# A New Approach for Mapping Slow Electrical Conduction Areas in Atypical Atrial Flutter

Rosalia Martino[1], Laura Volpe[1], Claudio Fabbri[1], Simone Attala[2], Stefano Severi[1], Nicola Trevisi[2], Cristiana Corsi[1]

[1]University of Bologna, Cesena Campus, Italy
[2]Infermi Hospital - AUSL della Romagna, Rimini, Italy

## Abstract

*Detection of slow electrical conduction areas is crucial for providing an effective ablation therapy in atypical atrial flutter. To this aim local atrial activations and their duration should be accurately identified. Currently mapping systems identify the precocity or lateness of a local activation with respect to a fixed reference without considering its duration. In this study we developed an automatic approach to compute local activation durations from electrograms (EGMs). EGMs were acquired with two different commercial mapping catheters (Advisor™ FL Circular and HD Grid) in two patients. Signals were pass-band filtered before processing and the analysis was based on the EGMs histogram and similarity techniques. The proposed approach was validated against 3875 activations manually annotated (GS) by an expert electrophysiologist. The mean error in the computation of the activation durations over each signal for each patient was 0.05±1.3ms (GS activation duration: 49.5±8.6ms) and -0.37±1.87ms (GS activation duration: 45.9±10.1ms) for the FL Circular and -5.3±0.8ms (GS activation duration: 65.8±7.5ms) and -0.1±9.7ms (GS activation duration: 55.8±11.0ms) for the HD Grid. The developed algorithm is accurate, and the 3D maps showing slow electrical conduction areas may represent a useful tool to be integrated with activation and voltage maps to plan and assist therapeutic interventions in atypical atrial flutter.*

## 1. Introduction

Differently from typical atrial flutter, atypical atrial flutter (AFL) includes a broad spectrum of macro-re-entrant tachycardias in which the wave front does not travel around the tricuspid annulus.

When AFL is not tolerated and is not controlled with antiarrhythmic drugs, catheter ablation should be considered [1]. Indeed, there are no clear guidelines for catheter ablation of atypical macro-re-entrant tachycardia circuits. And, unfortunately, ablation success is inferior to common typical flutter probably due to multifactorial issues, and the recurrence rate is higher [2].

Usually, mapping systems are necessary to define the focal mechanisms and localise the focal sources [3]. To properly recognize slow electrical conduction areas in atypical atrial flutter, local atrial activations must be accurately identified. To date, mapping systems identify the precocity or lateness of a local activation with respect to a fixed time reference by considering its first deflection. Additional information about activation duration could be crucial to reconstruct slow conduction patterns and areas; unfortunately, such information is not available.

In this study we developed an automatic approach to compute local activation durations from EGMs acquired using two Advisor™ mapping catheters (Abbott©) from which patient-specific 3D maps showing slow electrical conduction areas were reconstructed.

## 2. Materials and Methods

### 2.1. Clinical Data Acquisition

EGMs were acquired using two Advisor™ mapping catheters (Abbott©), the FL Circular (FL) and the HD Grid (HD) (Figure 1) in four patients during the ablation procedure performed in the Electrophysiology Lab at the Infermi Hospital in Rimini (Italy) using the EnSite Velocity™ Cardiac Mapping System (Abbott©). EGMs were acquired when the catheter position was stable, for few seconds.

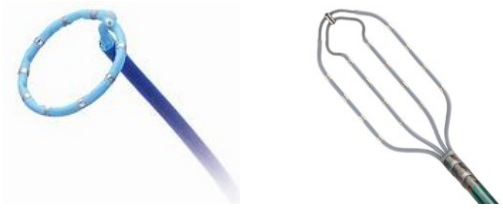

Figure 1. Left panel: the Advisor™ FL Circular mapping catheter; right panel: the Advisor™ HD Grid mapping catheter.

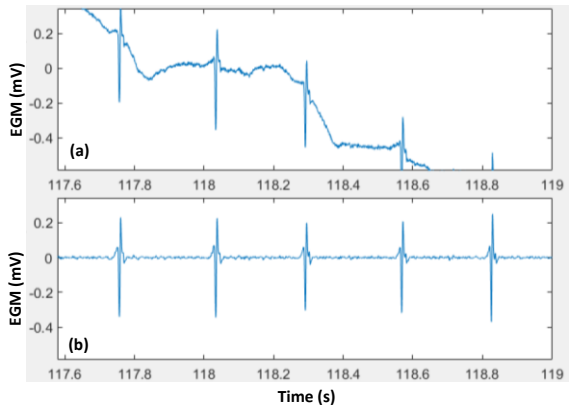


Figure 2. Example of the filtering in one short EGM segment acquired with the Advisor™ FL Circular mapping catheter: (a) EGM before filtering and (b) EGM after filtering.

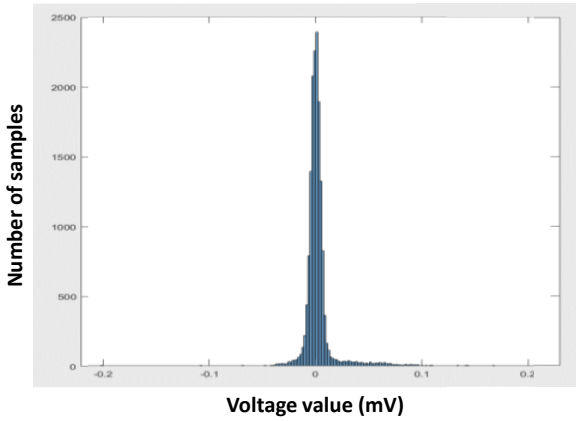


Figure 3. Example of the histogram of an EGM segment.

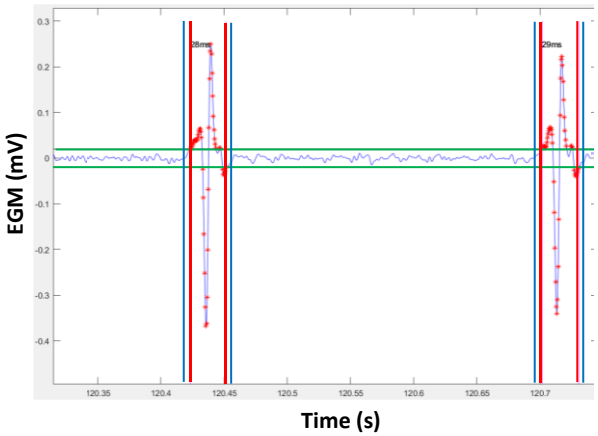


Figure 4. Example of EGM segmentation. The signal has been acquired with the the Advisor™ FL Circular mapping catheter.

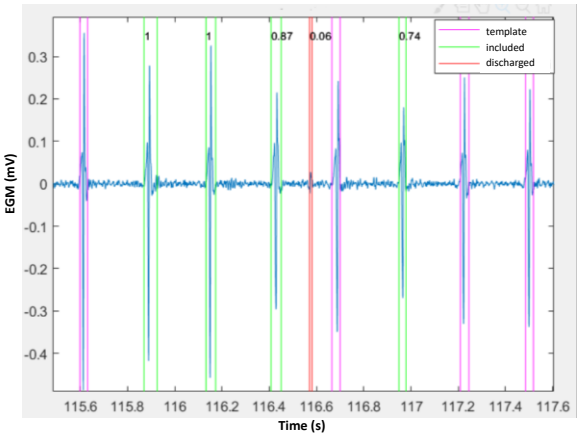


Figure 5. Example of shape similarity technique results applied to a signal acquired with the the Advisor™ FL circular mapping catheter (see text for details).

## 2.2. Data processing

Bipolar EGMs sampled at 2KHz were exported from the mapping system and analyzed off-line. Signals were divided in segments of length 3÷10sec.

EGMs were pass-band filtered (30 to 300Hz) applying a second order Butterworth filter (Figure 2). This range was selected to filter the signal from artifacts due to respiration and to attenuate high frequency noise.

Then, the histogram of each EGM was computed. An example is shown in Figure 3. The higher number of samples correspond to the baseline of the EGM; while the tails of the distribution correspond to the voltage values of the signal which are linked to local activations.

Aiming at detecting only signal portions corresponding to activations, we selected a pair of thresholds based on the percentiles of the histogram to perform EGM segmentation. Starting from the beginning of the EGM segment, if the value of the sample was included in the threshold range (Figure 4, green horizontal lines) the sample was discharged; the next sample was then evaluated until a value out of the range was detected (Figure 4, red circles); this sample was considered part of an activation; to verify this hypothesis the next sample was evaluated and the time distance between them computed; in case this distance was greater than a cut-off value set to 30ms, then the two samples were assigned to two different activations. The activation was then recognized as the portion of the signal from the first sample out of range and the last sample satisfying the cut-off constrain (Figure 4, red vertical lines). This procedure was repeated until the end of the EGM.

The EGM segmentation was optimized increasing the duration of each activation by detecting the first sample of the EGM before and after the recognized activation in which the EGM second derivative changes its sign (e.g. Figure 4, blue vertical lines).

The activation duration is then computed as the time between these two points.

To correct potential errors due to ventricular far field detection, an additional step based on the shape similarity was added. The mean duration of the detected activations was calculated and all the activations whose duration was in the range [mean duration-10% mean duration+10%] (Figure 5, activations between magenta lines) were used to define a template of the activation shape. The template was compared with each activation which was not used to build it (Figure 5, activations between green and red lines) by computing the cross-correlation between the template and the current activation; when the cross-correlation value was less than 0.6 the activation was discharged (Figure 5, activations between red lines).

The information about activation duration was used to build 3D maps showing slow electrical conduction areas: the patient-specific anatomical model of the atrium was exported from the mapping system together with the position of the mapping catheter during the acquisition of the EGMs. This information allowed us to map the duration information on the anatomical model.

Data analysis was performed using Matlab 2018b (The Matworks® Inc.).

## 2.3. Validation

To define the best pair of thresholds to perform EGM segmentation, three different pairs of thresholds based on the histogram were tested: the 6°-94°, 5°-95°and 3°-97° percentiles.

The developed approach was validated against 1392 activations from 63 EGM segments (in 2 patients) for the FL and 2483 activations from 115 EGM segments (in 2 patients) for the HD. All these activations were manually annotated by an expert electrophysiologist (gold standard, GS).

# 3. Results

EGM analysis to compute activation duration is indeed very fast requiring less than 15 sec.

For the FL mapping catheter, the thresholds which resulted in the best performance were the pairs 6°-94° percentiles, showing sensibility equal to 99%, specificity 99% and accuracy 99%.

For the HD mapping catheter, the thresholds which resulted in the best performance were the pairs 5°-95° percentiles with a sensibility of 94.5%, specificity of 99.4% and accuracy 96.8%.

The mean error in the computation of the activation durations over each segment for each patient was -0.38±1.9ms (GS activation duration: 49.5±8.6ms) and 0.05±1.4ms (GS activation duration: 45.9±10.1ms) for the FL and -5.3±0.8ms (GS activation duration: 65.8±7.5ms) and -0.1±9.7ms (GS activation duration: 55.8±11.0ms) for the HD (see Table 1).

Table 1: Mean error in the computation of the activation duration over each EGM segment

| | | GS activation duration (ms) | Mean error (ms) |
|---|---|---|---|
| Advisor™ FL circular | Pt 1 | 49.5±8.6 | -0.38±1.9 |
| Advisor™ FL circular | Pt 2 | 45.9±10.1 | 0.05±1.4 |
| Advisor™ HD Grid | Pt 1 | 65.8±7.5 | -5.3±0.8 |
| Advisor™ HD Grid | Pt 2 | 55.8±11.0 | -0.1±9.7 |

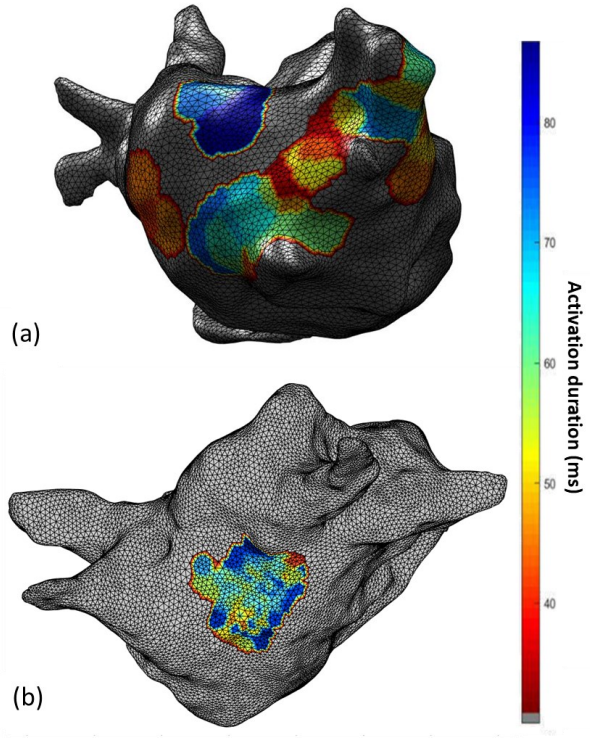


Figure 6. Examples of 3D maps showing slow electrical conduction areas in two patients with two different mapping catheters. (a) map obtained with the FL circular catheter; (b) map obtained with the HD Grid catheter. Grey areas represent atrium regions which were not mapped.

Two examples of the 3D maps are shown in Figure 6. On the surface of the anatomical model of the atrium obtained in two patients, the activation duration computed applying the proposed approached is mapped.

# 4. Discussion & Conclusions

In this study we developed an automated approach for local activation duration computation in atypical atrial

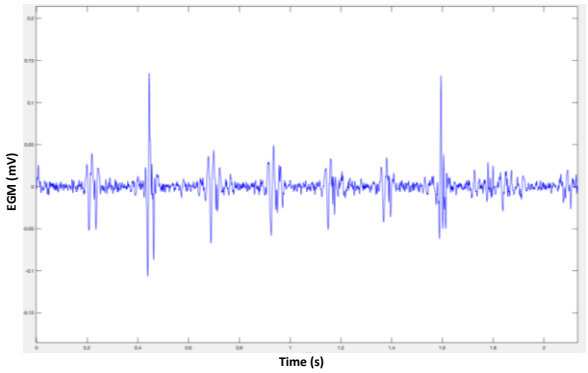


Figure 7. Example of a filtered EGM acquired with the Advisor™ HD Grid mapping catheter. Please note the smaller and variable amplitude of the activations compared with the EGMs acquired with the Advisor™ FL circular mapping catheter.

flutter. The proposed technique was tested with data acquired with two different mapping catheters and validated against manual annotation in 3875 activations.

In both cases results were accurate but showed better performance for the Advisor™ FL Circular mapping catheter Results on data acquired with the Advisor™ HD Grid mapping catheter showed higher errors probably due to the different amplitude of the EGMs: as can be appreciated from Figure 7 compared to Figure 2 (bottom panel) the EGMs acquired with FL are more stable and of higher amplitude. This may also justify the slightly different voltage thresholds for the two mapping catheters, which make the analysis catheter/dependent.

Our approach has other limitations.

We analyzed data acquired in only 4 patients and increasing the data sample will be important to confirm our results and assess its generalizability.

Unfortunately, we are missing an objective reference annotation: our experience suggests manual annotation depends on the electrophysiology experience and the assessment of variability for the reference technique may help in better evaluating the performance of our approach.

Importantly the algorithm will be further tested on low amplitude EGMs in which overlapping between local atrial activation and ventricular far field would complicate the local atrial activation duration computation [4].

Very preliminary results on biphasic EGMs (Figure 8) were successful.

To conclude, the knowledge of activation durations may help in detect pathological mechanisms based on complex local activations in atypical atrial flutter. In addition, the visual representation of 3D maps may represent a useful tool to be integrated with activation and voltage maps to plan and assist therapeutic interventions.

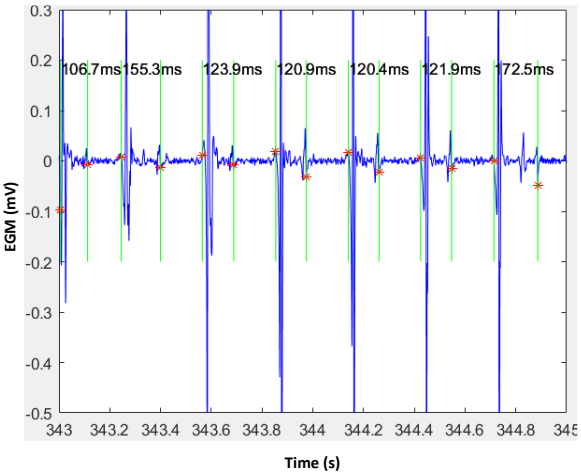


Figure 8. Duration detection on biphasic EGM activations. Activation start and end are highlighted by red stars and delimited by green vertical lines. The duration for each detected activation is reported in ms.

## References

[1] Cosio FG. Atrial flutter, typical and atypical: a review. Arrhythmia & Electrophysiology Review 2017;6(2):55–62. DOI: 10.15420/aer.2017:5:2.

[2] Coffey JO, d'Avila A, Dukkipati S, segnali bifasiciet al. Catheter ablation of scar-related atypical atrial flutter. Europace 2013;15:414–9, 2013.

[3] Jaïs P, Shah DC, Haïssaguerre M et al. Mapping and ablation of left atrial flutters. Circulation 2000; 101:2928-34.

[4] Frontera A, Masateru T, Ruairidh M et al. Electrogram signature of specific activation patterns: analysis of atrial tachycardias at high-density endocardial mapping. Heart Rhythm 2018;15.1:28-37.

Address for correspondence:
Cristiana Corsi, PhD
Department of Electrical, Electronic and Information Engineering,
University of Bologna,
Via dell'Università 50, 47522 Cesena (FC), Italy
cristiana,corsi3@unibo.it