

Non-Invasive Estimates of Left Atrial Activation in a Patient with Dissociated Left Atrial Tachycardia following Ablation of Atrial Fibrillation

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Abstract

Introduction: Interatrial frequency gradient is used to guide catheter ablation of atrial fibrillation (AF) but reliable tools for its non-invasive estimation are lacking. We present a patient with dissociated left and right atrial rhythms that allows identification of surface ECG leads that closely reflect left atrial activity.

Methods: 12-lead ECG was recorded simultaneously with electrograms from the right and left atrial appendages (RAA/LAA). AF frequency spectra have been calculated from all 12 leads using spatiotemporal QRST cancellation and Welch periodogram. The dominating atrial cycle length (ACL) in the surface ECG leads was subsequently compared with ACL_{LAA} .

Results: RAA and LAA cycle lengths were 1276 ms and 252 ms respectively. Of all surface ECG leads, AF frequency spectra in leads VI and aVR demonstrated the best agreement with ACL_{LAA} showing prominent peaks corresponding to the LAA activation frequency.

Conclusion: Leads VI and aVR contain a prominent left atrial component that has to be considered when interpreting fibrillatory activity from surface ECG.

1. Introduction

Interatrial frequency gradient is observed in atrial fibrillation (AF) [1,2] and used to guide catheter ablation but reliable tools for its non-invasive estimation are lacking. It was earlier shown that atrial fibrillatory cycle length may be reliably measured from lead VI and endocardial validation studies have shown its good agreement with right atrial fibrillatory activity [3,4]. However, robust non-invasive estimates of left atrial fibrillatory activity are still lacking. Previous attempts to non-invasively assess the left atrial fibrillatory cycle length have been hampered by the lack of major differences in AFCL between the right and left atria, commonly observed in patients with long-standing

arrhythmia.

We present a patient with dissociated right and left atrial rhythms. The extreme difference in the atrial rate between RA and LA enables analysis of individual ECG leads for the presence of distinct right and left atrial components and thus allows identification of surface ECG leads that most closely reflect left atrial fibrillatory activity.

2. Methods

2.1. Case description

Fifty-three year old female was admitted for catheter ablation of left atrial tachycardia following ablation for AF. She was known with hypertrophic cardiomyopathy, for which she had septal myectomy and AV node ablation plus dual chamber pacing in the past. She suffered from symptomatic persistent AF and had previously undergone RF ablation for AF to try and restore AV synchrony and left atrial transport function. After the first ablation, she developed an atrial tachycardia and was scheduled for a repeat procedure. Upon arrival to the EP lab, the patient was in atrial tachycardia. Activation and entrainment mapping identified a mitral isthmus dependant macroreentrant tachycardia and sinus rhythm was restored by ablation. However, while both atria were in sinus rhythm, a rapid activity, dissociated from the atria was recorded in the left atrial appendage (LAA).

Surface ECG in conventional 12 leads was acquired simultaneously with endocardial electrograms from 4-polar ablation catheter (Thermocool, Biosense Webster, Diamond Bar, CA, USA) placed in LAA and 4-polar diagnostic catheter (5-mm electrode spacing, Xtrem, ELA Medical, Le-Plessis-Robinson, France) in the right atrial appendage (RAA) using BARD LabSystem™ Pro™ electrophysiological system. Despite the rhythm conversion, the ablation catheter still recorded regular

atrial tachycardia at 238 b.p.m. that was confined to the electrically isolated LAA while the rest of the left and entire right atrium demonstrated sinus bradycardia at 47 b.p.m.

2.2. Signal-processing

Sixty-second long endograms from RAA and LAA together with simultaneously recorded surface 12-lead ECG were retrieved for off-line processing and estimation of atrial cycle length (ACL) from surface ECG (Figure 1).

In this work, the FAF-ECG was used to analyze the dominant repetition rate of both ECG and intra-atrial recordings[3]. In this method, a Welch periodogram is computed using 2048 points and a Hanning window length of 512 samples with an interval overlap of 128 samples, giving a frequency resolution better than 0.1 Hz.

The preprocessing needed to analyze the surface ECG signals were baseline filtering, pacemaker spike detection and suppression, beat detection and classification, spatiotemporal QRST cancellation[5], and decimation to 200 Hz. The intra-atrial signals have a completely different structure and require preprocessing including only baseline filtering and pacemaker spike detection and suppression.

The dominating ACL in the surface ECG leads was subsequently compared with the ACL_{LAA} for each individual ECG lead.

3. Results

Right atrial cycle length was 1276 ms (47 b.p.m.) while ACL_{LAA} of the atrial tachycardia confined to LAA was as short as 252 ms (238 b.p.m.).

Frequency spectra in leads II, aVF, aVR, V1 and V6 demonstrated the presence of dominating ACL at 238 ms, 14 ms shorter than ACL_{LAA} . ACL_{V2} was 228 ms while in the remaining chest and extremity leads the difference in regard to ACL_{LAA} exceeded 60 ms (Table 1).

Among the leads showing good agreement with

ACL_{LAA} , the dominating ACL peaks were most distinct in the leads V1 and aVR (Figure 2).

Lead	AFR _{ECG} , f.p.m.	ACL _{ECG} , ms	ACL _{ECG} - ACL _{LAA} , ms
I	193	310	58
II	252	238	- 14
III	416	144	-108
aVL	416	144	-108
aVF	252	238	- 14
aVR	252	238	- 14
V1	252	238	- 14
V2	263	227	- 25
V3	387	155	- 97
V4	182	330	78
V5	387	155	- 97
V6	252	238	- 14

Table 1. Non-invasive assessment of atrial fibrillatory rate (AFR_{ECG}) and atrial cycle length (ACL_{ECG}) from 12 surface ECG leads. Right column represents and absolute difference between ACL recorded from surface ECG leads and from left atrial appendage (ACL_{LAA} = 252 ms)

4. Discussion and conclusions

It has been suggested that AF may be driven by high-frequency sources in the left or right atrium and ablation of those using so called frequency mapping should be one of the targets during ablation procedure[2]. In the majority of patients with paroxysmal AF, fibrillatory rate recorded from LA is higher than in RA[6] and ablation in LA only commonly results in restoration of sinus rhythm during ablation procedure. Interestingly, patients with long-standing persistent AF do not have any remarkable frequency gradient between LA and RA[6]. Disappearance of the frequency gradient over time may therefore be considered as a sign of remodeling caused by persistent AF. The frequency gradient is a dynamic process and some patients still remaining in AF after extensive ablation in the LA may have their driving reentry circle moved to RA that in those cases exhibits

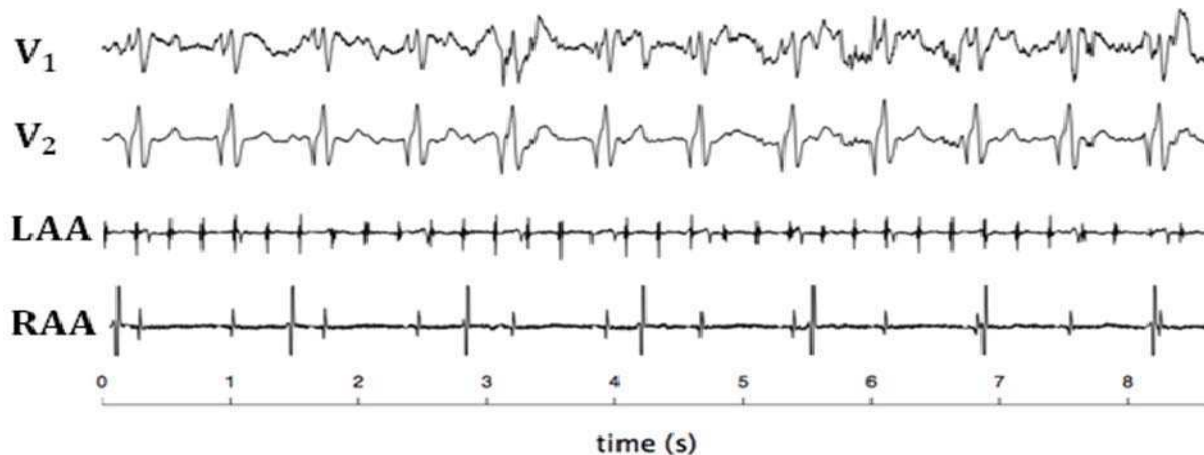


Figure 1. Surface ECG leads V_1 and V_2 and endocardial registrations from left and right atrial appendages

higher activation frequency than LA. Though still hypothetical, pre-procedural identification of interatrial frequency gradient in AF patients can be considered as an indicator of higher ablation success rate and used as a patient selection tool.

Non-invasive estimation of AFR separately for LA and RA could have been used for the pre-procedural patient screening and for guiding AF ablation procedure. Unfortunately, any robust methodology for non-invasive estimation of interatrial frequency gradient is still lacking.

Frequency analysis of fibrillatory ECG (FAF-ECG) technique introduced 1996[3] was based on the frequency spectral analysis of QRST-cancelled signal from the lead V1 that in a series of endocardial EP studies showed good agreement with fibrillatory activity in RA. In majority of patients with long-standing persistent AF, any significant interatrial frequency gradient is lacking[6] and, in a series of publications[7-9], the methodology has been applied to lead V1 as an integral indicator of AFR.

However, the value of other standard or alternative ECG leads has recently been studied in order to evaluate their ability to pick up local activation signal from coronary sinus[10] or LA[11]. Despite some cautious optimism, these and similar studies have been hampered by the low magnitude of differences in frequency between LA and RA.

The case presented in this paper allows overcoming this limitation as the difference in activation rate between RAA and LAA is extreme. This eliminates the risk of misinterpreting left atrial frequency peaks in the frequency power spectra and gives a possibility to identify ECG leads closely reflecting right vs. left atrial electrical activity.

Interestingly, the lead that contains the signal showing the best agreement with LAA cycle length in the frequency power spectrum is the same that has traditionally been linked to RA only, i.e. lead V1. At the same time, atrial signal in the leads that have earlier been suggested for estimations of fibrillatory activity in LA, i.e. leads I, V5 and aVL[11], demonstrated dominating frequency that was not only markedly different from the LAA signal but also showed both over- and underestimation of the true atrial frequency by using spectral analysis of surface ECG, e.g. $ACL_{ECG} - ACL_{LAA} = +58$ ms in the lead I and -108 ms in the lead aVL (see Table 1 for details).

Overall, the leads that demonstrated the minimal absolute difference in ACL between the surface ECG and endogram recorded from LAA, with exception of the lead V6, appeared to be “clustered” along the north-west/south-east axis in the frontal plane (leads aVR, II, aVF) and lead V1 in the transverse plane. Of those, only signal from the leads V1 and aVR have noise-free

appearance in the frequency-power spectra that allows unambiguous identification of the dominating frequency peak that corresponds to the left atrial cycle length (Figure 2).

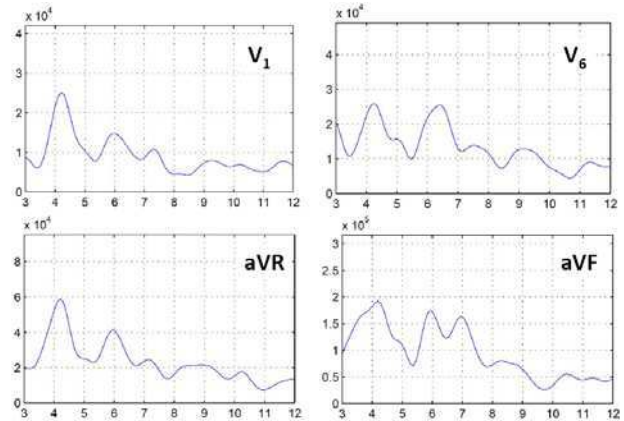


Figure 2. Frequency-power spectra of QRST-cancelled ECG signal from leads that demonstrated the minimal absolute difference in atrial cycle length between the surface ECG and endogram recorded from LAA. Only leads V1 and aVR present with clear and distinct frequency peak corresponding to the rate of atrial activation recorded from LAA.

Frequency mapping aimed at identification of atrial Lead V1 reflects not only right but also left atrial fibrillatory activity and can therefore not be used for assessment of interatrial gradient but rather as a crude estimate of ‘global’ atrial fibrillatory rate. Lead aVR demonstrates easily definable dominating frequency peak in the frequency spectrum corresponding to the LAA activity but has not been tested for AFCL measurements using power frequency spectrum earlier. Informative value of frequency content in leads V6, II and aVF demands further investigations.

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