The Recording of Monophasic Action Potentials with Fractal Coated Quadripolar Catheters

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Summary

The feasibility of recording monophasic action potentials with a quadripolar Josephson type catheter with fractal coated iridium electrodes was evaluated in 11 patients during a standard electrophysiological examination. The average age of the patients was 47 years (range 26 - 67). Seven patients suffered from coronary artery disease and four had no evidence of structural heart disease. The mean ejection fraction amounted to 55 % ± 18 % (average ± standard deviation). During sinus rhythm, the measured monophasic action potential amplitudes were 3.3 ± 2.8 mV and the monophasic action potential duration at 90 % of repolarization was 274 ± 88 ms. The study demonstrated excellent performance of the fractal coated quadripolar catheters in the recording of the right ventricular monophasic action potentials. The monophasic action potential and its characteristic variations reflecting cellular depolarization and repolarization processes may be a new tool for risk stratification of sudden cardiac death.

Key Words

Monophasic action potential, fractal coated electrode, quadripolar catheter, electrophysiological study

Introduction

The recording of monophasic action potentials (MAPs) has opened new perspectives in experimental and clinical electrophysiology. It allows monitoring of the impact of heart frequency, antiarrhythmic drugs, and ischemia on cellular electrophysiology [2]. In the past, it was possible to record MAPs only during electrophysiological investigations, as accurate MAP measurements required special leads and electrode surfaces (e.g., silver-silverchloride electrodes) unsuitable for long-term applications [3,4]. A large Helmholz capacitance at the electrode-tissue interface is mandatory for good sensing of the intracardiac signals. To achieve this, the electrochemically active surface area of the electrode must be large and the geometrical surface area in the range of several square mm [8]. In order to solve the apparent contradiction between the need for a large active surface but small geometrical dimension, the surface of modern catheters for MAP registration has to be structured [1,7]. The fractal surface structure provides an optimal ratio between the active and geometrical surface area of more than 1000:1 [1,7]. The large active surface area also reduces the polarization artifacts, improving the detection of cardiac signals (e.g., MAP) after the pacing spike. In addition, the fractal coating ensures a low charge transfer impedance (Figure 1), allowing good sensing performance in the low frequency range of the MAP signal.

Modern fractal coated pacemaker and defibrillator leads allow monitoring of MAP signals with long-term stability [5,6,9]. Quadripolar pre-shaped diagnostic catheters (MultiCath, Biotronik, Germany) with fractal coated iridium electrodes instead of a polished electrode surface represent the most recent development in the field. The aim of the present study was to evaluate the feasibility of MAP recording using the fractal coated quadripolar pre-shaped catheter (with the so-called "Josephson type" curve) in the course of a standard electrophysiological study (EPS).

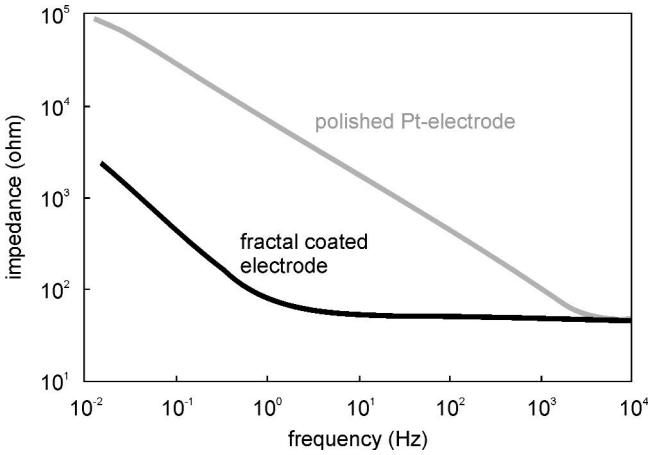

Figure 1. Charge transfer impedance of a polished platinum electrode (gray line) and the fractal coated iridium electrode (black line).

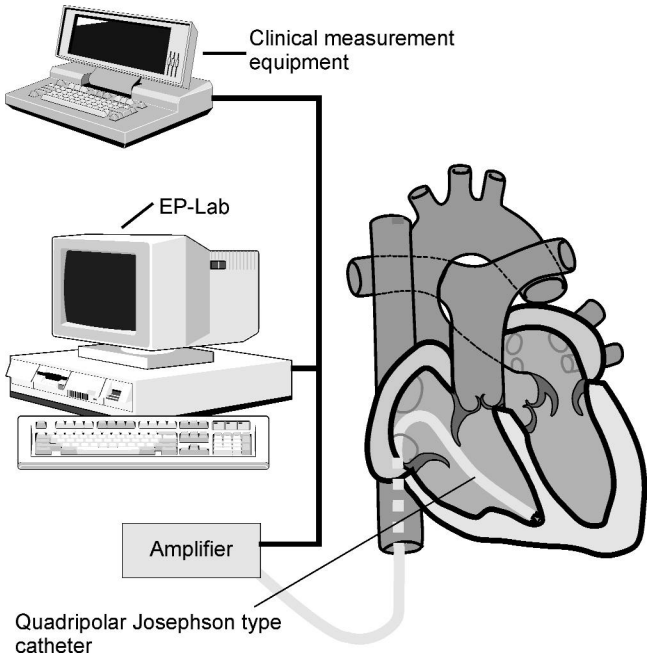

Figure 2. Clinical equipment for monophasic action potential measurements in our study.

Material and Methods

In the period from September 1998 to February 2000, 177 patients underwent EPS in our institution. In 11 subjects, the fractal coated quadripolar Josephson type catheter was utilized. The average age of the studied patients was 47 years (range 26 - 67). Seven patients suffered from coronary artery disease and four had no evidence of structural heart disease. The mean ejection fraction amounted to 55 % ± 18 % (average ± standard deviation).

During EPS, the fractal coated quadripolar catheter was placed in the right ventricular apex. The catheter was attached to an EP-Lab and subsequently the MAP was measured between the tip and the first distal ring of the catheter. Only catheter positions with stable MAP recordings were accepted. Custom designed clinical measurement equipment (Biotronik, Germany) was used to measure and store the MAP signal. An integrated isolation amplifier with adjustable amplification boosted the MAP signal. The amplification range was programmed to ± 5 V and ± 250 mV in different patients. The amplified signals were forwarded to an A/D converter (12 bits, 500 Hz sampling rate) and were stored in a PC to analyze the MAP after registration (Figure 2). The quality of the measured intracardiac signal was controlled online, using the presentation of the signal on the PC screen. The stored MAP was analyzed offline by using a semiautomatic program Bioview (Biotronik, Germany), calculating the amplitude of MAP, as well as MAP duration at 50 % and 90 % of repolarization (MAPd50 and MAPd90, respectively).

During the EPS, the following measurements were carried out in the right ventricle:

- Intrinsic MAP for 30 seconds;
- MAP during right atrial stimulation with basic cycle lengths (CLs) of 600 ms, 500 ms, 400 ms, and 330 ms, for 30 seconds;
- MAP during right ventricular stimulation consisting of up to 3 extrastimuli, with CLs = 600 ms, 500 ms, 400 ms, and 330 ms;
- In the case of induced ventricular tachyarrhythmia (VT) the MAP was measured during the induction and the termination phase of the VT.

Results

With the fractal coated quadripolar Josephson type catheter, a continuous recording of MAP signals from the right ventricle was feasible (Figure 3). During the right atrial and right ventricular stimulation, an excellent MAP signal morphology was constantly observed. Reduction of the MAP amplitude was not perceived. During sinus rhythm, the amplitudes aggregated to an average value of 3.3 ± 2.8 mV. Concerning the plateau

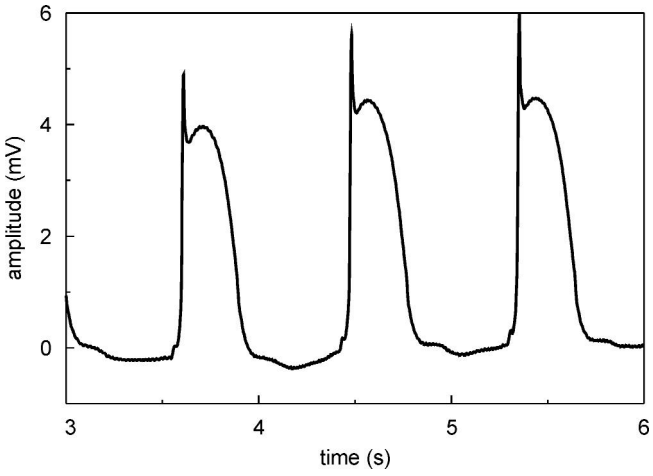

Figure 3. Monophasic action potential during sinus rhythm.

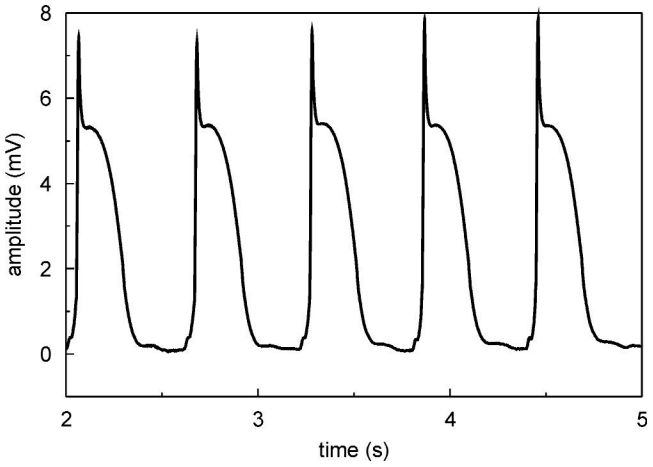

Figure 4. Monophasic action potential during atrial stimulation with CL = 600 ms.

of the MAP signal, the MAPd90 value amounted to 274 ± 88 ms (Table 1). The stored intrinsic ventricular MAP as well as the MAP signal during atrial stimulation at CL = 600 ms are illustrated in Figures 3 and 4, respectively. The circle length, the MAP amplitude, and the MAP duration at 50 % and 90 % of repolarization are shown in Table 1, averaged for all patients studied.

Figures 5 - 7 show MAP recordings during EPS in a 63-year old male patient suffering from coronary artery disease and VTs. Monomorphic VT was induced by programmed ventricular stimulation using the basic cycle length of 600 ms, followed by 3 extrastimuli. Figure 5 illustrates the MAP during the induction of the VT and Figure 6 the MAP at the end of the overdrive stimulation and early after restoration of the sinus rhythm. Figure 7 represents the stable sinus rhythm later after termination of the VT.

Heart rate	Circle length (ms)	Amplitude (mV)	MAPd50 (ms)	MAPd90 (ms)
Sinus	788 ± 187	3.3 ± 2.8	245 ± 82	274 ± 88
600 ms	632 ± 79	3.7 ± 3.0	221 ± 73	258 ± 89
500 ms	528 ± 82	3.7 ± 3.1	203 ± 46	238 ± 53
400 ms	496 ± 155	3.5 ± 2.9	184 ± 59	215 ± 63
330 ms	613 ± 216	4.5 ± 4.0	221 ± 52	255 ± 54

Table 1. Measured values during sinus rhythm and during atrial stimulation at cycle lengths ranging from 330 to 600 ms: ventricular circle length, the monophasic action potential amplitude, and the monophasic action potential duration at 50 % (MAPd50) and 90 % (MAPd90) of repolarization.

Conclusion

Our investigation demonstrated the utility of the quadripolar Josephson type catheter with fractal coated iridium electrodes in the recording of the right ventricular MAP signals during EPS. The software used for MAP analysis (Bioview) allowed a standard evaluation of the recorded MAP sequences. The MAP registration will increasingly become an additional diagnostic tool, utilized during standard EPS. The recording of MAPs

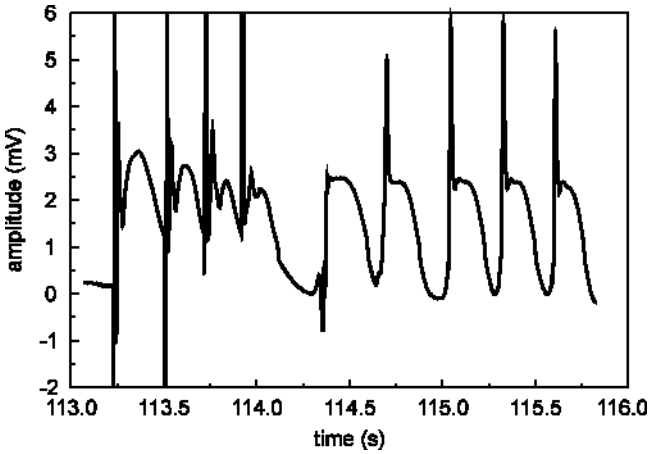

Figure 5. Monophasic action potential recorded during induction of ventricular tachycardia using 3 extra stimuli.

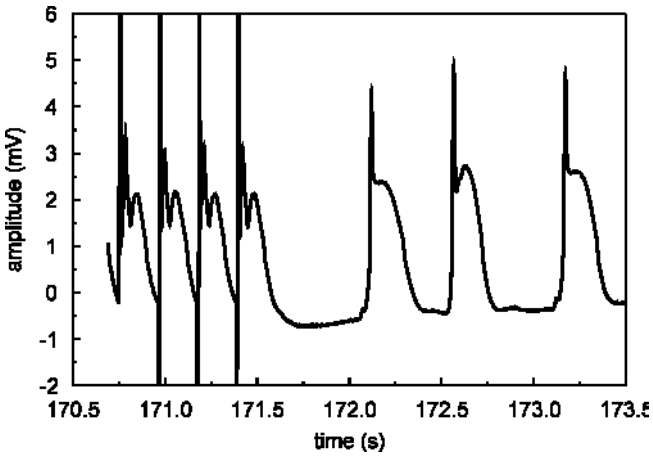

Figure 6. Monophasic action potential during termination of ventricular tachycardia by overdrive stimulation.

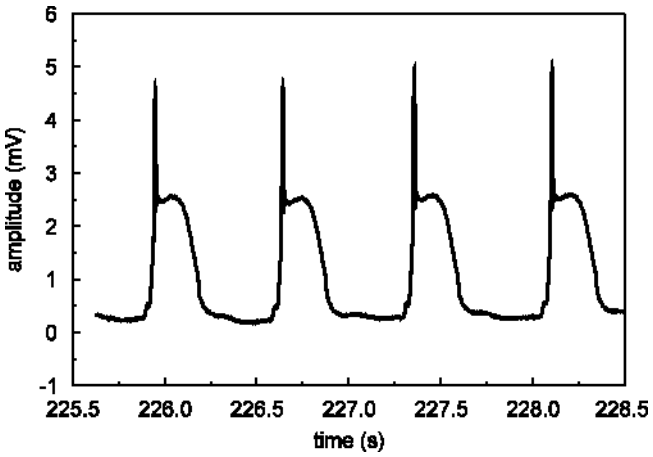

Figure 7. Monophasic action potential during sinus rhythm after termination of ventricular tachycardia.

offers a new dimension in the evaluation of the right ventricular signal during standard EPS procedures. The MAP and its characteristic variations reflecting cellular depolarization and repolarization processes may be a new tool for risk stratification of sudden cardiac death. Changes in the MAP signal in patients suffering from coronary artery disease, dilated cardiomyopathy and especially in survivors of sudden cardiac death have not been systematically investigated thus far.

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