Monophasic Action Potential as a Predictor of the Onset of Atrial Fibrillation after Cardiac Surgery

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Summary

After routine cardiac surgery, disturbances in heart rhythm, mainly supraventricular in origin, represent one of the major costs in terms of patient morbidity and hospitalization. Their incidence averages around 30%. The aim of this study was to asses whether the monophasic action potential (MAP), continuously recorded from the atrial epicardium, might be used to predict the onset of supraventricular arrhythmias during the first few days after surgery. Bipolar epicardial MAP leads were attached to the right atrium in 15 consented patients, 8 M and 7 F with mean age of 63 ± 11 years, that underwent myocardial revascularization. For the duration of the hospital stay, MAPs were recorded continuously. MAP leads were removed at the time of patient discharge and MAP recordings were analyzed using dedicated software. The average observation period was 4 ± 1 days/patient (cumulative 63.3 days). Six episodes of atrial fibrillation (AF) were observed in five patients. One to three hours prior to AF onset, specific alterations of the MAP morphology were reproducibly detected. The MAP signal developed a triangular shape, the MAPd90 shortened (-25 ± 4 %), and the plateau amplitude decreased from 10 ± 2 mV to 4 ± 1 mV. The administration of drugs including sotalol and a combination of verapamil, digoxin, and quinidine, successfully treated the AF. After treatment, the MAP morphology returned to normal. This preliminary study shows that atrial MAP is a valid predictor of AF onset after cardiac surgery. Some improvements in lead size and the development of a dedicated analyzer device for routine, continuous, in-patient MAP monitoring will facilitate administering to the patient a prophylactic, dosage-optimized treatment to prevent the occurrence of AF.

Key Words

Monophasic action potential (MAP), atrial fibrillation, cardiac surgery, fractal coated electrode

Introduction

Patients suffering from cardiac arrhythmias consume a significant proportion of medical resources. Of all supraventricular tachycardias, atrial fibrillation (AF) is by far the most common, affecting 1.6 % of the population in Europe [1]. It has long been known that AF is a progressive disease. While it may first reveal itself in the form of shorter or longer paroxysms of AF, in many cases after some time AF no longer terminates spontaneously, and the arrhythmia becomes persistent. Finally, as an end stage, it can no longer be defibrillated, or the arrhythmia recurs almost immediately after defibrillation. To a large extent, the natural history of AF is due to a progression of pathological and anatomical changes in the atria resulting from age (fibrosis,

fatty degeneration) or due to an underlying heart disease (mitral valve disease, hypertension, coronary atherosclerosis). On the other hand, the possibility should be considered that, irrespective of the progression of an underlying heart disease, AF per se might cause progressive changes to either the structure or the electrophysiological properties of the atria (electrical remodeling).

Therefore, the aim of clinical research must be to elucidate the mechanism of arrhythmias, identify those patients that will develop arrhythmias, and implement a specific prophylactic therapy. In order to predict the onset of arrhythmias, immediate, detailed information on the electrical activity of the myocytes would be required. The behavior of the individual cardiac myocytes, as well as the heart as an organ, is governed by the strength and duration of the transmembrane ion currents [2]. Therefore, the transmembrane action potential, which reflects these ion currents, allows the monitoring of physiological and pathological processes, as well as the effects of pharmacological intervention [3]. To date, recording the transmembrane action potential has been a time-limited, invasive procedure resulting in cellular damage [4]. For long-term use in clinical practice, a method that is not harmful to cells is required. Recording of the monophasic action potential (MAP) represents a possible alternative solution [5].

The MAP is defined as the electrical event of a cardiac cycle, recorded with a differential DC recording technique between a probe electrode that is in direct contact with an area of depolarized myocardium and an indifferent electrode that is in close proximity to the probe electrode. In the early history of MAP measurements in humans, suction electrodes were used for acute, endocardiac recordings [6]. To avoid injuring the local myocardium, this technique could not be used for long-term MAP recordings. In 1983, a further step towards safer and better quality MAP recordings was reported by Franz et al. [7] who used Ag/AgCl contact electrodes. This technique is based on the principle that the mechanical pressure exerted against the myocardium depolarizes and inactivates the group of cells that is subjacent to the electrode while leaving the adjacent cells largely unaffected. The limitation of Ag/AgCl electrodes is their lack of long-term signal stability (< 3 h) [5,7] and their biocompatibility. In 1995, Frohlich et al. [8] reported that a fractally coated lead can be used for MAP recording with satisfactory quality and long-term stability due to improvements in the electrode-tissue interface. As a result of their increased Helmotz capacities, fractally coated leads facilitate pacing and virtually undisturbed recording of MAP with the same pair of leads. In addition to the nontoxicity of this material, this new lead can be implanted permanently [9, 10].

Disturbances in heart rhythm, mainly supraventricular in origin, represent one of the major costs in terms of patient morbidity and hospitalization after routine cardiac surgery. Their incidence averages around 30 % [11]. The aim of this study was to assess whether morphological variations of the MAP, continuously recorded from the atrial epicardium, may be used as a predictor of the onset of supraventricular arrhythmias during the first few days after surgery.

Materials and Methods

A preliminary animal test on a pig indicated that the best lead implant site in terms of signal stability and the limitations imposed by surgery was the area between the auricula and the atrial wall. Bipolar epicardial MAP leads (MAPOX 50/02 BP; Biotronik, Germany) that are coated with fractal iridium (Figure 1) were affixed to the right atrium, using 6/0 prolene sutures, in 15 consented patients undergoing myocardial revascularisation (mean age = 63 ± 11 years, 8 male and 7 female). Similar to conventional, temporary pacing, wire leads were transcutaneously implanted after cannulation in a silicon-sealed drainage tube.

For the duration of the hospital stay, MAPs were continuously recorded by a DC insulation amplifier, digitized by an A/D converter (sampling rate 500 S/s,

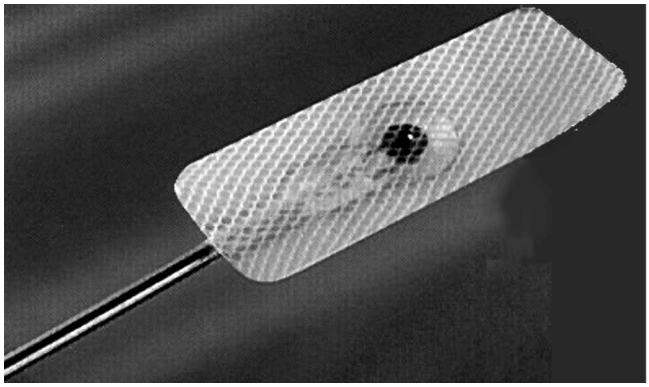

Figure 1. Fractal coated, epicardial lead (MAPOX 50/02, Biotronik, Germany) specifically designed for monophasic action potential measurements.

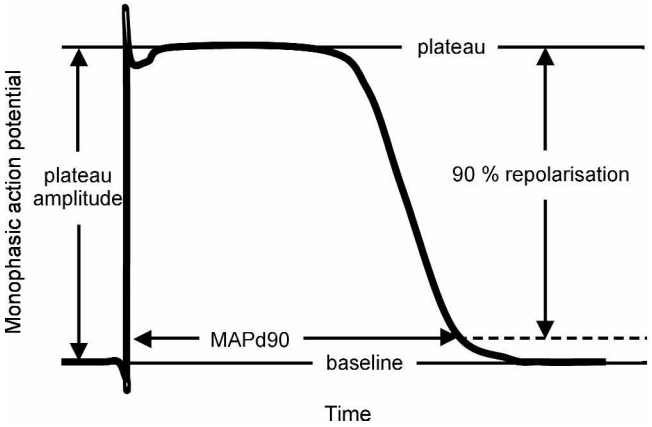

Figure 2. Morphology and parameters of the monophasic action potential (MAP) signal.

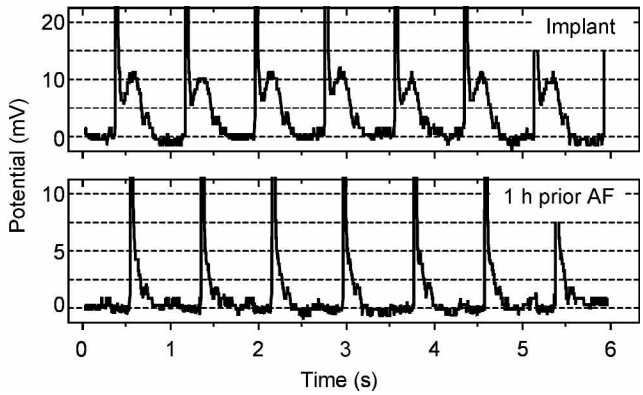

Figure 3. Atrial monophasic action potential at implant and 1 hour prior to the onset of atrial fibrillation.

12-bit resolution), and stored in a laptop PC. MAP leads were removed by traction at the time of patient discharge from the intensive care unit. MAP records were analyzed using a dedicated, semi-automatic software. The plateau amplitude, MAPd90, MAPd25, and cardiac cycle length were calculated (Figure 2). The onset of AF was correlated with the normalized MAP duration in respect to the cardiac cycle length (nMAPd90 = MAPd90/cardiac cycle length). At the onset of AF, all patients were treated by administering commonly used antiarrhythmic drugs.

Results

During a cumulative observation period of 63.3 days (mean 4 ± 1 days per patient), six episodes of AF were observed in five patients on the second day after surgery. One to three hours prior to AF onset, substantial alterations of the MAP morphology were reproducibly detected:

- The MAP signal developed a triangular shape (nMAPd90-nMAPd25: -24 ± 8 %) (Figure 3);
- The MAPd90 shortened, independent of the heart rate, (nMAPd90: -25 ± 4 %);
- The plateau amplitude decreased from 10 ± 2 mV to 4 ± 1 mV.

In all patients, the administration of drugs, such as sotalol and a combination of verapamil, digoxin, and quinidine, successfully treated AF. After treatment, the MAP morphology reverted to normal.

Conclusion

In conclusion, the recorded, preliminary data show that continuous monitoring of atrial MAP supplies helpful information for predicting the onset of AF after cardiac surgery. The accuracy with which the variations in MAP morphology predict AF occurrence make it possible to administer a specific, dosage-optimized treatment for prophylaxis to the patient.

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