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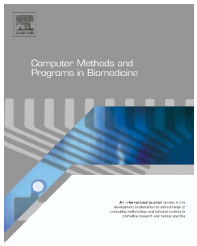

A framework for the atrial fibrillation prediction in electrophysiological studies

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ABSTRACT

Background and objective: Cardiac arrhythmias are disorders in terms of speed or rhythm in the heart's electrical system. Atrial fibrillation (AFib) is the most common sustained arrhythmia that affects a large number of persons. Electrophysiologic study (EPS) procedures are used to study fibrillation in patients; they consist of inducing a controlled fibrillation in surgical room to analyze electrical heart reactions or to decide for implanting medical devices (i.e., pacemaker). Nevertheless, the spontaneous induction may generate an undesired AFib, which may induce risk for patient and thus a critical issue for physicians. We study the unexpected AFib onset, aiming to identify signal patterns occurring in time interval preceding an event of spontaneous (i.e., not inducted) fibrillation. Profiling such signal patterns allowed to design and implement an AFib prediction algorithm able to early identify a spontaneous fibrillation. The objective is to increase the reliability of EPS procedures.

Methods: We gathered data signals collected by a General Electric Healthcare's CardioLab electrophysiology recording system (i.e., a polygraph). We extracted superficial and intracavitary cardiac signals regarding 50 different patients studied at the University Magna Graecia Cardiology Department. By studying waveform (i.e., amplitude and energy) of intracavitary signals before the onset of the arrhythmia, we were able to define patterns related to AFib onsets that are side effects of an inducted fibrillation.

Results: A framework for atrial fibrillation prediction during electrophysiological studies has been developed. It includes a prediction algorithm to alert an upcoming AFib onset. Tests have been performed on an intracavitary cardiac signals data set, related to patients studied in electrophysiological room. Also, results have been validated by the clinicians, proving that the framework can be useful in case of integration with the polygraph, helping physicians in managing and controlling of patient status during EPS.

1. Introduction

Cardiac arrhythmias are abnormalities or perturbations of the normal activation sequence of the myocardium, the muscular tissue of the heart. Atrial fibrillation (AFib) is the most common sustained arrhythmia, characterized by chaotic and

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uncoordinated atrial activation of the atrial cells. Patients affected by cardiac arrhythmias must perform a specialistic visit conforming to analyze heart electrical activity. Superficial and intracavitary cardiac signal analysis represents the best way to study, identify and classify heart signals and to study cardiac arrhythmias. Electrocardiogram (ECG) is a non-invasive technique that acquires the signals by skin surface electrodes and reports the electrical activity of heart, mainly used as a primary diagnosis tool for cardiovascular diseases [1]. Intracavitary electrogram, also indicated as electrophysiologic study (EPS), is an invasive technique consisting in recording and studying signals captured directly from inner heart part (intracavitary signals).

Nevertheless, EPS studies consist in external pacing which sometimes may induce spontaneous AFib onset. Indeed, during EPS an intraprocedural run of AFib can be elicited, mostly during atrial incremental stimulation, which requires aggressive manoeuvres for restoration of sinus rhythm, like electric transthoracic synchronous defibrillation or pharmacologic cardioversion, the latter being often excluded because it can jeopardize the actual arrhythmia that is affecting the patient (rarely atrial fibrillation pertains young individuals). The occurrence of atrial fibrillation during the invasive EPS is an undesired situation, which can be self-limiting, or can last several minutes, sometimes requiring electric external cardioversion. Early detection of an AFib occurrence is thus an important research topic both for biomedical engineers and for clinicians. Indeed, even if they expose patient to risky situation, EPS studies are often required in many cases. For instance, young patients with unexplained palpitations are usually difficult to treat, mainly because the aetiology is unclear from several non-invasive examinations performed. To date, the invasive electrophysiologic study (EPS) is helpful for diagnosing and risk stratification, and it is considered a class I indication (to be performed) for those patients with atrioventricular reentrant tachycardias such as the Wolff–Parkinson–White syndrome.

Under this circumstance, we started by investigating the origin of the signals from the atrial electrocatheter in order to check whether the occurrence of AFib could be predicted somehow during the EPS and thus prevented. In this direction, a new device that evaluates the triggering activity during the stimulation protocol and promptly alerts the physician to stop the stimulation for avoiding atrial fibrillation induction is indeed needed. In this scenario, we present results of three years experience of collaboration among bioinformaticians and cardiologists sharing activities in electrophysiologic room where many procedures have been studied in terms of data signals and semantics, identifying useful information for AFib early prediction. As results we propose a framework hosting a prediction algorithm that allows to predict AFib events during electrophysiological studies. The prediction algorithm allows to analyze and extract predictive information from intracavitary signals. Experimental results show that it is possible to perform early detection of AFib onset during EPS, allowing the possibility of inserting such an algorithm into an online monitoring system to alert physicians during EPS studies. A preliminary version of the algorithm has been presented in [2].

In the remaining part of the section we report about state of the art and background, while the rest of the paper is organized as follows. Section 2 reports basic information about heart electrophysiology useful for algorithm comprehension. Section 3 reports the signal analysis procedures used to design the prediction algorithm. Section 4 reports results about the application of the proposed prediction framework, which includes preprocessing and signal analysis, on real patient data that have been anonymized. Finally, Section 5 concludes the paper.

1.1. *State of the art*

Many computer-based approaches for automated detection and classification of cardiac arrhythmias have been described in literature. Signal processing methods performed on ECG signals have been proposed to extract clinical information about cardiac activities and to perform identification and classification of cardiac arrhythmias [3,4]. In [5] wavelet-based analysis has been performed to denoising ECG and to detect the specific waves of the signal. Authors in [6] present an algorithm for the detection of cardiac arrhythmias using an online database. Other contributions in terms of arrhythmias classification have been proposed in [7,8], where Support Vector Machine (SVM) technique has been applied to ECG signals, and artificial neural network and data mining methods have been used to select and extract interesting parameters from ECG signals respectively.

ECG features extraction in time and frequency domains and methods as heart rate variability (HRV) and non-linear ECG analysis have been proposed for a quantitative prediction of clinical cardiac events, prevalently used for AFib disease [9]. In [10] authors show different approaches to atrial activity extraction from ECG signal in terms of spectral properties. Information extraction from ECG signals in patients with AFib by using bispectrum and extreme learning machine is proposed in [11]. AFib prediction examples can be found in [12,13] based on the analysis of the HRV signal; both contributions work on superficial cardiac signals implementing different types of analysis. AFib termination prediction is reported in [14], in which authors present an algorithm by using HRV signals analysis. Sosnowski et al. in [15] investigate the influence on heart rate variability (HRV) in patients with permanent atrial fibrillation. In [16] authors evaluate atrial activity with HRV analysis in patients with AFib. The prediction of AFib recurrence is also proposed in [17], analyzing pre-cardioversion heart rate variability. Other examples of features extraction are reported in [18,19] in which authors investigate for the prediction of AFib in terms of HRV on normal sinus rhythms and AFib data.

The above reported papers represent the interest on the here treated topic. Nevertheless, to the best of our knowledge, in literature, there are still few works on intracavitary signal analysis and prediction; some preliminary results and studies are reported in [20,21], while recent works have contributed to the understanding of AFib by intracardiac recording [22,23] and by spectral analysis of intracardiac electrograms [24,25]. In order to better understand AF events, one of the most adopted techniques is complex fractionated atrial electrograms [26], which is able to relate AF with heart morphology, physical and