HANDS ON

Recording and interpreting unipolar electrograms to guide catheter ablation

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Introduction

Electrophysiology laboratories commonly use closely spaced bipolar recordings for mapping. However, unipolar recordings have some useful features that can provide additional complimentary information, provided the limitations of these recordings and the particular recording techniques are recognized.

Unipolar recordings

A cardiac electrogram is the result of the voltage difference between two recording electrodes. For clinical systems, the exploring distal electrode is connected to the anodal (positive) input of the recording amplifier. For unipolar recordings, the cathodal (negative) input of the amplifier is connected to a remote electrode (referred to as an indifferent or reference electrode) that is distant from the heart. In most systems, selection of the unipolar recording mode connects the indifferent input to the Wilson central terminal, which can have substantial electrical noise. Noise may be reduced by using an indifferent electrode in the inferior vena cava. The amplifier is left in the bipolar configuration, but the negative input is connected to the intravascular electrode, which in our laboratory is located 15 to 20 cm proximal to the tip electrode of a custom hexapolar catheter positioned at the His bundle.[1]

The genesis of a unipolar recording is illustrated in Figure 1. A depolarization wavefront propagating toward the exploring electrode generates a positive deflection. As the wavefront reaches the electrode and propagates away, the deflection sweeps steeply negative. Thus, an RS complex is generated. In a sheet of uniformly conducting tissue, depolarization of tissue beneath the electrode coincides with the maximum negative slope ($-dV/dt$) of the signal.

The morphology of the recording indicates the direction of wavefront propagation. When the exploring electrode is located at the site of initial activation (e.g., the left-hand side of the tissue in Figure 1A), depolarization produces a wavefront that spreads away from the electrode, generating a monophasic QS complex.[1,2] At sites remote from the tachycardia origin, an initial R wave is recorded.

For focal arrhythmias, a QS complex is typically recorded at the successful ablation site (Figure 2A). A QS complex may be recorded over an area larger than the successful ablation site and should not be the only mapping finding used to guide ablation. Successful ablation is unusual, however, at sites with an initial R wave in the unipolar recordings (Figure 2B). It is also important to realize that a QS complex can be recorded when the exploring electrode is not in contact with the myocardium. With poor or absent electrode contact, the initial S wave is slurred, suggesting that the electrogram is a far-field signal.

The major disadvantage of unipolar recordings is the contribution of substantial far-field signal generated by depolarization of tissue remote from the recording electrode. In normal tissue, the maximum negative slope is a good indication of local depolarization. In abnormal regions, such as infarct scars, the tissue beneath the recording electrode may be small relative to the surrounding myocardium outside the scar. A large far-field signal can obscure low-amplitude local potentials of interest (Figure 5A). With clinical recording systems, unipolar signals are of limited value for mapping in areas of scar unless they are filtered to remove far-field signal (discussed later).

Bipolar recordings

Bipolar recordings are obtained by connecting two electrodes in the area of interest to the recording amplifier (Figure 1B).[2] Much of the far-field signal is similar at each electrode and is subtracted out. In homogeneous tissue, the initial peak of the bipolar signal coincides with depolarization beneath the recording electrode and is typically selected for activation time.

Bipolar recording facilitates the identification of local depolarization in abnormal areas of infarction or scar (Figure 5). Multiple sharp deflections that represent asynchronous activation of multiple myocyte bundles are often recorded in scars and may be obscured in unipolar recordings. In bipolar recordings, however, a potential of interest may originate beneath either or both recording electrodes (Figure 5B). Ablation energy is applied only to the distal electrode, so ablation may fail when the focus is beneath the proximal electrode.

KEYWORDS Ablation; Conduction block; Mapping

ABBREVIATION **VT** = ventricular tachycardia (Heart Rhythm 2011;8: 791–796)

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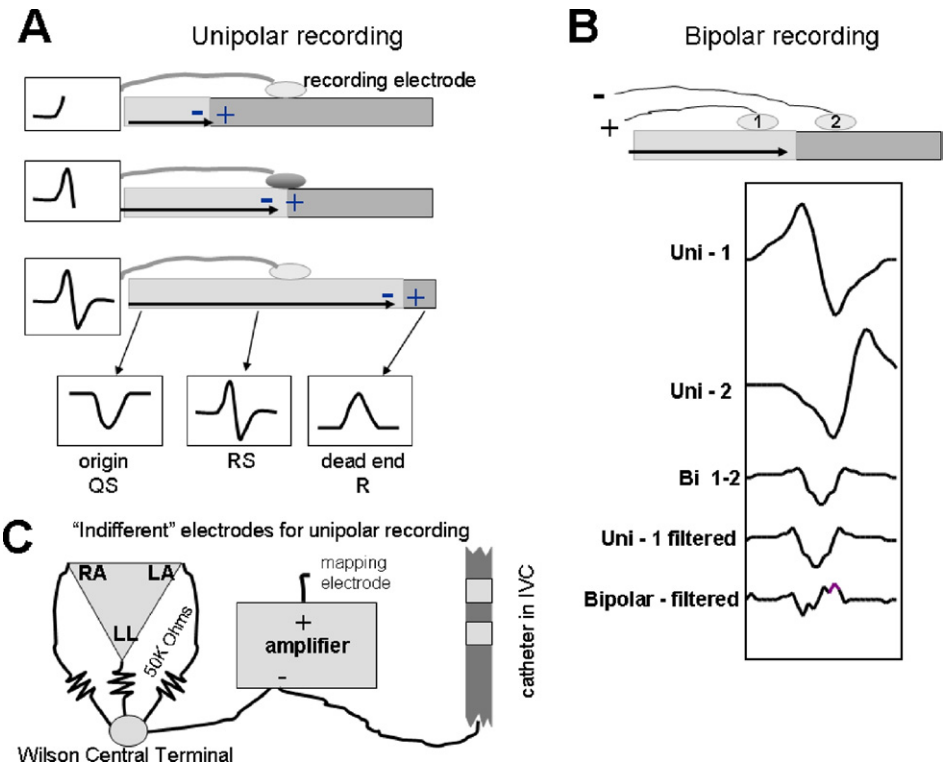

Figure 1 Genesis of unipolar and bipolar electrograms. **A:** Schematic diagram showing the unipolar recording electrode on a uniform sheet of tissue. Excitation of this tissue proceeds from left to right; the *lighter gray* areas indicate depolarized tissue. Theoretical recordings from three different sites along the tissue are shown in the bottom panel. Recordings from the initial site of depolarization generate a QS complex. Recordings from the last site to be depolarized generate a monophasic R wave (see text for discussion). **B:** Simulated unipolar and bipolar electrograms. The unipolar signal seen at the positive input to the recording amplifier (Uni-1) is an R-S. The unipolar signal from the second electrode (Uni-2) is in the negative input to the amplifier and therefore is inverted. The summation of these two signals generates the bipolar signal (Bi 1-2). Much of the far-field signal is the same at the two electrodes and therefore is subtracted out. **C:** Setup for unipolar recording, using either the Wilson central terminal or an indifferent electrode in the inferior vena cava (IVC). RA indicates the right arm; LA, the left arm; and LL the left leg ECG electrodes. (Reproduced with permission from Stevenson WG, Soejima K. Recording techniques for clinical electrophysiology. J Cardiovasc Electrophysiol 2005;16:1017–1022.)

In contrast to the amplitude of unipolar recordings, the amplitude of a bipolar electrogram is influenced by the direction of wavefront propagation.[2] Signal amplitude is largest for a wavefront propagating parallel to the axis of the recording electrodes and is reduced when propagation is perpendicular to the electrodes. The bipolar electrogram is also influenced by catheter orientation relative to the tissue. If the proximal electrode is off the tissue, a "semi-unipolar" recording results that has less far-field signal than the unipolar recording from the electrode that is in contact with the tissue. These factors can potentially influence voltage maps as well as activation maps.

Signal processing

Electrograms can be considered the sum of waveforms of different frequencies. The distance between the signal source and the recording electrodes also influences the signal. The amplitude of the signal diminishes as a function of signal frequency. The faster the frequency, the greater it will decrease in amplitude with respect to distance from the source. Thus, we recognize that "sharp potentials" are often due to local depolarization and rounded potentials are often "far field" from depolarization of distant tissue. Techniques of analog-to-digital conversion and filtering also influence the frequency content of electrograms.

High-pass filtering

High-pass filters attenuate low-frequency signals, but filters are imperfect and do not completely suppress these frequencies. The selected corner frequency provides an indication of the frequencies that will be attenuated, but the slope relating amplitude to frequency varies with different filters. In general, high-pass filtering can be viewed as differentiating the signal, such that the amplitude is proportional not just to the potential amplitude but also to the rate of change of the signal. The effect of differentiating signals, which can introduce additional peaks and complexity, is shown in Figure 1B.

Filtering unipolar recordings

Unipolar signals are commonly high-pass filtered at low corner frequencies of 0.05 to 0.5 Hz, which removes baseline drift without substantial alteration of the electrogram appearance. With these filter settings, a QS complex is observed at the site of origin of focal arrhythmias.

The far-field component of unipolar signals can be reduced by high-pass filtering at corner frequencies of 30 Hz and above. This can facilitate identification of low-amplitude local potentials that would be otherwise obscured, (Figure 5B, with low-amplitude potential seen under electrode 1), but alters the morphology such that QS and RS