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## Coronary sinus cannulation predicts atrioventricular nodal reentry as mechanism of supraventricular tachycardia

Tiago Luiz Luz Leiria <sup>a,\*</sup>, Mauricio Branchi <sup>a</sup>, Roberto Tofani Sant'anna <sup>a</sup>,  
Eduardo Dytz Almeida <sup>a</sup>, Leonardo Martins Pires <sup>a</sup>, Marcelo Lapa Kruse <sup>a</sup>, Vidal Essebagg <sup>b</sup>,  
Marco Aurélio Lumertz Saffi <sup>c</sup>, Gustavo Glotz de Lima <sup>a</sup>

<sup>a</sup> Electrophysiology Department of the Instituto de Cardiologia do Rio Grande do Sul / Fundação Universitária de Cardiologia, Porto Alegre, Rio Grande do Sul, Brazil

<sup>b</sup> Electrophysiology Department of McGill University Health Centre - Director of Cardiac Electrophysiology, McGill University Health Centre, Canada

<sup>c</sup> Hospital de Clínicas de Porto Alegre, Porto Alegre, Rio Grande do Sul, Brazil

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## ABSTRACT

**Introduction:** Common clinical teaching, for invasive electrophysiology, is that if the first year fellow cannulates the coronary sinus (CS) in his first attempt, the arrhythmia is more likely to be atrioventricular nodal reentry tachycardia (AVNRT). This general perception has not yet been clinically tested. We evaluated this theory in prospective patients undergoing an electrophysiological study (EPS) for paroxysmal supraventricular tachycardia (PSVT).

**Methods:** Cohort study. CS ease of cannulation (CSCS) was graded as: 1) 1st year fellow cannulates in first attempt; 2) 1st year fellow needs more than one attempt or maneuver to cannulate the CS; 3) staff physician cannulates in first attempt after the fellow was unsuccessful; 4) staff physician requires more than one maneuver to cannulate the CS; 5) staff physician judges that the cannulation process was extremely difficult.

**Results:** Of the 1361 patients undergoing EPS in our institution, 165 were selected. Age was  $49 \pm 15$  years. AVNRT occurred in 77.6%, atrioventricular reentry tachycardia (AVRT) in 15.1% and atrial tachycardia (AT) in 7.3% of cases. The CSCS = 1 was more prevalent in AVNRT, 89% versus 68% AVRT and 58.3% of AT ( $P = 0.0005$ ). Patients with CSCS = 1 have a higher chance of the PSVT being AVNRT (odds ratio: 4.41; 95CI: 1.84–10.56;  $P = 0.0009$ ).

**Conclusion:** The CSCS predicts the likelihood of the induced PSVT being AVNRT as compared to AVRT and AT. More studies are required to try to associate this finding to clinical patient characteristics to create a score for PSVT mechanism prediction.

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## 1. Introduction

Atrioventricular nodal reentry tachycardia (AVNRT) is the most common cause of paroxysmal supraventricular tachycardia (PSVT) [1]. The differentiation of this type of supraventricular tachycardia from atrioventricular reentry tachycardias (AVRT) that are due to bypass tracts, atrial tachycardias (AT) and junctional ectopic tachycardia (JET) is crucial for the electrophysiologist when

planning for an ablation procedure [2]. When performing the electrophysiological study (EPS) and the ablation procedure, most laboratories use a coronary sinus (CS) catheter for aiding in the diagnostic maneuvers required for the differential diagnosis of the tachyarrhythmia mechanism.

Common clinical teaching during fellowship training, for invasive electrophysiology, is that if the first year fellow cannulates the CS in his first attempt the arrhythmia is most likely to be AVNRT. There is probably an anatomical reason for this impression. The CS ostial diameter is larger in patients with AVNRT when compared with other forms of PSVT [3,4]. However, this general perception has not yet been clinically tested in a prospective way in patients with PSVT.

Therefore, we decided to resolve this question by conducting a

\* Corresponding author. Av. Princesa Isabel, 395, Santana, CEP 90620-000, Porto Alegre, RS, Brazil.

E-mail address: [drleiria@gmail.com](mailto:drleiria@gmail.com) (T.L.L. Leiria).

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prospective study to evaluate the ease of CS cannulation in patients undergoing to an EPS for the investigation and treatment of PSVT.

## 2. Methods

This is a prospective study of consecutive patients that were referred for an EPS, from March 2016 until September 2017, in our Institution, the Instituto de Cardiologia – Porto Alegre, Brazil, an academic cardiology center, for the investigation of PSVT.

### 2.1. Inclusion criteria

Patients referred for an EPS to investigate PSVT, with a previous ECG recording of PSVT or a medical history of emergency room visit due to palpitations were included in the study. All patients or their legal representatives agreed to participate in the study by providing informed consent.

### 2.2. Exclusion criteria

We excluded patients referred for EPS because of the presence of ventricular pre-excitation, atrial flutter, atrial fibrillation, ventricular tachycardia, bradycardia or syncope investigation, ventricular ectopic focus and Brugada syndrome. Also, patients investigating palpitations without a previous record or hospital visit due to these symptoms were excluded.

### 2.3. Paroxysmal supraventricular tachycardia definition

PSVT was defined according to the current guidelines as a clinical syndrome characterized by the presence of a regular and rapid tachycardia of abrupt onset and termination. These features are characteristic of AVNRT or AVRT, and, less frequently, AT [5].

AVNRT, AVRT and AT were diagnosed during the EPS according to the established criteria during detailed atrial and ventricular mapping and pacing manoeuvres [2].

### 2.4. EPS protocol

All patients were brought to the electrophysiology laboratory in a fasting state and received conscious sedation administered by an anesthesiologist using intravenous propofol (100–150 mcg/kg/min), midazolam (0.02–0.04 mg/kg) and fentanyl (0.5–2 µg/kg). Femoral access was acquired with three venous sheaths in the femoral vein and an additional sheath was introduced into the femoral artery for the ablation of left side pathways. For the diagnostic part of the study a quadripolar Supreme™ (St. Jude, NJ, USA) catheter was placed in the region of the His bundle electrogram and an additional one was placed in the right ventricle apex. The CS was always cannulated, using a large or medium curve decapolar deflectable 6 french Inquiry™ (St. Jude, NJ, USA) catheter, for pacing and mapping. All signals were recorded using the EP-WorkMate™ (St. Jude, NJ, USA) a fully computerized system for capturing and measuring electrophysiological data.

### 2.5. CS cannulation and ease of cannulation score

All CS were cannulated through femoral vein approach and using the same catheter (Inquiry™ St. Jude, NJ, USA), technique and EPS lab. As described elsewhere [6], first the tip of the catheter is placed into RV using right anterior oblique view (RAO) and flexed downward toward the RV inferior wall. Afterwards, the catheter is withdrawn until the inferoseptal portion of the tricuspid annulus. In the left anterior oblique view (LAO), the catheter is slowly withdrawn with clockwise rotation until the tip drops into the CS

ostium. Finally, the catheter can be advanced while the curve is released until it reaches the final position.

All first attempts were made by the same operator, which was a first year fellow that started his training 3 months before we started including patients for this study until the end of patient inclusion. All staff members are experienced electrophysiologists that perform at least 600 Em/year. We did not perform any attempt for cannulating the CS via the superior vena cava (subclavian, axillary or jugular access).

The CS ease of cannulation was graded as follows: 1) 1st year fellow cannulates in his first attempt; 2) 1st year fellow needs more than one attempt or maneuver to cannulate the CS; 3) staff physician cannulates in his first attempt after the fellow was unsuccessful; 4) staff physician needs more than one maneuver to cannulate the CS; 5) staff physician judges that the cannulation process was extremely difficult. This score was developed based on the clinical experience and intuitive feel of our institution's electrophysiology team.

### 2.6. Statistical analysis

Statistical analyses were performed using MedCalc for Windows, version 8.2 (MedCalc Software, Ostend, Belgium). Continuous variables were expressed as mean ± standard deviation and compared by Student's t-test for independent samples. Categorical variables were expressed as percentages and compared using the  $\chi^2$  test. Bonferroni method was used to calculate the multiple comparisons of proportions. A  $P < 0.05$  was considered statistically significant.

### 2.7. Ethics

The study was conducted in accordance with the Declaration of Helsinki, and the research protocol was approved by the Ethics and Research Committee of our Institution.

## 3. Results

During the study period we performed 1361 procedures, of these, 165 were due to PSVT.

### 3.1. Baseline characteristics

Table 1 summarizes clinical characteristics of included patients. Mean age was  $49 \pm 15$  years, 66% were female. There was a significant age difference between groups ( $52 \pm 14$  years for AVNRT vs.  $36 \pm 16$  years for AVRT vs.  $53 \pm 20$  years for AT,  $P < 0.01$ ). We were not able to find any difference in the prevalence of hypertension, diabetes or ischemic heart disease. Patients had a previous documented episode of supraventricular tachycardia in 69.4% of the cases, in the remaining the EPS was indicated based on characteristic symptoms.

### 3.2. Electrophysiological study

The tachycardia diagnoses, mean tachycardia cycle lengths, mean RP intervals on the ECG are summarized in Table 2. AVNRT was diagnosed in 77.5% of our cases, AVRT in 15.2% and AT in 7.3% respectively. There were no cases in our series with multiple mechanisms for the PSVT (eg., both AVNRT and AVRT).

There were no differences in tachycardia cycle lengths across subgroups. Mean RP interval was 84 ms in those with AVNRT versus 128 ms in AVRT and 160 ms in AT ( $P < 0.05$  for AVNRT vs. AVRT and AT).

**Table 1**  
Patient characteristics stratified by paroxysmal supraventricular tachycardia type.

| Characteristics         | AVNRT (n = 128) | AVRT (n = 25) | AT (n = 12) | P value |
|-------------------------|-----------------|---------------|-------------|---------|
| Age, years              | 52 ± 14         | 36 ± 16       | 53 ± 20     | <0.01   |
| Age 1st symptoms        | 45 ± 15         | 28 ± 16       | 49 ± 20     | <0.01   |
| Body mass index         | 28.3 ± 5.7      | 26.4 ± 6.4    | 24.8 ± 3.4  | 0.08    |
| Female gender           | 67%             | 52%           | 75%         | 0.76    |
| Hypertension            | 35.9%           | 16%           | 33.3%       | 0.26    |
| Diabetes                | 8.6%            | 4%            | 0%          | 0.19    |
| Ischemic heart disease  | 3.1%            | 0%            | 0%          | 0.31    |
| Drugs                   |                 |               |             |         |
| Amiodarone              | 3.1%            | 8%            | 16.7%       | 0.08    |
| Betablocker             | 35.4%           | 32%           | 25%         | 0.74    |
| Calcium channel blocker | 3.1%            | 0%            | 0%          | 1.19    |

Data are mean ± SD or number (%) of patients. AVNRT: atrioventricular nodal reentry tachycardia, AVRT: atrioventricular reentry tachycardia, AT: atrial tachycardia.

**Table 2**  
Electrophysiological study findings: tachycardia diagnoses, mean tachycardia cycle lengths, mean RP intervals on the ECG.

| Tachycardia characteristics          | AVNRT (n = 128) | AVRT (n = 25) | AT (n = 12) | P value |
|--------------------------------------|-----------------|---------------|-------------|---------|
| TCL (ms)                             | 236 ± 173       | 212 ± 168     | 283 ± 183   | 0.09    |
| RP interval during tachycardia in ms | 84 ± 29*        | 128 ± 34      | 160 ± 73    | <0.05   |

\*P < 0.05 for the comparison of AVNRT vs. AT and AVRT. Tests are adjusted for all pairwise comparisons using the Bonferroni correction. AVNRT: atrioventricular nodal reentry tachycardia, AVRT: atrioventricular reentry tachycardia, AT: atrial tachycardia, ms: millisecond.

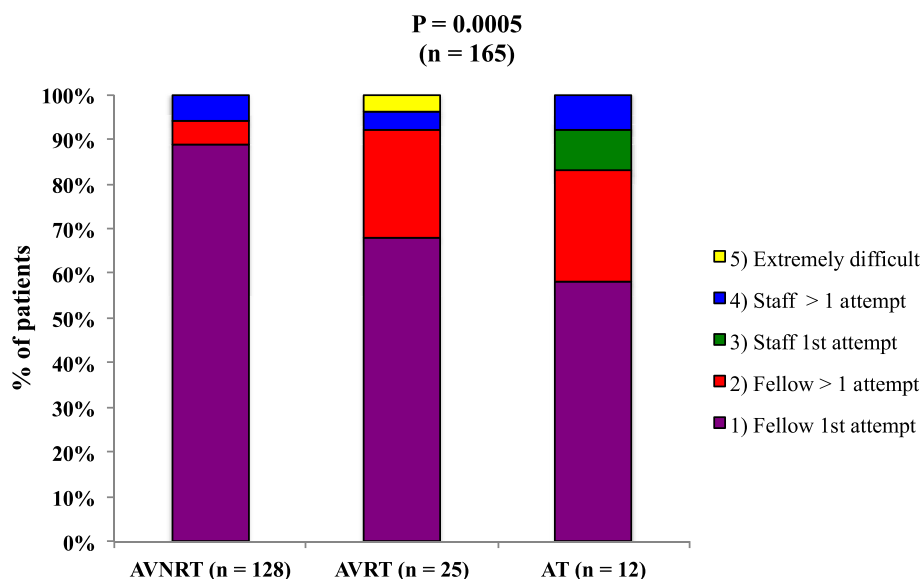
### 3.3. CS ease of cannulation score and probability of AVNRT

A CS cannulation score of 1 was present in a higher proportion of AVNRT cases, 89% vs. 68% AVRT and 58.3% of AT (P = 0.0005; Bonferroni P < 0.05 for AVNRT vs. AVRT + AT). There was no difference in the other score grades with relation to the supraventricular tachycardia (SVT) type (Fig. 1). Patients with CS cannulation score of 1, compared to higher values, had a higher chance of the induced SVT being an AVNRT (odds ratio 4.41; 95CI: 1.84–10.56; P = 0.0009). We performed a logistic regression analysis using age as possible confounder. Our findings showed that age was a predictor of the etiology of the PSVT. The chance of having AVNRT as the cause of the PSVT increases by 4.8% (IC95%: 2.1–7.5%) for each year of age (P < 0.001).

### 4. Discussion

Understanding the CS anatomy is important for the electrophysiologist. The morphology of this vessel can quite variable [7,8]. These variations include different vessel lengths, branches, morphologies and the presence of several forms of Thebesian valves – that sometimes can even occlude the CS ostium [9]. The nuances of these structures may correlate with different arrhythmia mechanisms. Our study corroborates the clinical perception that in those patients referred for an EPS due to PSVT, the ease of CS cannulation reflects a higher odds ratio of AVNRT as a final diagnosis.

The larger CS ostia in patients with AVNRT may produce pathophysiological modifications. A larger CS could create separation of atrial inputs into the AV node or increase anisotropic conduction, predisposing to a different AV nodal physiology. Ong et al. [10]



**Fig. 1.** Coronary sinus cannulation difficulty score according to type of supraventricular tachycardia. AVNRT: atrioventricular nodal reentry tachycardia, AVRT: atrioventricular reentry tachycardia, AT: atrial tachycardia.

using angiography compared the size and morphology of the CS among patients with different types of SVT. They found that patients with typical AVNRT had bigger CS size and a higher prevalence of windsock morphology than the other groups, which can explain why cannulation was easier in patients with AVNRT than in those with AT or AVRT. Doig et al. [11] also reported similar results. On his paper patients with AVNRT had an ostium that was 44% larger and it remained more dilated to at least 10 mm from its opening when compared to control subjects. Also its morphology resembles a wind sock in AVNRT patients and tubular in the control cases. More recently, Ezhumalai et al. [3] demonstrated with the use of echocardiography instead of angiography that the CS ostia also had a larger diameter in patients with AVNRT when compared with patients with AVRT.

In contrast, Weiss et al. [12] did not find any significant difference in the width of the CS ostium between patients with AVNRT compared with their control group. Even though they reported several anatomical variations in their patient population, including a CS ostium greater than 25 mm in 5% of their AVNRT cases. Karagöz A et al. [13] using multidetector computed tomographic, for the evaluation of the CS anatomy in patients with supraventricular reentrant tachycardia, did not find any difference the diameter or morphology of the CS in patients with AVNRT compared to AVRT. The lack of significant difference in this study may be related to its small sample size (less than 20 patients in each group).

The observation that it is easier to cannulate the CS also may not be fully explained only by its ostium size. Maybe some other anatomical variants, such as those related to the Thebesian valve may explain this finding. However, we have not found in the literature any study that mentions a relation between the characteristics of the Thebesian valve in relation to the different types of tachyarrhythmia.

The clinical implication of our finds reside, in our opinion, in this era of busy EP laboratories and health care resources constrains, there is an urge for optimization in time. Also, if the procedure is performed in an expedite and focused way, we believe that it will be translated into better patient care. If the procedure takes too long, we increase the risk of micro-aspiration due to the conscious sedation, we use more drugs, we increase radiation exposure, we increase the risks related to the femoral access complications such as DVT and bruises and, finally, we may increase costs. At the same time, we always try to gather as much information as we can regard each case. In the patient medical history, we always check for the presence of neck pounding, shirt bouncing and mode of initiation and termination of the symptoms. During the EP study the presence of dual nodal physiology, mode of induction of the PSVT, the form of retrograde conduction, all this information makes one mechanism of PSVT more probable than the other. So, we think that the CS cannulation difficulty is another information to be utilized into the electrophysiologist armamentarium for guiding a concise and time efficient procedure.

Our study has the following limitations: 1) All CS were cannulated using a femoral approach. It may be easier to cannulate the CS using the right internal or left subclavian vein because the CS valve is oriented anterosuperiorly. In cases where this valve is prominent, the femoral access may be inadequate. We used a deflectable catheter in all cases to overcome this limitation; 2) All cases included in the study were performed by the same fellow. His ability may not be representative of the overall ability of EP fellows and it is expected that his skills improved during this study. Furthermore, our score considers the EP staff experience of a high volume center, which might not be representative of all EP labs; 3) Our Institution is a public hospital and no additional budget was spent. We did not perform any additional image modality to assess the CS morphology and CS ostium size due to this restriction. Also,

an imaging study of the CS anatomy would expose the patients to further radiation and possibly to ionic contrast agents.

## 5. Conclusion

In our study we were able to demonstrate that when CS is easily cannulated without the need for any additional maneuver by the fellow in electrophysiology, there is a greater probability that the arrhythmia is AVNRT. The reasons for which this phenomenon occurs are not fully explained. A possible cause may be related to a larger dimension of the CS ostium in this type of arrhythmia. Further studies using new imaging technologies such as the use of 4D echocardiography may help better elucidate the anatomical differences accounting for this finding.

## Informed consent

Informed consent was obtained from all individual participants included in the study.

## Conflicts of interest

The authors declare no conflicts of interest relevant to this manuscript.

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## Declarations of interest

None.

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