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Transseptal versus transaortic approach for radiofrequency ablation in patients with cardioverter–defibrillator and electrical storm

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Abstract
Purpose Radiofrequency current ablation (RFCA) of ventricular tachycardia (VT) is usually performed using a retrograde transaortic approach. We compared the mapping accuracy, procedural course, safety, and results of VT ablation using transseptal and transaortic route.
Methods Twenty-one consecutive patients with ischemic cardiomyopathy and history of electrical storm underwent RFCA with electro-anatomic mapping system. In six patients, ablation was performed with transseptal approach (transseptal group); in 15, retrograde approach to the left ventricle was used (retrograde group).
Results The endocardial surface of the left ventricle was similarly accessible in both methods. Less detailed maps of interventricular septum were constructed with the use of transseptal approach. The RFCA success rate was similar in the transseptal and retrograde groups (83 vs. 80%, p = NS). The median procedural time was 112 min in transseptal vs. 145 min in the retrograde group; radiation exposure was 200 vs. 67 mGy, respectively (both $p<0.05$), and fluoroscopy time was 22 vs.16 min (p = NS). During the 3-month follow-up, VT recurrence occurred in one patient in the transseptal group and in three patients in the retrograde group (p = NS).
Conclusions Transseptal approach is an accurate, safe, feasible, and effective method of RF ablation in patients with malignant, recurrent ventricular arrhythmias. However, limited access to the septal regions with the use of this method has to be remembered. Transseptal approach may be considered as an alternative to the transaortic route in patients with contraindication to the latter.

Keywords Ablation · Ventricular tachycardia · Electrical storm · Transseptal approach · Transaortic approach

1 Background

In 10–19% of patients with implantable cardioverter–defibrillator (ICD), multiple shocks occur due to repetitive episodes of ventricular tachycardia (VT), known as electrical storm (ES) [1, 2]. Recurrent ICD shocks cause clinically significant anxiety and depression in more than 50% of patients [3]. Furthermore, ES is associated with poor short- and long-term prognosis, being a strong independent predictor of total and cardiac mortality [2, 4].

The usual method used during the ablation of ischemic VT is a retrograde transaortic approach; however, in some patients (older, with aortic stenosis, artificial aortic valve, peripheral vascular disease, or aortic aneurysm), this approach may be contraindicated. In this group of patients, the alternative route has to be considered. Therefore, we performed a comparison analysis of transseptal vs. transaortic approach of VT ablation in terms of the accessibility to endocardial surface, mapping accuracy, procedural course, as well as safety and results of both methods.

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2 Methods

2.1 Patient selection

Twenty-one consecutive patients with ischemic cardiomyopathy and recurrence of electrical storm due to unstable VT resistant to pharmacotherapy underwent radiofrequency current ablation (RFCA) using electro-anatomic mapping system. ES was defined as the occurrence of three or more episodes of VT within 24 h, resulting in appropriate ICD shocks [5] documented by electrograms stored in the ICD. RFCA had to be performed at latest 3 months after the episode of the ES.

In six patients, ablation was performed with transseptal approach (transseptal group) due to moderate aortic stenosis (two patients, 33%) or significant peripheral vascular disease (four patients). In 15 patients, RFCA was performed using retrograde transaortic approach (retrograde group). One patient with prior antero-lateral infarction in whom transaortic RFCA of VT failed and who underwent the second, successful procedure using transseptal approach has been excluded from the analysis.

Both groups did not differ with respect to the age, gender, comorbidities, number of ICD therapies, and cycle of clinical VT. Left ventricular volume was higher and ejection fraction (EF) lower in the retrograde group, but the differences did not reach statistical significance (Table 1). Similarly, the location of previous infarctions did not differ between both groups. Four patients (67%) in the transseptal group had prior anterior myocardial infarction (MI) and two patients (33%) inferior MI. Eight patients (53%) in the retrograde group underwent anterior, six (40%) inferior infarction, and one (7%) both anterior and inferior MI.

There were also no differences in treatment of ES in both groups. All patients were monitored in the acute cardiac care unit during index event or shortly thereafter. Four subjects in the transseptal and 12 in the retrograde group (67% vs. 80%; p = NS) were receiving intravenous beta-blockers, and all of them were treated with intravenous amiodarone. Furthermore, two patients in transseptal and three in the retrograde group (33% vs. 20%) required catecholamine administration due to hemodynamic compromise, and two of them (one in the transseptal and one in the retrograde group, both P = NS) were treated with intra-aortic balloon counterpulsation. Similarly, chronic pharmacotherapy regimen was comparable in the transseptal and the retrograde groups (Table 1).

2.2 Mapping and ablation procedure

The electro-anatomical substrate mapping of the left ventricle with the use of CARTO system (Biosense Webster, Inc. Diamond Bar, CA, USA) was performed in all patients during sinus rhythm. Transseptal puncture was performed routinely under fluoroscopic guidance using left atrial pressures as control. Scarred areas were defined by

Table 1 Baseline characteristics of the studied groups

	Transseptal group	Retrograde group	p
Male, *n* (%)	5 (83)	10 (66)	NS
Age, years (range)	65 (36–69)	66 (49–81)	NS
EF, % (range)	32 (26–33)	26 (15–36)	NS
Echo-derived LV end-diastolic volume, mL (range)	144 (100–277)	202 (104–298)	NS
Diabetes mellitus, *n* (%)	1 (17)	2 (13)	NS
Hypertension, *n* (%)	1 (17)	4 (27)	NS
ICD episodes per patient within 3 months prior to ablation			
ICD therapies due to VT, *n* (range)	11 (10–13)	11 (6–17)	NS
ICD therapies due to VF, *n* (range)	0.5 (0–1)	1 (0–4)	NS
High-voltage ICD therapies (range)	5.5 (5–10)	5.0 (5–15)	NS
Cycle length of spontaneous VT, ms (range)	317 (270–373)	325 (260–385)	NS
Chronic pharmacotherapy			
Beta blocker, *n* (%)	6 (100)	13 (87)	NS
Amiodarone, *n* (%)	6 (100)	12 (80)	NS
Class I AAD, *n* (%)	0	1 (7)	NS
Sotalol, *n* (%)	0	1 (7)	NS
ACE-I/ARB, *n* (%)	6 (100)	13 (87)	NS

EF left ventricular ejection fraction, *LV* left ventricular, *VT* ventricular tachycardia, *VF* ventricular fibrillation, *AAD* anti-arrhythmic drug, *ACE-I* angiotensin-converting enzyme inhibitor, *ARA* angiotensin receptor antagonist electrograms with an amplitude <0.5 mV. Myocardium with amplitudes within the range of 0.5–1.5 mV was defined as a border zone. Multiple linear lesions were performed along all the aspects of border zone. In patients with inducible VT after this procedure, linear ablation completely surrounding scar area and connecting it to a biological border (usually mitral annulus) was additionally performed [6, 7]. Ablation lesions were obtained by the delivery of radiofrequency current with progressive power titration up to 50 W based on temperature values not exceeding 50°C. Mapping and ablation procedures were performed in all patients using cool-tip ablation electrodes (Navistar Termocool, Biosense Webster) with saline flow rate of 25–30 mL/min during application. All patients received intravenous heparin during the procedure, with a target activation clotting time of 250–300 s. Ablation efficacy was assessed with the use of a programmed stimulation of the right ventricular apex. Pacing protocol consisted of programmed stimulation with up to two extrastimuli and of burst pacing with progressively shortened cycle length.

2.3 Definitions, measurements, and data collection

Ablation procedure was considered successful if no VT (even a non-clinical) could be induced with the programmed stimulation of the right ventricular apex after the last application. Procedure duration was defined as door-to-door time.

To assess indirectly the ability to reach the whole endocardial surface with the electrode in both approaches (transseptal and retrograde), CARTO-derived volume of the left ventricle was obtained in every patient. The echocardiographically calculated end-diastolic volumes of the left ventricle were then subtracted from such obtained CARTO volumes. Both absolute values and CARTO-ECHO differences were subsequently compared between both groups.

Assuming the spherical shape of the left ventricle, on the basis of the chamber volume calculated by CARTO, we approximated the left ventricular area in every patient. Furthermore, we counted the number of mapping and application points on the map. To assess the mapping accuracy, the absolute number of mapping/application points, as well as point density per square centimeter of approximated left ventricular area, was compared between both groups.

Finally, the local distribution of mapping/ablation points was analyzed to answer the question whether the operator was able to map more precisely the particular area of the ventricle with one of the methods. In order to perform it, we divided the left ventricular maps into four segments using horizontal and sagittal clipping planes in the antero-posterior position of the map. All segments obtained in such a way were roughly concordant with the septal, anterior, lateral, and inferior wall of the left ventricle (Fig. 1). Subsequently, the number of mapping points was counted manually in every segment and expressed as the percent of all points gathered on the whole map.

Demographic, clinical, echocardiographic, and procedural data of all patients analyzed in this study were collected prospectively in a computerized database as a part of single-center RFCA registry. Detailed data of the left ventricular CARTO maps (volume of the ventricle, number of points acquired) were collected retrospectively using off-line analysis of the maps stored on a hard disc of the CARTO system.

Follow-up was obtained at the outpatient clinic every month or whenever any clinical event occurred. During clinical visits, interrogation of ICD was performed. Total follow-up time was 3 months.

2.4 Statistical analysis

The continuous parameters were expressed as median ± range; discrete variables were presented as numbers and percentages. Mann–Whitney *U* test was used for continuous parameters and McNemar's test for dichotomous variables. Values of $p < 0.05$ were considered statistically significant. The software package Statistica (version 6.0, StatSoft Inc., Tulsa, OK, USA) was used for statistical analysis.

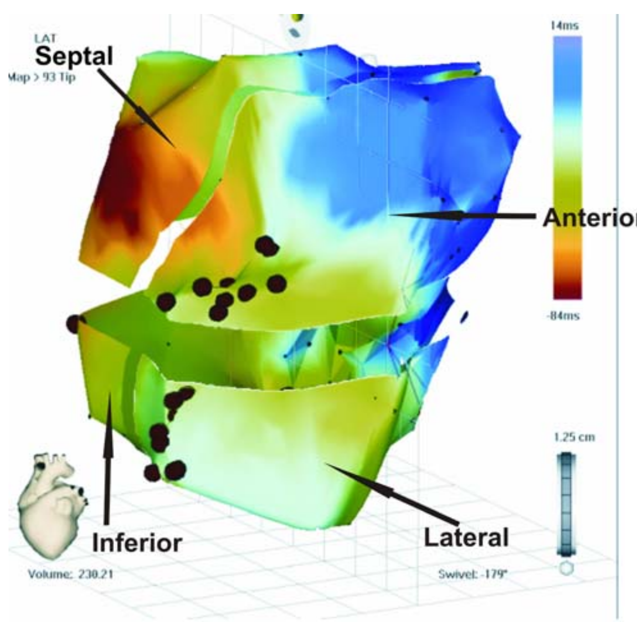

Fig. 1 CARTO activation map of the left ventricle divided into four segments. The map is shown in the left lateral 60° cranial 15° view. Particular segments were obtained by applying sagittal and horizontal clipping planes to the map in antero-posterior view. Such selected segments correspond with septal, anterior, lateral, and inferior wall of the ventricle (segments separated on the picture)

3 Results

3.1 Mapping efficacy and accuracy

Both groups did not differ with respect to the number of mapping and application points collected during the procedure. Retrograde group presented with higher CARTO-derived left ventricular volumes (210 vs. 177 mL) and greater disparity between echocardiographic and CARTO measurements (20 vs. −1.3 mL, respectively) than the transseptal group; however, these inter-group differences did not reach statistical significance (p = NS). The density of mapping and ablation points per square centimeter of the map was virtually identical in both methods. However, the percentage of points collected in particular regions of the ventricle revealed some differences between both approaches. Transseptal group had fewer points collected in a septal region than the retrograde group (median 12% vs. 25%, $p<0.05$), whereas a trend toward less detailed mapping of lateral wall was observed in the retrograde group (Table 2).

3.2 Procedural course and outcomes

In three patients (one in the transseptal and two in the retrograde group, p = NS) with inducible VT after RFCA, a more extensive approach had to be undertaken, which is the complete surrounding of the scarred area with applications. RFCA was successful in five patients in the transseptal and 12 in the retrograde groups (83% vs. 80%, p = NS).

Total procedural time was 112 min in the transseptal group and 145 min in the transaortic group ($p<0.05$). The median fluoroscopy time was similar in both groups (p = NS); however, the radiation exposure was higher in the transseptal than in the retrograde group (200 vs. 67 mGy, respectively, $p<0.05$). No complications associated with specific approach were noted in either group. During the 3-month follow-up, recurrence of VT treated with ICD shock occurred in one patient in the transseptal group and in three patients in the retrograde group (p = NS). No electrical storms were observed during the follow-up.

4 Discussion

In patients with implanted ICD due to secondary prevention, the electrical storm is not a rare phenomenon. In accordance with current guidelines, RFCA is indicated as adjunctive therapy in patients with ICD and electrical storm [5]. Successful treatment of ES by means of RFCA in a large group of patients with various underlying cardiac diseases was reported by Carbucicchio et al. [8].

Table 2 Mapping accuracy, procedural course, acute, and mid-term outcomes in both groups

	Transseptal group	Retrograde group	p
Mapping accuracy			
No of mapping points on LV map, n (range)	127 (69–214)	114 (84–464)	NS
No of RF points on LV map, n (range)	127 (50–216)	188 (54–405)	NS
Mapping+RF points on LV map, n (range)	294 (119–319)	378 (138–569)	NS
CARTO-acquired LV volume, mL (range)	177 (100–299)	210 (130–429)	NS
CARTO LV volume − ECHO LV volume difference, mL (range)	−1.3 (−75 to 180)	20 (−66 to 143)	NS
Approximate LV map area, cm^2 (range)	152 (104–217)	171 (124–275)	NS
Density of CARTO mapping points on LV map point/cm^2 (range)	0.8 (0.3–2)	0.7 (0.1–2.9)	NS
Density of CARTO mapping+RF points on LV map point/cm^2 (range)	1.9 (0.8–3)	1.7 (0.8–3.7)	NS
Mapping points acquired in particular LV segment/all points on CARTO map			
Septal, % (range)	12 (4–43)	25 (12–40)	<0.05
Anterior, % (range)	23 (18–39)	22 (8–52)	NS
Lateral, % (range)	29 (19–44)	22 (14–35)	0.09
Inferior, % (range)	35 (11–47)	26 (10–47)	NS
Procedural course			
Procedural time, min (range)	112 (90–145)	145 (60–180)	<0.05
Fluoroscopy time, min (range)	22 (5–31)	16 (5–35)	NS
Radiation exposure, mGy (range)	200 (51–374)	67 (7–358)	<0.05
Outcomes			
Acute success, n (%)	5 (83)	12 (80)	NS
Recurrences, n (%)	1 (17)	3 (20)	NS

LV left ventricular, *RF* radiofrequency

In the majority of cases, RFCA is performed using transaortic approach. However, in some patients with contraindications, an alternative (transseptal) approach is to be considered. To our knowledge, no available data compare the accuracy, course, safety, and results of VT ablation using both approaches.

Many previous studies indicated that RFCA of VT using both transaortic and transseptal approach is safe and feasible for reentrant and focal arrhythmias; however, as yet, no data compared these two approaches [6, 9, 10]. Marchlinski et al. [6] evaluated 16 patients (nine with ischemic cardiomyopathy) with unmappable VT in whom RFCA was performed either with retrograde approach (14 patients) or transseptal approach (two patients). Volkmer et al. [9] compared the substrate mapping and tachycardia mapping using CARTO in 47 patients with ischemic VT. In their study, transseptal access to the left ventricle was used in six patients (due to severe atherosclerosis of the aorta and of peripheral arteries), and in six other patients, RFCA was performed with combined access.

Our data indicate that both approaches allow comparable access to the endocardial surface of the left ventricle. CARTO-derived volumes of the chamber, the number, and density of mapping/ablation points on maps were very similar in both groups. However, while transseptally derived maps had virtually the same volumes as those assessed echocardiographically, the maps collected with retrograde method tended to overestimate the chamber size (by a median of 20 mL). This finding can be probably attributed to a greater stability of ablation electrode “entrapped” in inter-atrial septum in patients in whom transseptal approach was used. The less stable tip of the ablation catheter introduced retrogradely (especially in extremely large ventricles) requires more pressure against the wall and may stretch the ventricle. Conversely, the catheter stabilized by an inter-atrial septum does not need to be pushed firmly against the wall to remain in a stable position.

On the other hand, the accessibility to some particular regions of the ventricle is distinct in both approaches. Septal areas had significantly less detailed maps in the transseptal than transaortic group. Conversely, a trend toward less detailed maps of the lateral wall (especially of basal regions, data not shown) was observed in the retrograde group. These differences should be considered when planning RFCA with transseptal method in a patient with known scar within the interventricular septum. Of note, moreover, is that the only patient who had both approaches at our center underwent at first RFCA via transaortic approach, which was unsuccessful probably due to the instability of the electrode in the basolateral region of a very enlarged ventricle. This patient underwent subsequently the second, successful procedure with the transseptal method.

The total success rate of ablation in our study population was 81% and was similar to results reported by other authors [6, 8, 9, 11]. We noted similar success rate of RFCA irrespectively of method used (83% vs. 80%, p = NS). We also did not find statistically significant differences with respect to mid-term results between the transseptal and transaortic groups.

Our study demonstrated significant differences with regard to procedural time and radiation exposure, with no differences in fluoroscopy time and success rate of RFCA between both approaches. Radiation exposure was higher in the transseptal group, which can probably be explained by the continuous fluoroscopy needed for the puncture and the oblique projections used during this procedure. Better stabilization and more precise manipulation with the ablation catheter “entrapped” in the inter-atrial septum may in turn account for significantly shorter procedural time in a transseptal group.

Pratola et al. [12] reported feasibility of the transseptal approach for unstable VT using a non-contact mapping system. Procedural and fluoroscopy time in their study was comparable to those parameters reported by other authors using standard retrograde approach for the same procedures. Because RFCA using a non-contact mapping system requires a double transseptal puncture, the procedure duration could have probably been prolonged compared to RFCA using the CARTO system. This suggests that the transseptal technique would be even more attractive when used with the CARTO system.

When planning RFCA in a patient with frequent VT and electrical storm, it should be remembered that the procedure may be extremely difficult and the complex approach could be necessary in some cases. Volkmer et al. [9] reported the necessity of combined retrograde and transseptal access on six out of 47 patients (13%) with recurrent VT because the retrograde approach alone was not sufficient to permit mapping of the entire left ventricle due to anatomical variations. What is more is that in some patients with epicardially located area of critical isthmus, epicardial approach may be required. Carbucichio et al. [8] reported that both epi- and endocardial approach was needed in 11% of patients with ES, the majority of which presented with idiopathic cardiomyopathy. Therefore, the selection of optimal method in a particular patient has to be meticulously thought out and always patient-customized.

5 Study limitations

Our study population is small, and this could be responsible for the underestimation of some important associations. The follow-up period was relatively short, leaving the question on the long-term outcomes in this group unanswered.

Although the majority of data were archived prospectively, some of them were collected in a retrospective manner, with all potential drawbacks coupled to retrospectively designed studies. Transseptal and retrograde groups had to some degree different baseline characteristics (lower EF, larger ventricles in retrograde group, possibly more advanced atherosclerosis in transseptal group), which makes inter-group comparisons more difficult to be interpreted. Therefore, the present study can be considered as the preliminary data only.

6 Conclusions

These preliminary results suggest that the transseptal approach is an accurate, safe, feasible, and effective method of RF ablation in patients with malignant, recurrent ventricular arrhythmias. However, limited access to the septal regions with the use of this method has to be remembered. This approach may be considered as an alternative to the transaortic approach in patients with contraindication to the latter. Our results need to be confirmed in more extensive studies.

Conflict of interest Dr. Sredniawa was receiving consulting fees from Medtronic. No other potential conflict of interest relevant to this article are reported.

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