VIA MEDICA

ORIGINAL ARTICLE

Folia Cardiol.
2006, Vol. 13, No. 6, pp. 494–502

ISSN 1507–4145

Arrhythmogenic focus localization in patients with right outflow tract ventricular arrhythmias

Mariusz Pytkowski, Aleksander Maciąg, Maciej Sterliński, Agnieszka Jankowska, Alicja Kraska, Azzam Matar and Hanna Szwed

Coronary Disease Department, Institute of Cardiology, Warsaw, Poland

Abstract

Background: *Vast majority of ventricular arrhythmias in patients (pts) without structural heart disease (NHVA) originate from the right ventricular outflow tract (RVOT). Premature ventricular contractions (PVC) and ventricular tachycardia (VT) ECG morphology are proposed to localize the site of radiofrequency ablation (RFA). An ECG algorithm to localize the arrhythmogenic focus in RVOT was designed and verified in a prospective study.*

Methods: *Analysis of ECG morphology of spontaneous PVC and VT was performed in 30 pts (25 women), mean age 42 ± 10, after successful RFA of arrhythmogenic focus (AFo) in RVOT (PVC in 11 pts, VT in 5 pts, PVC + VT in 14 pts). In the first step ECG data and fluoroscopic RVOT sites of successful RFA were combined to gain the characteristic QRS morphology patterns for exact sites of successful ablation (first 16 pts). This own algorithm was used to recognize AFo in the following 14 pts.*

Results: *First step: RVOT in RAO 30° view was divided into 9 zones: 3 vertical (1, 2, 3) and 3 horizontal (superior, intermediate and inferior). Q, R and S waves < 0.5 mV in 12-lead ECG were coded as q, r, s and waves ≥ 0.5 mV as Q, R, S. Vertical zones: zone 1 (RVOT postero-lateral part): r in lead I; zone 3 (RVOT anterior wall): QS/qs in lead I. Other QRS morphologies in lead I: zone 2. Horizontal zones: superior — transition from QS wave or r < S in V1 into R > s in lead V4, intermediate — R = S or r = s in V4, inferior — transition from qs/QS or r < S in V1–V4 into r, R in V6. Second step. Concordant ECG locations were predicted by two independent cardiologists in 14 pts. Concordant AFo locations (ECG and fluoroscopic) were achieved: in all 14 pts in horizontal zones and in 13 pts in vertical zones. Overall (30 pts) no AFo discordances were noted in horizontal zones. In vertical zones AFo location was concordant in 28 pts (93.3%).*

Conclusions: *Our data show that simple ECG algorithm based on spontaneous arrhythmia morphology precisely localizes the arrhythmogenic focus in RVOT. This analysis applied before RFA may shorten and simplify ablation procedure in patients with RVOT arrhythmia.* (Folia Cardiol. 2006; 13: 494–502)

Key words: transcatheter ablation, arrhythmia morphology analysis

Introduction

Focal ventricular arrhythmias seem to be a rare condition and they can be found in 4% of patients with ventricular arrhythmias [1]. Its mechanism and etiology is subject of discussion but they are generated by micro focus of ectopy. No structural heart

Address for correspondence: Mariusz Pytkowski, MD
Coronary Disease Department, Institute of Cardiology
Spartańska 1, 02–637 Warsaw, Poland
Tel./fax: +48 22 844 95 10; e-mail: mpytkowski@ikardl.pl
Received: 3.03.2006 Accepted: 12.06.2006

disease can be found in vast majority of patients with focal ventricular arrhythmias, so these arrhythmias are called normal heart ventricular arrhythmias (NHVA). Ablative therapy is usually implemented only in symptomatic patients (pts) with ventricular tachycardia. Arrhythmogenic focus ablation is performed in highly symptomatic patients (palpitations, vertigo, presyncope, syncope, shortness of breath, weakness and chest discomfort) with frequent, resistant to antiarrhythmic drugs, premature ventricular ectopy [2, 3]. In the whole population treated with RFA there is 10% of normal heart ventricular arrhythmia patients. Vast majority of NHVA population (70% of cases) has arrhythmogenic foci in the right ventricular outflow tract (RVOT) [2, 3]. In NHVA patients QRS morphology is related to localization of the arrhythmogenic focus.

The electrocardiographic pattern of RVOT arrhythmias is typical and easily recognizable (Fig. 1). In precordial leads those arrhythmias have LBBB morphology (rS or QS waves in leads V1–V3) with inferior QRS axis in limb leads.

Due to relatively large RVOT surface and complex structure there were efforts to combine sites of successful ablations with RVOT arrhythmia morphologies to gain characteristic QRS patterns for exact locations in right ventricular outflow tract. Endocardial mapping in patients with RVOT arrhythmias may be prolonged by extended step-by-step mapping of the relatively large RVOT area, so preliminary localization of RVOT arrhythmogenic focus before RFA is helpful and can shorten and simplify the ablation procedure. The basis of existing algorithms for localization of RVOT arrhythmogenic foci is provided by comparative analysis of paced QRS complex morphologies recorded during EP studies and RVOT regions (fluoroscopy) [4–6]. In many EP centers during electrophysiologic studies ECG electrode placement (limb and precordial leads) differs from standards for 12-lead ECG. That is the reason for altered shapes of arrhythmia QRS morphology recorded during EP studies.

The aim of this study was to create the algorithm based on spontaneous ventricular arrhythmia QRS morphology analysis for localizing the arrhythmogenic focus in RVOT.

Methods

We analyzed 12-lead ECG in 30 patients, 25 women, in mean age 42 ± 10 years, with QRS morphology characteristic for arrhythmia arising from right ventricular outflow tract. Premature ventricular contractions (PVC) with frequent periods of bigeminy and trigeminy were the only indication for transcatheter ablation in 11 patients. In 14 ablated patients, PVC coexisted with non-sustained ventricular tachycardia (VT) and in 5 patients with sustained VT. Complete elimination of arrhythmogenic foci was possible in all 30 patients.

Electrophysiological study in patients with normal heart ventricular arrhythmias

All antiarrhythmic drugs were discontinued at least five half times before the procedure. Attention was paid to correct lead placement. The study was performed using local anaesthesia with 1% lidocaine. In the same time opioids (fentanyl) with anxiolytics (midazolam) were given intravenously.

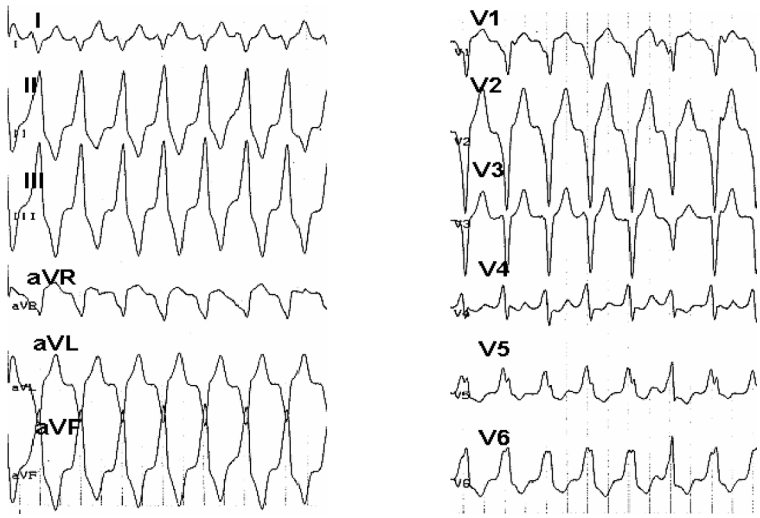

Figure 1. Typical example of ventricular tachycardia from right ventricular outflow tract (right axis deviation).

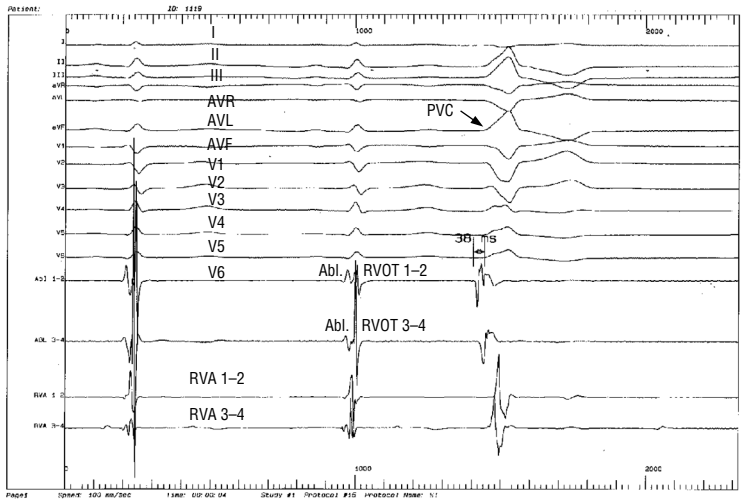

Figure 2. Recording of earliest intracardiac activation (activation mapping) in right ventricle outflow tract. Intracardiac activation of arrhythmogenic focus precedes surface ECG QRS complex on 38 ms (PVC). I, II...V5, V6 — 12-lead ECG, PVC — premature ventricular contraction from right ventricle outflow tract, Abl. RVOT — endocardial electrogram from quadripolar ablation catheter placed in right ventricular outflow tract; RVA — endocardial activation from right ventricular apex (quadripolar electrode-catheter); 1–2 — distal bipol; 3–4 — proximal bipol.

Using the femoral approach, three quadripolar 6F electrode-catheters were introduced and placed in the right atrium, right ventricular apex and under the tricuspid valve to obtain the His bundle potential. For 12-lead and intracardiac ECG monitoring and recording BARD EP Lab was used. Blood pressure and arterial saturation were monitored non-invasively during all RF procedures.

Two techniques were used to localize the arrhythmogenic focus:

— recording of the earliest ventricular activation during arrhythmia (activation mapping) (Fig. 2);
— possibility to obtain the concordant QRS morphology during endocardial pacing (Fig. 3A) with QRS morphology of spontaneous arrhythmia (pace mapping) (Fig. 3B).

In case when spontaneous arrhythmia was not present and we were not able to induce it by pacing the isoproterenol infusion was given (1–5 μg/min) to provoke the arrhythmia.

Transcatheter ablation of ventricular arrhythmias in patients with no structural heart disease

The 7 F ablation electrode was placed in the RVOT using the right femoral vein approach. The position of the electrode was controlled by fluoroscopy performed in the RAO 30° view, using AP, and LAO 30–60° views as needed. Fluoroscopic schematic RVOT view was presented on Figure 4. After arrhythmogenic focus was located, 10–15 s of RF current application was performed. If the arrhythmia disappearance was observed at this site, the RF energy was given for up to 60 s in the temperature mode (maximal temperature at the electrode tip of 65°C with maximal power of 50 W). The immediate efficacy of RFA was assessed by cessation of the arrhythmia (Fig. 5) and non-inducibility of sustained arrhythmia during electrophysiological study both with and without pharmacological provocation with intravenous isoprenaline.

After the procedure, the patients were monitored for few hours in the CCU. All patients received 150 mg of aspirin for 4–6 weeks after the procedure.

Total efficacy of the procedure was defined as complete elimination of both spontaneous and induced arrhythmia of the morphology identical with that of clinical arrhythmia. Partial success was defined as a substantial reduction in the frequency and quantity of arrhythmia (no VT or 500 times reduction in PVC number). During the long-term follow-up symptomatic recurrences of arrhythmia as well as standard ECG and 24-hour ECG Holter monitoring were analysed.

Localization of the arrhythmogenic focus in right ventricular outflow tract

Step 1. Creation of own algorithm to localize the arrhythmia in right ventricular outflow tract (16 patients). Analysis of arrhythmia QRS morphology recorded in surface 12-lead ECG was

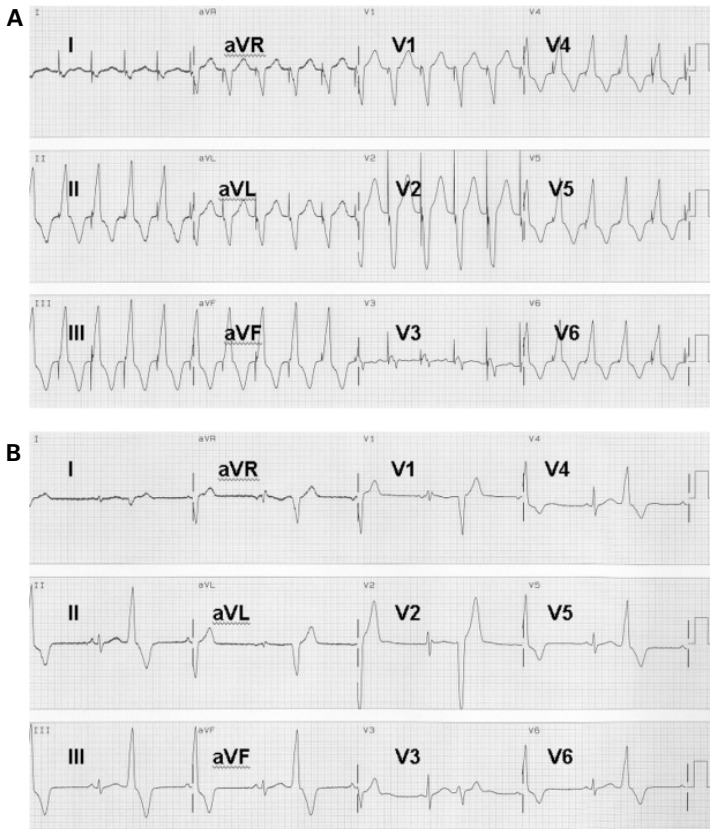

Figure 3. Concordant ECG morphology of paced QRS complexes and spontaneous arrhythmia during EP study — pace-mapping technique (pts 11). **A.** Paced QRS complex morphology from RF ablation site. **B.** Spontaneous arrhythmia in 12-lead ECG.

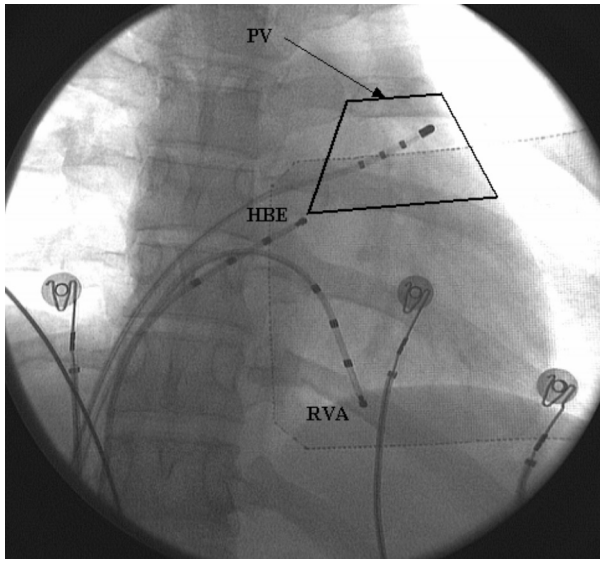

Figure 4. Schematic presentation of right ventricular outflow tract (fluoroscopic view RAO 30°). PV — pulmonary artery valve level, HBE — tricuspid valve level and His potential registration (distal electrodes), RVA — right ventricle apex electrode. RVOT is presented as trapezium.

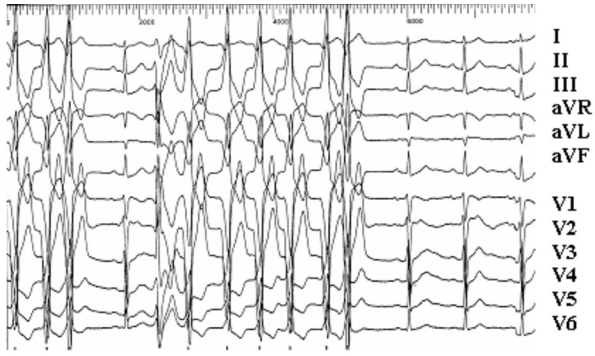

Figure 5. Arrhythmogenic focus ablation in right ventricular outflow tract. Aggravation of arrhythmogenic focus activity in the first seconds of RF heating with restoration of sinus rhythm with the 12th QRS complex.

performed and results were written down in the table. The QRS deflections were coded in great letters when their amplitude was ≥ 0.5 mV and in small letters (q, r, s) when QRS wave amplitude was smaller than 0.5 mV.

The results of ECG analysis were related to RVOT regions of successful ablation obtained in RAO 30° fluoroscopic projection. RVOT borders were defined in RAO 30° view. Inferior RVOT border was formed by horizontal line on the level were the His potential was recorded. The superior RVOT border was formed by pulmonary valve where the endocardial potentials disappear (Fig. 4). Septal part of RVOT was mapped with RAO 30° flouoroscopic view. RVOT free wall was mapped by rotation of the ablation catheter in various RVOT levels.

Step 2. Localization of sites of successful ablation in RVOT on the basis of own algorithm constructed in step 1. Two independent cardiologists localized arrhythmogenic foci in certain RVOT zones using the ECG algorithm. The results were compared and were matched with sites of successful ablation.

Results

Step 1. Development of own algorithm for RVOT arrhythmia localization (16 patients)

In limb leads in all patients, R waves were present in lead II, III and aVF. In 3 patients with arrhythmogenic focus located in right ventricular outflow free wall, R waves in leads II, III and aVF were notched and had lower amplitude in comparison to the patients with arrhythmia located in septal part of RVOT. In all patients, QS waves were found in lead aVR. In all patients, in precordial leads V1 and V2, QS or rS waves were observed and in lead V6 r,R wave were present. In limb leads, arrhythmia QRS morphology analysis revealed differences in leads I and aVL. In lead I, qs(QS), qr, rs, rsr' and r(R) waves were present [qs (QS) waves in 7 pts, qr in 2 pts, rs in 1 pt, rsr' in 1 pt and r(R) waves in 5 pts]. In lead aVL, QS waves were met in 15 pts and qr wave in 1 patient.

In precordial leads, transition from QS(qs) or r < S (negative QRS polarity) to R, (r) or R > s (positive QRS polarity) was present in leads V2–V6. Two following precordial leads in which QRS polarity was changed from negative to positive were defined as transitional zone: [e.g. transition from QS(qs) or r < S in V3 to R, (r) or R > s in V4]. In the same way transitional zone in precordial leads was also defined as r(R) = s(S) in certain lead (e.g. V4) with negative QRS polarity in preceding lead (V3) and positive QRS polarity in following lead (V5). Transitional zone was found: in leads V2–V3 in 2 pts, in V3 in 1 pt, in V3–V4 in 5 pts, in V4 in 3 pts and between V4–V6 in 5 pts (Table 1).

Vertical zones of the right ventricular outflow tract

On the basis of correlation between QRS morphology with localization of arrhythmogenic foci in first 16 patients RVOT (RAO 30° fluoroscopic view) was divided into three vertical zones which reflect

Table 1. QRS morphology analysis of ventricular arrhythmia from right ventricular outflow tract in 16 patients.

Patient's numbers	Limb leads						Precardial leads					
	I	II	III	AVR	aVL	aVF	V1	V2	V3	V4	V5	V6
1	rs	R	R	QS	QS	R	QS	QS	QS	r = s	R	R
2	qs	R	R	QS	QS	R	r < S	r < S	r < S	r < S	R	R
3	R	R	R	QS	QS	R	QS	QS	r < S	r < S	R = S	R
4	qr	R	R	QS	QS	R	r < S	r < S	r < S	r > s	R	R
5	qs	R	R	QS	QS	R	QS	r < S	r < S	r < S	r = s	r
6	r	R	R	QS	QS	R	QS	r < S	R	R	R	R
7	r	R	R	QS	QS	R	r < S	r < S	r < S	R	R	R
8	QS	R	R	QS	QS	R	QS	r < S	R	R	R	R
9	QS	R	R	QS	QS	R	QS	r < S	r < S	r < S	r = s	r
10	qs	R	R	QS	QS	R	QS	QS	QS	r = s	R	R
11	qs	R	R	QS	QS	R	QS	QS	r < S	R	R	R
12	qs	R	R	QS	QS	R	r < S	r < S	r < S	r < S	r = s	R
13	rsr'	R	R	QS	QS	R	r < S	r < S	r = s	R	R	R
14	qr	R	R	QS	QS	R	QS	r < S	r < S	R	R	R
15	r	R	R	QS	QS	R	QS	r < S	r < S	R	R	R
16	r	R	R	QS	Qr	R	QS	r < S	r < S	r = s	R	R

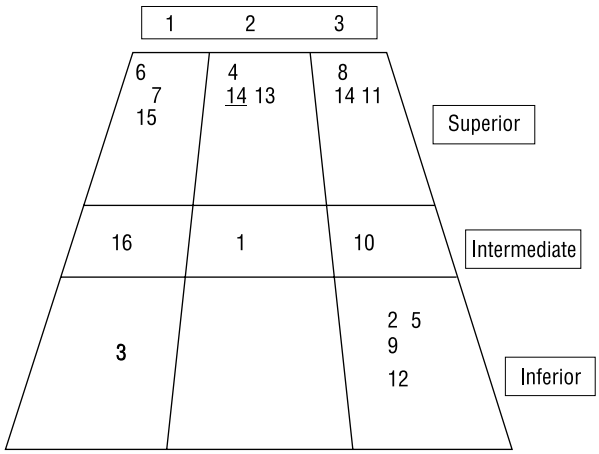

Figure 6. Localization of arrhythmogenic foci in RVOT in 16 patients. QRS arrhythmia morphology patterns were combined with exact sites of successful ablation to create an algorithm for arrhythmogenic focus localization. 1–16 localization of successful RFA application in 16 pts. 14 — localization of arrhythmogenic focus based on ECG morphology which was different from successful RF application and pace mapping.

findings in limb lead I. Those zones were marked 1, 2 and 3 starting from posterolateral part of RVOT (zone 1) to RVOT anterior wall (zone 3). The second zone lies between zone 1 and 3 (Fig. 6). In the first zone r/R in lead I was always present. Second zone was characterized by rs or rsr' in lead I. The qs/QS waves were present in lead I in third zone (Table 2 and Fig. 7). According to the observations of other authors, qr morphology in lead I (patients numbers: 4 and 14) were arbitrary attributed to zone 2. Discordance between ECG (zone 2) and ablation sites (zone 3) was observed in 1 patient with qr wave in lead I (patient no. 14). There were no significant differences in lead aVL to influence on arrhythmia focus location in RVOT.

Horizontal zones of the right ventricular outflow tract

Transition between QS or r < S waves into R/r or R > s in precordial leads let to divide RVOT into 3 horizontal zones: superior, intermediate and inferior (Fig. 6). Transitional zone between leads V1-V4 (transition from QS or r < S in lead V1 to r, R or R > s in lead V4) indicated arrhythmogenic focus location in subpulmonary valve region: superior zone. Intermediate zone was defined as R(r)=S(s) in lead V4. In inferior zone qs,QS and r< S were observed in leads V1–V4 and transition from r<S to r,R appeared between leads V4–V6 (Table 3 and Fig. 8).

Table 2. Division of right ventricular outflow tract on 3 vertical zones based on QRS arrhythmia morphology.

Zone 1	r/R
Zone 2	rs, rsr', qr
Zone 3	qs/QS

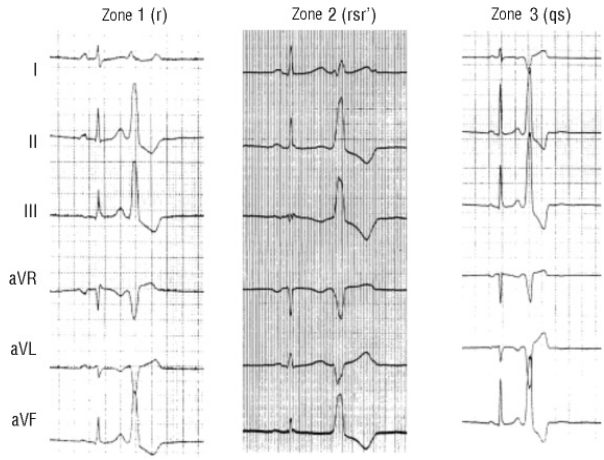

Figure 7. Arrhythmogenic focus localization in vertical zones of RVOT — differences of QRS morphology in lead I.

Final right ventricular outflow tract division

On the basis of differences in limb lead I and in the precordial leads ventricular outflow tract was divided in nine sub-regions in RAO 30° fluoroscopic view. Vertical zones 1, 2, 3 are equal. Horizontal zone intermediate because of the exact morphology in lead V4 [R(r) = S(s) in V4] occupies a small part of median part of RVOT and separates superior and inferior zones (Fig. 6).

Step 2. Localization of arrhythmogenic focus using own algorithm in right ventricular outflow tract in a prospective study

Results of arrhythmogenic foci analysis using new algorithm made by 2 independent cardiologists were concordant. ECG (Table 4) and fluoroscopic (sites of RF ablations) localizations laid in the same zones in 13 from 14 patients (92.8%). In the patient no 22, ECG algorithm localized the arrhythmogenic focus in zone 1 superior (r wave in lead I; transitional zone in precordial leads between V1–V4) but the successful RF application was applied in zone 2 superior. Complete concordance was observed in ECG and fluoroscopic localizations of arrhythmogenic foci in horizontal zones (Fig. 9). An algorithm identified exact arrhythmogenic foci localization in patients with free wall RVOT arrhythmias.

Table 3. Division of right ventricular outflow tract on 3 horizontal zones based on arrhythmia QRS morphology in precordial leads.

Superior zone	Transition from QS or r < S in V1 into r, R or R > s in V4
Intermediate zone	R = S (r = s) in V4
Inferior zone	Transition from r < S in V4 into r, R in V6

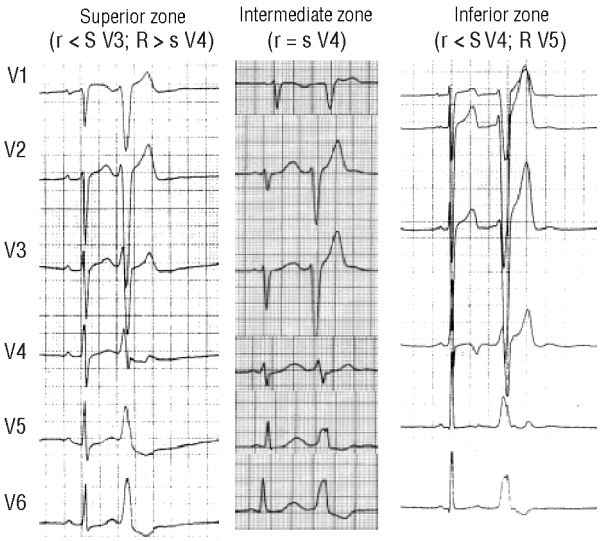

Figure 8. Arrhythmogenic focus localization in horizontal zones of RVOT — differences of QRS morphology in precordial leads.

In summary, in 28 patients (93.3%) the algorithm based on arrhythmia QRS morphology precisely localized arrhythmogenic foci. In 5 patients with free wall RVOT arrhythmogenic foci, RVOT zones indicated by the algorithm were concordant with RF sites. The differences were seen only in vertical RVOT zones (2 patients with septal arrhythmogenic foci). In patient no. 14, algorithm showed the 2 superior RVOT zone, but RF ablation was successfully performed in zone 3 superior. In the patient no. 22, ECG pointed to 1 superior zone, but RFA was completed in 2 superior zone (Fig. 10).

Discussion

Among frequent arrhythmias with ECG bundle branch block pattern those originating in RVOT can be the target for catheter ablation [7–9]. The procedure is effective in 75–95% of cases and is performed in symptomatic patients resistant to antiarrhythmic drug therapy or not accepting antiarrhythmic drugs treatment [2, 10–12]. Arrhythmogenic focus in RVOT is located in majority of patients on the anterior or antero-lateral wall of subpulmonary valve right ventricular region. In other patients arrhythmogenic focus is located in right ventricular outflow tract free wall. The size of septal part of RVOT is about 10 cm^2 while focus size usually does not exceed several mm^2 [8, 13, 14]. Thus mapping of the region without any earlier

Table 4. Prognosis of arrhythmogenic RVOT focuses localizations based on 12-leads ECG analysis in 14 pts (patient's numbers 17–30).

Patient's numbers	Limb leads						Precardial leads					
	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
17	qs	R	R	QS	QS	R	QS	r < S	r < S	R > s	R	R
18	rs	R	R	QS	QS	R	QS	r < S	r < S	R = S	R	R
19	r	R	R	QS	QS	R	QS	r < S	r < S	R > s	R	R
20	rs	R	R	QS	QS	R	r < S	r < S	r < S	R > s	R	R
21	qr	R	R	QS	QS	R	r < S	r < S	r = s	R	R	R
22	r	R	R	QS	QS	R	r < S	r < S	r < S	R > s	R	R
23	rs	R	R	QS	QS	R	QS	QS	r < S	r < S	R > s	R
24	qs	R	R	QS	QS	R	QS	QS	r < S	r < S	R	R
25	QS	R	R	QS	QS	R	QS	QS	r < S	r < S	R	R
26	qs	R	R	QS	QS	R	QS	QS	r < S	r = s	R	R
27	r	R	R	QS	QS	R	QS	QS	r < S	R	R	R
28	rs	R	R	QS	QS	R	r < S	r < S	r < S	R	R	R
29	rs	R	R	QS	QS	R	QS	r < S	r < S	R	R	R
30	rs	R	R	qs	qs	R	QS	r < S	r < S	r < S	r > s	R

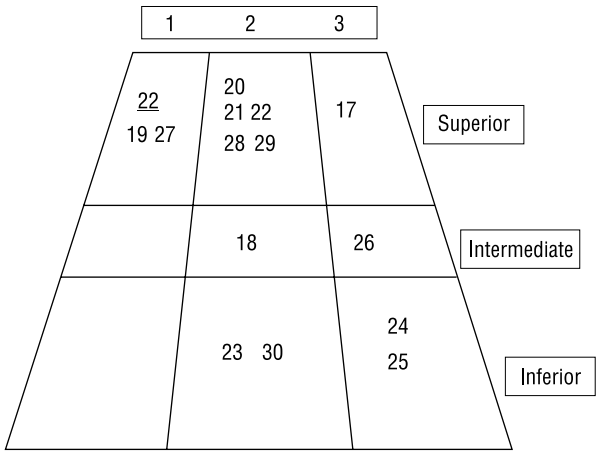

Figure 9. 12-leads ECG arrhythmia localization and sites of successful ablation site in RVOT (patients 17–30). 17–30 successful RFA application sites in 14 patients with RVOT arrhythmia. 22 — localization of arrhythmogenic focus based on ECG morphology which was different from successful RF application and pace mapping.

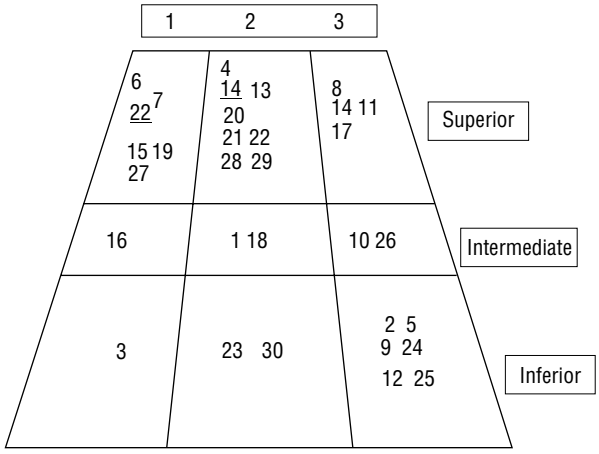

Figure 10. RVOT arrhythmia focuses localization in 30 patients (RVOT — RAO 30° fluoroscopic projection). 1–30 successful RFA application sites in 30 patients with RVOT arrhythmia. 14, 22 — localizations of arrhythmogenic focuses based on ECG morphology which were different from successful RF applications and pace mapping.

ECG-guided suggestions on arrhythmogenic focus localization may need longer procedure and fluoroscopy times.

On the basis of critical review of existing ECG algorithms constructed by Marchlinski's group [4], our own algorithm, based on arrhythmia QRS morphology, was designed to localize the arrhythmogenic focus in RVOT [15]. Due to using originally recorded arrhythmia morphologies in 12-lead ECG we were able to avoid differences and artifacts caused by pacing during pace mapping and other ECG electrode placing on the patient's body during the EP study and ablation. Target site marked by our algorithm was confirmed by successfully applied RF current with arrhythmogenic focus elimination. Our algorithm was designed by correlation of originally existing arrhythmias with sites of successful RF ablation. Utility of this algorithm was confirmed by 2 independent cardiologists. An algorithm is sufficient to localize the arrhythmias located in septal and free wall RVOT. At present there is an increasing interest in original arrhythmia ECG morphologies analysis [16, 17]. Additionally the results of lately published data based on electroanatomical analyses (CARTO) support the value of the algorithm designed in our center [17, 18]. A high concordance of ECG algorithm locations and sites of successful ablation of RVOT arrhythmias legitimate the use of this algorithm in the process of preablation target site analysis. In the same time our results suggests that classic electrophysiological techniques in RVOT arrhythmia elimination are quite sufficient and using the expensive electroanatomical systems should be restricted to selected patients.

Conclusion

Our ECG algorithm localizing the arrhythmogenic focus in right ventricular outflow tract based on spontaneous arrhythmia morphology analysis precisely localizes the arrhythmogenic focus in RVOT. This analysis applied before RFA may simplify and shorten ablation procedure in patients with RVOT arrhythmias.

References

1. Tsai Ch-F, Chen S-A, Tai Ch-T et al. Idiopathic monomorphic ventricular tachycardia: clinical outcome, electrophysiologic characteristics and long--term results of catheter ablation. Int J Cardiol, 1997; 62: 143–150.
2. Coggins DL, Lee RJ, Sweeney J et al. Radiofrequency catheter ablation as a cure for idiopathic tachycardia of both left and right ventricular origin. J Am Coll Cardiol, 1994; 23: 1333–1341.
3. Ouyang F, Fotuhi P, Ho SJ et al. Repetitive monomorphic ventricular tachycardia originating from the aortic cusp (electrocardiographic characterization for guiding catheter ablation). J Am Coll Cardiol, 2002; 39: 500–508.
4. Jadonath RL, Schwartzman DS, Preminger MW, Gottlieb CD, Marchlinski FE. Utility of the 12-lead

electrogram in localizing the origin of right ventricular outflow tract tachycardia. Am Heart J, 1995; 130: 1107–1113.
5. Wilber DJ, Baeman J, Olshansky B et al. Adenosine-sensitive tachycardia: clinical characteristics and response to catheter ablation. Circulation, 1993; 87: 126–134.
6. Movsowitz C, Schwartzman D, Callans DJ et al. Idiopathic right ventricular outflow tract tachycardia: narrowing the anatomic location for successful ablation. Am Heart J, 1996; 131: 930–936.
7. Kim YH, Goldberger J, Kadish A. Treatment of ventricular tachycardia-induced cardiomyopathy by transcatheter radiofrequency ablation. Heart, 1996; 76: 550–552.
8. Klein LS, Shih HT, Hackett K, Zipes DP, Miles WM. Radiofrequency catheter ablation of ventricular tachycardia in patients without structural heart disease. Circulation, 1992; 85: 1666–1674.
9. Reiter MJ, Smith WM, Gallagher JJ. Clinical spectrum of ventricular tachycardia with left bundle branch morphology. Am J Cardiol 1983; 51: 113–121.
10. Calkins H, Kalbfleisch SJ, El-Atassi R, Langberg JJ, Morday F. Relation between efficacy of radiofrequency catheter ablation and site of origin of idiopathic ventricular tachycardia. Am J Cardiol. 1993; 71: 827–833.
11. Lauribe P, Shah D, Jais P, Takahashi A, Haissaguerre M, Clementy J. Radiofrequency catheter ablation of drug refractory symptomatic ventricular ectopy: short and long term results. PACE, 1999; 22: 783–789.
12. Gursoy S, Brugada J, Souza O, Steurer G, Andries E, Brugada P. Radiofrequency ablation of symptomatic benign ventricular arrhythmias. PACE, 1992; 15: 738–741.
13. Aizawa Y, Chinushi M, Naioh N, Kusano Y, Kitazawa H, Takahashi K. Catheter ablation with radiofrequency current of ventricular tachycardia originating from the right ventricle. Am Heart J, 1993; 125: 1269–1275.
14. Buxton AE, Waxman HL, Marchlinski FE, Simson MB, Cassidy D, Josephsonn ME. Right ventricular tachycardia: clinical and electrophysiological characteristics. Circulation 1983; 68: 917–927.
15. Pytkowski M, Maciąg A, Sterliński M et al. QRS morphology analysis to localize the arrhythmogenic focus in patients with right ventricular outflow tract arrhythmias. Abstract. CARDIOSTIM 2002. Nicea 19–22.06.2002.
16. Gerstenfeld EP, Dixit S, Callans DJ et al. Quantitative comparison of spontaneous and paced 12-lead electrocardiogram during right ventricular outflow tract tachycardia. J Am Coll Cardiol, 2003; 41: 2046–2053.
17. Dixit S, Gerstenfeld EP, Callans DJ et al. Electrocardiographic patterns of superior right ventricular outflow tract tachycardias: Distinguishing septal and free-wall sites of origin. J Cardiovasc Electrophysiol, 2003; 14: 1–7.
18. Dixit S. 12-lead ECG localization of arrhythmogenic focus in patients without structural heart disease. Congress of the Heart Rhythm Society, New Orleans 2005 (abstract).