**REVIEW**

**Classification and differential diagnosis of atrioventricular nodal re-entrant tachycardia**

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Recent evidence on atrioventricular nodal re-entrant tachycardia has identified several types of this common arrhythmia, with potential therapeutic implications. This article reviews the relevant new information, discusses the differential diagnosis of atrioventricular nodal re-entrant tachycardia, and summarizes the electrophysiological criteria for classification of the various forms of the arrhythmia.

**KEYWORDS**

Atrioventricular nodal re-entrant tachycardia

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Atrioventricular nodal re-entrant tachycardia (AVNRT) results from re-entry in the region of the AV junction,\(^1,2\) i.e. the part of the atrioventricular-specialized conducting system consisting of the transitional cell zone, the AV node and its extensions, and the penetrating part of the bundle of His.\(^3\) Although AVNRT represents the most common paroxysmal supraventricular arrhythmia in the human,\(^1,4\) several questions and obscure points remain. The old model of the re-entrant circuit comprised two anatomically distinct limbs confined to the AV node can provide explanations for many aspects of the electrophysiological behaviour of these tachycardias. However, these pathways have not been demonstrated historically and, despite several attempts to provide a reasonable model based on anatomic or functional anisotropic characteristics,\(^5\)–\(^10\) the exact circuit responsible for the re-entrant tachycardia is unknown. Furthermore, there is no unanimously accepted scheme for the diagnosis and classification of various AVNRT forms. Recognition of the various types of AVNRT, however, is of clinical importance because an anatomically guided catheter ablation technique may now offer quick eradication of the arrhythmia. In addition, some forms of AVNRT are associated with an increased risk of catheter ablation-induced AV block and special care is needed to avoid such a complication. This review discusses the differential diagnosis of AVNRT and summarizes the proposed electrophysiological criteria for classification of the various forms of the arrhythmia.

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**Diagnostic problems**

**Dual atrioventricular nodal conduction**

Following the initial description of Denes et al. in 1973,\(^11\) the presence of dual atrioventricular nodal pathways at electrophysiological study has been a time-honoured criterion for the diagnosis of AVNRT. It is now known that discontinuous refractory periodic curves may not be present in all patients with AVNRT. Antegrade dual pathways are demonstrable in \(~75\%) of patients with tachycardia,\(^12\) and AVNRT may occur in the presence of continuous AV nodal conduction curves.\(^13\)–\(^15\) Conversely, antegrade dual pathways can be demonstrated in subjects without tachycardia.\(^16\)–\(^20\)

In patients with the fast–slow variety of AVNRT, antegrade conduction curves are mostly not discontinuous.\(^21,22\) Retrograde stimulation curves may demonstrate a jump if the retrograde refractory period of the fast pathway exceeds the retrograde refractory period of the slow one. The pattern of conduction as well as the incessant nature seen in patients with the fast–slow form of AVNRT can also be seen in atrioventricular re-entrant tachycardia (AVRT) due to the presence of concealed septal accessory pathways with decremental properties.\(^23\)

**Retrograde atrial activation sequence**

AVNRT has been traditionally classified as slow–fast or typical AVNRT, and fast–slow or atypical AVNRT, according to the conventional description of dual AV junctional pathways. The fast pathway of the re-entry circuit runs superiorly and anteriorly in the triangle of Koch, whereas the slow pathway runs inferiorly and posteriorly close to the
coronary sinus ostium. Indeed, in the majority of slow–fast cases of AVNRT, the site of the earliest atrial activation is close to the apex of Koch’s triangle, near the AV node–His bundle junction, i.e. anterior to the AV node. In the fast–slow form, the site of the earliest atrial activation is usually recorded posterior to the AV node near the orifice of the coronary sinus. The recognition of the fact that AVNRT may present with atypical retrograde atrial activation has made diagnosis of the arrhythmia as well as classification attempts more complicated. Previous studies have reported on a posterior (or type B) variety of presumed slow–fast AVNRT, with long ventriculoatrial (VA) intervals and the earliest retrograde atrial activation near the coronary sinus ostium.36,37

Posterior fast pathways have been reported in up to 6% of patients with AVNRT36,39 and require special attention for the avoidance of AV block when delivering radiofrequency energy at the anatomical site of the slow pathway. These observations should be considered in the context of the documented multiple, heterogeneous sites of early atrial activation, rather than a focal breakthrough site, during the arrhythmia in the majority of patients with AVNRT.30

Eccentric retrograde atrial activation of the fast–slow31,32 as well as the slow–slow31,32 forms has also been reported. It is now becoming evident that fast–slow AVNRT may be of the (usual) posterior, anterior, and middle type according to the mapped location of the retrograde slow pathway.32 In certain cases of fast–slow or slow–slow AVNRT, retrograde activation is even suggestive of a left lateral accessory pathway.31,33 Appropriate diagnosis in this setting is of importance for the avoidance of prolonged procedures with high fluoroscopy times and unnecessary radiofrequency lesions.

**VA conduction time**

Traditionally, a VA interval measured from the onset of ventricular activation on surface ECG to the earliest deflection of the atrial activation in the His bundle electrogram <60 ms, or a VA interval measured at the high right atrium <95 ms,34 has been considered as diagnostic for the slow–fast form of AVNRT. Retrograde AV junctional pathways have been characterized as fast (HA interval <100 ms), intermediate (100–200 ms), or slow (>200 ms).28 Conduction times are sensitive to autonomic changes and isoprenaline administration that is often used during diagnostic studies. However, a septal VA interval <70 ms is highly suggestive of slow–fast AVNRT provided, of course, that atrial tachycardia has been excluded.35,36

**Lower common pathway**

The lower common pathway is defined as the conduction path between the distal turnaround point of the antegrade and retrograde conduction pathways of the AVNRT circuit and the His bundle. Its presence is indicated by demonstrating that the retrograde fast pathway as well as the conduction time over it are the same during ventricular pacing and tachycardia and that the beginning of the antegrade His bundle potential during tachycardia and the end of the retrograde His bundle potential during ventricular pacing represent activation at the same site.27,38 The conduction time over the lower common pathway has been usually estimated by subtracting the HA interval during tachycardia from that during ventricular pacing at the same cycle length and considered a measurable interval in the majority of typical AVNRT cases.37 Studies utilizing para-Hisian pacing, however, have failed to detect evidence of a lower common pathway in typical slow–fast AVNRT, as opposed to fast–slow or slow–slow AVNRT, and have actually used the demonstration of a lower common pathway in order to categorize AVNRT as atypical (either fast–slow or slow–slow).38,39 Application of this criterion requires recording of a retrograde His bundle electrogram during ventricular pacing, and this is not always feasible in the electrophysiological laboratory.

**AVNRT types**

Heterogeneity of both fast and slow conduction patterns has been well described and in certain patients all types of AVNRT may be inducible.39,40 (Figure 1). A definitive diagnosis as well as the identification of a single AVNRT type may, therefore, not always be possible. These observations could be considered in the context of the inferior nodal extensions model of the AVNRT circuit. The inferior nodal extensions are basically part of the AV node and facilitate atrial inputs that also contain transitional cells connecting atrial myocardium with the nodal extensions. They have been proposed as the anatomic substrate of the slow pathway.9,42,43 Recently, we have shown that extrastimuli delivered at the left inferoparaseptal area, close to the His bundle, may reset the AVNRT probably by engaging the left inferior nodal extension (Figure 2).43 Thus, various AVNRT types could be explained on the basis of variable anatomical characteristics and orientation of these extensions. Observations on simultaneous recording of His bundle activation from both sites of the septum during slow pathway ablation43 as well as reports of successful slow pathway ablation from the left septum are also in support of this hypothesis.44,45

Considering the published evidence so far, the following diagnostic criteria and classification of AVNRT types can be proposed (Table 1).

**Typical AVNRT**

**Slow–fast**

In the slow–fast form of AVNRT, the onset of atrial activation appears early, at the onset or just after the QRS complex thus maintaining an atrial-His/His-atrial ratio AH/HA > 1. In particular, an AH/HA ratio >3,25 and a VA interval measured from the onset of ventricular activation on surface ECG to the earliest deflection of the atrial activation in the His bundle electrogram <60 ms, or a VA interval measured at the high right atrium <95 ms,34 are diagnostic of the slow–fast AVNRT type. Although, typically, the earliest retrograde atrial activation is being recorded at the His bundle electrogram, cases of posterior retrograde fast pathways, i.e. with the earliest retrograde atrial activation at the CS os28 have been described.

**Atypical AVNRT**

**Fast–slow**

In the fast–slow form of AVNRT (~5–10% of all AVNRT cases), retrograde atrial electrograms begin well after ventricular activation with an AH/HA ratio <1, indicating that
retrograde conduction is slower than antegrade conduction. The VA interval measured from the onset of ventricular activation on surface ECG to the earliest deflection of the atrial activation in the His bundle electrogram is 60 ms, and in the high right atrium 100 ms. In the majority of fast–slow cases, the site of the earliest atrial activation is posterior to the AV node near the orifice of the coronary sinus. However, anterior and mid-forms of fast–slow AVNRT have also been described. Slow–slow In the slow–slow form, the AH/HA ratio is but the VA interval is 60 ms, suggesting that two slow pathways are utilized for both anterograde and retrograde activations. Usually, but not always, the earliest atrial activation is at the posterior septum (coronary sinus ostium). The so-called posterior or type B AVNRT has been demonstrated in 2% of patients with the anterior form of slow–fast AVNRT. In posterior tachycardia, the VA times (as measured from the onset of ventricular activity to the onset of atrial activity by whichever electrode recorded the earliest interval) may be prolonged, ranging from 76 to 168 ms. The atrial-His/His-atrial ratio, however, remains more than 1. It seems that the reported cases of posterior slow–fast AV junctional re-entry tachycardia (AVJRT) may actually represent the slow–slow form.

Differential diagnosis
In the presence of a narrow-QRS tachycardia, AVNRT should be differentiated from atrial tachycardia or orthodromic atrioventricular re-entrant tachycardia (AVRT) due to an accessory pathway. When a wide-QRS tachycardia is encountered, antidromic AVRT should be differentiated from AVNRT with a bystanding accessory pathway and the possibilities of AVNRT or atrial tachycardia with aberrant conduction due to bundle branch block should also be considered.

AVNRT vs. atrial tachycardia
Demonstration of change in AA interval when a ventricular extrastimulus is delivered during tachycardia, tachycardia termination by a ventricular extrastimulus that did not conduct to the atrium, constant His-atrial interval of the return cycle after introduction of a premature atrial impulse with a wide range of coupling intervals during tachycardia, and demonstration of ventricle to atrium sequence during retrograde initiation of tachycardia indicate aetiology other than atrial tachycardia. In particular, the atrial response upon cessation of ventricular pacing associated with 1:1 VA conduction during tachycardia can distinguish between atrial tachycardia and AVNRT or AVRT. Atrial tachycardia is associated with an A-A-V response whereas AVNRT or AVRT produce an A-V response. This rule
does not always hold in the presence of a long HV interval.\textsuperscript{53} The His deflection should also be considered in this respect, since a late V electrogram might give an apparent AAV response that is actually AH/AV response in the presence of AVNRT or AVRT, as opposed to an AA/HV one in the presence of atrial tachycardia.\textsuperscript{53,54} The difference in the AH interval between atrial pacing and the tachycardia may also allow differentiation of atypical AVNRT from other types of long RP tachycardias. A $\Delta$AH $>$ 40 ms indicates AVNRT, whereas in patients with AVRT due to septal pathways or atrial tachycardia these differences are $<$20 and 10 ms, respectively.\textsuperscript{50}

Finally, the difference of the post-pacing interval and the tachycardia cycle length (PPI–TCL interval) as described by Michaud et al.\textsuperscript{46} may also be of help.

### AVNRT vs. AVRT due to septal accessory pathways

The eccentric retrograde atrial activation during ventricular stimulation or tachycardia and the demonstration of continuous AV or VA conduction curves usually characterizing non-septal concealed accessory pathways differentiate this form of atrioventricular re-entry from AVNRT. However, AVNRT is now known to occur with eccentric atrial activation and, in addition, decremental septal pathways may mimic AVNRT especially of the fast–slow or slow–slow forms. Septal pathways may have the property of decremental conduction and normal atrial retrograde activation during tachycardia.\textsuperscript{55}

### ECG criteria

In case of relatively delayed retrograde conduction that allows the identification of retrograde P waves, ECG criteria can be applied for diagnosis. The presence of a pseudo-r' wave in lead V1 or a pseudo-S wave in leads II, III, and aVF has been reported to indicate anterior AVNRT with an accuracy of 100%. A difference of $>$20 ms in RP intervals in leads V1 and III was indicative of posterior AVNRT rather than AVRT due to a posteroseptal pathway.\textsuperscript{54}
Development of AV block or bundle branch block
The documentation of pre-excited beats as well as AV dissociation and the induction of bundle branch block during tachycardia may assist the differential diagnosis. The demonstration of AV block or AV dissociation during tachycardia is characteristic of AVNRT excluding the presence of an accessory pathway.\textsuperscript{57,58} Similarly, the development of bundle branch block either spontaneously or after introduction of ventricular extrastimuli during AVNRT does not change the AA or HH intervals. A significant change in the VA interval with the development of bundle branch block is diagnostic of orthodromic AVRT and localizes the pathway to the same side as the block.\textsuperscript{59}

His-synchronous ventricular extrastimulation
In the presence of septal decremental pathways, ventricular extrastimuli introduced whereas the His bundle is refractory during tachycardia (i.e. delivered coincident with the His potential or up to 50 ms before this) may advance or delay subsequent atrial activation (extranodal capture).\textsuperscript{60} In AVNRT, atrial activity is not perturbed with His-synchronous ventricular extrastimulation (Figure 3). Failure to reset the atria suggests, but does not prove, that an accessory pathway is not present or that it is relatively far from the site of premature stimulation.\textsuperscript{61} Theoretically, it is possible that resetting of the atrium might be a result of an increase in conduction time over such a pathway of a magnitude equal to the interval by which the extrastimulus preceded atrial activation, but such a coincidence is rare. In addition, at the time of His bundle activation the accessory pathway may be refractory and resetting by ventricular extrastimuli may not be seen. Thus, resetting or termination of the tachycardia with His-refractory ventricular extrastimuli is specific but not a highly sensitive criterion for differential diagnosis.

AH conduction
The difference in the AH interval between atrial pacing and the tachycardia may allow differentiation of atypical AVNRT from other types of long RP\textsuperscript{0} tachycardias. A $\Delta$AH > 40 ms has been reported to indicate AVNRT, whereas in patients with AVRT due to septal pathways or atrial tachycardia these differences were < 20 and 10 ms, respectively.\textsuperscript{50}

VA conduction indices
Using ventricular-induced atrial pre-excitation, Miles et al.\textsuperscript{62} devised a pre-excitation index for the differentiation of AVNRT and AVRT using an accessory pathway. Progressively premature right ventricular extrastimuli were introduced during tachycardia and the difference between the TCL and the longest stimulation interval at which atrial pre-excitation occurred defined the pre-excitation index. A pre-excitation index of 100 ms or greater characterized AVJRT, whereas an index less than 45 ms characterized AVRT using a septal pathway. In another report of 16 patients with AVNRT and 23 patients

![Figure 3](https://academic.oup.com/europace/article-abstract/8/1/29/2398612)

**Figure 3** Absence of resetting of slow–fast AVNRT by His-synchronous ventricular extrastimuli. The tachycardia cycle length is 424 ms. At 380 ms following the His bundle electrogram, a ventricular extrastimulus is delivered at a time when the His bundle is expected to be refractory and fails to reset the next atrial electrogram. I and II: ECG leads, LRA: low right atrium, His: His bundle, CS: coronary sinus.
with AVRT studied at St George’s Hospital in London, the ratio between the minimum VA interval during tachycardia and ventricular pacing was 0.32–0.27 in AVNRT, 0.91–1.08 in AVRT using a posteroseptal pathway, and 0.94–1.29 in AVRT using an anteroseptal pathway. A difference in the VA interval during tachycardia and right apical ventricular pacing >90 ms has also been reported to differentiate patients with AVNRT from those with AVRT. The difference between the VA interval obtained during apical pacing and that obtained during posterobasal pacing (VA index) can also discriminate between patients with posteroseptal pathways (>10 ms) and patients with nodal retrograde conduction (<5 ms).

Retrograde conduction (HA)
Miller et al. found the His to atrial (HA) intervals to offer more precise discrimination. Their criterion is the difference between His to atrial intervals during pacing and during tachycardia (ΔHA). In 84 patients, a retrograde His was present in 93% of them and the ΔHA was >0 ms in AVNRT and <−27 ms in orthodromic AVRT incorporating a septal accessory pathway. Thus an intermediate value of ΔHA = −10 ms had 100% sensitivity, specificity, and predictive accuracy in differentiating the two forms of tachycardia. Para-Hisian pacing and the change in timing and sequence of retrograde atrial activation between His and proximal right bundle branch capture and non-capture have also been used for differentiation between AV nodal and septal pathway retrograde conductions. The response is considered extranodal when the retrograde atrial activation during His bundle capture is the same as during ventricular capture without His bundle capture. These techniques, however, require recording of both antegrade and retrograde His bundle activations.

Tachycardia resetting criteria
Right apical stimulation is relatively close to the insertion of a septal accessory pathway as opposed to the AV junction. Thus, ventricular fusion during resetting or entrainment of tachycardia has been reported to occur in patients with AVRT due to septal pathways but not with AVNRT. Michaud et al. have proposed two additional criteria for differential diagnosis. The VA interval and total cycle length (TCL) were measured during tachycardia, and entrainment of the tachycardia was accomplished with right apical ventricular pacing. The intervals between the last ventricular pacing stimulus and the last entrained atrial depolarization during tachycardia (SA) as well as the PPI were considered. All patients with AVNRT had SA–VA intervals >85 ms and PPI–TCL intervals >114 ms. It should be noted that in clinical practice, pacing or other manoeuvres cannot be applied to all cases and multiple criteria have to be used for the differential diagnosis of narrow complex tachycardias with atypical characteristics.

AVNRT with bystanding accessory pathway vs. antidromic AVRT
Antidromic AVRT, i.e. tachycardia using the accessory pathway for antegrade conduction and the AV node for retrograde conduction, may be induced in ~6% of patients with accessory pathways located in the left or right free wall, or the anterior septum at an adequate distance from the AV node. In some cases, atrioventricular junctional re-entry may be the underlying mechanism of the pre-excited tachycardia and the possibility of AVRT conducting over a bystanding accessory pathway should be considered in the presence of transition from narrow to wide complex tachycardia of a similar cycle length and without disturbing the HH intervals. In this case, atrial extra-stimuli fail to induce advancement of the following pre-excited QRS complex, the next retrograde His bundle deflection where apparent, and the subsequent atrial deflection, as may happen in the presence of a macro-reentrant loop.

AVNRT vs. non-paroxysmal AV junctional tachycardia and focal junctional tachycardia
Non-paroxysmal junctional tachycardia was frequently diagnosed in the past as a junctional rhythm of gradual onset and termination with a rate between 70 and 130 b.p.m., and was considered a typical example of digitalis-induced arrhythmias. It may also occur in patients with underlying heart disease such as myocardial infarction, or after open heart surgery, and, very rarely, even in apparently normal persons. Although these tachycardias can be induced by atrial ectopics or atrial pacing, they are not re-entrant; most cases, especially the digitalis-induced, are caused by delayed after-depolarizations and triggered activity in the AV node.

Focal junctional tachycardia, also called automatic junctional tachycardia, junctional ectopic tachycardias, and His bundle tachycardia, may occur as a congenital arrhythmia or early after infant open heart surgery. Diagnosis is made on the ECG which shows a narrow QRS tachycardia with slower and dissociated P waves. At electrophysiological study, there are normal HV intervals and normal AV conduction curves. In adult patients, this tachycardia is associated with a structurally normal heart and the prognosis is usually benign. The usual electrocardiographic finding is a narrow QRS tachycardia with AV dissociation. Occasionally, the tachycardia might be irregular thus resembling atrial fibrillation. In the electrophysiological laboratory, the arrhythmia is not inducible by programmed electrical stimulation but is sensitive to isoprenaline administration, and in some cases, rapid atrial or ventricular pacing may result in tachycardia induction. During tachycardia, there is a normal or increased HV interval with atrioventricular dissociation that is interrupted by frequent episodes of VA conduction with the earliest atrial activation in the posteroseptal, anteroseptal, or mid-septal regions. At times, the mode of tachycardia induction resembles a double AV nodal response that is characteristic of AVNRT.

Conclusions
(i) Recent evidence has identified several types of AVNRT which is the most common paroxysmal supraventricular arrhythmia in the human.
(ii) AVNRT types are classified as typical (slow–fast) and atypical (fast–slow and slow–slow), according to the ratio of atrial-His/His-atrial intervals, the VA interval measured on the His bundle and high right atrial electrograms, and the site of the earliest retrograde
atrial activation. However, variable sites of retrograde atrial activation have been described for all types of this arrhythmia.

(iii) Several electrocardiographic and electrophysiological criteria have been used for differential diagnosis of AVNRT vs. atrial tachycardia, AVNRRT vs. AVRT due to a septal accessory pathway, AVNRRT with bystanding accessory pathway vs. antidromic AVRT, and AVNRRT vs. non-paroxysmal junctional tachycardia and focal junctional tachycardia. In clinical practice, not all proposed manoeuvres can be universally applied and multiple criteria have to be used for the differential diagnosis of narrow complex tachycardias with atypical characteristics.

References
