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## The HAV pattern in pediatric patients with atrioventricular node reentrant tachycardia

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### ABSTRACT

**Objectives:** The purpose of this study is to assess the prevalence of a His-Atrial-Ventricular (HAV) pattern, i.e. the atrial electrogram following the His bundle -HB- electrogram and preceding the ventricular one, on the catheter placed in the His position in pediatric patients during typical atrioventricular node reentry (AVNRT).

**Materials and methods:** The pediatric electrophysiology databases of two separate institutions were queried for patients with a diagnosis of AVNRT. Demographic, clinical data and the electrophysiology study (EPS) information were assessed.

**Results:** Thirty-nine consecutive patients were included. Twenty-five were female. The average age at the time of the EPS was  $12 \pm 3.7$  years. Induction was achieved with atrial pacing in 23, with a single atrial extra stimulus in 8 and with dual atrial extra stimuli in 8. Isoproterenol was needed to induce tachycardia in 21. Tachycardia cycle length averaged  $320 \pm 50$  ms. An HAV pattern was present in 35 (74%) of the patients, and in 100% of the patients younger than 8.

**Conclusions:** An HAV pattern on the catheter placed in the His position, is common in pediatric patients with AVNRT, occurring in up to 74% of the patients in this population, being more common in younger patients.

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### 1. Introduction

Atrioventricular node reentry tachycardia (AVNRT) is the most common form of supraventricular tachycardia in the adult population [1,2]. In the pediatric age group, the prevalence of AVNRT is much lower, accounting for 32% of SVT taken to the electrophysiology laboratory [3]. It is an extremely rare mechanism in children younger than 2 years of age. The prevalence of AVNRT increases with age [3].

There are different theories regarding the mechanisms of AVNRT. The two leading ones propose either the presence of dual AV nodal pathways or of differential inputs to the AV node, with

specialized conduction tissues with different electrophysiological properties, providing the substrate for a reentrant circuit confined to this structure. Specific characteristics for dual AV nodal physiology and of AVNRT have been previously described in pediatric patients compared to adults [4,5].

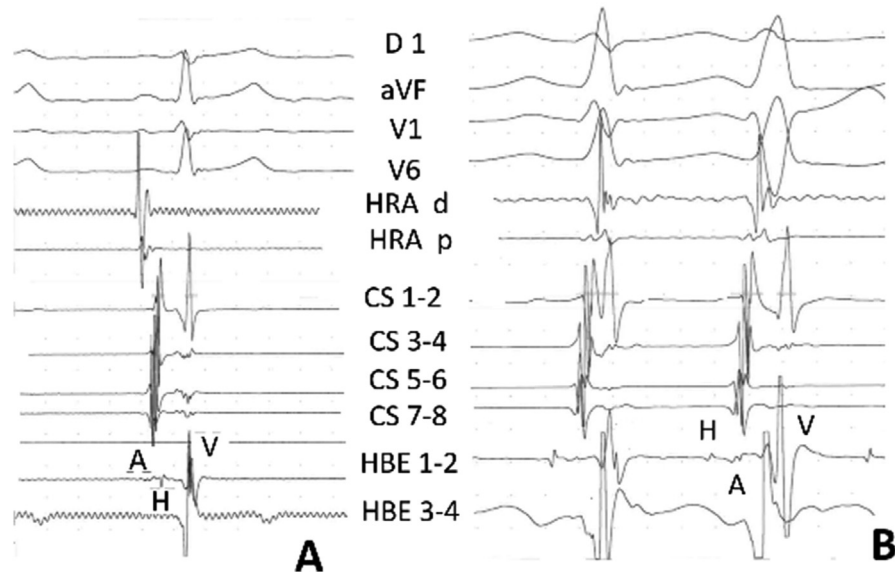
In most adult patients with AVNRT the activation of the atrial and ventricular myocardium occurs simultaneously. Interestingly, the pattern of activation in pediatric patients is different, with the frequent finding in the catheter placed in the His position of the atrial electrogram preceding the ventricular one.

The specific aim of this study is to describe how often the presence of a His-atrial-ventricular electrogram (HAV) pattern (Fig. 1 A and 1 B, 2 A, 2 B) occurs in the catheter placed in the His position in pediatric patients with AVNRT. To the best of our knowledge, this specific pattern in pediatric patients with typical AVNRT has not been previously reported.

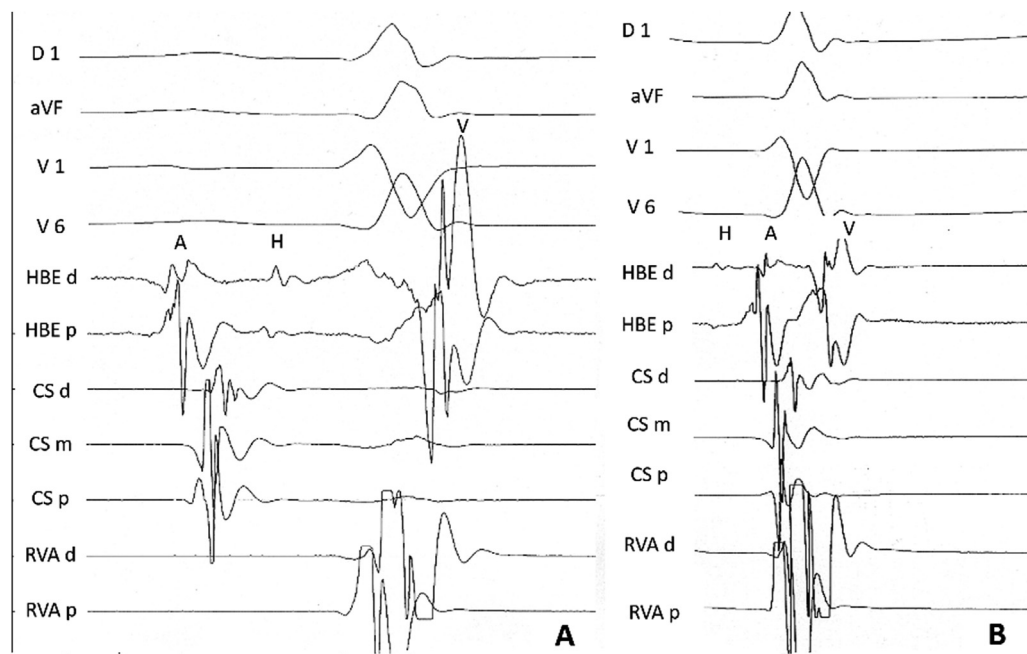
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**Fig. 1.** A. In sinus rhythm, the first four channels show the surface ECG. There are catheters positioned in the high right atrium (HRA), the coronary sinus (CS) and in the His position (HBE). In the HB channel (HBE 1–2 and 3–4) three electrograms can be identified, the atrial (A), the His bundle (H) and the ventricular (V) electrograms. B. During AVNRT, the H-A-V pattern is observed, with the atrial (A) electrogram following the His bundle (H) electrogram and preceding the ventricular one (V).



**Fig. 2.** A. In sinus rhythm, the first four channels show the surface ECG. There are catheters positioned in the His position (HBE), in the coronary sinus (CS) and in the right ventricular apex (RVA). In the HBE three electrograms can be identified, the atrial (A), the His bundle (H) and the ventricular (V) electrograms. The atrial component in the HBE is larger than in Fig. 1. B. During AVNRT, the H-A-V pattern is observed, with the atrial (A) electrogram following the His bundle (H) electrogram and preceding the ventricular one (V).

## 2. Methods

The clinical records and electrophysiology data bases of two different institutions were reviewed and all the pediatric patients with a diagnosis of typical AVNRT that underwent electrophysiology studies and ablation were identified. Clinical data was obtained, and the studies were reviewed to gather the electrophysiological information, including baseline intervals, methods of tachycardia induction and termination, tachycardia cycle length, need of isoproterenol for induction or sustainment

and to assess the presence of an HAV pattern in the His channel.

All patients underwent electrophysiology study under conscious sedation or general anesthesia. Those who were receiving antiarrhythmic medications stopped receiving them at least 5 half-lives prior to the procedure. Three or four catheters were used at the discretion of the operating electrophysiologist. Catheters were positioned in the high right atrium and/or coronary sinus, His position (showing an atrial, a His bundle and a ventricular electrogram) and right ventricular apex. The catheter positioned in this His area was always a quadripolar diagnostic catheter, either



**Fig. 3.** The first four channels show the surface ECG. There are catheters positioned in the His position (HBE), in the coronary sinus (CS) and in the right ventricular apex (RVA). One atrial extra stimulus at 270 ms is placed, pacing from the proximal dipole of the catheter placed in the CS, there is a prolongation of the AH interval and tachycardia is induced. In the atrial extra stimulus, the HBE channel shows the atrial (A) electrogram, followed by the His (H) electrogram and then the ventricular (V) one. When tachycardia is induced the H-A-V pattern is observed.

deflectable or not (based on the operators' choice), 5 or 6 Fr. in size with the typical interelectrode spacing. It was positioned following the standard technique, advancing across the tricuspid valve between the anterior and septal leaflets and lying with a gentle clockwise rotation against the septum, where the His bundle penetrates ventricular myocardium. A well-balanced relationship between the size of the atrial and ventricular electrograms was always pursued, aiming for good sized atrial and ventricular components, with a sharp His signal recorded between them. Stability was crucial for measurements during tachycardia and the catheter was held still by the catheter operator if needed.

Baseline intervals were measured prior to the initiation of the stimulation protocols after the catheters were appropriately positioned. Standard pacing protocols, asynchronous atrial and ventricular pacing and incremental atrial and ventricular extra stimulus, until the refractory periods of the fast and slow AV nodal pathways effective refractory periods were achieved and/or AVNRT was induced. In those in whom AVNRT was not inducible isoproterenol was administered titrating the dose based on the heart rate response. Once tachycardia was induced the diagnosis of AVNRT was confirmed during the study through the use of typical pacing maneuvers previously described: introducing ventricular extra stimulus in tachycardia and assessing whether this extra stimulus advanced the atrium, and ventricular pacing during tachycardia assessing the response upon cessation of pacing (V-A-V response) and to confirm AVNRT based on the post pacing interval [5]. The His bundle channel electrograms were assessed to define the presence of the analyzed pattern. In order to be included the atrial electrogram needed to be identified clearly and distinctly from the ventricular one.

Values are expressed in means  $\pm$  SD and range. Categorical variables were described according to their relative frequency. Mean tachycardia cycle length was compared between different age groups (younger or older than 10 years of age) and according to the need to administrate isoproterenol to induce tachycardia, using the Student Test with a level of significance of 0.05.

### 3. Results

Thirty-nine patients with a diagnosis of typical AVNRT who underwent an electrophysiology study were identified. Of these, 25 were female. The mean age at the time of the intervention was  $12 \pm 3.7$  years (range 5–18 years). All but two patients had inducible and sustained typical AVNRT during the study.

Tachycardia was induced with asynchronous atrial pacing in 23 patients (60%), with one atrial extra stimulus in 8 (20%) (Fig. 3) and with 2 atrial extra stimuli in 8 (20%). In 21 (53%) patients in whom tachycardia was not inducible at baseline, isoproterenol was administered, and it was successful for the induction of tachycardia. In two patients only non-sustained episodes of typical AVNRT were induced.

The general mean tachycardia cycle length was  $320 \pm 50$  ms (ms). In those patients in which isoproterenol was not used for tachycardia induction the mean cycle length was  $328 \pm 57$  ms, and in those that required isoproterenol for induction it was  $314 \pm 55$  ms. There were no statistically significant differences regarding tachycardia cycle lengths between the group of patients that needed isoproterenol for induction of SVT versus those that did not.

An HAV pattern was observed in 29 of 39 patients (74%). Breakdown according to patients' ages was the following: it was present in 7/7 (100%) of the patients younger than 10 years of age and in 22/32 (68%) of the older ones. When comparing the presence of the pattern depending on isoproterenol use, it was present in 16/21 (76%) patients in whom it was needed for induction and in 13/18 (72%) in whom isoproterenol was not administered, rendering a non-statistically significant difference.

### 4. Discussion

Atrioventricular node reentry is the most common form of supraventricular tachycardia in adult patients, and the main characteristic is the simultaneous activation of atria and ventricles.

Pediatric patients with AVNRT have a distinct activation in the catheter placed in the His position. This report, to the best of our knowledge, is the first one to describe the presence of an HAV pattern in the His bundle channel, a unique finding of typical AVNRT in pediatric patients.

The characteristics of our population are similar to previously presented series of pediatric AVNRT. There were no differences regarding the age of our patients and the fact that AVNRT appeared to be more frequent in females [2,3].

Several previously reported papers have addressed the fact that the morphological and functional changes in the AV node and in the autonomic inputs to the AV node, could potentially explain the different prevalence of AVNRT in children [6,7]. These could also be the reason for the appearance of this interesting finding in this tachycardia in younger patients. In the study by Waki et al. [7], the anatomical and histological appearance of the AV node was analyzed in autopsy samples at different ages. They described histological changes, including an increase in the fibro fatty tissue within the area of the transitional cells with aging, compared to the tightly packed area observed in the younger hearts.

The changes in the shape and size, and in the position of the compact AVN, along the so-called AV septum, were also addressed by this group. In addition to that, they described the modifications observed in the size ratio of the compact node and the rightward and leftward inferior extensions. In older hearts this ratio was significantly increased. With aging, the length of the rightward extension increased five times. There are studies that have documented that these extensions could provide the substrate for slow pathway conduction, providing the anatomical and functional basis for AVNRT. Together the changes in histology of the transitional zone, modifications in the size, the shape and the orientation of the compact AV node, and the changes in the length of the inferior extensions could potentially explain the rapid activation of the atrial tissue, accounting for the finding of the HAV in AVNRT in younger and smaller patients [7].

Along with these anatomical findings there are changes in the anterograde functional properties of the AV node's fast and slow pathways [6,7]. Previously published data specifically addressed the presence of longer effective refractory periods (ERPs) in older pediatric patients. It has been shown that the ERPs of the fast and slow pathways prolong with time [6].

Moreover, a study by Tseng et al. [7] demonstrated that together with the changes in the anterograde conduction properties, there are changes in the fast and slow pathways retrograde ERPs, providing additional evidence supporting that these functional changes that develop with age could potentially explain the finding of the HAV pattern in His channel in younger patients [8,9].

Interestingly the presence of an HAV pattern was not affected by the use of isoproterenol for tachycardia induction. This finding may

indicate that, rather than a finding secondary to the effect of drugs that have effects on the dromotropism of specialized conduction tissue, the presence of the HAV pattern is related to the morphological and functional changes that occur with maturation and aging, previously described.

The potentially confounding effect of anesthetic drugs in the conduction properties of the AV node is overruled by the fact that all the patients had the procedure done under general anesthesia, and consequently they were all exposed to them, regardless of the presence of the HAV pattern.

## 5. Conclusions

The presence of an HAV pattern in the His bundle channel appears to be a very frequent finding in pediatric patients with AVNRT. Its appearance can be explained by maturational AV nodal morphological and functional changes. It is uniformly present in those younger than 10 years of age and can be considered diagnostic of this mechanism of tachycardia in this age group. Further studies should be performed to confirm these findings and to specifically compare this finding in children with AVNRT with adult patients.

## Declaration of competing interest

The authors have no conflict of interest.

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