

Prognostic value of time dependent voltage abatement during remote magnetic navigation guided ablation in idiopathic right ventricular outflow tract arrhythmias

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SOUHRN

Kontext: Naším cílem bylo zjistit, zda časově závislé snížení voltáže (dV/dt) na komorových elektrogramech (EGM) během katetrizační ablace idiopatických arytmií z výtokového traktu pravé komory (right ventricular outflow tract, RVOT) s použitím systému Stereotaxis Niobe II představuje účinný ukazatel dlouhodobé úspěšnosti výkonu.

Metody: Do studie bylo zařazeno 26 po sobě následujících pacientů s akutní úspěšnou ablací RVOT pro předčasné komorové stahy (premature ventricular contractions, PVC) a/nebo komorové tachykardie (KT) s původem nejspíše v RVOT. Pozdní úspěšnost byla definována jako vymizení komorových ektopií z RVOT po tříměsíčním sledování bez antiarytmik (antiarrhythmic drug, AAD).

Výsledky: Po tříměsíčním sledování vymizely symptomy i arytmie u 20 (skupina 1) z 26 pacientů (77 %), přičemž k recidivě došlo u šesti pacientů (23 %) (skupina 2). Během RF ablace byl „warming up“ fenomén pozorován u 85 %, resp. 83,33 % pacientů ($p = 0,46$) po průměrné době (dt 2) $4,72 \pm 9,42$, resp. $10,75 \pm 11,34$ s ($p = 0,045$). Doba od zahájení aplikace RF energie (t0) do významného snížení voltáže (> 90 %) nebo obrácení polarity EGM (t1) u obou skupin činila $9,11 \pm 5,11$, resp. $32,16 \pm 10,33$ ($p = 0,00006$). Hodnota dV/dt1 byla $95,44 \pm 87,6$, resp. $23,5 \pm 16,97$ $\mu V/s$ ($p = 0,024$).

Závěr: Časově závislé snížení voltáže na komorovém EGM spolu s dobou od zahájení RF ablace do významného snížení voltáže (> 90 %) nebo obrácení polarity EGM a dobou od aplikace RF energie do vzniku „warming up“ fenoménu představují možné prediktory dlouhodobé úspěšnosti RF ablace idiopatických arytmií vycházejících z RVOT.

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ABSTRACT

Backgrounds: We set out to evaluate if time related voltage abatement (dV/dt) of ventricular electrograms (EGM) during catheter ablation of idiopathic right ventricular outflow tract (RVOT) arrhythmias using the Stereotaxis Niobe II system is an efficient marker of long-term procedural success.

Methods: Twenty-six consecutive patients with acute success of RVOT ablation for premature ventricular contractions (PVCs) and/or ventricular tachycardia (VT) suggestive of RVOT origin were included. Late success was defined as freedom of ventricular ectopies originating from the RVOT after 3 months of follow-up without antiarrhythmic drugs (AAD).

Results: After 3-month follow-up 20 of 26 patients (77%) remained free of symptoms and arrhythmias (group 1) and recurrences occurred in 6 patients (23%) (group 2). 'Warming up' during RF applications occurred respectively in 85% and 83.33% of patients ($p = 0.46$), after a mean period (dt 2) of 4.72 ± 9.42 vs 10.75 ± 11.34 s ($p = 0.045$). The time intervals from the onset of RF delivery (t0) to significant voltage abatement ($>90\%$) or reversal of EGM polarity (t1) between the two groups were: 9.11 ± 5.11 vs 32.16 ± 10.33 ($p = 0.00006$). dV/dt1 was 95.44 ± 87.6 vs 23.5 ± 16.97 $\mu V/s$ ($p = 0.024$).

Conclusions: Time related voltage abatement of ventricular EGM together with time interval from onset of RF ablation to significant voltage abatement ($>90\%$) or reversal of EGM polarity and time interval from RF delivery to onset 'warming up' are possible predictors of long-term success after RF ablation of idiopathic RVOT arrhythmias.

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Introduction

Arrhythmias originating from the right ventricular outflow tract (RVOT) tend to present as isolated premature ventricular complexes (PVCs), runs of non-sustained VT or sustained VT.¹ Unless it is the initial sign of an arrhythmogenic right ventricular dysplasia (ARVD), the prognosis is generally good, with an excellent long-term survival. For symptomatic patients in whom β -adrenergic blockers, calcium channel blockers^{2,3} or anti-arrhythmic drugs (AAD) class IC and III are ineffective⁴ or not desired and for patients in whom left ventricular (LV) dysfunction occurs⁵⁻⁷ radiofrequency (RF) ablation is a safe and effective treatment option.⁸

The acute success rate for ablation of RVOT ectopies in non-structural heart disease ranges from 65 to 97%.⁹⁻¹¹ When RF ablation is not successful,¹²⁻¹⁴ this can be due to intramural or epicardial origin of ectopies, occurrence of multiple morphologies of ectopic beats in the same patient or matching between the clinical VT and pace-map being less than 11 out of 12 leads. Despite high acute success rates, there is a recurrence rate of 5–23% during a follow up to 2 years.¹⁵⁻¹⁷

Endocardial activation time at the successful ablation site is the only predictor of long-term tachycardia recurrence reported in literature to our knowledge.¹⁸ Remote magnetic navigation (RMN) mapping and ablation of RVOT ectopies guided by the Stereotaxis Niobe II system (Stereotaxis, Inc., St Louis, MO, USA) appears to be safe, fast, and effective.¹⁹ The aim of our study was to evaluate if time related voltage abatement (dV/dt) of ventricular electrograms (EGM) during catheter ablation of idiopathic RVOT arrhythmias guided by RMN is an efficient marker of long-term procedural success.

Methods

Study population

Between July 2015 and January 2018, 26 patients with acute success of RVOT ablation for premature ventricular contractions (PVCs) and/or VT suggestive of RVOT origin were included in this study. All patients provided written informed consent. Patients were symptomatic and have been refractory to at least one AAD. Transthoracic echocardiography was performed in all patients for assessing right and left ventricle dimensions and left ventricle ejection fraction.

Mapping and ablation

PVCs were documented on the LabSystem PRO™ EP recording system (Bard Electrophysiology Division, Lowell, MA, USA). All procedures were performed under local anaesthesia. After obtaining vascular access, one 8F sheath was positioned in the right femoral vein. Navigation to the RVOT was performed utilizing a 3.5 mm tip irrigated magnetic catheter (NaviStar RMT ThermoCool, Biosense Webster, Diamond Bar, CA, USA). Detailed mapping was performed with the CARTO 3D mapping system (Biosense Webster, Diamond Bar, CA, USA). The catheter movement within the RVOT was guided remotely by the Stereotaxis Niobe II system.

An activation map was made for each patient in order to determine the earliest local bipolar activation point (≥ 30 ms from the onset of the QRS) (Fig. 1). If PVCs were not

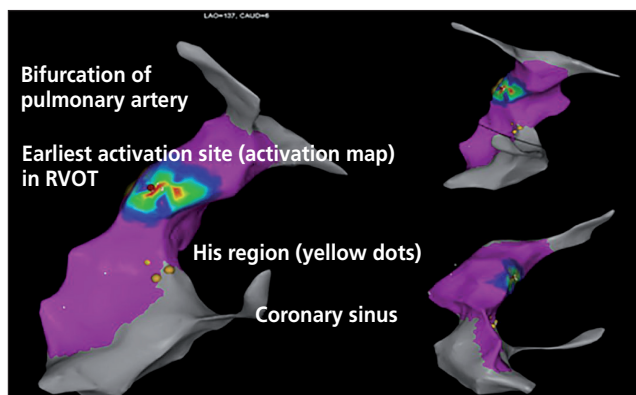


Fig. 1 – Illustration shows 3D activation map of right ventricular outflow tract LAO 137° – the earliest activation site where RF ablation was performed.

occurring frequently, Isoproterenol (15 to 30 μ g/min) was administered, and if this did not successfully increase the amount of ectopic beats, ablation was finally performed using pace mapping only. Pacing with output just above the threshold targeted the most optimal pace map ($\geq 11/12$ leads). After the focus of PVCs was identified, RF delivery was applied with a maximal power of 40 W, maximal temperature of 48 °C during 60 to 120 seconds and catheter irrigation flow set at 17 ml/min. Catheter stability was analysed semi quantitatively. If the ablation catheter displaced during application, RF delivery was interrupted. Procedural endpoint was the elimination of spontaneous clinical PVCs at baseline and after Isoproterenol (15 μ g/min) infusion post-ablation. A waiting period of 30 min was applied for all procedures. On the basis of the 3D anatomical mapping, RVOT was divided into six distinct sites to facilitate the description of the origin of PVC based on the successful ablation site: anterior, middle, and posterior septal sites and anterior, middle, and posterior free wall sites.

Parameters

The ventricular EGM amplitude during baseline (V0) and the new EGM amplitude during RF delivery at the moment of significant voltage abatement or reversal of EGM polarity (V1), were registered for each site of RF application. EGM amplitude was measured from the peak of the positive reflection of the EGM to the baseline. Thereafter, the difference between EGM amplitude (dV = V0–V1) and the time interval between t0–t1 (dt1) were calculated for each site of RF application. If warming up during RF occurred, time interval from onset of RF ablation to warming up of the arrhythmia (dt2) was also registered. Procedural time, radiofrequency application time, and fluoroscopy time were collected at the end of the procedure.

Post-procedural management

AAD were discontinued after RF ablation. All patients underwent follow-up at 1 and 3 months. Follow-up examinations consisted of symptom-based evaluation, 12-lead ECG, and 24-h Holter-monitoring. Late success of ablation was characterized by a significant decrease in PVC burden and absence of VT episodes with less than 500 PVC on the 24-h Holter-monitoring at 1 and 3 months after ablation. Otherwise, the case was defined as recurrence.

Endpoints

The primary endpoints were defined as recurrence of clinical PVCs at 3 months after ablation, the relationship between dV/dt1, dt1, dt2 and the recurrence versus the absence of PVCs and/or VT. Recurrence of clinical PVCs was considered in case of more than 500 PVC and/or of VT episodes on the 24-h Holter-monitoring at 3 months after ablation.

Statistical analysis

Categorical variables are expressed as frequencies and percentages. Continuous data are presented as mean value plus standard deviation. Continuous variables were analysed with a paired t-test. A p -value <0.05 was considered statistically significant. Statistical analysis was performed with SPSS 22 and Microsoft Excel Analyse-it software.

Results

Procedural data

Data are summarized in Table 1. RVOT was identified as the origin of the VES/VT in all 26 patients. Successful RVOT ablation sites were identified using a combined activation and pacing map in 19 patients (73%) and only a pacing map in 7 patients (27%). Acute success was obtained in all patients. After a waiting time of 30 minutes, no patient presented PVC recurrence with the same morphology as the clinical arrhythmia. Median total procedural time was 101 ± 32 min, median total fluoroscopy time 204 ± 98 s and median radiofrequency ablation time was 338 ± 180 s. Median RF applications/patient was 5. During and after the procedure, no pericardial tamponade, cardiac perforation or other major adverse events occurred.

Outcome after RVOT ablation

At 3 months of follow-up, 20 of 26 patients (76.92%) remained free of symptoms and arrhythmias (group 1). During a mean period of follow-up thereafter of 13.55 ± 10.15 months, these patients presented no recurrence. During the 3 months of follow-up, recurrences occurred with evidence of VES or/and VT in 6 patients (group 2): one patient with ablation in an anteroseptal site, 4 patients in a posteroseptal site and one patient in posterior free wall site. Three out of 6 patients underwent a second RF ablation. After 3 months of follow-up after the second procedure, all patients were free of arrhythmias and symptoms. In one of these 3 patients, success was obtained after both right- and left-sided ablation.

Among patients with ablation based on pacing map, only one had arrhythmia recurrence (14.28%). In the ablation group based on both activation and pacing map, the recurrence rate was 26.31% (5 out of 19 patients). There was no significant difference with regard to clinical characteristics (gender, age) and several electrophysiological findings (type of map, the location of ectopic focus, and the type of arrhythmia) between patients with long-term successful ablation and those with recurrence of arrhythmia.

When comparing the two groups, 'warming up' during RF applications occurred respectively in 85% and 83.33 % of patients ($p = 0.46$), after a mean time (dt 2) of 4.72 ± 9.42 vs 10.75 ± 11.34 s ($p = 0.045$). The time intervals from the

onset of RF delivery (t0) to significant voltage abatement ($>90\%$) or reversal of EGM polarity (t1) between the two groups were: 9 ± 5 vs 32 ± 10 ($p = 0.00006$) and dV/dt1 was 95 ± 87 vs 23 ± 16 $\mu\text{V/s}$ ($p = 0.024$) (Table 2). Total RF application times for the two groups were 351 ± 206 versus 370 ± 120 s ($p = 0.4$).

Discussion

The rate of recurrence of 23.08% after a follow period of 13.55 ± 10.15 months is slightly higher compared to those reported in literature (4–20%).^{20,21} The 76.92% success rate from the series suggests that long-term successful ablation of RVOT arrhythmia can be achieved in patients who present during RF ablation with a short time interval between onset of RF delivery (t0) to significant voltage abatement ($>90\%$) or reversal of EGM polarity (t1) and a higher value of voltage abatement correlated to time interval between t0 and t1.

Although 'warming up' during RF ablation occurs when the origin site of the arrhythmia site is heated, in our study, 'warming up' was not a predictor of procedural success in the long run, even though shorter time intervals between the onset of RF delivery and onset of 'warming up' (dt2) tend towards predicting long-term success. This could be explained by RF delivery in the vicinity of the origin site of arrhythmia in group 2, close enough to produce 'warming up' due to delayed myocardial injury, but not sufficient to produce complete lesion at the origin of the ectopy.²²

Successful transmural lesion formation during RF ablation is the result of an ideal combination of contact force, power, duration of energy application, catheter stability, tissue temperature wall thickness and ablation catheter tip size and orientation.^{23–25} The mechanisms underlying long-term recurrence of ventricular arrhythmias originating from RVOT are unknown, but are likely due to inadequate lesion formation during the initial procedure. This may be due to the inability of achieving transmural lesions caused by poor catheter stability or insufficient wall contact creating acute tissue oedema causing only temporary suppression of arrhythmias. In standard electrophysiological settings, changes in EGM morphology may be helpful in determining successful transmural lesion formation.

The speed at which this reduction in EGM amplitude occurs, now seems to represent the most ideal combination of wall contact, catheter precision, and efficient transmural lesion formation.

Although RMN ablation was thought to be unstable and less effective in highly mobile cardiac regions as RVOT compared to RF ablations with manual navigation (MN), studies revealed that the lesion dimensions were larger with RMN compared to MN in the presence of simulated wall motion, consistent with greater catheter stability.²⁶

Several studies already proved the superiority of RMN guided ablation of VT compared with manual navigation in terms of acute success rate and procedure and fluoroscopy times.²⁷ First, this finding could be explained by the higher navigation capability, even in difficult positions, due to the absence of pre-defined catheter curves. Secondly, the positioning of the tip, the catheter stability, and contact are improved due to the constant magnetic

force directing the tip during application, allowing appropriate lesion formation.

Thirdly, RMN requires lower forces to maintain stable tissue contact than conventional manual ablation while creating equivalent lesions, making it also very suitable to be used in thin walled regions such as the outflow tracts.

It has been previously reported that mural swelling develops acutely in response to focal RF application.²⁸ This tissue swelling persists throughout the time of the ablation procedure and appears to resolve only within weeks to months. The swelling is most marked at the site of RF delivery, but also tends to spread, presumably through extension of interstitial oedema through the adjacent tissue, preventing optimal catheter tissue contact and RF energy delivery, leading to incomplete lesion and next to arrhythmia recurrence. Therefore it is paramount to achieve adequate lesion formation as soon as possible during the ablation procedure without causing too much 'collateral damage' by oedema formation.

Study limitations

This study has some limitations: the number of patients included is relatively small and this is a non-randomized, retrospective study. However, since the dt1, dt2, dV/dt1, were identified in our study as long-term outcome predictors post RVOT ablation, we believe that further studies and investigations are appropriate to confirm and establish a cut-off value of dt1, dt2, and dV/dt1 as possible predictors of long-term success.

There was no significant difference of time of RF application between our 2 groups, and thus the hypothesis, that some patients are more prone to development of oedema, exists.

Conclusions

Time related voltage abatement of ventricular EGM together with time interval from onset of RF ablation to significant voltage abatement (>90%) or reversal of EGM polarity and time interval from onset of RF ablation to 'warming up' are possible predictors of long-term success after RF ablation of idiopathic RVOT arrhythmias. Presence of 'warming up', however, is not significantly correlated to procedural success in the long run.

Conflict of interest

None declared.

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