A Comparative Study of the Sensing Behavior of Electroactive Coated Catheter Electrodes Versus Conventional Electrodes

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Summary

For electrophysiologic investigations, it is essential to obtain high resolution intracardiac electrograms that consist of signals with small distortions and high amplitudes. Thus, the optimization of the sensing performance of catheters used in examinations leads to a better diagnosis of the various heart diseases. This article presents the results of a comparison between conventional and electroactive coated catheter electrodes. The electrodes in this comparative study were coated with iridium oxide (IrO_2), an electroactive material. This study examined whether cost-effective IrO_2 coating will optimize the intracardiac electrograms for electrophysiologic investigations. The sensing properties of the two electrode types have been analyzed with recorded intracardiac signals that were measured from the right atrium, the right ventricle, and the His-bundle. The determination of the peak amplitudes showed that the measurement with electroactive coated electrodes yields an average amplitude increase of 15.7 % (P-wave) to 32.6 % (R-wave) compared to the signals measured with uncoated electrodes. The examination of the sharpness (width) of the signal peaks leads to the result that the measurement with the new electrode type produces significantly narrowed peak widths. If signal detection and stimulation are performed through identical electrodes, the detection of heart potentials is possible with electroactive coated electrodes, in contrast to measurements with conventional electrodes. Higher amplitudes of the signals, a sharper display of the peaks, and especially the quality of poststimulatory potentials are displayed in an outstanding performance by the electroactive coated electrodes. Thus, catheters fitted with electroactive coated electrodes offer a number of improvements to clinical practice in electrophysiologic investigations.

Key Words

electrophysiologic investigation, electroactive coating, sensing performance, stimulation artifact, His-bundle signal

Introduction

The clinical diagnosis of heart diseases during electrophysiologic investigations requires catheters with excellent sensing performance. One important requirement is that the intracardiac signal detection should yield amplitudes as high as possible to enable an unmistakable distinction of very small signal peaks, i.e., far-field potentials. Yet heart potentials should not be obscured by pacing artifacts that might occur given such sensitivity in amplitude detection. This sensing capability allows for the analysis of heart potentials after stimulation.

Sensing and stimulation behaviors of the electrodes are determined by the interface between the electrode and the tissue. From the physical point of view, the electrode must have low interface impedance and low polarizability [1]. This demand can be fulfilled by enlarging the active surface area of the electrode, using techniques such as sintering, etching, or fractal coating [2]. For the production of short-term catheters, a variation of the fractal coating technique is more cost-effective; impedance is still reduced by simply coating the electrode with electroactive IrO_2 [3].

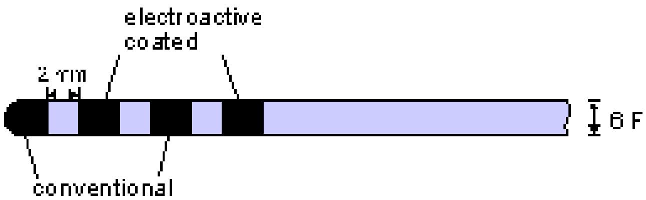

Figure 1. Catheter for simultaneous measurement with electroactive and conventional electrodes.

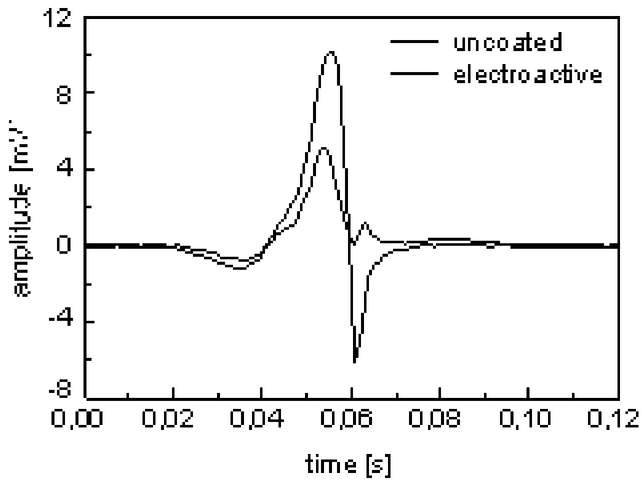

Figure 2. R-wave measurement with conventional and electroactive coated electrodes (data from patient BR).

This study was designed to determine whether elec-trodes coated with an electroactive substance could compete favorably with conventional electrodes, without the necessity of adding fractal coating. Initial trials with electroactive coated electrodes showed that the sensing and pacing performance is similar to the properties expressed by fractal coated electrodes [4]. The goal of this study was to compare electroactive coated and uncoated electrodes directly and to examine whether the coating of catheter electrodes indeed optimizes the sensing and pacing performances in electrophysiologic investigations. Only with a simultaneous measurement using conventional and electroactive coated electrodes and a comparative analysis of result-ing signals can it be demonstrated that the expected advantages based on theoretical predictions are useful in clinical practice. Therefore, this paper presents the results of simultaneous measurements by applying a catheter specifically designed to contain both the conventional and electroactive coated electrodes.

Methods

Intracardiac signals were recorded from the atrium, ventricle and His-bundle in 10 patients (2 female, 8 male, mean age 53 ± 14 years) during electrophysiologic investigations. The potentials were registered during sinus rhythm. Additionally, intracardiac signals during pacing were recorded from the right atrium via the measuring electrodes. The signals were stored for 30 seconds from each catheter position. For the simultaneous measurement with both types of electrodes, a quadrupolar catheter with two conventional and two electroactive coated electrodes was developed. To minimize the distance between the measuring regions of the two types, the electrodes were fixed on the catheter in alternating order (see Figure 1). The distance between all electrodes is 2 mm. The signals did not pass through the electrophysiologic investigation equipment at the clinic, but instead were directly recorded with a filter-free measurement amplifier. This was done to avoid signal distortions and filter-effects. The intracardiac signals were amplified, converted to digital data with an AD converter, and stored on the hard drive of a laptop computer.

For the analysis of the data, software was used that can automatically measure amplitude and time values (BIOVIEW, BIOTRONIK). The mean values of P-wave, R-wave and His-bundle amplitudes were calculated for each patient. Additionally, graphic comparisons of the "sharpness" of the peaks and of the sensing behavior after a stimulation were performed qualitatively.

Results

The analysis of the peak amplitudes shows significantly higher values in the signals measured with the electroactive coated electrodes in all patients. An example of an R-wave measurement is given in Figure 2. For a more detailed quantitative analysis of the data, the mean values of the peak amplitudes are shown in Table 1.

The total result demonstrates that the measurements with electroactive coated electrodes yield an amplitude increase with an average of 15.7 % (P-wave) and 32.6 % (R-wave), as shown in Table 2. The results of a paired, single-sided t-test show that the amplitude values of the measurement with coated electrodes are significantly higher.

Another aspect in analyzing the measured heart poten-

Pat. Code	P [mV] conv.	P [mV] e.act.	R [mV] conv.	R [mV] e.act.	HIS [mV] conv.	HIS [mV] e.act.
SZ	2.20	2.42	1.30	2.26	0.05	0.08
DG	2.63	4.31	1.94	5.65	0.02	0.05
PR	2.16	2.38	0.86	2.99	0.15	0.33
RL	1.60	1.57	9.11	9.87	0.18	0.10
SE	3.26	4.00	1.77	2.78	0.13	0.13
PH	1.15	1.40	2.90	3.98	0.18	0.20
KR	1.58	1.78	3.05	5.00	0.06	0.13
GR	4.41	4.46	9.61	6.76	0.19	0.22
BR	6.52	7.68	6.06	9.74	0.09	0.07
BK	2.54	2.45	2.68	3.03	0.09	0.12

Table 1. Mean values of the peak amplitudes of P-, R- and His-signals comparing conventional (conv.) and electroactive (e.act.) coated electrodes.

tials is the sharpness of the signal peaks. A narrow signal allows a better determination of the corresponding event times and prevents the fusion of the peak with neighboring signals. The widths of the intracardiac signals measured with electroactive coated electrodes are significantly smaller than in the data detected with the uncoated electrodes. The narrowing of a P-wave through the use of electroactive coated electrodes is shown in an example in Figure 3. With conventional,

	P	R	HIS
conventional	2.81±1.60 mV	3.93±3.20 mV	0.11±0.06 mV
electroactive	3.25±1.92 mV	5.21±2.80 mV	0.14±0.08 mV
mean amplitude increase with electroactive coated electrodes	15.7 %	32.6 %	27.3 %
significance of U(electroactive) > U(conventional)	p<0.02	p<0.03	p<0.10

Table 2. Amplitude values and amplitude increases with electroactive coated electrodes compared to conventional electrodes taken from all 10 patients.

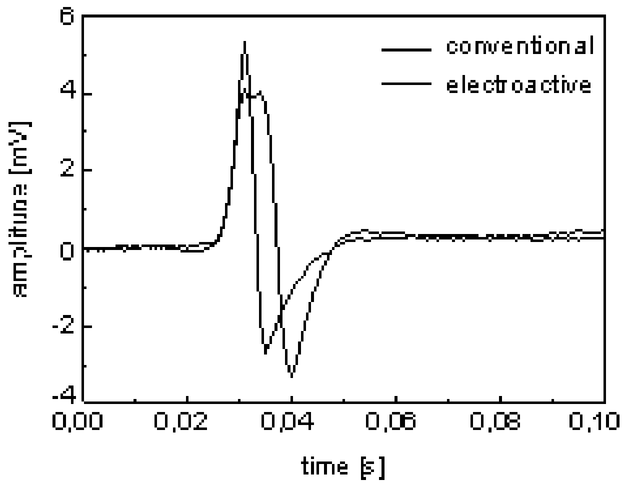

Figure 3. Demonstration of the difference in the sharpness of intracardiac signals in an example of a P wave (data from patient GR).

uncoated electrodes, it is almost impossible to examine the heart potentials after pacing when using the same electrodes for both detection and stimulation. The results of the intracardiac electrograms show that the data gathered with uncoated electrodes are comprised only of pacing artifacts. The complete time period between two paced events is filled with a polarization masurements performed with electroactive coated electrodes also show stimulation artifacts, but the time taken for the artifact potential to decrease to zero is less than 100 ms (Figure 4). Thus, the main period of the evoked response of the heart can be recorded and analyzed.

Discussion

The analysis of the simultaneous intracardiac measurements for the comparison of the two types of electrodes demonstrates that electroactive coated leads are superior in all aspects examined in this study. For interpretation of the results, the position of the electrodes on the catheter should be considered. Usually, the tip electrode yields better intracardiac signals than the ring electrodes due to its direct contact with the myocardium. Neither of the two electroactive coated electrodes were located at the tip. In spite of this disadvantage, the signals detected with the electroactive coated electrodes yielded better signal performances.

The significant increase in peak amplitude offers a better signal-to-noise ratio and forms the basis for an easier detection of very small signals, such as those

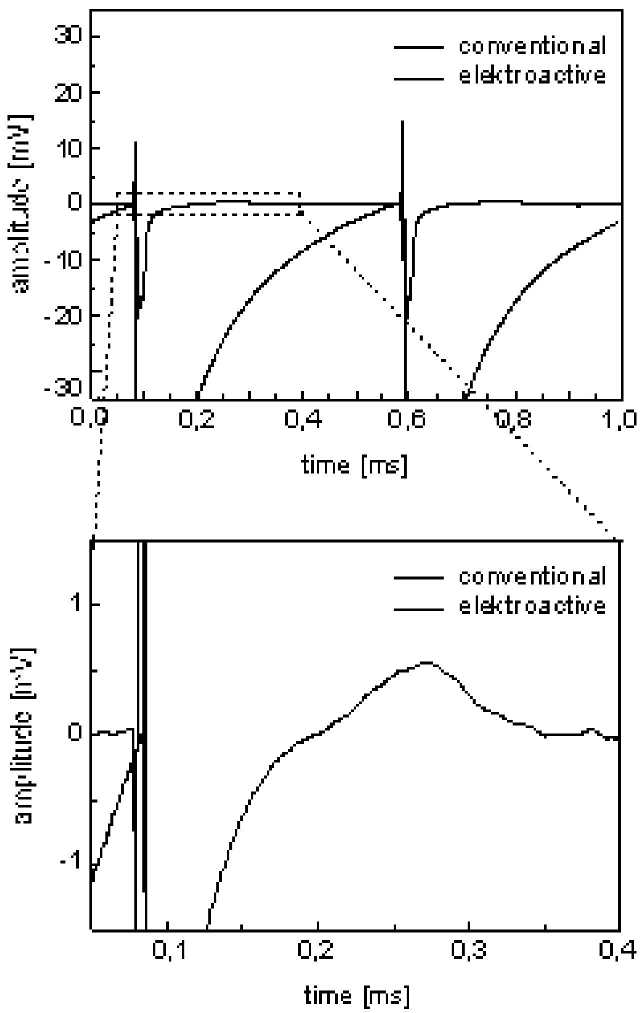

Figure 4. Atrial measurement during stimulation and detection using the same electrodes.

from the His-bundle or far-field potentials. Furthermore, the sharper display of peaks with the electroactive coated electrodes facilitates the distinction between small heart potentials and noise signals, even under difficult anatomic conditions, and provides an exact determination of the various time parameters.

Beyond the optimized sensing properties, the reduced appearance of stimulation artifacts is an outstanding improvement offered by the electroactive coated electrodes. In contrast to the measurements with conventional electrodes, a comprehensive investigation of the evoked response is possible. This leads to new aspects in diagnosis within the framework of electrophysiologic investigations [5][6].

Conclusion

Catheters with electroactive coated electrodes offer a number of improvements for electrophysiologic investigations in clinical practice. The sensing performances during spontaneous and paced episodes are optimized by this surface technology, and thus the diagnosis of heart diseases is rendered simpler and more specific. The analysis of post-stimulatory signals has been made possible for the first time with short-term catheters comprised of electroactive coated electrodes.

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