left septal side should be tried. Ablation targeting earliest atrial activation sites during typical atrioventricular nodal reentrant tachycardia or the fast pathway in general for any kind of typical or atypical atrioventricular nodal reentrant tachycardia, are not justified. In this review we discuss current concepts about the tachycardia circuit, electrophysiologic diagnosis, and ablation of this arrhythmia.

Keywords

Atrioventricular, nodal, reentrant, tachycardia

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Atrioventricular nodal reentrant tachycardia (AVNRT) denotes re-entry in the area of the AV node, and represents the most common regular arrhythmia in the human.¹ Although several models have been proposed to explain the mechanism of the arrhythmia in the context of the complex anatomy and the anisotropic properties of the atrioventricular (AV) node and its atrial extensions (see *Figure 1*),² the actual circuit of AVNRT still remains elusive. Recent studies suggest a three-dimensional AV node with greater variability in the space constant of tissue and poor gap junction connectivity due to differential expression of connexin isoforms, that provide an explanation of dual conduction and nodal reentrant arrhythmogenesis.^{3,4}

AV junctional arrhythmias are presented in *Table 1*. Classification schemes for AVNRT have been mainly based on the conventional concept of longitudinally dissociated dual AV nodal pathways that conduct around a central obstacle (see *Table 2*).

In typical slow-fast AVNRT the onset of atrial activation appears prior to, at the onset, or just after the QRS complex, thus maintaining an atrial–His/His–atrial ratio, AH/HA >1. The HA interval is usually <70 ms, measured from earliest deflection of the His bundle activation to the earliest rapid deflection of the atrial activation in the His bundle electrogram, and the VA interval, measured from the onset of ventricular activation on surface ECG to the earliest rapid deflection of the atrial activation on the His bundle electrogram, is <60 ms.^{1,5,6} In atypical, fast-slow form of atypical AVNRT, the retrograde atrial electrogram begins after ventricular activation with an AH/HA ratio <1. The HA interval is prolonged, ≥70 msec, and the VA interval is ≥60

msec.^{5,6} The atypical, slow-slow form, represents, by definition, an arrhythmia utilising two slow pathways. The AH/HA ratio is ≥1 but the HA interval is ≥70 msec, and the AH interval exceeds 200 ms.^{7–9}

There are several inherent limitations of this classification. The distinction between fast-slow and slow-slow atypical AVNRT is often arbitrary in view of the lack of a unanimously accepted definition. In order to establish the diagnosis of a truly fast-slow form, it has been proposed that the AH interval should be less than 185 ms¹⁰ or 200 ms.⁶ This criterion, however, has not been adopted by other investigators.^{11–13} Thus, tachycardias with a relatively prolonged AH interval but an AH/HA ratio <1 cannot be reliably classified as either fast-slow or slow-slow (see *Figure 2*). Furthermore, the term 'fast-slow' implies that the fast component of slow-fast AVNRT is the same as the fast in the fast-slow type. There is now evidence that this is not the case in patients who present with both types of tachycardia.^{14,15} Typical slow-fast and atypical fast-slow AVNRT appear to utilise different anatomical pathways for fast conduction. In addition, electrophysiological behaviour compatible with multiple pathways may also be seen, and in some patients, several forms of AVNRT may be inducible at electrophysiology study.

We have previously published a simplified classification scheme (see *Table 2*) that takes into account the shortcomings of conventional classification, and reflects evolving concepts regarding the nature of the AVNRT circuit in various forms of the arrhythmia (see *Figure 1*).⁵ AVNRT should be classified either as typical or atypical. In addition, not only the AH/HA and absolute HA intervals should be necessarily used as criteria for diagnosis of typical AVNRT. The ventriculo-atrial (VA) interval is also a

Figure 1: Proposed Circuit of Atrioventricular Nodal Reentrant Tachycardia

During typical AVNRT (slow-fast), right- or left-sided circuits may occur with antegrade conduction through the inferior inputs and retrograde conduction through the superior inputs (S) or the anisotropic atrioventricular transitional area (AAT). In atypical AVNRT conduction occurs anterogradely through one of the inferior inputs, left (L) or right (R) and retrogradely through the inferior inputs and retrogradely through the other one. Depending on the orientation of the circuit we may record the so-called 'fast-slow' or 'slow-slow' types. AVNRT = atrioventricular nodal re-entrant tachycardia; CS = coronary sinus; FO = foramen ovale; TV = tricuspid valve.⁵

Table 1: Atrioventricular Junctional Arrhythmias

Atrioventricular nodal reentrant tachycardia
Non-reentrant junctional tachycardia
Non-paroxysmal junctional tachycardia
Focal junctional tachycardia
Other non-reentrant variants

Table 2: Conventional Classification of Atrioventricular Nodal Reentrant Tachycardia Types

	AH/HA	VA (His)	Usual ERAA
Typical AVNRT			
Slow-Fast	>1	<60 msec	RHis, CS os, LHs
Atypical AVNRT			
Fast-Slow	<1	>60 msec	CS os, LRAS, dCS
Slow-Slow	>1	>60 msec	CS os, dCS

Variable earliest retrograde atrial activation has been described for all types. AH = atrial-His interval; CS os = ostium of the coronary sinus; dCS = distal coronary sinus; ERAA = earliest retrograde atrial activation; HA = His-atrium interval; LHs = His bundle electrogram recorded from the left septum; LRAS = low right atrial septum; RHis = His bundle electrogram recorded from the right septum. Interval measured from the onset of ventricular activation (VA) on surface ECG to the earliest deflection of the atrial activation in the His bundle electrogram.¹

practical and easily obtainable criterion, when the His bundle potential cannot be reproducibly and reliably recorded during tachycardia (see Table 3). As discussed later, retrograde atrial activation sequence or demonstration of a lower common pathway, should not be necessarily considered as reliable criteria for classification of AVNRT types.

Electrophysiological Features

Earliest Atrial Retrograde Activation

Heterogeneity of both fast and slow conduction patterns has been well described, and all forms of AVNRT may display anterior, posterior and middle retrograde activation patterns. In typical, slow-fast AVNRT, posterior or even left atrial Fast pathways may occur in $\leq 8\%$ of patients.^{12,13,16,17} There has also been evidence that were left septal His recordings routinely performed in patients with AVNRT, the proportion

Figure 2: Atypical Atrioventricular Nodal Reentrant Tachycardia

The form is fast-slow according to the AH-HA definition, but slow-slow according to the AH >200 ms criterion. AH = atrial-His; CS = coronary sinus; HA = His-atrium; HRA = high right atrium; RV = right ventricle; VA = ventriculo-atrial interval.⁵

Table 3: Novel Proposed Classification of Atrioventricular Nodal Reentrant Tachycardia Types

	HA	VA (His)	AH/HA
Typical AVNRT	≤ 70 ms	≤ 60 msec	>1
Atypical AVNRT	>70 ms	>60 msec	Variable

The distinction is for categorisation only, and not relevant for mechanism or therapy. Atypical AVNRT has been traditionally classified as fast-slow (HA >70 ms, VA >60, AH/HA <1, and AH <200 ms) or slow-slow (HA >70 ms, VA >60 ms, AH/HA >1, and AH >200 ms). Not all of these criteria are always met and atypical AVNRT may not be sub-classified accordingly. AH = atrial-His interval; HA = His-atrium interval. Interval measured from the onset of ventricular activation (VA) on surface ECG to the earliest deflection of the atrial activation on the His bundle electrogram.⁵

Figure 3: Typical Slow-Fast Atrioventricular Nodal Reentrant Tachycardia

Earliest retrograde atrial activation is simultaneously recorded at distal CS (CS 1-2) and proximal His (His 3-4). I to V6: 12-lead ECG leads. CS = coronary sinus; His = His bundle electrogram; HRA = high right atrium.⁵

of left-sided retrograde Fast pathways might be considerably higher than previously reported.¹⁸ Figure 3 and Figure 4 present typical AVNRT (slow-fast) with variable earliest retrograde atrial activation.

Figure 4: Typical Slow-Fast Atrioventricular Nodal Reentrant Tachycardia

Simultaneous mapping of the right septum (R His), left septum (L His) and the anatomic area of the Slow pathway is undertaken. Earliest retrograde atrial activation is recorded on the left septum. I to V6: 12-lead ECG leads. Abl = ablation electrode at the anatomical area of the Slow pathway; CS = coronary sinus; His = His bundle electrogram; HRA = high right atrium.⁵

In atypical AVNRT, the earliest retrograde atrial activation is traditionally reported at the base of the triangle of Koch, near the coronary sinus ostium. Detailed mapping of retrograde atrial activation in large series of patients, however, has produced variable results. Earliest atrial activation can be well recorded at the coronary sinus ostium, the low right atrial septum, or the His bundle area.^{11-13,17} In certain cases of atypical AVNRT, retrograde atrial activation is even suggestive of a left lateral accessory pathway.^{8,9}

It is obvious, therefore, that classification based on earliest atrial retrograde activation is inappropriate. Figure 5 and Figure 6 depicts fast-slow and slow-slow AVNRT, respectively, with earliest retrograde atrial activation at the His bundle electrode.

Relative AH/HA Intervals

The AH time and the relative AH/HA intervals have been proposed as a criterion for distinction between fast-slow and slow-slow AVNRT. However, both absolute and relative values may be meaningless in certain occasions. They depend on autonomic status, age, use of isoprenaline and sedatives and conduction properties of pathways involved, and may change during a single electrophysiology study. We have often noticed different AH/HA times in the same patient at similar or different tachycardia cycle lengths. Furthermore, when a His bundle electrogram cannot be recorded during tachycardia, a diagnosis based exclusively on them is impossible.¹⁹

Upper and Lower Common Pathways

Early studies have considered the possibility of additional AV nodal tissue extrinsic to the tachycardia circuit in order to explain various electrophysiologic phenomena observed during AVNRT,²⁰ and the concepts of upper and lower common pathways have been long-standing controversies of AVNRT. The existence of an upper common pathway can now be rather easily refuted by subsequent evidence indicating that multiple atrial breakthroughs are extremely common,

Figure 5: Atypical Atrioventricular Nodal Reentrant Tachycardia

The form is conventionally fast-slow ($AH < HA$, $HA > 70$ ms, $AH < 200$ ms), and earliest retrograde atrial activation recorded at the His bundle electrode. I to V6: 12-lead ECG leads; CS = coronary sinus; His = His bundle electrogram; HRA = high right atrium; LV = left ventricle; RV = right ventricle.⁵

Figure 6: Atypical Atrioventricular Nodal Reentrant Tachycardia

The form is conventionally slow-slow ($AH > HA$, $HA > 60$ ms, $AH > 200$ ms), and earliest retrograde atrial activation is recorded at the His bundle.⁵

and retrograde activation often changes in timing and/or activation without significant alteration in tachycardia cycle, thus negating the notion of a simplistic focal atrial exit site.²¹⁻²³ The perinodal transitional tissue is the route to the atrium, and in this context it may be considered as a common pathway of tissue but not a discrete site. The breakthrough is whatever leads to atrial activation via transitional tissue; thus there are many possibilities (see Figures 3-6).

The lower common pathway, as initially considered by Mendez and Moe,²⁴ has a more sound physiological basis. The notion of a lower

Table 4: Electrophysiology Techniques for the Differential Diagnosis of Narrow QRS Tachycardias

	V Pacing in SR	V Pacing During Tachycardia	A Pacing in SR	A Pacing During Tachycardia
Easily Applicable	VA ratios during V pacing and tachycardia ^{33,34}	His-synchronous extrastimuli ⁴¹	Comparison of AH during pacing and tachycardia ⁵⁷	
	Ventriculoatrial index ³⁵	Entrainment		
		- AAV/AAHV response ⁴²		
		- With and without stable fusion ⁴³		
		- SA-VA and cPPI-TCL intervals ⁴⁴⁻⁴⁷		
		- Differential entrainment or cessation ⁴⁸		
Cumbersome	Delta HA during V pacing and tachycardia ³⁶	Pre-excitation index ⁴⁹		Differential entrainment ⁵⁸
		Entrainment		
	VHA pattern ³⁷	- Anterograde His capture ⁵⁰		
	Para-Hisian pacing ³⁸	- Progressive fusion during or after the transition zone ^{51,52}		
	Induction of retrograde RBBB ³⁹	Delta HA during entrainment and tachycardia ⁵³		
	SA _{init} -VA and cPPI _{init} -TCL intervals during induction of tachycardia ⁴⁰	- Para-Hisian entrainment ⁵⁴⁻⁵⁶		

A = atrial; AH = atrio-His interval; cPPI = corrected post-pacing interval; HA = His-atrial interval; RBBB = right bundle branch block; SA = stimulus to atrium interval; SR = sinus rhythm; TCL = tachycardia cycle length; V = ventricular; VA = ventriculo-atrial interval.¹⁹

common pathway has been utilised in order to explain phenomena of AV block without recording of a His electrogram as well as retrograde Wenckebach periodicity during AVNRT.²⁵⁻²⁸ The lower common pathway is defined as the conduction path between the distal turnaround point of the AVNRT circuit and the His bundle. The conduction time over the lower common pathway has been usually estimated by subtracting the His to atrium interval during tachycardia (measured from the onset of the His electrogram to the onset of the atrial electrogram) from that during ventricular pacing (measured from the end of the His electrogram to the onset of the atrial electrogram) at the same cycle length and considered a measurable interval in the majority of typical AVNRT cases. Initially, a lower common pathway was demonstrated in up to 75 % of 28 patients with AVNRT who were studied,²⁰ whereas in subsequent studies with the use of para-Hisian pacing, the presence of a lower common pathway was identified in 78 % of 23 patients studied.²⁷ No evidence of a lower common pathway has been detected in typical slow-fast AVNRT.²⁹

However, AV block during AVNRT without recording activation of the His bundle can also be explained by proximal intra-Hisian block.³⁰ In up to one-third of patients with AVNRT the lower turnaround point of the circuit is within the His bundle, thus arguing against an intranodal circuit as a universal feature of AVNRT.³¹ Differences in the location of the lower turnaround sites of AV nodal reentry relatively to the His bundle have also been shown in experimental studies.³² Thus, block during AVNRT does not necessarily define a 'lower common pathway'; it just defines longer refractory period below the circuit. This is often seen at the onset of very fast AVNRT, which may expose the His-Purkinje tissue to long-short periods and can lead to functional phase 3 block, having nothing to do with the reentrant circuit.

The electrophysiological proof of the existence of a lower common pathway depends on several assumptions that may not be valid, in a way that even if a lower common pathway exists, applied methodologies

are unable to accurately detect and measure it.²³ Furthermore, there are certain cases in the electrophysiology laboratory where an antegrade, let alone a retrograde, His bundle electrogram may not be reproducibly and reliably recorded.¹⁹ Thus, upper and lower common pathways seem to represent concepts the mechanism, relevance and practical applicability of which remain speculative.

Differential Diagnosis

Differential diagnosis of a narrow QRS tachycardia, such as AVNRT, may be difficult.¹⁷ Although several ECG clues may assist differential diagnosis, this is usually accomplished at electrophysiology study and, most often, is between atrioventricular nodal reentrant tachycardia, atrioventricular reentrant tachycardia due to a concealed accessory pathway, and atrial tachycardia. Atrial and, mainly, ventricular pacing manoeuvres during sinus rhythm or tachycardia have been used with variable success rate. In clinical practice, these techniques cannot be applied to all cases, and multiple criteria have to be used for the differential diagnosis of narrow complex tachycardias with atypical characteristics. In *Table 4* we summarise our experience with various techniques and manoeuvres for the differential diagnosis of narrow-QRS tachycardias in the electrophysiology laboratory.³³⁻⁵⁹

Ablation

Chronic administration of antiarrhythmic drugs (such as β -blockers, non-dihydropyridine calcium channel blockers, flecainide or propafenone) may be ineffective in up to 50 % of cases.¹ Thus, catheter ablation is the current treatment of choice. Slow pathway ablation or modification is effective in both typical and atypical AVNRT. Usually, a combined anatomical and mapping approach is employed with ablation lesions delivered at the inferior or mid part of the triangle of Koch.^{60,61} Multicomponent atrial electrograms or low amplitude potentials, although not specific for identification of slow pathway

conduction, are successfully used to guide ablation at these areas. Ablation should be only directed towards the anatomic position of the slow pathway. If right septal attempts are unsuccessful, the left septal side should be tried.^{62,63}

This approach offers a success rate of 95 %, is associated with a risk of 0.5–1 % AV block and has approximately 4 % recurrence rate. There

is no mortality associated with this procedure.^{64,65} Advanced age is not a contraindication for slow pathway ablation.⁶⁶ The preexistence of first-degree heart block may carry a higher risk for late AV block and slow pathway modification, as opposed to complete elimination, is probably preferable in this setting.⁶⁷ Cryoablation may carry a lower risk of AV block, but it is negligible and this mode of therapy is associated with a significantly higher recurrence rate.⁶⁷ ■

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