Archives of Cardiology and Cardiovascular Diseases

ISSN: 2638-4744

Volume 3, Issue 2, 2020, PP: 17-25

Catheter Ablation of Premature Ventricular Complexes Exclusively by A 3D Electroanatomic Pace-Mapping Software Technique: Long-Term Follow-Up

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Abstract

INTRODUCTION/OBJECTIVE: *Ablation of premature ventricular complexes (PVCs) is a challenge in routine electrophysiology. Results depend on factors such as location, tools, and technologies available. The study aimed to analyze the exclusive use of the pace-mapping technique with module of Score Map™ (SM) Software of Ensite Velocity/Precision and evaluate long term success.*

METHODS/RESULTS: *Forty-three procedures were retrospectively analyzed between March 2018 and August 2019. Ablation was conducted with an irrigated tip catheter with a power of 20–40 W and a pump flow rate of 30ml/min. Mapping with a duodecapolar was conducted in 36 (83.72%) cases, and the HDGrid catheter was used in seven (16.28%) cases. The patients included 22 (51.16%) females, and the mean age was 51.65 years (19–78). Thirty-five patients (81.40%) had hypertension; six (13.95%) had chronic coronary disease; four (9.30%) had myocarditis; two (4.65%) had diabetes; and none had implanted defibrillators. Mean ejection fraction was 63.17% (47.35%–77.32%). Average radiofrequency time was 597.72 (176–1356) s, and mean X-Ray time was 7.74 min. During the procedure, median SM was 93.81% (84%–100%) and only seven (18.42%) ablations were considered unsuccessful due to maintenance of extrasystoles or reduction of PVCs. After a follow-up of 19.58 (12–30) months, 37 (86.05%) patients achieved success. Failure was observed in cases with an SM score ≤ 92%, ablation cases with conscious sedation, female sex, both side ventricle ablation and associated with cardiac veins, and more than 900 seconds of RF application.*

CONCLUSION: *Score Map™ is useful as an exclusive technique for ablation of premature ventricular complexes with very good acute success and low complications, and an SM score higher than 92% had high long-term success. Failure was related to conscious sedation, female gender, both side ventricle with cardiac veins ablation, and longer radiofrequency time.*

Keywords: *Premature ventricular beats, catheter ablation, pace-mapping, electroanatomic mapping, activation map.*

Introduction

Radiofrequency (RF) catheter ablation (CA) is an effective treatment for symptomatic, idiopathic premature ventricular complexes (PVCs)[1-4]. The mechanisms of these arrhythmias tend to be triggered activity or abnormal automaticity, as opposed to re-entry, which more commonly underlies sustained ventricular arrhythmias most common in patients with structural heart disease[5-7]. Today, in the era of electroanatomic systems supporting the ablation of PVCs, activation

mapping is the preferred strategy to localize the site of origin and guide successful application of RF[8-11]. However, detailed activation mapping requires sufficient intraprocedural PVC numbers, which is a common issue since anesthetic medications are used during the procedure, leading to a reduction and occasionally the absence of PVCs despite the utilization of all available stimulation protocols and medications to sensitize the foci of the arrhythmia. Pace-mapping (PM) has been long utilized to guide ablation of idiopathic PVCs[12-14], but there is a lack of clinical data on the use of commercial PM software available in the electroanatomic mappings as an exclusive strategy for ablation of infrequent PVCs[15].

Objective

The aim of this study was to investigate the long-term outcomes of CA in patients with very infrequent intraprocedural PVCs guided exclusively by a commercial PM software and to determine its long-term feasibility as a routine approach.

Materials and Methods

This was an observational, retrospective study that utilized patients submitted to catheter ablation for treatment and elimination of symptomatic ventricular ectopic beats exclusively with the support of a PM score software named Score Map™ presented at the EnSite Velocity/Precision Electroanatomic Mapping System (St Jude Medical/Abbott USA).

Study Population

We retrospectively analyzed 43 procedures performed in 40 patients with symptomatic[16], premature ventricular complexes between March 2018 and August 2020, with a rate of 1.08 procedures per patients. Most common symptoms were palpitations, fatigue, shortness of breath, and new onset of functional limitation. Participants included 22 females (51.16%), and the mean age was 51.65 years (19–78). Thirty-five had hypertension (81.40%); six (13.95%) had chronic coronary disease; four (9.30%) had myocarditis; two (4.65%) had diabetes; and none had an implanted defibrillator. Mean ejection fraction was 63.17% (47.35–77.32%) with a mean end diastolic diameter of 47.56 (42–62) mm. Previously administered medications before ablation included beta-blockers in 31 (72.09%) patients, amiodarone in 14 (32.56%) patients, and sotalol in 13 (30.23%) patients. The mean time between catheter ablation and the documentation of the symptoms was 10.4 (3–21) months. Clinical features are described in Table 1.

Table1. *Clinical features.*

CLINICAL FEATURES	NUMBER (%)
AGE	51.65 years (19-78)
FEMALE	22 (51.16%)
HYPERTENSION	35 (81.40%)
CORONARY DISEASE	6 (13.95%)
MYOCARDITIS	4 (9.30%)
DIABETES	2 (4.65%)
EJECTION FRACTION	63.17% (47.35-77.32%)
DIASTOLIC DIAMETER	47.56mm (42-62)
BETA-BLOCKERS	31 (72.09%)
AMIODARONE	14 (32.56%)
SOTALOL	13 (30.23%)
TIME FROM DIAGNOSIS TO ABLATION (months)	10.4m (3-21)

EnSite Velocity AutoMap Module

The EnSite™ AutoMap Module is a software entitlement feature within the EnSite™ Cardiac Mapping System. AutoMap Module automates the point collection process based on the user-defined settings. As the mapping catheter is moved, points are collected when the user-defined settings are met. SM is a map type that plots the surface ECG morphology match score associated with each mapping point collected compared to the originally collected template beat surface lead morphology. The physician may want to use this feature during PM using an adjustable percentage morphology match score in the area of interest. The operator may also sort the points list by score (from highest to lowest) comparing to surface ECG morphology beat. This may be useful to determine which surface leads are different from the template beat. SM can also be used during a

automated mapping to allow users to automatically collect only those points with morphology match scores that are XX% similar or higher compared to the template beat and automatically reject those points that are not XX% similar or higher compared to the original template beat. When Start AutoMap is activated, the software automatically records the data from 10 s before the EnSite™ AutoMap feature is activated and continues recording as long as the EnSite™ Auto Map feature is active[17,18].

Pace-Mapping Technique and Catheter Ablatio

The procedure was done in a fasting state. Twelve lead ECG was recorded on the electrophysiologic (EP) recording system and also at the EnSite Velocity 5.0 to document several clinical PVCs morphologies for proceeding with ablation. Then, at the discretion of the operator, the anesthesia and electrophysiologic study was started. The minimum SM points for the achievement and construction of the morphology of the chamber was 90%, and if this goal was not reached, we started a new map in another chamber. This objective was achieved in all except seven (16.28%) cases in which the best SM score attained was between 84% and 92% (Figure 1). If this approach did not result in better SM, we then reduced the match score to 80% and attempted a new map in the coronary sinus and their branches (Figures 2, 3 and 4). The ablation procedure was done with Flexability™ in 38 (88.37%) cases and Tacticath SE™ in five (11.63%) cases of redo procedures with a power of 40 W and a pump flow rate of 30ml/min. In the cases of ablation in the coronary and non-coronary cusps, coronary sinus and venous branches, power was titrated to 20 W and the flow pump was maintained in the same flux. The mapping catheters utilized included the Livewire Duodecapolar 2-2-2™ catheter in 36 (83.72%) cases and the Advisory HDGrid™ catheter in seven (16.28%) cases. The reference of the 3D mapping system was an Irvine decapolar catheter inserted in the coronary sinus that was attached in the femoral access (all catheters in the St. Jude Medical/Abbott – USA portfolio).

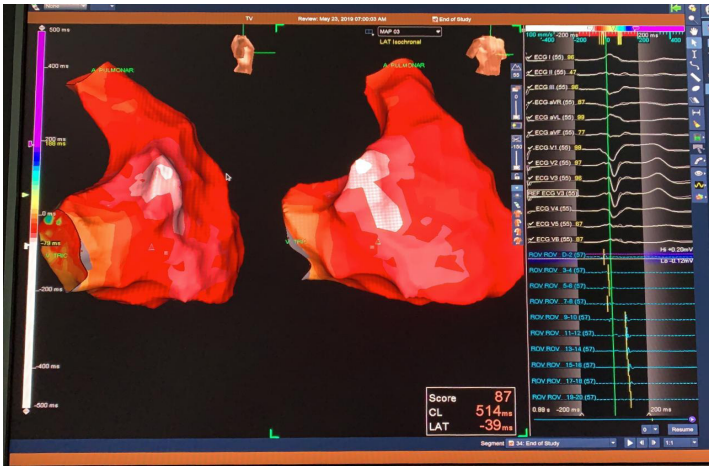

Fig1. *A Score Map (SM) of 87% in an unsuccessful case with extensive pace-mapping in the left ventricle.*

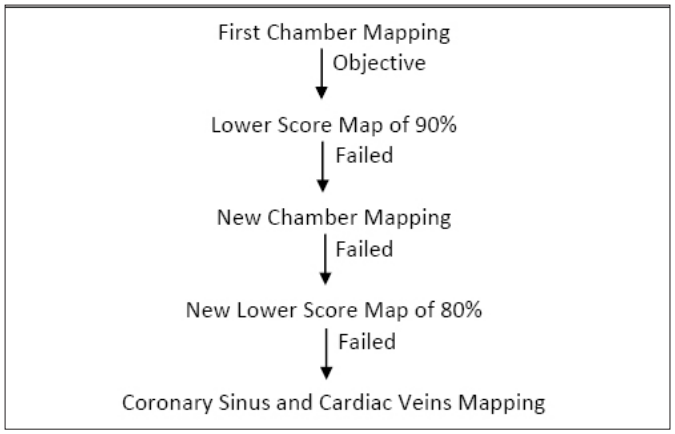

Fig2. *Study Workflow.*

Fig3, Fig4. *EnSite Mapping of a redo case showing the flow chart of the procedures. First attempt of pace-mapping in the right ventricle without a good Score Map (SM) followed by a SM of only 66% in the left coronary cusp and later a SM of 99% in the great cardiac vein.*

Informed Consent Ethical Considerations

All patients signed the informed consent form according to the standards of the institution, which follows national and international standards[19,20]. The study was conducted by the Research Ethics Committee of the Institution.

Post-Ablation Follow-up

Patients were discharged from the Hospital on the day after the catheter ablation and received orientations and scheduled two appointments within 7 and 30 days and within 3, 6, and 12 months after the procedure. On these clinical examinations, a clinical questionnaire and an electrocardiogram with a 5–10 min monitoring session to locate PVCS were done in all cases. Furthermore, 24-hour Holter monitoring was performed in all cases at 3, 6, and 12 months after the index procedure.

Statistical Analysis

All tests were performed using BioStat statistical software (by AnalystSoft Walnut, CA). Continuous variables were expressed as mean ± SD or (Min / Max) or as median and interquartile range (IQR). P value was considered significant if <0.05 by the chi-square test.

Results

We performed 43 procedures between March 2018 and February 2020 with a total median SM of 93.81% (84–100) with SM of 95.91% (93-100) and 89.15% (84-92) in successful and unsuccessful cases, respectively and an interesting significant P value of 0.039. Radiofrequency (RF) time was of 597.72 seconds (176–1356) with shorter times for success and longer times for unsuccessful cases, at 388.55 and 1122.79 seconds, respectively and this difference in RF times was also significant with a P value of 0.031. Mean X Ray time was 7.74 (1.9–33) min (Table 2). In 14 (32.56%) patients, we observed an accelerated ventricular rhythm with a high similarity with the clinical PVCs during the RF application. Common localization of the PVCs included the right ventricle only in 20 (46.51%) cases, left ventricle in 10 (22.26%) cases, and the coronary and non-coronary cusps in five (11.62%) cases. In the other eight (18.60%) cases, ablation sites were done in both ventricles or in the right or left ventricle or the aortic cusps plus venous system, and the most common sites were the LV summit (aortic cusps/left ventricle outflow tract and distal coronary sinus).

Table2. *Study results.*

Features	Total Cases	Successful	Unsuccessful	P value
Score Map	93.81%	95.91%	89.15%	0.039
Radiofrequency Time (seconds)	597.72	388.55	1122.79	0.031
X Ray Time (minutes)	7.74	5.12	8.16	NS

In this cohort, as a practical approach, we considered patients as representing cases of ablation failure when more than five PVCs per minute at 30-day follow-up were found or when more than 3% of PVCs at the 24-hour Holter monitoring at 6 and 12 months after index procedure follow-up.

Only seven (16.28%) ablations were considered unsuccessful due to the maintenance of the same PVC density duration ablation or due their return after the recovery of the anesthetic status. In these cases, most unsuccessful sites were LV solely in four (57.14%) cases (Figure 5), and LV plus RV plus cardiac veins in three (42.86%) procedures. At 30 days of follow-up, a total of 9 (20.93%) patients were seen with frequent PVCs: the same patients with intraprocedural failure accompanied by two patients with recurrence of the clinical PVCs in a RV ablation. The follow-up performed at 6 months demonstrated a maintenance in eight (18.63%) of the nine patients with clinical PVCs at one-month follow-up. Between the sixth month and at one-year follow-up, we observed a mild reduction in the patients with clinical symptomatic PVCs, and they included only six (13.95%) patients who had maintained arrhythmias (Table 3).

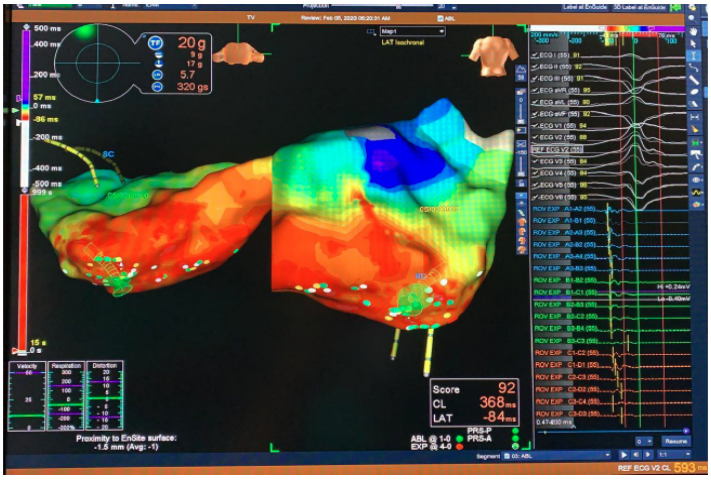

Fig5. *EnSite mapping system with a Score Map of 92 % in the left ventricle in a papillary muscle PVC ablation.*

Table3. *Study number of successful and unsuccessful cases in different evaluation periods.*

Evaluation	Success (%)	Unsuccess (%)
Procedure	36 (83.72%)	7 (16.28%)
30 days follow-up	34 (79.07%)	9 (20.93%)
6 months follow-up	35 (81.37%)	8 (18.63%)
12 months follow-up	37 (86.05%)	6 (13.95%)

In unsuccessful cases, all patients who had an SM less or equal to 92%, underwent ablation with conscious sedation, six of seven (85.71%) cases were females, PVCs were ablated at left or left plus right ventricles plus cardiac veins and RF time was more than 900 seconds as depicted in Table 4. When we considered the type of anesthetic approach as a marker of intra-procedural success, we observed conscious sedation in all five (83.33%) cases of failure at one-year follow-up and in the four (10.81%) successful cases (P = 0.002).

Table4. *Predictors of ablation failure.*

Predictors of Ablation Failure
Score Map ≤ 92
Female Gender
Left or Left + Right ventricles + Cardiac Veins
Radiofrequency Time > 900 seconds
Conscious Sedation

We conducted a secondary analysis by considering the localization of the chamber receiving the catheter ablation and its correlation with success or failure when ablation was done in LV associated or not with other chambers, RV or coronary sinus showing these characteristics as a marker of failure with a P value of 0.002. However, this was not the case when we compared LV-only ablation with other chambers as a marker of an unsuccessful procedure with a non-significant P of 0.08.

The rate of complications was low, with only one (2.33%) pericardial effusion managed with a percutaneous pericardial drainage, one pseudoaneurysm (2.33%) resolved with local doppler compression, and four (9.32%) cases of local bruises or hematomas. All these patients were subjected to left ventricle ablation.

Discussion

As the mechanism of idiopathic premature ventricular complexes is mostly triggered activity or abnormal automaticity, activation mapping is the preferred strategy to localize the site of origin and guide successful ablation; however, fluctuations in PVC burden during catheter ablation procedures is a common finding with multiple explanations, including circadian variability[21,28], emotional status, and effects related to the type of anesthesia and anesthetic drugs used. Shirai et all.[24] demonstrated a solely strategy of the mapping and ablation outcomes for patients in whom intraprocedural PVCs after conscientious sedation or general anesthesia is so low or absent that this impacts in the adequate construction of a trustful activation mapping. This exclusive approach with extensive PM-guided modules with automated morphology-matching capability with posterior ablation demonstrated PM match scores of 97% and achieved a reasonably high clinical success rate of 79% at 9 months of follow-up. Compared to these results, we observed a less efficient SM score of 93.81% but a slightly higher success rate of 86.05% at one-year follow-up, probably due to a delayed effect seen in ablation lesions healing.

Another previous study by Gerstenfeld[14] et al. demonstrated that pace-mapping with the utilization of a 12-lead ECG quantified waveform mean absolute deviation score was sensitive enough to avoid ablation at poor sites and on their manuscript septal locations was associated with less successful ablations. Two years later, Azegami et al[22] reported that pace-mapping, based on a 24-point matched score, provided similar localizing information as in activation mapping using the Carto Mapping System. In this study, although multiple best PM sites were separated by a greatest distance of 18 ± 5 mm, the probability of obtaining an exact perfect PM match was higher within 5 mm of the site of earliest activation. In 2008, Bojun et al[22], also with the Carto system, utilizing a 12-point scoring system, reported that the spatial resolution of a good pace-map in the RVOT was 1.8 cm^2, which was inferior to the spatial resolution of activation mapping as assessed by isochronal activation but still able to reliably identify the site of origin in 82% of patients. In addition, in this particular study, mapping of the LVOT was not performed, allowing for the possibility of earlier activation directly across from the septal RVOT. These two studies indicated that using PM score techniques comparable with activation maps were feasible for performing PVC ablations. Fedida et al.[28] called for paying particular attention to the capture threshold during pacing. The use of high output pacing should be avoided because this technique can result in the capture of the surrounding tissue with a potential mismatch between the paced QRS morphology and the clinical PVC. In some cases, this could be suggested by a short stimulus-to-QRS interval due to the far-field capture. In particular, the use of PM for parahisian PVCs could be less accurate owing to capture of the adjacent myocardium (large QRS) instead of the conduction system (small QRS). Therefore, the minimal capturing threshold should always be identified to avoid misinterpretation. The morphology of single-paced QRS complexes may vary depending on coupling interval; therefore, QRS morphology during pacing is affected by the pacing cycle length.

Another point that should be discussed is the challenge of PM during the procedure. There are several factors that can limit success even in labs with high volume and experience. We address some here: First, high current outputs to achieve capture is occasionally required within certain fibrous regions, such as the RV/pulmonary transition and the coronary cusps. It can result in a large virtual electrode effect with the possibility of deformation of the paced electrocardiogram and simultaneous capture of remote areas, potentially decreasing the precision of the SM. Therefore, it is crucial to gradually

decrease the output in an effort to capture individual fibers that can result in a reproducibly longer stimulus to QRS interval and a change in QRS morphology. Pace-mapping just above the capture threshold and with a coupling interval similar to the targeted PVC was performed to identify the putative site of origin. Second, as in previous reports[24,25,29], besides a good correlation, sites with the earliest activation time can be spatially distant from sites with better PM due to the presence of abnormal insulated fibers of myocardium on epicardial aspect of the fibrous walls of the valvar sinuses. Another site with these characteristics is the papillary muscles. Third, for a reasonable PM matched technique, it is imperative that the basal PVC used in the system is achieved with the ECG acquired in the EP Lab. This is our routine on cases submitted to PVC ablation because if there are no PVCs during the monitoring of patients, it is more likely to put the ECG leads on different positions, and the success of the ablation will be certainly limited because small changes in electrode location can lead to important changes in morphology[26]. Fourth, in some cases, sites of PVC origin can be intramural with distinct exit sites depending on the myofiber or myolaminar orientation, and when these occur, RF delivery at the best ablation site can alter the PVC morphology, reflecting a change in exit sites without eliminating then. In a recent study, Li et al.[27] demonstrated that significant differences in spatial resolution of PM existed within the heart. With this knowledge, when PM matched score is the option to guide ablation, an adequate number of points around the area of interest is required to obtain higher success rates. Therefore, in cases of an exclusive PM score approach, even with a high SM rate, it may be reasonable in comparison to activation map to make more extensive PM with more RF ablation lesions since the absence or even a low burden of PVCs limits the success end-point. This is our personal approach to make RF applications surrounding the best site of SM safer unless there is close proximity to important structures, such as the proximal conduction system and epicardial coronary arteries: locations that might require high precision to avoid collateral damage. Lastly, caution is warranted when relying on quantitative PM automated algorithms. Despite technological improvements, ECG matching programs are imperfect and programable according to the discretion of the physician and/or the technician, and as electrophysiologists, we cannot forget to make visual comparisons on the EP recording systems.

Study Limitations

Our study had several limitations. First, it had a small sample size, and it was retrospective and single center in design. Second, since there were several differences regarding the type of mapping used by the various catheter operators. Pace mapping techniques and ablation approaches were allowed to be modified at the discretion of operator even with a prespecified protocol approach standardized at our institutions. Since the follow-up was made with ECG monitoring for 5–10 min at 30 days and with only 24-hour Holter monitoring at 6 and 12 months, a more prolonged rhythm monitoring could demonstrate different results.

Conclusion

SM™ is useful as an exclusive technique for ablation of premature ventricular complexes with very good acute success and low complications, and an SM higher than 92% had high long-term success rates. Failure was related to conscious sedation, female gender, both side ventricle associated with cardiac veins ablation, and longer RF time exceeding 900s.

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Citation: **Fabricio Vassallo, Edevaldo da Silva, Eduardo Serpa, Rafael Zeni, et.al.** *Catheter Ablation of Premature Ventricular Complexes Exclusively by A 3D Electroanatomic Pace-Mapping Software Technique: Long-Term Follow-Up. Archives of Cardiology and Cardiovascular Diseases. 2020; 3(2): 17-25*