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ORIGINAL RESEARCH ARTICLE

Validation of qrs-polarity algorithm with special emphasis in parahisian pathways

Validación del algoritmo de la polaridad del qrs con especial énfasis en vías parahisianas

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Abstract

Background: *In 1996 Iturralde et al. published an algorithm based on the QRS polarity to determine the location of the accessory pathways (AP), this algorithm was developed before the massive practice of invasive electrophysiology.* **Purpose:** *To validate the QRS-Polarity algorithm in a modern cohort of subjects submitted to radiofrequency catheter ablation (RFCA). Our objective was to determinate its global accuracy and its accuracy for parahisian AP.* **Methods:** *We conducted a retrospective analysis of patients with Wolff-Parkinson-White (WPW) syndrome who underwent an electrophysiological study (EPS) and RFCA. We employed the QRS-Polarity algorithm to predict the AP anatomical location and we compared this result with the real anatomic location determined in the EPS. To determine accuracy, the Cohen's kappa coefficient (κ) and the Pearson correlation coefficient were used.* **Results:** *A total of 364 patients were included (mean age 30 years, 57% male). The global κ score was 0.78 and the Pearson's coefficient was 0.90. The accuracy for each zone was also evaluated, the best correlation was for the left lateral AP (κ of 0.97). There were 26 patients with a parahisian AP, who showed a great variability in the ECG features. Employing the QRS-Polarity algorithm, 34.6% patients had a correct anatomical location, 42.3% had an adjacent location and only 23% an incorrect location.* **Conclusion:** *The QRS-Polarity algorithm has a good global accuracy; its precision is high, especially for left lateral AP. This algorithm is also useful for the parahisian AP.*

Keywords: Wolff-Parkinson-White syndrome. Accessory pathways. Parahisian accessory pathways. QRS-Polarity algorithm.

Resumen

Antecedentes: *En 1996 Iturralde y colaboradores publicaron un algoritmo basado en la polaridad del QRS para determinar la ubicación de las vías accesorias (VA), este algoritmo fue desarrollado antes de la práctica masiva de la electrofisiología invasiva.* **Objetivo:** *Validar el algoritmo de la polaridad del QRS en una cohorte moderna de sujetos sometidos a ablación con catéter por radiofrecuencia (ACRF). Nuestro objetivo fue determinar su precisión global y su precisión para las VA parahisianas.* **Métodos:** *Realizamos un análisis retrospectivo de pacientes con síndrome de Wolff-Parkinson-White (WPW) a los que se les realizó estudio electrofisiológico (EEF) y ACRF. Empleamos el algoritmo de la polaridad del QRS para predecir la ubicación anatómica de la VA y comparamos este resultado con la ubicación anatómica real determinada en el EEF. Para determinar la precisión se utilizaron el coeficiente kappa de Cohen (κ) y el coeficiente de correlación de Pearson.*

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Resultados: *Se incluyeron un total de 364 pacientes (edad media 30 años, 57 % varones). La puntuación κ global fue de 0,78 y el coeficiente de Pearson de 0,90. También se evaluó la precisión para cada zona, la mejor correlación fue para las VA laterales izquierdas (κ de 0.97). Hubo 26 pacientes con VA parahisianas, que mostraron una gran variabilidad en las características del ECG. Empleando el algoritmo de la polaridad del QRS, el 34,6 % de los pacientes tenía una ubicación anatómica correcta, el 42,3 % tenía una ubicación adyacente y solo el 23 % una ubicación incorrecta.* **Conclusión:** *El algoritmo de la polaridad del QRS tiene una buena precisión global; su precisión es alta, especialmente para VA lateral izquierdo. Este algoritmo también es útil para la VA parahisiana.*

Palabras clave: *Síndrome de Wolff-Parkinson-White. Vías accesorias. Vías accesorias parahisianas. Algoritmo de polaridad del QRS.*

Introduction

Accessory pathways (AP) are thin strands of myocardial tissue that communicate the atrial myocardium with the ventricular myocardium, they can have antegrade and/or retrograde conduction. When an AP has antegrade conduction and manifests itself in sinus rhythm, the preexcitation pattern is generated, which allows us to predict its anatomical location[1].

Wolff-Parkinson-White (WPW) syndrome is the coexistence of the preexcitation pattern in sinus rhythm with symptoms or documented tachycardia; currently the first-line treatment in these patients is the electrophysiological study (EPS) with radiofrequency catheter ablation (RFCA), which will give us the exact location of the AP[2,3].

It is important to have an idea of the possible anatomical location of the AP prior to the RFCA. Multiple algorithms have been created to predict the location of the AP, some of them have more steps than others and are therefore more complex[3,4]. The most complex algorithms are not necessarily the most accurate because when there are more steps to follow and therefore more possible anatomical locations, the risk of making a mistake is greater and the accuracy will decrease. And generally, more complex algorithms have less inter-observer agreement[4,5].

In 1996 Iturralde et al. published an algorithm based on the QRS polarity to determine the location of the AP, this algorithm only use three leads: DIII, V1 and V2. (Figure 1). For this work, we will call it QRS-Polarity algorithm. This is one of the easiest to use and has high sensitivity and specificity[6]. Currently, articles about algorithms to locate AP continue to be published[7], because of this, we have considered it convenient to carry out a validation of the QRS-Polarity algorithm, since to date it had not been validated yet, as well to determine its usefulness for parahisian AP.

Methods

Patients

We performed a retrospective analysis of patients with WPW syndrome who underwent EPS and RFCA in our center between January 2000 and December 2012. Eligible patients were those who had a resting electrocardiogram (ECG) of adequate quality and standard calibration (25mm/s and 10mm/mV) which revealed an obvious preexcitation pattern with the following characteristics: 1) QRS duration ≥ 120 ms, 2) short PR interval and 3) Clear delta wave. Patients with congenital or acquired heart disease, multiple AP, bundle branch block or previous attempt of catheter ablation were excluded.

ECG analysis

The best available ECG of each patient taken before ablation, showing a clear preexcitation pattern, was analyzed by three experts who were unaware of the outcome in the RFCA. Using the QRS-Polarity algorithm the experts localized de AP in one of the five possible anatomical positions of this algorithm: Left anterolateral/left lateral (LAL/LL), Right antero septal (RAS), left postero septal/left posterior (LPS/LP), right posteroseptal/right posterolateral (RPS/RPL) and right lateral (RL) (Figure 1). To assess the concordance of the interpretation of the algorithm, the scores obtained by each researcher were compared to the average among the 3 researchers combined.

The results were regarded to be consistent when the three researchers came to the same conclusion about the location of the AP, regardless the location was correct or not, and were regarded to be jarring when they predicted different locations. The locations inferred by the algorithm were validated using the anatomical locations of AP that had already identified in the EPS with a successful RFCA. Prediction of the location of

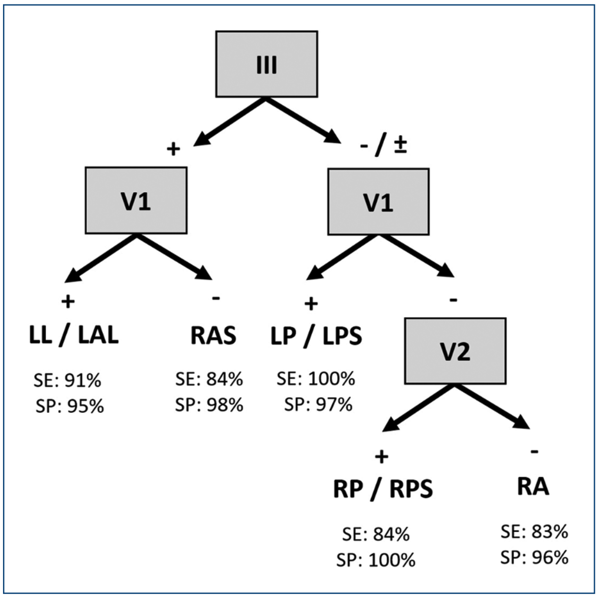

Figure 1. QRS-Polarity algorithm showing its five anatomical locations with the original sensitivity and specificity, LL left lateral, LAL left anterolateral, RAS Right anteroseptal, LP left posterior, LPS left posteroseptal, RP right posterior, RPS right posteroseptal, RA right anterior, SE sensitivity, SP specificity.

the AP employing the algorithm were considered *accurate* if it corresponded to the same anatomical position as the one identified in the EPS, was considered *adjacent* when the location was in a surrounding location and *incorrect* when it was far from the exact anatomical region determined in by the EPS.

Electrophysiological testing

EPS was carried out after signing the informed consent, we used general anesthesia in children and if it required sedation in adults. The presence and AP location was determined by conventional methods of mapping with multipole catheters (identifying the earliest ventricular or atrial signal during anterograde or retrograde conduction through the AP, respectively, or directly recording the potential of the AP)[8].

The location of the AP was assessed using the right and left anterior oblique views according to the position of the ablation catheter at the successful ablation site. For the left AP, a transaortic approach was used with heparin infusion to maintain an activated clotting time (ACT) between 250 to 350 seconds. To determine the site of a successful ablation we look for sites where the atrial electrogram merged with the preexcited ventricular electrogram. These ventricular electrograms should precede the beginning of the delta wave registered in the surface ECG. The final location was confirmed in the place where the ablation was successful, attempts were considered successful when the disappearance of the delta wave occurred in < 10 seconds after applying temperature-controlled radiofrequency[9], finally, the anatomical site was determined by the fluoroscopic position of the ablation catheter on the plane of the mitral or tricuspid annulus.

Parahisian AP have great variability in terms of electrocardiographic findings[9]. Although the QRS polarity algorithm was not designed for parahisian AP the vast majority of these are antero-septal and mid-septal pathways[10], therefore the algorithm could be useful to give an approximation of the location of these AP in the right antero septal position. An AP was classified as parahisian if the potential of the His bundle was recorded simultaneously with the ventricular or atrial insertion of the pathway in the ablation catheter.[10].

Statistical analysis

Baseline characteristics were presented as numbers (percentage,%) for categorical variables and mean (± SD) for continuous variables. We applicated Cohen's kappa coefficient and Pearson coefficient to determine the correlation between the locations predicted employing the surface ECG with the locations found in the EPS, after that we determinate the global accuracy. We also determined the specific accuracy for each of the five zones of the QRS-Polarity algorithm and we determined the algorithm's precision for the parahisian AP, and we compared it with the results obtained by other 5 algorithms: D' Avila[12], Fitzpatrick[13], Arruda[14], Chiang[15] and Boersma[16].

Results

A total of 364 patients were included, the mean age was 30 ± 14 years, and 57% were male, the mean of fluoroscopic time was 20 ± 14 minutes, and the mean time since the beginning of the radiofrequency to the loss of the preexcitation was 3.4 ± 2.3 seconds. Regarding these characteristics, there were no significant differences between each of the anatomical locations (Table 1). We found that the distribution on the anatomical location was as it follows: 44% for de LAL/LL, 28% for the RPS/RP, 17% for RAS, 7% for RL and 4% for LPS/LPL (Figure 2).

Table 1. Characteristics of the overall patients and for each anatomical location

Parameter	Overall	LL/LAL	RAS	LPS/LPL	RPS/RPL	RL	p value
Age (years)	30 ± 14	19 ± 14	19 ± 9	32 ± 14	32 ± 15	25 ± 14	0.06
Male (percentage)	207 (57%)	101 (64%)	8 (61%)	33 (55%)	53 (52%)	12 (42%)	0.22
Fluoroscopic time (minutes)	20 ± 14	17 ± 11	22 ± 14	21 ± 14	20 ± 15	31 ± 20	0.29
Loss of preexcitation (seconds)	3.4 ± 2.3	3.1 ± 1.9	3.6 ± 2.4	3.8 ± 2	3.6 ± 2.6	3.4 ± 3.2	0.29

Global accuracy

When we correlated the location predicted by the algorithm and the true location determined by the EPS and RFCA, to determine the accuracy of the algorithm we obtained a global kappa coefficient score of 0.78 and Pearson's coefficient of 0.90. We found that for the left lateral AP the correlation was very good with a kappa coefficient close to 1; in this group, 144 patients had correct correlation (97.9%), only 3 patients had adjacent locations and no patient an erroneous location. On the other hand, the right and left posterior AP had greater variability (Table 2).

The algorithm had a better diagnostic performance for the AP in the LL/LAL zone, with 90% of sensitivity, 98% of specificity, 98% of positive predictive value (PPV) and 93% of negative predictive value (NPV). The sensitivity and PPV for the other areas were lower, but all of them had specificity and NPV above 90% (Table 3).

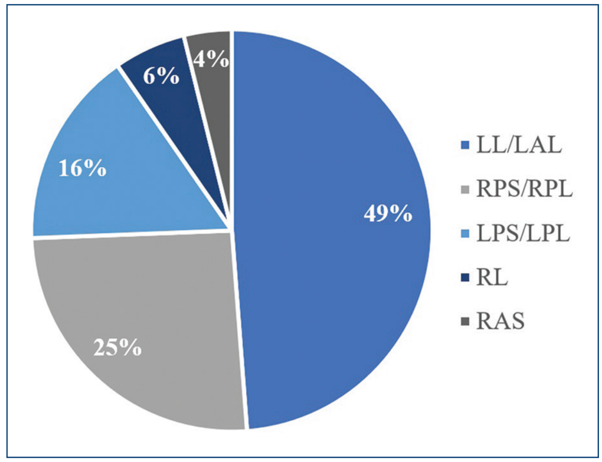

Figure 2. Distribution of the accessory pathway anatomical locations in our investigation.

Accuracy for the parahisian AP

There were 26 patients with a parahisian AP, which represents an incidence of 7.14%. In these patients the mean age was 24 ± 17 years, and 61% were male, the mean of fluoroscopic time was 27 ± 20 minutes, and the mean time since the beginning of the radiofrequency to the loss of the preexcitation was 3.6 ± 2.5 seconds, similar values comparing with the other locations (Table 4).

Patients with parahisian AP had a greater heterogenicity in the electrocardiographic features. We found a great variability in the polarity of the QRS complex in DIII, V1 and V2 leads, which are employed in the QRS-Polarity algorithm. The QRS polarity in DIII were positive in 34.6% patients and negative in 61.5%, in V1 7.6% were positive and 88.4% were negative and in V2 57% were positive and 38.4% were negative (Table 5).

Another important finding is that in patients with parahisian AP, the QRS polarity in the DI was always positive, finding that had been previously reported by Haïssaguerre et al[10]. We also noted that these patients had a great variability in the concordance of the QRS polarity in inferior leads, 50% had concordance in leads DIII and DII, while 34.6% showed discordance in the same leads (Table 5).

Finally, we made a comparison of the accuracy between the QRS-Polarity algorithm with the others algorithm which are much more complex. Comparing with the rest of the algorithms, the QRS-Polarity has an accuracy as high as the Fitzpatrick's algorithm, which is probably the most complex.

Employing the QRS-Polarity algorithm, 34.6% patients had a correct anatomical location, 42.3% had an adjacent location and only 23% an incorrect location. While, with the Fitzpatrick's algorithm, 30.7% had a correct anatomical location, 50.0% had an adjacent location, and 19.2% an incorrect location, on the other hand employing Arruda's algorithm, only 11.5% had a correct anatomical location, 73.1% had an adjacent location, and 15.4% an incorrect location. The others (d'Avila, Chiang and Boersma) do not achieve comparable levels of accuracy (Figure 3).

Table 2. Correlation between the anatomical location by the ECG with the QRS-Polarity algorithm and true location determinate by the electrophysiological study (EP)

Location		EP				
		LL/LAL	RAS	LPS/LPL	RPS/RPL	RL
ECG	LL/LAL	144	0	3	0	0
	RAS	4	12	1	0	3
	LPS/LPL	10	0	49	8	1
	RPS/RPL	0	1	7	81	2
	RL	1	1	1	13	22

In the green boxes there are the number of patients with correct location; in the yellow boxes there are the number of patients with adjacent locations; and in the white boxes there are the number of patients with erroneous location.

Table 3. Diagnostic performance for each of the anatomical locations

Parameter	LL/LAL	RAS	LPS/LPL	RPS/RPL	RL
Sensitivity	90%	85%	80%	89%	79%
Specificity	98%	98%	93%	92%	95%
Positive predictive value	98%	60%	72%	79%	58%
Negative predictive value	93%	99%	96%	96%	98%

Table 4. Characteristics of the patient's whit parahisian AP

Parameter	Parahisian AP
Age (years)	24 ± 17
Male (percentage)	16 (61%)
Fluoroscopic time (minutes)	27 ± 20
Loss of preexcitation (seconds)	3.6 ± 2.5

Discussion

The knowledge of the possible anatomical location of the AP before the EPS with RFCA is very important, because it allows to us planning the approach and it is useful for predicting possible complications[4,11]. There are many algorithms that we can employ to determinate de anatomical location of the AP, some of them are more complex than others[6,12-16].

It should be mentioned that all the algorithms published before the year 2018 have used only the traditional fluoroscopic projections to correctly locate the AP during the EPS with RFCA. This method of fluoroscopic projections has important limitations due to anatomical variations among patients such as body habitus and heart rotation[17,18], precisely the QRS-polarity algorithm, being one of the first, has these limitations. That is why all the algorithms could be validated using an electroanatomical mapping system.

With greater complexity in the algorithm, the probability of making an error in determining the correct location increases and the interobserver agreement decreases[1]. Texeira et al, reported the interobserver agreement for some algorithms, they found that Arruda's algorithms which is one of the most complex had the lowest interobserver agreement (40%), while other more simply algorithms like the QRS-Polarity had a better interobserver agreement (70%)[5].

Despite QRS-Polarity algorithm described by Iturralde and colleagues is one of the first published algorithms, it has not been validated previously. This algorithm is also the less complex, other algorithms such as those published by d'Avila, Arruda and Chiang have been previously validated.[12,14,15] Maden et al, made a comparison between some algorithms, they found that Arruda's algorithm had a kappa coefficient for all the possible anatomical location of 0.86, while d'Avila's had 0.73 and Chiang's 0.76[4]. In the present trial, we demonstrated that QRS-Polarity algorithm has a global kappa coefficient of 0.78, discreetly higher than the coefficients reported by Maden for the d'Avila and Chiang's algorithms.

All the algorithms are better for left AP, because the pre-excitation pattern is more evident in this area and therefore the precision of the algorithms is better[4]. Maden, et al also reported the accuracy of some algorithms only for left AP: the Arruda's algorithm had a kappa coefficient of 0.91, d'Avila had 0.79 and Chiang 0.83[4]. We found that the QRS-Polarity algorithm has a very good accuracy for left AP with a Kappa coefficient of 0.97, higher than the afore mentioned.

Recently Moskal et al, compared the precision of some algorithms to predict the exact or adjacent anatomically location employing both the resting ECG and the ECG with maximum preexcitation[19]. They found that the QRS-Polarity algorithm had an accuracy of 53% for the exact anatomically position employing the resting ECG, and when they considered useful an adjacent anatomically position too, the accuracy increased to 69.7%, these values are lower than those found by us, this could be explained by the fact that we only included patients with a wide QRS wide (> 120 ms), those where

Table 5. Electrocardiographic features of the parahisians AP

Patients	DIII		V1		V2		DI		DII		avL		avF	
	QRS	Delta	QRS	Delta	QRS	Delta	QRS	Delta	QRS	Delta	QRS	Delta	QRS	Delta
1	+	+	-	-	-	-	+	+	+	+	-	+	+	+
2	+	-	-	-	0	0	+	+	+	+	0	+	+	+
3	-	-	-	-	+	+	+	+	+	+	+	+	0	+
4	-	-	+	+	+	+	+	+	-	-	+	+	-	-
5	-	-	-	-	+	+	+	+	-	+	+	+	-	-
6	-	-	0	-	+	+	+	+	0	0	+	+	-	-
7	+	+	-	-	-	+	+	+	+	+	+	+	+	+
8	+	+	-	+	+	+	+	+	+	+	+	+	+	+
9	-	+	-	-	+	+	+	+	+	+	+	+	0	0
10	+	+	-	-	-	-	+	0	+	+	+	+	+	+
11	-	+	-	-	-	-	+	+	+	+	+	+	0	+
12	0	+	-	+	+	+	+	+	+	+	+	+	+	+
13	-	-	-	-	+	0	+	+	+	+	+	+	+	0
14	-	-	-	+	-	0	+	+	+	+	+	+	-	+
15	-	-	-	-	+	+	+	+	+	+	+	+	+	+
16	-	-	+	-	+	+	+	+	0	0	+	+	-	-
17	+	+	-	+	+	+	+	+	+	+	0	+	+	+
18	-	-	-	-	+	+	+	+	+	+	+	+	-	+
19	-	-	-	-	-	+	+	+	+	+	+	+	+	+
20	-	-	-	-	-	+	+	+	+	+	+	+	-	0
21	-	-	-	-	-	-	+	+	-	+	+	+	-	+
22	+	-	-	0	+	+	+	+	+	+	+	+	+	+
23	-	-	-	-	+	+	+	+	-	+	+	+	-	-
24	-	-	-	-	+	+	+	+	0	+	+	+	-	-
25	+	+	-	+	-	+	+	+	+	+	0	0	+	+
26	+	+	-	+	-	+	+	+	+	+	+	+	+	+

QRS polarity: - Negative, + Positive, 0 isoelectric.

the preexcitation pattern was more obvious. On the other hand, during the maximal preexcitation the accuracy of the QRS-Polarity algorithm was 67.7%, and when the adjacent anatomically position is also considered useful the accuracy was 86.7%.

The aforementioned emphasizes the influence of the degree of preexcitation in the accuracy of any algorithm. Previously, Pambrum et al published an algorithm to determine the location of the AP using the ECG with maximum preexcitation[20], although this requires atrial stimulation during the EPS, it could be also useful if we employ the ECG of an antidromic tachycardia, where the anterograde conduction occurs exclusively through the AP.

In 2013, Taguchi et al published a new algorithm to predict the location of the AP's using the R/S ratio in the leads V1, V2 and avF, as well as the QRS-Polarity algorithm this new algorithm locates the AP in 5 zones [21]. They found that their algorithm had good precision,

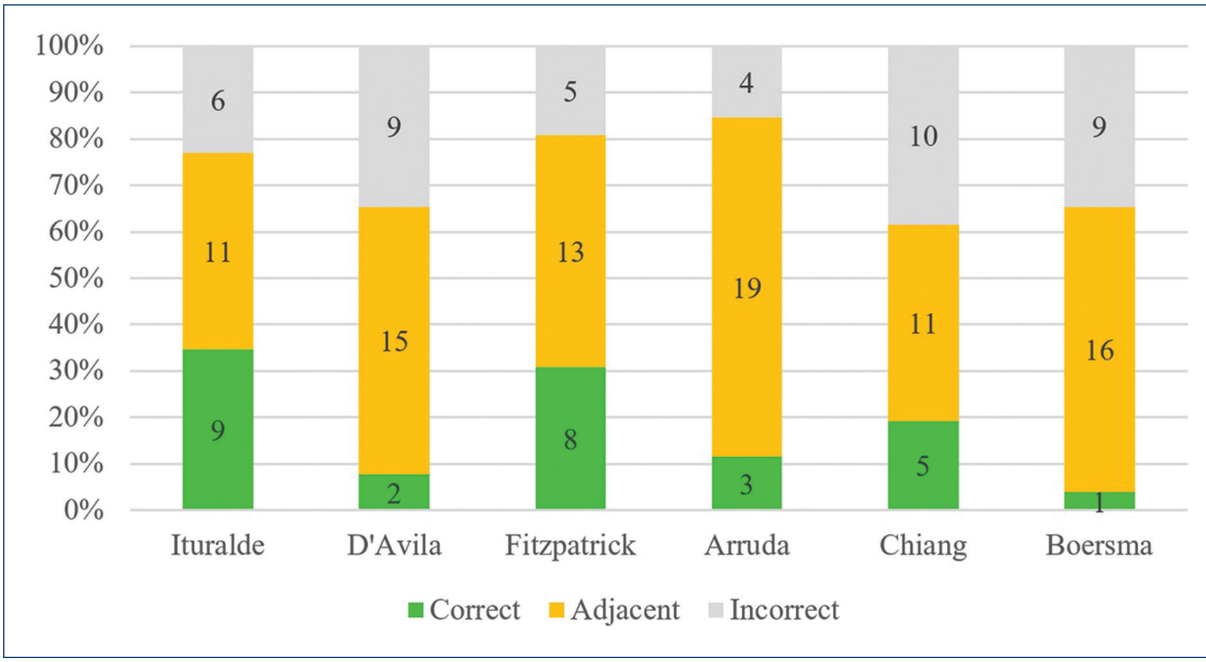

Figure 3. Accuracy of the different algorithms for parahisian accessory pathways.

mainly for left lateral AP, with a sensitivity of 98%, specificity of 100%, and a PPV of 100%. Findings very similar to those reported by us.

Finally, it should be mentioned that there is only one clinical utility of all the algorithms to predict the AP location is to plan the ablation approach. Crinion and Baranchuk recently published a practical algorithm useful for determining the approach and avoiding possible complications: "Simplified Topographic Algorithm" (STA)[17]. This algorithm locates the AP in three zones: left lateral, posteroseptal or paraseptal, and right anterior or right anteroseptal. The left lateral AP may be approached by retro-aortic access or with transseptal puncture, the posteroseptal AP could be approached from the right or left side and even from within the coronary sinus (CS) and may require a CS venography, and the anterior right AP should be approached with caution due to its proximity to the conduction system[17].

Accuracy for parahisian accessory pathways

There are many difficulties for all algorithms, one of them is the location of the AP in the parahisian zone, since the proximity with the normal conduction system, can make the preexcitation patter not as evident as other locations also generates much heterogeneity in ECG findings[10,11]. Wren et al. demonstrated that in children with WPW syndrome, no algorithm has a good accuracy for mid septal AP and right antero septal AP, areas where the parahisian AP are located[1]. Nonetheless, we demonstrated that if we considered useful the exact and the adjacent anatomical location, the QRS-polarity algorithm has an accuracy of 76.9% for parahisian AP.

Our results are different from those reported by Texeira et al, they also considered the exact and the adjacent positions as good locations for determinate the accuracy, they found that for septal AP the accuracy of the QRS-polarity algorithm was 68.6% and for Fitzpatrick's algorithm was 69.6%[5]. These differences could be explained because the anteroseptal AP are not necessarily Parahisian.

We must clarify that, although the QRS-polarity algorithm does not include specifically the mid septal and parahisian pathway, it does not reduce its power. These anatomical positions were not considered due to the fact, that in these locations it is less common to see a clear preexcitation pattern, this affects the precision of any algorithm. A recent publication considers that the anteroseptal and parahisian zones are the same[7] but the AP will be considered as parahisian only if the His bundle potential is recorded at the same time as the ventricular or atrial insertion. Therefore, a correct location for the parahisian AP according to the QRS-Polarity algorithm would be the right anteroseptal region.

Limitations

Like all algorithms there is an inherently limitation produced by biologic variability in anatomy, presence of multiple pathways, intrinsic ECG abnormalities and variation in degree of pre-excitation. Most algorithms attempt to determine the AP location using the resting ECG, but the degree of preexcitation at rest varies from one patient to another[22]. Interobserver variation also plays an important role.

This trial has the inherent limitations of any retrospective analysis. It is also unicentric. The relatively small number of parahisian AP in our population is probably one of the more important limitations, so our results about the parahisian AP need to be confirmed by another trial or meta-analysis.

Conclusions

The QRS-polarity algorithm has a good global accuracy with a kappa coefficient of 0.78 and Pearson coefficient of 0.90, the accuracy is higher for the left lateral AP with the kappa coefficient of 0.98. The preexcitation pattern generated by a parahisian AP is highly variable, the QRS-Polarity algorithm has one of the highest accuracies for the parahisian AP.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical responsibilities

Protection of people and animals. The authors declare that the procedures followed were in accordance with the ethical standards of the responsible human experimentation committee and in accordance with the World Medical Association and the Declaration of Helsinki.

Data confidentiality. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

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