New technical and clinical aspects in the management of radiofrequency catheter ablation of frequent premature ventricular contractions

PH.D. thesis

Author: Csaba Herczku, MD

Project leader: Prof. Kálmán Tóth, MD, DSc

1st Department of Medicine

University of Pécs, Medical School

Tutors: Antonio Berruezo, MD, PhD

Cardiology Department, Thorax Institute, Hospital Clinic, Barcelona

and

Zoltán Csanádi, MD, PhD

Institute of Cardiology, University of Debrecen

2014

I. New mapping data predictors of a left ventricular outflow tract origin of idiopathic ventricular arrhythmias

I.1. Introduction

Radiofrequency catheter ablation (RFCA) was introduced in the early 1990's for the definitve treatment of idiopathic right ventricular (RV) and left ventricular (LV) outflow tract (OT) ventricular arrhythmias (VA) with high success and low complication rate. The technical aspects, difficulties and risk of RFCA significantly differ depending on the arrhythmia focus therefore several ECG algorithms have been developed to determine the site of origin (SOO). However, the close proximity of the OTs, the presence of ECG abnormalities and cardiomyopathy frequently result in an overlap in surface ECG features. In addition, intracardiac electrogram (EG) precocity, which is basically used for mapping the arrhythmia focus, varies greatly, showing an overlap between successful and unsuccessful RFCA sites. Based on the surface ECG analysis, when the transition in the precordial leads occurs in V3 and during intracardiac mapping the maximum EG precocity is located in the septal RVOT, there are no reliable criteria to predict RV versus LV origin. This circumstance may result in extensive, unsuccessful, and unnecessary radiofrequency (RF) applications which could be unnecessary if we had a right ventricular mapping parameter, what predicts the SOO accurately.

I.2. Aims and the corresponding electrophysiological considerations

The aim of the recent work was to find new mapping data predictors of a LV origin in OT VAs. We hypothesized that data derived from the isochronal map area measurement and analyses during electroanatomical mapping could provide new predictors to reduce mapping requirements and unnecessary RF applications in OT VAs with V3 transition

and septal earliest activation. It has also been suggested that mapping the distal coronary sinus (CS) could help in identifying the actual SOO.

I.3. Methods

I.3.1. Patient characteristics

From a series of 38 consecutive patients submitted for OT VA ablation, the subgroup meeting the following two criteria (n=15) was selected: 1) a transition of QRS complex during premature ventricular complex (PVC) in the precordial lead V3 and 2) the earliest EG during activation mapping being located septally in the RVOT. Patients with baseline ECG abnormalities or structural heart disease (except arrhythmogenic RV cardiomyopathy) were not excluded from the study.

I.3.2. Electrophysiologic study

The CARTO (Biosense Webster, Diamond Bar, CA, USA) electroanatomic mapping system was used to guide ablation in all cases. The 12 surface ECG leads and intracardiac EGs were recorded by EP tracer (CardioTek, Maastricht, The Netherlands) or Bard Labsystem (CR Bard Inc., Lowell, MA, USA).

I.3.3. Mapping and ablation

A bipolar endocardial activation map was sequentially taken during either PVC or VT in the RVOT, the distal portion of the CS, the LVOT and in the epicardium in one case. The minimum density of points required to consider whether the electroanatomic map of a given chamber was acceptable was defined as a fill threshold of 15 mm. Radiofrequency was delivered at the earliest activated site after careful mapping of all the structures.

I.3.4. Data collection

ECG data known to differentiate between RVOT and LVOT SOO, the R-wave duration index and R/S wave ratio in leads V1 and V2, the V2 transition ratio, and the PVC transition occurring earlier/later than during sinus rhythm, were collected for analysis. (Figure 1)

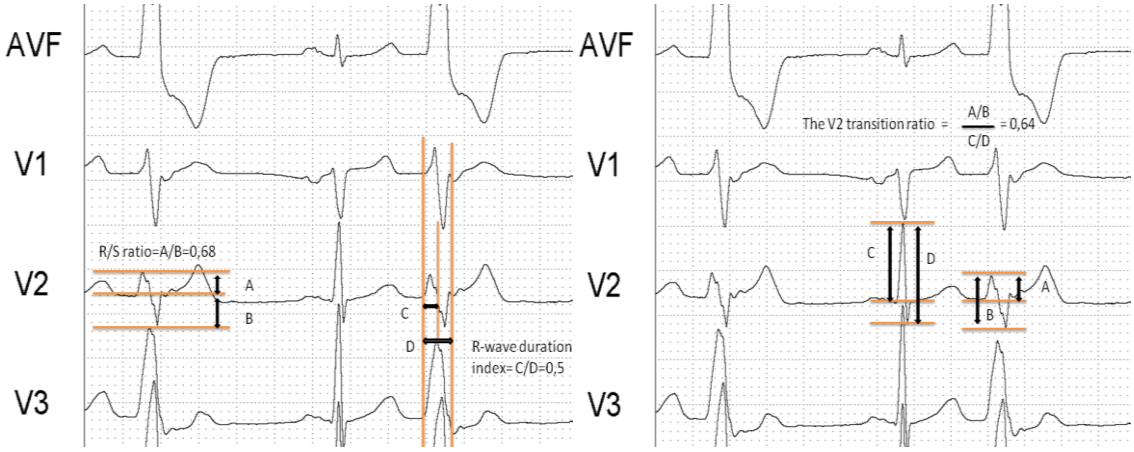

Figure 1. Illustration of the ECG measurements Left: the R/S ratio and R-wave duration index. If the R/S ratio ≥ 30 % or the R-wave duration index ≥ 50 % in V1 or in V2 then the focus is on the left side.Right: The V2 transition ratio for the prediction of the SOO. If the calculated ratio ≥ 0,6 then the predicted SOO is in the LVOT as in this case.

The earliest activation time was used to decide the RF application location, after comparing data from the different structures. To obtain reproducible results, the minimum fill threshold value required to fully fill the RV 10 ms isochronal map was measured. The spread of activation was characterized by defining the longitudinal and perpendicular diameters of the isochronal areas relative to the RVOT axis (Figure 2). A new variable, the ratio between the longitudinal and perpendicular RV 10 and 20 ms isochronal map area diameters, was created to characterize the shape area.

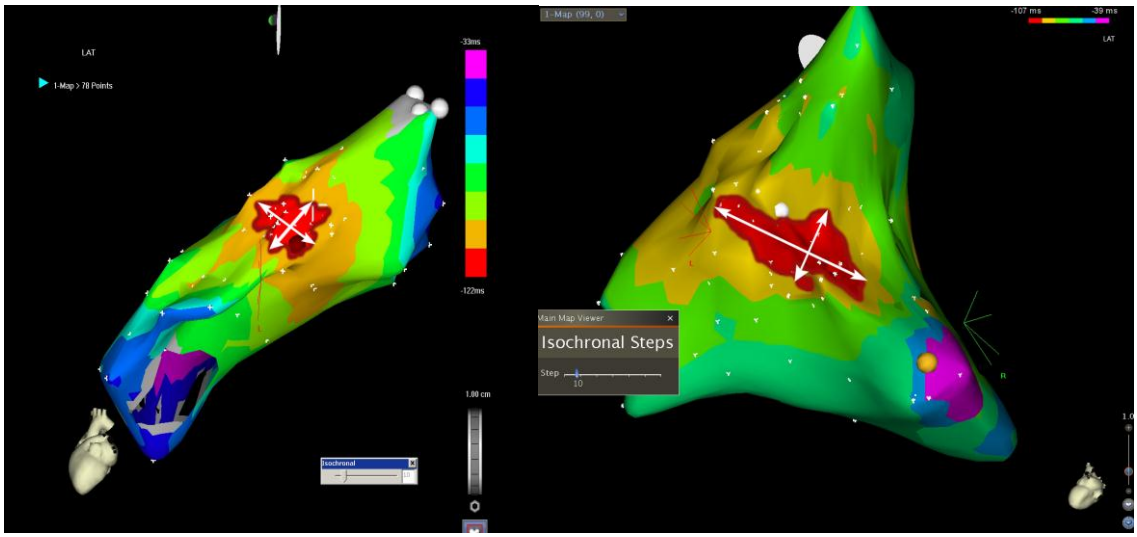

Figure 2. The typical 10-ms isochronal (dark) area in the right ventricular outflow tract in patients with a ventricular arrhythmia originated in the RVOT (left) and the left ventricular outflow tract (right). Note the elliptic form with a shorter longitudinal and longer perpendicular diameter in the case of LVOT site of origin. The arrows define the longitudinal and perpendicular axis diameters of the ellipse.

I.3.5. Statistical analysis

Data are reported as median and interquartile range (IQR). The comparison between populations was performed with Mann-Whitney U test. Proportions were compared with Fisher exact test. We used the likelihood ratio (LR +), defined as Sensitivity/(1-Specificity), to evaluate the optimal cut-off value for predicting a left-sided arrhythmia in our sample. A *P*-value of ≤0.05 was considered statistically significant.

I.4. Results

I.4.1 Patient Population

These patients represent 39.5% of a series of 38 consecutive patients submitted for ablation. Ablation was successful in all these 15 patients, 7 of them in the LVOT and 8 in the RVOT. There was no significant difference between the two groups in the baseline characteristics

I.4.2. Surface ECG and RVOT Mapping Data

Differences between the surface ECG variables were analyzed depending on the SOO. Significant differences were only found for the R wave duration ratio in V2 during PVC, being higher in the case of LVOT SOO (0.31 (0.22-0.41) vs. 0.47 (0.39-0.5); P=0.037). (Table 1)

Table 1. The results of ECG data analysis.depending on the SOO (expressed as median and IQR (U Mann-Whitney test) or absolute frequencies with percentages (Fisher exact test).

	RVOT (n=8)	**LVOT (n=7)**	***P* value**
Electrocardiographic parameters depending on the site of origin			
QRS width in sinus rhythm (ms)	89 [75-108]	108 [87-142]	0.13
QRS width during PVC (ms)	151 [135-155]	148 [141-159]	0.73
Presence of baseline LBBB, n (%)	0 (0)	3 (43)	0.077
R wave duration ratio V1 PVC	0.36 [0.19-0.43]	0.4 [0.31-0.44]	0.8
R wave duration ratio V2 PVC	0.31 [0.22-0.41]	0.47 [0.39-0.5]	0.037
R/S ratio V1 PVC	0.17 [0.12-0.23]	0.35 [0.19-0.43]	0.16
R/S ratio V2 PVC	0.22 [0.10-0.29]	0.37 [0.27-0.47]	0.16
PVC R/S transition later than in SR, n (%)	3 (37)	1(14)	0.56
V2 transition ratio	0.51 [0.37-2.99]	0.87 [0.28-5.8]	0.49

The electroanatomic map analysis demonstrated that the 10 ms isochronal map area in the RVOT was significantly smaller in the RVOT than in the LVOT SOO group (1.2

[0.4-2.1] vs. 3.4 [2.4-3.9] cm^2 respectively; P=0.004). A cut-off value of >2.3 cm^2 was able to predict a LVOT SOO with 85.7 % sensitivity and 87.5 % specificity (Figure 3 left). The shape of the 10 ms isochrone area also differed depending on the SOO. While the longitudinal diameter did not differ significantly depending on the RVOT vs LVOT SOO (12 mm [8-16] vs. 14 mm [12-16]; P=0.9), the perpendicular diameter was significantly greater in the LVOT group (13 mm [7-17] vs. 28 mm [20-29]; P=0.001), explaining the differences in the 10 ms isochronal map areas.

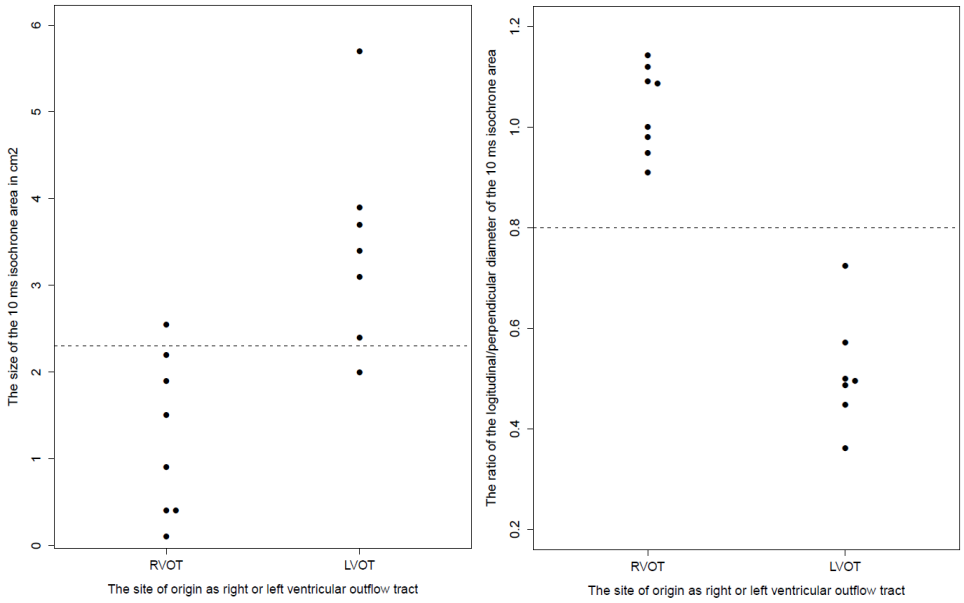

Figure 3. Left: The 10 ms isochronal map area differed significantly between the different sites of origin with an overlap, which results in low sensitivity and specificity when defining a cut-off value (horizontal line at 2.3 cm^2). Right: The ratio of the longitudinal / perpendicular diameter of the 10 ms isochrone area differed significantly between the two groups, without overlapping. A cut-off value of 0.8 (horizontal line) separated all values from the two groups.

The longitudinal to perpendicular diameter ratio was significantly smaller in the LVOT SOO (1.04 [0.95-1.11] vs 0.49 [0.44-0.57]; P=0.001). The differences between groups were smaller when the 20 ms isochronal map area was analyzed, but still statistically significant for the isochronal map area (8.3 (4.3-12.1) vs. 14 (7.5-23) cm^2; P=0.045), the perpendicular diameter (35 (21-41] vs. 45 (41-50) mm; P=0.024) and the longitudinal to

perpendicular diameter ratio (0.96 (0.92-1.05) vs. 0.75 (0.7-0.85); P=0.005). The minimal fill threshold value, which indicates the mapping density of the area of interest did not differ significantly and the median value of this parameter in the 10 ms early activated area was 6 (4-9) mm. The sensitivity and specificity of the ECG variables and mapping data for the VAs with a V3 transition and septal earliest activation is shown in Table 2. A cut-off value of the longitudinal to perpendicular diameter ration <0.8 predicted a LVOT SOO with 100% specificity and 100% sensitivity (Figure 3 right).

Table 2. The sensitivity and specificity of different criteria to predict a left sided origin of outflow tract ventricular arrhythmias with a V3 transition.

	Sensitivity ***(%)***	Specificity ***(%)***
R wave duration index > 50 % or R/S ratio > 30 % in V1 or V2	71.5 **(29.0-96.3)**	62.5 **(24.5-91.5)**
The V2 transition ratio	57 **(18.4-90.1)**	62 **(24.5-91.5)**
The 10 ms isochronal map area >2.3 cm^2	87.5 **(42.1-99.6)**	85.7 **(47.3-99.7)**
Longitudinal/perpendicular axis ratio <0.8 ***of the 10 ms isochronal map area***	100 **(47.3-100)**	100 **(51.8-100)**

I.4.3. Coronary Sinus Mapping

The usefulness of CS mapping to distinguish between the RVOT and LVOT SOO was evaluated by comparing the measured precocity between the distal CS and the RVOT in both groups of patients. In the RVOT group all patients had a higher precocity in the septal RVOT than in the distal CS. In the LVOT group an earlier distal CS activation was found in 28% (n=2), while 72% (n=5) of them had a higher precocity in the septal RVOT. In all cases in the LVOT group, in which the higher precocity was found in the septal RVOT, the SOO was located in the right sinus of Valsalva.

I.5. Discussion

The main finding of the study is that intracardiac mapping data can predict the LVOT versus RVOT SOO with a very high sensitivity and specificity in the population of patients with a V3 transition and septal earliest activation.

I.5.1. Surface ECG

A recent study showed that the "V2 transition ratio" could be used to predict the RVOT versus LVOT SOO in patients with V3 transition. This parameter has been tested in the present study; however, sensitivity and specificity were lower than previously published in this specific subgroup of patients (Table 2)

I.5.2. Mapping Data

As expected, because of the close anatomical SOO of the two groups in the present series (72% of the LVOT VAs originated from the right sinus of Valsalva), intracardiac EG precocity in the RVOT showed a big overlap between the two groups. Therefore, absolute precocity in the RVOT is not helpful in deciding the right place for RF application in a case of a V3 transition.

The distal CS mapping was not found to be useful to predict the SOO of OT VTs with a V3 transition and a septal earliest activation presumably because only a small proportion of patients (n=1, 14%) had a left sinus of Valsalva SOO in the present study.

To our knowledge no previous study has described the characteristic RVOT activation pattern that predicts a left-sided origin of OT VAs. In the case of a RVOT SOO, the 10 ms isochronal map area in the RVOT was 1.2 [0.4-2.1] cm2. This area was significantly greater in cases with LVOT origin (3.4 [2.4-3.9] cm^2), although with a small overlap between groups (mapping was performed without the use of isoproterenol).

The shape of the 10 ms isochrone area is dependent on the chamber geometry and the myocardial fiber orientation, as the velocity of impulse propagation is higher in the longitudinal direction. The myocardial fiber orientation in the RV is circumferential and parallel to the atrioventricular groove in the subepicardial region, while there are longitudinally aligned myocardial fibers in the endocardial surface. In the present study we have found a characteristic activation pattern in the subendocardial RVOT that significantly differs depending on the SOO . If the SOO is located in the LVOT then the shape of activation shows an elliptic pattern with the long axis perpendicular to the OT axis orientation and parallel to the subepicardial fiber orientation. In the case of a septal RVOT SOO, the 10 ms icochronal map has a rounded shape.

Finally, in order to make these results reproducible and clinically applicable, the minimum fill threshold to fully fill the 10 ms isochronal area in the septal RVOT should be set up as ≤10 mm, according to the measured values in our study (median 6 (4 to 9)).

I.5.3. Study limitations

The retrospective nature of the study and the small sample population are the main limitations and thus the value of the described criteria should be evaluated in a prospective study.

I.6. Conclusions

A different activation pattern in the RVOT 10 ms isochronal maps exists in OT VTs with a V3 transition and a septal earliest activation, depending on the RVOT versus LVOT SOO. This information can be used to predict the SOO of OT VTs with a high accuracy, thereby avoiding extensive RVOT ablation or unnecessary CS or LVOT mapping.

II. The impact of RFCA of frequent PVC on left ventricular systolic function in patients with cardiac resynchronization therapy

II.1. Introduction

Cardiac resynchronization pacemaker therapy (CRT) has evolved as a highly successful treatment modality in congestive heart failure associated with an intra- and/or interventricular conduction delay. However, a certain subgroup of patients exhibits only a minimal or no response after a technically successful implantation procedure. The deteriorating effect of frequent PVC for the LV systolic function was known before our study, although it was mainly investigated in patients without organic heart disease where the arrhythmia was responsible for the diminished LV systolic function. It was also known that PVCs frequently occur in patients with organic heart disease, and especially in those with poor left ventricular function. Somewhat surprisingly, we have found no publication before our case in which the underlying mechanism of a nonresponse to resynchronization therapy was attributed to frequent PVCs. We reported the first case in which we ascribed the lack of a response to CRT to frequent PVCs, where a marked improvement was achieved by transcatheter elimination of the arrhythmia.

II.2. RFCA of PVC improved the left ventricular function in a nonresponder to cardiac resynchronization therapy, the first clinical description

II.2.1 Case report

A 57-year-old male with nonischemic dilated cardiomyopathy with an impaired systolic function and moderate mitral regurgitation was referred for CRT. He was in a status of NYHA III heart failure and was on optimal medical therapy. The 12-lead ECG showed a left bundle branch block with a QRS width of 140 msec. Frequent ventricular ectopy

(15% of all beats) and runs of nonsustained ventricular tachycardia were documented on 24-hour ambulatory monitoring. An Insync III CRT pacemaker (Medtronic Inc., Minneapolis, Minnesota) was implanted, with the left ventricular lead positioned in a posterior branch of the CS. The QRS width was reduced to 120 msec after the implantation. During the following 6 months, the clinical status of the patient did not improve; in fact, he was hospitalized for acute heart failure on 5 occasions. Frequent monomorphic PVCs were still present in the 12-lead ECG recordings and also evidenced by the 20 % rate of ventricular sensed beats in the device log. The echocardiographic parameters indicated no significant change except for a worsening of the mitral regurgitation. A decision was made to attempt the RFCA of the monomorphic PVCs, guided by CARTO electroanatomical mapping system (CARTO™, Biosense Webster, Diamond Bar, CA) and the arrhythmia was eliminated. The focus of the PVCs was localized to the postero-inferior left ventricle. A marked clinical improvement was observed within a few weeks post-RFCA: the functional class decreased to NYHA I, with no need for hospitalization during the following 6 months, and the dose of oral diuretics was reduced. Interrogation of the device log revealed that the sensed ventricular event rate had fallen to less than 4%. Improvements were also evident on echocardiography.

II.2.2.Clinical considerations

In most of the reports of PVC-induced tachycardiomyopathy, the extrasystoles originated from the RVOT and the LV dysfunction thought to be the consequence of asynchronous ventricular activation, similar to that often due to a left bundle branch block. In our patient, however, the PVCs originated from the left ventricle. One explanation for this phenomenon could be the truncation of the diastole by the premature beats, leading to insufficient ventricular filling. Another possibility is that the

frequent PVCs eliminated the beneficial effect of the CRT. The resolution of the tachycardia-mediated cardiomyopathy, the more effective resynchronization therapy and the increase in the proportion of paced beats might all contribute to the positive changes observed after effective arrhythmia control had been achieved.

II.3. Further investigations

On the basis of the previous finding, we have made a screening in our center among patients with CRT. 125 consecutive patients were screened after technically successful CRT device implantation (ejection fraction (EF) 26±5 %, 91 male (73%), 34 female (27 %), 50 CRT-D (40%), 75 CRT-P (60%), 38 ischemic (30 %), 87 non ischemic (70%) dilated cardiomyopathy). These patients were followed up for at least 12 months. LV function, functional class and frequency of PVC based on the ratio of ventricular sensed beats in holter memory of the device were evaluated after the implantation and every 3 months. PVCs were considered frequent if their rate exceeded 10 % of all ventricular beats. Elimination of frequent PVC was attempted if the patient was a "non-responder" to CRT after at least 6 months. Frequent PVC were found after the implantation at predischarge in 10 out of 125 patients (8%). Gradual decrease of PVC frequency along with improving LV function and functional status was observed in 4 patients after CRT. A responder with no symptoms had no specific treatment of the arrhythmia. In 5 non-responders, the arrhythmia was successfully eliminated (or significantly reduced) by radiofrequency ablation (in 2 patients), amiodarone (in 2 patients) or ablation and programming of the device to a higher basic rate (in 1 patient). The elimination or significant reduction of frequent PVC resulted in significant improvement of LV function (EF before treatment: 21±5 % after treatment: 34±7 % p: 0,003) and functional class in all (NYHA before treatment: 3,2±0,4 after treatment: 1,6±0,5 p:0,002) (Table

3). This study confirmed our finding in our case report and a proper control of frequent PVC became a routine management for our CRT patients.

Table 3. Echocardiographic and clinical data before and after RFCA or amiodarone treatment of PVC in patient with frequent PVC and non response to CRT

n	Treatment (Tx)	LV EF after CRT (%)	LV EF before PVC Tx (%)	LV EF after PVC Tx (%)	PVC ratio before Tx	PVC ratio after Tx	NYHA before Tx	NYHA after Tx
1	Ablation	20	16	38	20	3	IV	II
2	Ablation	22	30	48	25	1	III	II
3	Ablation + programming	20	20	30	50	15	IV	II
4	Amiodarone	23	20	33	13	<1	III	I
5	Amiodarone	23	20	33	20	<1	III	II

II.4. Discussion

Although the presence of frequent PVC in structural heart disease and heart failure is well known in clinical practice and the patient population amenable for CRT belongs to this cohort, the beneficial effect of RFCA of frequent PVC for the response for CRT was not investigated before our reports. In our follow up study the prevalence of frequent PVC in the whole CRT population using a cut off value of 10% for significant PVC burden was 8% even though 50% of these patients became responder for CRT and thus did not require further therapy according to our protocol. The treatment of the remaining patients (4% of the whole study group) was successful either conservatively or with RFCA and these patients became responder after the elimination or significant reduction

of frequent PVC. Lakkireddy et al. verified the beneficial effect of RFCA of frequent PVC in a large group (2034) of CRT patients in a prospective multicentric study using a cut off value of > 10,000 PVC in a 24-hour period for the definition of frequent PVC. In their patients group the prevalence of non-responders with frequent PVC was 3,2%, which is comparable with our results (4%). It was demonstrated in their study that the beneficial effect of frequent PVC ablation was based on the more effective CRT function rather than the deteriorating effect of the PVC. Other studies demonstrated that the abolishment of frequent PVC alone has enough beneficial effect to improve the LV systolic function in patients without CRT which, in our opinion, may raise the question of RFCA of frequent PVC even before the CRT. As a summary, a proper screening for frequent especially monomorphic PVC amenable for ablation seems to be mandatory in this patient population either before or after CRT implantation.

II.5. Conclusion

The presence of frequent PVC in the CRT population is one of the possible reasons for the non response for this therapy. A thorough investigation for the presence of frequent PVC is mandatory in case of a low biventricular stimulation rate in those of non-responders since RFCA of the arrhythmia may render these patients to responder.

IV: New observations

Our investigations on frequent PVCs in different patients groups and clinical circumstances resulted in new technical and clinical considerations in the management of radiofrequency catheter ablation of this arrhythmia.

IV.1. Our work was the first which delineated the characteristic RVOT activation pattern that predicts a left-sided origin of OT VAs with V3 transition and septal earliest activation. A new variable, the ratio between the longitudinal and perpendicular diameters on the early activated (10 msec isochrone) area was created to achieve this.

IV2. The differences and predictive value of the size of the early activated area in the RVOT to differentiate between LVOT and RVOT VAs in this patient group was first described in our study.

IV.3. However it is routinely used in clinical practice our study demonstrated that coronary sinus mapping does not help to differentiate the SOO in VAs with V3 transition and septal earliest activation

IV.4. Our observation and investigation was the first which proved that the elimination of frequent PVC may render a CRT non-responder patient into responder and called the attention for routine screening of frequent PVCs during CRT follow up.

V. Acknowledgements

I would like to express my thanks to my project leader, Professor Kálmán Tóth for the encouragement, practical advice and help that he provided me to make a synthesis of my works. The recent study was partly performed in the Arrhythmia Section of the Cardiology Department in the Thorax Institute, Hospital Clinic, Barcelona and partly in the Institute of Cardiology at the University of Debrecen. I would like to express my gratitude to my tutors, Antonio Berruezo and Zoltán Csanádi for their fantastic ideas, support and guidance.

VI. List of the author's publications

The thesis is based on the following papers and abstract

Publications

Herczku C, Berruezo A, Andreu D, Fernández-Armenta J, Mont L, Borràs R, Arbelo E, Tolosana JM, Trucco E, Ríos J, Brugada J. Mapping data predictors of a left ventricular outflow tract origin of idiopathic ventricular tachycardia with V3 transition and septal earliest activation. Circ Arrhythm Electrophysiol. 2012; 5(3):484-91. IF: 6.462

Herczku C, Kun C, Edes I, Csanadi Z. Radiofrequency catheter ablation of premature ventricular complexes improved left ventricular function in a non-responder to cardiac resynchronization therapy. Europace. 2007; 9(5):285-8. IF: 1.376

Herczku Cs., Tóth K.: Kifolyótraktus eredetű kamrai ritmuszavarok diagnosztikája és kezelése mai szemmel (Current concepts in the diagnosis and treatment of outflow tract ventri-cular arrhythmias) Card Hung 2014; 44:34-8

Citable abstract (congress poster)

C. Herczku, C. Kun, M. Clemens, I. Edes, Z. Csanadi Clinical significance of frequent

ventricular premature beats after cardiac resynchronization therapy Eur J Heart Fail.Volume 7, Issue S1, June 2008, Page: 184

Other thesis related publication with co-authorship

Andreu D, Berruezo A, Fernández-Armenta J, Herczku C, Borràs R, Ortiz-Pérez JT, Mont L, Brugada J. Displacement of the target ablation site and ventricles during premature ventricular contractions: relevance for radiofrequency catheter ablation. Heart Rhythm. 2012; 9(7):1050-7. IF: 4.102

Other publications

1. Clemens M, Herczku C, Kun C, Edes I, Csanádi Z. Reduction in ventricular pacing after AV node modification in a patient with dual-chamber pacemaker: what is the mechanism? J Cardiovasc Electrophysiol. 2008; 19(10):1116-7. IF: 3.798

2. Szomják E, Dér H, Kerekes G, Veres K, Tóth J, Olvasztó S, Herczku C, Soltész P. Multiplex obliteratív érbetegség: Kihívás a diagnosztikában és a kezelésben [Multiple obliterative vascular disease. Challenge in diagnosis and in treatment]. Orv Hetil. 2008; 149(45):2135-40.

3.Clemens M, Nagy-Baló E, Herczku Cs, Karányi Zs, Édes I, Csanádi Z Correlation of body mass index and responder status in heart failure patients after cardiac resynchronization therapy : does the obesity paradox exist? Intervent Med Appl Sci 2010; 2(1):17-2.

4. Herczku C, Clemens M, Edes I, Csanadi Z. Pacemaker-mediated tachycardia over the upper rate limit in a biventricular pacemaker system: what is the mechanism? Pacing Clin Electrophysiol. 2010; 33(11):1421-4. IF:1.353

5. Tóth Z, Nagy-Baló E, Kertész A, Clemens M, Herczku C, Tint D, Kun C, Edes I, Csanádi Z. Pitvarfibrilláció kezelése a pulmonalis vénák krioballon izolációjával: Középtávú eredmények az első 55 beteg alapján [Cryoballon isolation of the pulmonary veins in atrial fibrillation: mid-term results after the first 55 patients]. Orv Hetil. 2010; 151(5):163-71.

6. Clemens M, Nagy-Baló E, Herczku C, Kun C, Edes I, Csanádi Z. Long-term arrhythmia variability after monomorphic ventricular tachycardia in patients with an implantable cardioverter defibrillator. Pacing Clin Electrophysiol. 2011; 34(10):1185-91. IF: 1.351

7. Berruezo A, Fernández-Armenta J, Mont L, Zeljko H, Andreu D, Herczku C, Boussy T, Tolosana JM, Arbelo E, Brugada J. Combined endocardial and epicardial catheter ablation in arrhythmogenic right ventricular dysplasia incorporating scar dechanneling technique. Circ Arrhythm Electrophysiol. 2012; 5(1):111-21. IF: 6.462

8. Fernández-Armenta J, Berruezo A, Ortiz-Pérez JT, Mont L, Andreu D, Herczku C, Boussy T, Brugada J. Improving safety of epicardial ventricular tachycardia ablation using the scar dechanneling technique and the integration of anatomy, scar components, and coronary arteries into the navigation system. Circulation. 2012; 125(11):e466-8. IF:14.739

Citable abstracts (congress posters)

1.Cs Kun, Cs Herczku, A Peter, I Hegedus, I Lorincz, I Édes, Z Csanádi Effects of biventricular pacing on ECG markers of ventricular repolarization Europace 2006; 8(Suppl. 1): 20PW/6

2.C Herczku, C. Kun, M. Clemens, A. Peter, I. Hegedus, I. Edes, Z. Csanadi Examination for empiric interventricular delay optimization in cardiac

resynchronization therapy Eur J Echocardiogr. 2007; 8(Suppl.1):(S70)504

3.C Herczku, C. Kun, M. Clemens, A. Peter, I. Hegedus, I. Edes, Z. Csanadi Patient selection for interventricular delay optimization in cardiac resynchronization therapy Eur J Echocardiogr. 2007; 8(Suppl.1):(S68)498

4.Clemens M, Nagy-Balo E, Herczku C, Kun C, Edes I, Csanadi Z Predictive Value of the Index Arrhythmia In Long Term Programming of Implantable Cardioverter Defibrillators. Circulation 2008; 118:(18) S673

5.Csaba Kun, Csaba Herczku, Marcell Clemens, Istvan Lorincz, Istvan Edes, Zoltan Csanadi Effect of biventricular pacing on dispersion of ventricular repolarization Europace 2008; 10 (Suppl. 1):75L-1

6.M Clemens, E Nagy-Balo, C Herczku, C Kun, Z Toth, I Edes, Z Csanadi Correlation of body mass index and responder status in heart failure patients after cardiac resynchronization therapy: Does obesity paradox exists? Europace 2009; 11(Suppl. 2), Abstract 1004

7.Marcell Clemens, Orsolya Bene, Zsuzsa Toth, Csaba Herczku, Attila Kertesz, Istvan Edes, Zoltan Csanadi Diastolic Dysfunction may Cause Heart Failure Symptoms in Patients Hyperresponder to Cardiac Resynchronization Therapy Circulation.2010; 122: A20284

8.D. Andreu, A. Berruezo, J. Fernandez-Armenta, C. Herczku, R. Borrás, J.T. Ortiz, L. Mont, J. Brugada: Displacement of the target ablation site and ventricles during premature ventricular contractions: Relevance for ventricular tachycardia ablation. Europace 2012; 14(Suppl. 1.):63_L5