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Paraseptal Accessory Pathway in Wolff-Parkinson-White-Syndrom: Ablation from the Right, from the Left or within the Coronary Sinus/Middle Cardiac Vein?

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***Abstract. Aims*: In 1999 the consensus statement "living anatomy of the atrioventricular junctions" was published. With that new nomenclature the former posteroseptal accessory pathway (APs) are termed paraseptal APs. The aim of this study was to identify ECG features of manifest APs located in this complex paraseptal space.**

***Methods and Results*: ECG characteristics of all patients who underwent radiofrequency ablation of an AP during a 3 year period were analyzed. Of the 239 patients with one or more APs, 30 patients had a paraseptal AP with preexcitation. Compared to APs within the coronary sinus (CS) or the middle cardiac vein (MCV) the right sided paraseptal APs significantly more often showed an isoelectric delta wave in lead II and/or a negative delta wave in aVR. The left sided paraseptal APs presented a negative delta wave in II significantly more often compared to the right sided APs.**

***Conclusions*: According to the site of radiofrequency ablation, paraseptal APs are classified into 4 subgroups: paraseptal right, paraseptal left, inside the CS or inside the MCV. Subtle differences in preexcitation patterns of the delta wave as well as of the QRS complex exist. However, the definitive localization of APs remains reserved to the periinterventional intracardiac electrogram analysis.**

***Key Words.* inferior pyramidal space, anatomical nomenclature, atrioventricular junctions, coronary sinus, paraseptal accessory pathway, Wolff-Parkinson-White syndrome**

Introduction

Radiofrequency catheter (RF) ablation has been established as the first line therapy for the curative treatment of patients with accessory pathways [1,2].

In 1999, the cardiac nomenclature group, working group of arrhythmias, European Society of Cardiology, and the Task Force on Cardiac Nomenclature from NASPE published the consensus statement "living anatomy of the atrioventricular junctions" [3]. With that new nomenclature the accessory pathways were classified as left, right, septal and the former posteroseptal accessory pathways (APs) were termed paraseptal APs now (Fig. 1).

The complex inferior paraseptal area corresponds anatomically to the so-called inferior pyramidal space [4]. This pyramid is bounded superiorly by the central fibrous body, anteriorly by the ventricular mass, and posteriorly by the convergence of the right and left atrial walls. From the central fibrous body, hinge-lines of the mitral and tricuspid valves diverge, forming discrete margins of the pyramid. The course of the coronary sinus (CS) passes through the base of this area [4]. This area is not septal in the strictest sense because an epicardial tissue plane, containing fibrofatty tissue, and carrying the artery to the atrioventricular node, extends between the atrial wall and the ventricular musculature [5]. Anderson et al. described this area as an atrioventricular muscular "sandwich" with the fibrofatty adipose tissue representing the "meat" in the sandwich [6].

There is no sharp demarcation between the paraseptal area and its surrounding regions. A cuff of striated muscle around the CS is extending about 40 mm from the ostium and connects the inferior right atrium and the left atrial myocardium [7]. Sleeve-like extensions of the CS myocardial coat covering the terminal portion of the middle cardiac vein (MCV) and posterior

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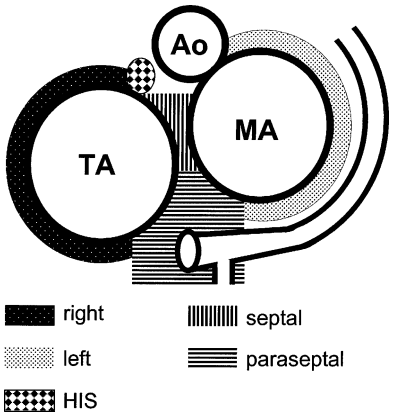

Fig. 1. *Schematic representation of the atrioventricular junctions in the left anterior oblique view. The paraseptal APs are subdivided into four compartments with relevance for the ablation approach: Paraseptal right, paraseptal left, within the CS and within the MCV. TA: tricuspid annulus. MA: mitral annulus. Ao: aorta.*

coronary vein (PCV) have been described in 3% and 2%, respectively [8]. More than one third of APs in theses locations have been described to arise from this muscular connections between the CS sleeve and the ventricle (more typical APs directly connect the atrium and the ventricle) [9].

Accessory pathways passing through this paraseptal space may be amenable to ablation through an ablation catheter positioned adjacent to either the tricudspid, or the mitral valvular annuli or placed within the coronary sinus or the middle cardiac vein.

The aim of this study was to identify ECG features distinguishing the different compartments of manifest paraseptal APs, and this way supporting the electrophysiologist to choose the adequate approach for ablation of these distinct APs.

Methods

Study Population

All consecutive patients with accessory pathways, who have been treated by RF catheter ablation during a 3 year period in our institution were retrospectively analyzed. The distribution of all APs and the procedure data were analyzed. The AP localization was approved according the site of successful RF ablation during the ablation procedure. The anatomical locations were described according to the consensus statement "living anatomy of the atrioventricular junctions" [3]. The paraseptal APs were categorized as left paraseptal, right paraseptal, in the CS or in MCV. Based on studies showing angiographically normal anatomy of the CS in most patients with APs within the coronary vein system [9], an angiogram of the CS was performed only if the electrophysiologist suspected CS or MCV anomalies.

ECG Analysis

In all patients with WPW syndrome and a paraseptal accessory pathway, preexcited 12-lead ECGs (paper speed 50 mm/sec) during sinus rhythm and during high rate atrial pacing (maximal preexcitation) were analyzed by two experienced electrophysiologists. The delta wave and QRS polarity in all 12 ECG leads were evaluated. Delta wave was determined by examining the initial 20 msec after earliest delta wave onset [11]. The polarity of the delta wave was categorized as positive, negative or isoelectric. As well, QRS polarity could be positive, isoelectric or negative, depending on whether the QRS complex was mainly above, equal, or under the baseline [12].

Statistics

Results are expressed as mean values ± 1 standard deviations (SD), median and range or numbers and percentages, as appropriate. Continuous variables were compared by a one-way analysis of variance (ANOVA) for parametric data and Mann-Whitney U test for unpaired, non-parametric data. For comparison of categorical variables chi-square testing or t-test for unpaired data was performed, as appropriate. Sensitivity, specificity and positive predictive value of different delta-wave polarities and QRS-morphologies for predicting the ablation site were calculated. For the statistical analysis the data of CS and MCV APs were grouped together. A p value of less than 0.05 was considered statistically significant. All statistics were performed by using STATVIEW 4.5^{TM}.

Results

In our institution 238 patients with a total of 247 APs (57% with preexcitation) were successfully treated by RF catheter ablation during a 3 year period. The patients' mean age was 38 ± 18 years, 55% were male.

The definitive localization according to the successful ablation site is shown in Table 1. The majority consisted of left-sided (58%) and paraseptal (20%) APs. Right-sided (12%) and septal (10%) APs appeared to be less common. 30 of the 47 paraseptal APs showed preexcitation.

The distribution of these 47 APs is presented in Table 1.

Procedure time, fluoroscopy time, number of RF impulses and amount of RF energy delivered did not show significant differences (Table 2).

Table 1. *Distribution of all accessory pathways*

Location	All	Manifest (% of all)	Concealed (% of all)
Right ($n = 30$; 12%)			
Superior	6	5 (80%)	1 (20%)
Anterior	17	16 (94%)	1 (6%)
Inferior	7	2 (29%)	5 (71%)
Left (n =140; 58%)			
Superior	16	7 (44%)	9 (56%)
Posterior	99	50 (51%)	49 (49%)
Inferior	25	13 (52%)	12 (48%)
Septal ($n = 24$; 10%)			
Right	21	17 (81%)	4 (19%)
Left	3	0 (0%)	3 (100%)
Paraseptal ($n = 47$; 20%)			
Right	29	19 (66%)	10 (34%)
Left	11	4 (36%)	7 (64%)
CS	4	4 (100%)	0 (0%)
MCV	3	3 (100%)	0 (0%)
Atypical ($n = 6$; 2%)			
RAA → RV	1	1 (100%)	0 (0%)
Fan-shaped	5	1 (20%)	4 (80%)
Total	247	142 (57%)	105 (43%)

RAA: right atrial appendage, RV: right ventricle, CS: coronary sinus, MCV: middle cardiac vein.

Among the 30 patients with manifest paraseptal AP, the AP was located right paraseptally in 19 (64%; Fig. 2), left paraseptally in 4 (13%), within the coronary sinus (CS) in 4 (13%) and within the middle cardiac vein (MCV) in 3 patients (10%), respectively. In 2 of these 7 patients with an APs in the coronary vein system, a diverticulum of the coronary sinus was detected.

In all 30 patients, a positive delta wave in lead I, aVL and V2 and a negative delta wave in lead aVF were registered.

Compared to the CS/MCV APs, in the paraseptal right APs the following preexcitation patterns were found more often (Table 3):

- Isoelectric delta wave in lead II ($p < 0.05$)
- Negative QRS polarity in lead V1 ($p < 0.05$)
- Negative delta wave in aVR ($p < 0.05$)

Regarding this 3 criteria, typical for right paraseptal AP, the positive predictive value was in the range between 84% and 92% (Table 4a). However, sensitivity for the differentiation from the remaining paraseptal compartments was limited.

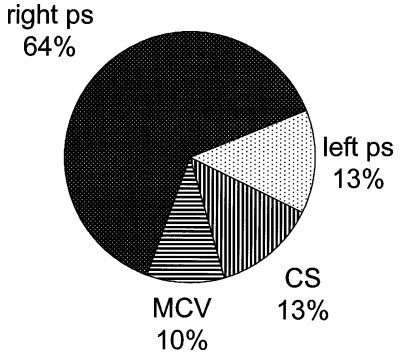

Fig. 2. *Distribution of patients with manifest paraseptal AP to the different compartments. ps: paraseptal; MCV: middle cardiac vein; CS: coronary sinus.*

Compared to the right paraseptal APs, the CS/MCV APs demonstrated the following patterns more frequently:

- Negative delta wave in lead II ($p < 0.05$)
- Positive delta wave in lead aVR ($p < 0.05$)

Positive delta wave polarity in lead aVR showed a high positive predictive value of 100%, but a low sensitivity, for differentiating CS/MCV APs from the other paraseptal compartments (Table 4b).

The left paraseptal APs demonstrated a negative delta wave in lead II more frequently compared to the right paraseptal APs ($p < 0.05$). As 86% of the CS/MCV APs present that pattern, too, it carries low specificity (Table 4c).

The delta wave and QRS polarity in lead III did not show any significant differences between the various paraseptal compartments.

Figure 3 shows typical ECG examples with preexcitation of APs located within the 4 paraseptal compartments.

Discussion

The paraseptal space is a complex, three-dimensional anatomical space with various possibilities for insertion of APs. Because of this complex anatomy, the ablation of APs in this

Table 2. *Periprocedural data of patients with paraseptal AP vs. AP of different localization*

	Paraseptal AP, median (range)	Non paraseptal AP	p value
Procedure time (min)	60 (20–140)	55 (15–235)	ns
Fluoroscopy time (min)	16 (2–52)	13 (2–68)	ns
Fluoroscopy dose (cGy/cm^2)	1717 (224–15000)	1278 (86–35969)	0.02
Number of RF impulses	4 (1–23)	4 (1–45)	ns
RF energy (Ws)	5231 (458–36209)	5444 (557–47348)	ns

RF: Radiofrequency; ns: non significant.

Table 3. *Prevalence of selected surface electrocardiographic parameters related to the localization*

	Right paraseptal ($n = 19$)	CS/MCV ($n = 7$)	Left paraseptal ($n = 4$)	p-value (right vs. CS/MCV; right vs. left)
Isoelectric delta wave in II	11 (58%)	1 (14%)	0 (0%)	<0.05; ns
Negative QRS in V1	16 (84%)	1 (14%)	2 (50%)	<0.05; ns
Negative delta wave in aVR	9 (47,4%)	0 (0%)	1 (25%)	<0.05; ns
Negative QRS in V1 + negative delta wave in aVR	8 (42,1%)	0 (0%)	1 (25%)	<0.05; ns
Positive delta wave in aVR	0 (0%)	4 (57,1%)	0 (0%)	<0.05; ns
Negative delta wave in II	7 (37%)	6 (86%)	4 (100%)	<0.05; <0.05

II: lead II; V1: lead V1; aVR: lead aVR. CS: coronary sinus, MCV: middle cardiac vein.

Table 4a. *Sensitivity, specificity and positive predictive values of the delta wave- and/or QRS polarity for correct localization of a right paraseptal accessory pathway compared with the other paraseptal APs*

	Sensitivity	Specificity	PPV
Isoelectric delta wave in lead II	58%	91%	92%
Negative QRS in lead V1	84%	73%	84%
Negative delta wave in lead aVR	47%	91%	90%
Negative QRS in V1 and negative delta wave in lead aVR	42%	91%	89%
Negative delta wave in lead II	37%	9%	41%

PPV: positive predictive value.

Table 4b. *Sensitivity, specificity and positive predictive values of the delta wave- and/or QRS polarity for correct localization of a CS/MCV accessory pathway compared with the other paraseptal APs*

	Sensitivity	Specificity	PPV
Positive delta wave in lead aVR	57%	100%	100%
Negative delta wave in lead II	86%	52%	35%
Negative QRS in lead V1	14%	22%	5%

PPV: positive predictive value.

Table 4c. *Sensitivity, specificity and positive predictive values of the delta wave-polarity for correct localization of a left paraseptal accessory pathway compared with the other paraseptal APs*

	Sensitivity	Specificity	PPV
Negative delta wave in lead II	100%	50%	24%

PPV: positive predictive value.

localization often can be difficult. But APs in this localization are frequent, in our study they represented 20% of all 247 APs during a 3 year period.

The paraseptal space is filled with epicardial fat and has its apex at the central fibrous body. It is bordered on two sides by the left and right atrial walls and, on the third side, by the crest of the ventricular wall. The space can be anatomically entered through the floor of the coronary sinus. Muscular AV connections can insert to either the left or right ventricular margins of the ventricular mass, and further, the CS itself and its afferent branches can be the anatomic substrate for accessory AV connections. In terms of ablation of accessory pathway the paraseptal space is subdivided into four compartments: Paraseptal right, paraseptal left, within the CS and within the MCV or their ramifications. In our study, the paraseptal right was the most frequent localization (61% of all paraseptal APs). For the interventional electrophysiologist it is important to assess the localization of the AP as accurate as possible prior to ablation. Various general algorithms for AP localization have been established and are broadly used [10–12]. Takahashi et al. described specific electrocardiographic features of APs ablated within the coronary venous system. They found a positive delta wave in lead aVR to be a highly specific feature and a negative delta wave in lead II to show the highest sensitivity for an AP within the coronary venous system [13]. Arruda et al. described a truly negative delta wave in lead II to predict ablation within the coronary venous system [11].

An exact idea of the localization allows the electrophysiologist to guide the ablation therapy without detours and to keep the procedure time as low as possible and with the lowest burden of fluoroscopy for the patient. With that objective, this study investigated the specific features of the named four paraseptal compartments using the delta wave polarity and the QRS morphology during maximal preexcitation. An isoelectric delta wave in lead II, a negative delta wave in lead aVR and the combination of a negative QRS polarity in lead V1 with a negative delta wave in lead aVR indicate a right paraseptal AP with a specificity of 91% for each parameter. It is important to differentiate the delta wave and the QRS polarity. A negative delta wave in lead II indicates an AP within the CS/MCV or a left paraseptal AP with

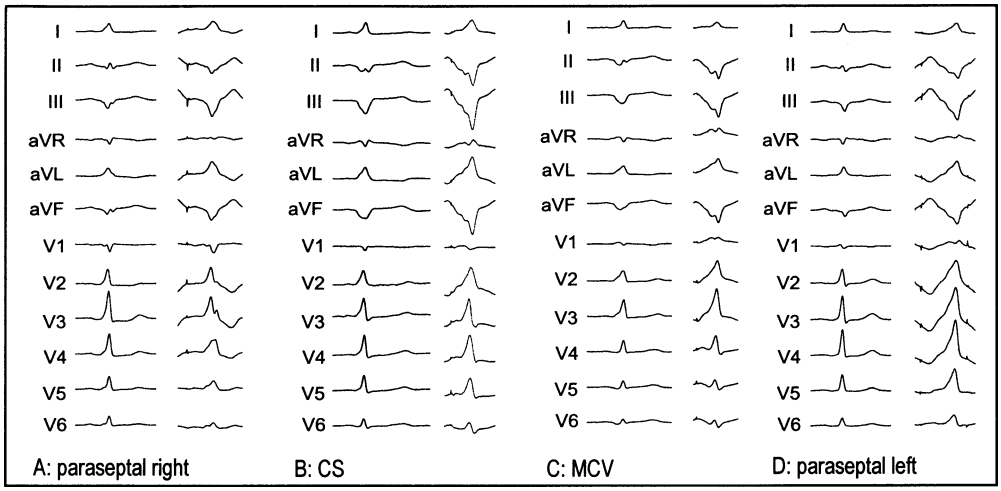

Fig. 3. *Typical ECG examples of the 4 paraseptal compartments. Left: Surface ECG during sinus rhythm. Right: Surface ECG during atrial pacing (for purposes of eliciting maximal preexcitation). A: Typical pattern of an isoelectric delta wave in lead II and a negative QRS in lead V1 in a paraseptal right AP. B–C: Typical patterns of a negative delta wave in lead II and a positive delta wave in lead aVR in APs within the coronary vein system (3b coronary sinus, 3c middle cardiac vein). D: Typical pattern of a negative delta wave in lead II in a paraseptal left AP.*

a high sensitivity but a low specificity. A positive delta wave in lead aVR indicates an AP within the CS or MCV with an excellent specificity of 100%, however 43% of the patients with an AP in this localization did not show this criterion at all. However, as the overall number of patients is relatively small, the broadly defined sensitivity and specificity definitions are somewhat limited.

In conclusion, the paraseptal right is the most frequently affected paraseptal compartment by an AP. Subtle differences in preexcitation patterns exists and the most helpful electrocardiographic features for classification of these paraseptal APs are seen in lead II. Due to their close localization, discrimination of left paraseptal APs and APs within the CS/MCV by use of surface ECG criteria is difficult. Finally, the definitive localization of paraseptal APs remains preserved to the peri-interventional intracardiac mapping.

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