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A Simplified Criterion of Successful Radiofrequency Ablation of the Cavo-Tricuspid Isthmus

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Abstract
Background: Radiofrequency ablation (RFA) of the cavo-tricuspid isthmus (CTI) is one of the most frequently performed procedures in electrophysiology. Cavotricuspidisthmus (CTI) ablation is the treatment of choice in preventing recurrences of typical atrial flutter (AFl). Bidirectional isthmus block is a criterion of successful ablation and is associated with the presence of different activation times on each side of the ablation line. Objective: The aim of this study was to determine a novel parameter clarify to improve a success rate in ablation of the CTI. Population and methods: We studied 35 patients with typical atrial flutter (60% male, mean age 48,5 +/- 10 years) who underwent successful ablation during tachycardia. The heart rhythm was sinus in 11% of patients and atrial flutter in 83% before the procedure. Electrophysiology mapping was used to confirm diagnosis of isthmus-dependent atrial flutter, electroanatomic position guide the ablation line creation and assess its efficacy. Before and after CTI ablation, activation times were measured on the low lateral right atrium under pacing from the proximal coronary sinus ostium (with a 600 ms cycle), on the proximal sinus coronary ostium under pacing from the low lateral right atrium. Results: Mean activation time between proximal sinus coronary ostium and atrial bipolar electrogram (SC-RA) enregistred from coronary sinus to low-lateral right atrium in sinus rhythm or in atrial flutter before the creation of the CTI block ablation were 103,7 ± 30,6 ms and. After the creation of the CTI block ablation, Mean activation times were 148,15±24,6 ms at low-lateral right atrium (LLRA)underpacing proximal sinus coronary ostium (PSCO) (PSCO -> LLRA) (P<0,001; r=0,54) and 143, 89± 30,36 ms at proximal sinus coronary ostium under pacing low-lateral right atrium to (LLRA -> PSCO) (P<0,001; r=0,62). The linear regression equation that best described this result was: LLRA -> PSCO = 0,581 * SC-RA + 83,540; PSCO -> LLRA = 0,437 * SC-RA + 102,863. Conclusion: After atrial flutter ablation, the activation time between proximal sinus coronary ostium and atrial bipolar electrogram enregistred at the low-lateral right atrium during atrial flutter or in the sinus rhythm of more than half this time before ablation plus 100 ms was associated with isthmus conduction block. This time criteria is very simplified criteria, make it easy to use in the routine ablation compared to others algorithm. This should however be confirmed before the end of the procedure through demonstration of bidirectional isthmus block.

1. Introduction

Typical atrial flutter (AFl) is characterized by a macroreentry circuit around the tricuspid annulus; this circuit contains a propagating wave and an excitable gap. The anterior barrier of the activation wave is formed by the tricuspid annulus, while the posterior barrier is formed by the crista terminalis, the eustaquian ridge and its prolongation, the eustaquian valve.(1)

Radiofrequency ablation (RFA) of the cavo-tricuspid isthmus (CTI) is one of the most frequently performed procedures in electrophysiology. Cavotricuspidisthmus (CTI) ablation is the treatment of choice in preventing recurrences of typical atrial flutter (AFl).A successful AFL ablation is achieved by creating a linear lesion with bidirectional conduction block in the cavotricuspidisthmus (CTI). The central part of the CTI (central CTI) is a reasonable site for creating the linear lesion, because it has a shorter length and thinner myocardium.(2)

Despite a high success rate, ablation of the CTI can be unusually difficult in some cases. A complete, bidirectional conduction block in the cavotricuspid isthmus (CTI) represents the end-point of the typical atrial flutter ablation.(3)

The aim of this study was to determine whether the time between proximal sinus coronary ostium and atrial bipolar electrogram enregistred at the low-lateral right atrium before ablation of the CTI during atrial flutter or in the sinus rhythm predicted the successful time between low-lateral right atrium and sinus coronary ostium and how calculated it. This criterion was very simplified criteria, make it easy to use compared to others algorithm.

2. Material and Methods

We conducted a prospective study in consecutive patients with ECG-documented flutter were undergoing ablation who underwent a first atrial flutter ablation during July 2009 - April 2014 in the Cardiology Departement at Abderrahmane mami Hospital.

Our study is a prospective analysis of collected data, which consisted of patients with symptomatic Atrial flutter. Exclusion criteria were patients who were mentally unstable; who had alcoholism, myocardial infarction within 1 month of the study, terminal disease, or left atrial (LA) thrombus, non CVI flutter; who could not commit to participate in scheduled outpatient follow-up. All patients signed informed consent.

All the procedures were performed using a previously described atrial flutter ablation technique(4). A 4-pole mapping catheter (St. Jude Medical) was positioned in the coronary sinus (CS), A 10-pole mapping catheter (St. Jude Medical) was situated at the lateral wall of the right atrium. A deflectable 7F catheter with an 8 mm tip electrode, (St. Jude Medical) was used as mapping and ablation catheter. In some cases when necessitated an irrigated-tip ablation catheter was used secondly. Therefore, AFL ablation targets the central CTI, which is speculated to be at a 6 o'clock position on left anterior oblique (LAO) view. The linear lesion for successful AFL ablation, however, varies from a 5 to 7 o'clock position on LAO view.(5) The RF energy was delivered by an IBI RF-Generator, using 60°C as cut-off temperature and a power of maximum 65 W. Consecutive 60-s radiofrequency lesions were applied to the CTI, from the tricuspid valve to inferior vena cava, with no catheter movement permitted during radiofrequency (RF) delivery. The ablation endpoint was durable CTI block at 20 min post-ablation.

The assessment of bidirectional CTI block was performed at the end of the procedure using the standard criteria (3), using the differential pacing criterion and the reversal in the right atrial depolarization sequence during CS pacing criterion. The conduction at the level of the CTI was evaluated immediately after conversion to sinus rhythm in the cases where ablation was carried out in atrial flutter or before the start of the ablation in the cases where the procedure was carried out in sinus rhythm. Pacing and recordings were performed in end points of the right atrium. We assessed the presence of a bidirectional block at the end of the procedure using the standard criteria(3). We then analyzed the time between the bipolar atrial electrograms situated in low-lateral right atrium from proximal coronary sinus ostium when stimulation was carried out from the proximal coronary sinus, or from the low-lateral right atrium before and after line ablation validated by CTI conduction block. If the patient was in flutter, the cycle of flutter was measured and the time of atrial depolarized conduction between low-lateral right atrium and proximal coronary sinus ostium.

We then analyzed the mean activation time between proximal sinus coronary ostium and atrial bipolar electrogram (SC-RA) enregistred from coronary sinus to low-lateral right atrium before the creation of the CTI block ablation in sinus rhythm or in atrial flutter using the direction af atrial deplorization. Mean activation times were meseared after CTI block ablation at low-lateral right atrium (LLRA) under pacing proximal sinus coronary ostium (PSCO) (PSCO -> LLRA) and at proximal sinus coronary ostiumunder pacing low-lateral right atrium to (LLRA -> PSCO).

The activation time for double atrial potential enregistred in catheter ablation for pacing in proximal coronary sinus ostium and for pacing low-lateral right atrium to proximal sinus coronary ostium were enregistred.

2.1. Anticoagulation Management

Patients were treated with warfarin to maintain an international normalized ratio (INR) between 2 and 3 for at least 3weeks before the ablation. Warfarin was discontinued 4days before the ablation. Patients were given enoxaparin sodium 1mg/kg subcutaneously every 12 hours before the ablation. Both warfarin and enoxaparin were restarted immediately after the procedure, but enoxaparin was discontinued 3 days later. Heparin was also used during the procedure. Warfarin continued one month after atrial flutter ablation and more if the patient had concomitant atrial fibrillation.

Patients underwent routine clinic follow-up post-operatively.

2.2. Statistical Analysis

Data are reported as mean and standard deviation (SD) for continuous variables and as proportion (%) for categorical variables. Median and quartiles are presented for skewed data.

Data were analyzed using the Wilcoxon Rank test and results are displayed as average ± standard deviation. The characteristics of patients were compared using the Student t test or Mann–Whitney test for continuous variables, and the Fisher exact test or $\chi2$ test for categorical data where applicable. A significant risk was determined if the 95% confidence interval (95% CI) exceeded 1, and the *P*-value was <0.05. All analyses were performed using the SPSS 19.0 software program (SPSS).

3. Results

3.1. Patients

From July 2009 through April 2014, we included 35consecutive patients with atrial flutter. The mean age was 48.5 ± 10 years (IQR 17-80 years), and 60% of the patients were men. Thirty three patients had CTI flutter.

3.2. Baseline Clinical Characteristics

Symptoms were present in all patients, mainly in the form of palpitations. However, there were other relevant symptoms associated to atrial flutter Fig1

A two third of patient (76%) had an underling disorders (Fig2)

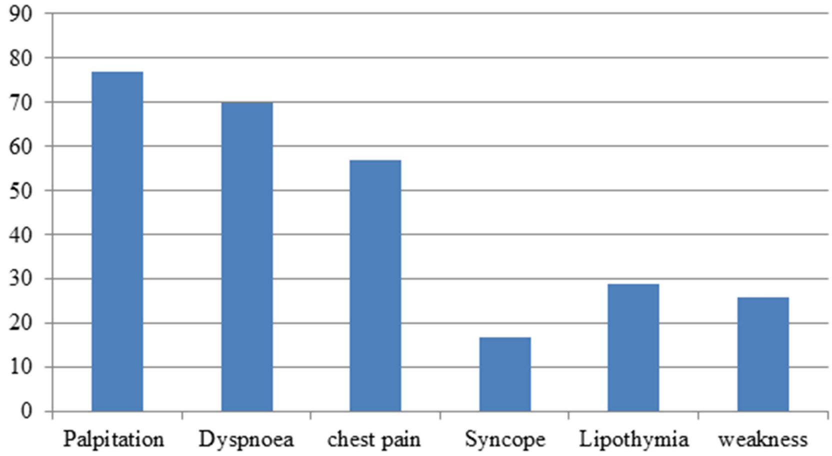


***Figure 1.** Symptoms of patients*

One third of patient had a lone atrial flutter. Seventy-six percent had a cardiac disease. fig 2

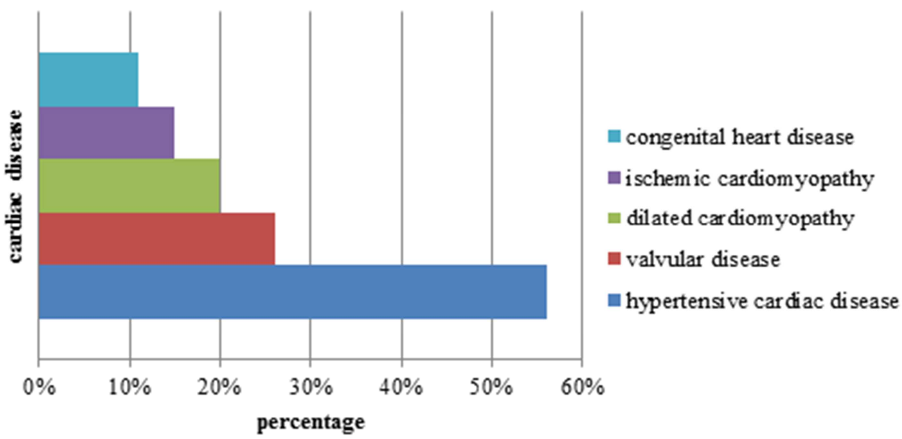


***Figure 2.** Underlying disorders*

3.3. Pre-Operative Evaluation

A baseline electrocardiogram at admission was performed in all patients. The heart rhythm was sinus in 11% of patients and atrial flutter in 83% before the procedure. 25 patients had electrocardiogram typical flutter and 4 had atypical flutter electrocardiogram.

An echocardiogram at admission was performed for all patients: 68% transthoracic, all patients had transesophageal 24-48 hours before ablation.

The median left atrial area was 24.7 cm² (IQR 15-61 cm²) and the median ejection fraction was 51%. All patients were with antiarrhythmic drugs fig 3

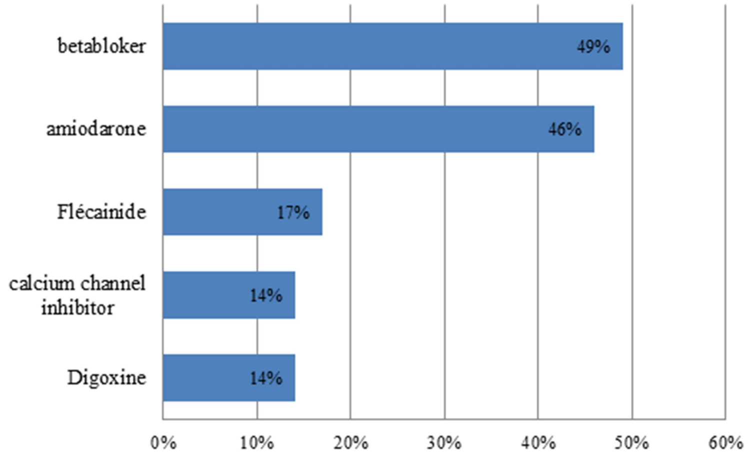


Figure 3. *Antiarrhythmias before ablation procedure*

3.4. Ablation Technique

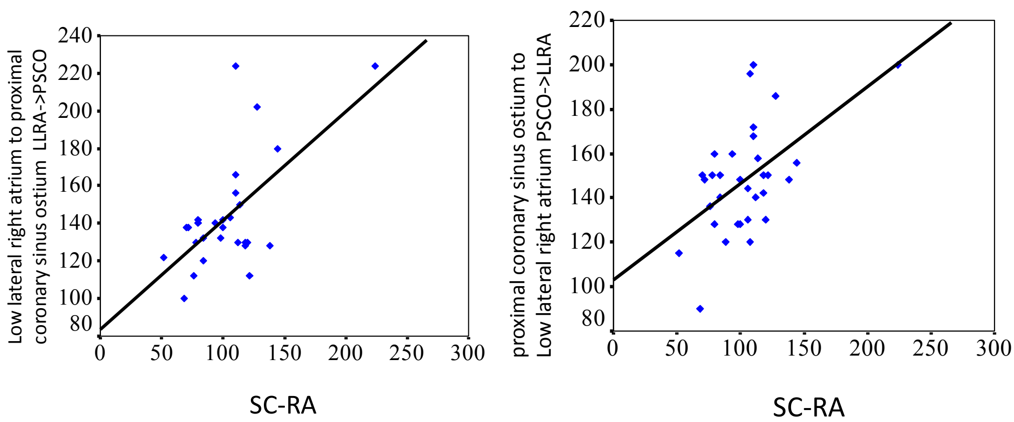
The procedure was performed under general anaesthesia. With regard to anticoagulation therapy, our centre used unfractionated heparin. The median duration of the procedure was 110.5min (IQR 40-240), with a median fluoroscopy time of 29.1 min (IQR 10-90 min). The ablation was performed with 8mm catheter, in three cases we changed to an open irrigation-tip catheter. Thirty three patients were CTI flutter; three are horaire, 29 antihoraire and one patient double loop antihoraire flutter. RF ablation was carried out with 8mm catheter between 60 and 70 W, a temperature of 60ºC for 60 seconds and with an irrigated-tip 4-mm with an energy output between 25 and 35 W, a temperature of 42ºC for 60 seconds, and a flow rate of saline irrigation set to 17 ml/min. 83% patients were in atrial flutter and mean flutter cycle length was 248.9 ± 38.8ms.

Using the standard evaluation criteria of CTI conduction block, bidirectional block was demonstrated for all patients.

Mean activation time between proximal sinus coronary ostium and atrial bipolar electrogram (SC-RA) enregistred from coronary sinus to low-lateral right atrium before the creation of the CTI block ablation were 103.7 ± 30.6 ms and. After the creation of the CTI block ablation, Mean activation times were 148.15±24.6 ms at low-lateral right atrium (LLRA)under pacing proximal sinus coronary ostium (PSCO) (PSCO -> LLRA) (P<0.001; r=0.54) and 143.89± 30.36 ms at proximal sinus coronary ostium under pacing low-lateral right atrium to (LLRA -> PSCO) (P<0.001; r=0.62). The linear regression equation that best described this result was: LLRA -> PSCO = 0.581 * SC-RA + 83.540; PSCO -> LLRA = 0.437 * SC-RA + 102.863

The activation time for double atrial potential enregistred in catheter ablation was 82.6± 20.74 ms for pacing in proximal coronary sinus ostium and 76.31± 17 ms for pacing low-lateral right atrium to proximal sinus coronary ostium.

Spearman's test showed a statistically significant correlation between the activation time between low-lateral right atrium (LLRA) and proximal sinus coronary ostium (PSCO) before and after CTI block ablation(P<0.001; r=0.54; r=0.62). The linear regression equation that best described (fig 4)



a b

Figure 4. *Correlation between the activation time between low-lateral right atrium (LLRA) and proximal sinus coronary ostium (PSCO) before and after CTI block ablation. The linear regression equation that best described this result was in a: LLRA -> PSCO = 0.581 * SC-RA + 83.540; and in b: PSCO -> LLRA = 0.437 * SC-RA + 102.863*

Based on symptoms, on scheduled 12-lead ECG and 24 hours monitoring ECG performed during a follow-up of 15 (IQR: 1-58 months), success without antiarrhythmic drugs was achieved in 100 % of patients.

4. Discussion

Atrial flutter is a frequent arrhythmia in clinical practice, its incidence being 180/100000 in general population(6). Nowadays, the gold standard therapy is catheter ablation of the CTI(7,8).This study was to determine a novel parameter clarify to improve a success rate of CTI ablation useful less time and less mapping catheter. Several criteria have been proposed for defining bidirectional block: reversal in the right atrial activation sequence during CS pacing(9), differential pacing(10), a change in the P wave morphology on surface ECG(11), the analysis of the unipolar electrogram(12), the demonstration of a large corridor of double potentials between the tricuspid valve and inferior vena cava (13)or incremental rapid pacing, as recently described by Marchlinski et al(14).The most accurate and standard criteria is represented by the reversal in the right atrial activation sequence during CS pacing, validated by differential pacing (15), by the morphology of the bipolar atrial electrograms(16), by bidirectional isthmus block,(3). All this criteria necessitate three mapping catheter in order to validate CTI bidirectional isthmus block, more time in the procedure. Our study demonstrated that the activation time between low-lateral right atrium and proximal sinus coronary ostium before CTI block ablation predicted the value of successful activation time between low-lateral right atrium and proximal sinus coronary ostium after bidirectional block. This activation time criteria is very simplified criteria, make it easy to use in routine CTI ablation compared to others algorithm.

Reis-Santos and al(17) demonstrated that the difference in isthmic activation times correlates with the length of the atrial flutter cycle. In fact, the flutter cycle, that is the speed at which the electrical stimulus travels through the RA and activates the same point of the atrium, depends on atrial size and conduction velocity. The latter in turn depends on the electrophysiological characteristics of the patient's atrial tissue, which can be modified by administration of drugs, particularly amiodarone. In the case of a large, dilated atrium or of slow conduction, it will take more time to complete the flutter circuit and the flutter cycle will therefore be long, and conversely, with a small atrium or rapid conduction, the cycle will be shorter. These characteristics (atrial size and conduction velocity) will also affect the time between low-lateral right atrium and proximal sinus coronary ostium before and after ICT block. With a large atrium or slow conduction, lateral activation time in the presence of isthmus block will present a more marked delay in relation to activation time between right atrium and proximal coronary sinus ostium than that obtained with an effective block in a small atrium or with rapid conduction. In other words, ablation of flutters with a long activation time between right atrium and proximal coronary sinus ostium should result in greater time between low-lateral right atrium and proximal sinus coronary ostium than effective ablation of flutters with a short cycle, since the conduction delay in the electrical stimulus reaching the lateral border of the isthmus block will be greater due to the RA dilation and/or slow conduction found in flutters with a long cycle and a long activation time between right atrium and proximal coronary sinus ostium. Thus, following ablation of atrial flutter, the time between low-lateral right atrium and proximal sinus coronary ostium before ICT ablation correlate with atrial size and conduction velocity, in other words with the flutter cycle length,(17) and the activation time between low-lateral right atrium and proximal sinus coronary ostium after ICT ablation can indicate successful ablation.

The 33 patients in this series presented typical atrial flutter, confirmed by electrophysiological study, in intracavitary electrograms. Criteria of success were achieved in all patients after ablation. Following ablation, under pacing from the coronary sinus, there was a consistent conduction delay on the lateral side of the ablation line, as shown by the short activation times on the lateral side before ICT ablation which was correlated in a statistically significant. This correlation can be expressed by the follow linear regression equation: PSCO -> LLRA = 0.437 * SC-RA + 102.863. In the same case, under pacing from low-lateral right atrium, the conduction delay on the septal side near proximal sinus coronary ostium was correlated between before and after ablation. This correlation can be expressed by the follow linear regression equation: LLRA -> PSCO = 0.581 * SC-RA+ 83.540

In simpler terms, in these successful ablations the activation time between low-lateral right atrium (LLRA) and proximal sinus coronary ostium (PSCO) before and after CTI block ablation was consistently more than half this activation time before ablation plus 102 ms, and so determining this type of activation time indicates the presence of isthmus block, and the procedure can be suspended in order to ascertain by the usual method whether the block is bidirectional. An activation time after ablation of less than predicted value suggests gaps in the ablation line, which should be checked for continuity.

We would point out that determining this activation time predicted value is quick and easy, as it can be obtained via the catheters used in the procedure – the coronary sinus catheter for stimulation and the mapping catheter, the only one that needs to be manipulated and positioned on lateral borders of the right atrium. The existence of a particular value for the desired delay may represent a further advantage.

A conduction delay on the lateral side of the ablation means effective isthmus block is extremely likely, but not absolutely sure. In certain situations, the cavo-tricuspid isthmus lesion may alter electrical conduction at that point, slowing down conduction but not achieving complete block. In such cases, there will also be a conduction delay on the lateral side, but this will be less marked than that seen when there is an effective block. It can therefore be postulated that in these situations it is possible to find a prolonged lateral activation time and a large activation time, but still smaller than activation time predicted value. Solutions of continuity in the ablation line have been found in such cases, with greater or lesser conduction velocities, which can be determined by intracavitary electrogramsalong the isthmus. The presence of double potentials would tend to confirm the existence of an effective block, while single or fragmented potentials in the interval between double potentials may indicate a solution of continuity (18).

5. Conclusion

Our study suggests that the activation time between proximal sinus coronary ostium and atrial bipolar electrogram enregistred at the low-lateral right atrium after ablation of the CTI during atrial flutter or in the sinus rhythm correlates with this activation time before CTI ablation. The activation time after ablation would be expected from the equation PSCO -> LLRA = 0,437 * SC-RA + 102,863 predicts isthmus conduction block and hence successful ablation.

In simpler terms, obtaining a conduction delay underling sinus coronary ostium pacing to low lateral right atrium of more than half this time before ablation plus 80 ms indicates successful treatment. This should however be confirmed before the end of the procedure through demonstration of bidirectional isthmus block, the current gold standard of efficacy in ablation of typical atrial flutter.

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