A Cause of Falsely High Noise Level in Signal Averaged Electrocardiogram Recordings

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ABSTRACT
Signal averaged electrocardiogram (SAECG) is a well-established noninvasive method of exploration in patients at risk for sudden cardiac death. The time-domain SAECG analysis has a set of well-defined standards, including the value of accepted noise level. In very rare instances, the final noise level appears to remain unacceptably high even after carefully preparing the skin of the patient and averaging a great number of QRS complexes. We encountered three such cases in patients who had a SAECG done for a 40 Hz high-pass filter, which showed a high noise level in contrast with the visual impression of a good quality of the recording.

KEY WORDS late ventricular potentials, epsilon wave

Introduction
Signal averaged electrocardiogram (SAECG) recording is a well-established noninvasive method of exploration in patients with documented, suspected or at risk of malignant ventricular arrhythmias or of sudden cardiac death [1-3]. SAECG is also useful in the evaluation of patients with syncope and for risk stratification in a variety of diseases including acute and old myocardial infarction [3, 4]. The time-domain SAECG analysis is therefore included in all the investigation protocols of such patients and has a set of well defined and generally accepted standards in what concerns the values for the high-pass filters used, the quality of the recordings in terms of noise level and for the parameters used to identify the presence of ventricular late potentials. These parameters include the duration of filtered QRS (QRSD or fQRS), the time that the filtered QRS remains below 40 μV or the high frequency low amplitude signal duration (LAS40 or HFLA) and the root mean square voltage of the terminal 40 ms of the filtered QRS (RMS40) [5, 6]. At the same time, in terms of quality, any SAECG recording should have a standard deviation of the noise level of < 1.0 μV with a 25 Hz high-pass filter or < 0.7 μV with a 40 Hz high-pass filter in order to be considered accurate [6]. We consider a SAECG recording to be of a very good quality if the noise level is below 0.3 μV.

All the commercially available devices that record SAECG use two averaging windows: one for the QRS complex and the other for the noise. The regions where the signal is averaged in these separate windows are either automatically established by the software of the device, and cannot be changed, or may be manually chosen by the operator. In practice, although the position of noise window is systematically displayed on the final SAECG recording, it is seldom noticed.

The nurses or technicians who record SAECG know very well the target amplitude for the noise and always try to achieve the lowest possible value for it. In very rare instances, at the best of their efforts, the final noise level appears to remain unacceptably high even after carefully preparing the skin of the patient for electrode contact and averaging a great number of QRS complexes.

Report
In our practice we encountered 3 such cases in patients who all had an ε (epsilon) wave on their surface ECG and had a SAECG done for a 40 Hz high-pass filter which showed a high noise level in contrast with the visual impression of a fairly good quality of the recording.

The first of these SAECGs (figure 1) was done in a 24 years old woman with recurrent ventricular tachycardia and arrhythmogenic right ventricular cardiomyopathy (ARVC). This recording shows the obvious presence of ventricular late potentials (fQRS = 247 ms, HFLA = 180 ms, RMS40 = 3 μV) but the noise level as measured by the device after averaging 300 beats is 2.22 μV. The isoelectric baseline of this SAECG suggests visually that the recording is of an acceptable if not a very good quality, in contrast with the noise value. On closer inspection of the recording, it can be seen that the averaging window for noise (marked with arrows) is partly superimposed on the last portion of the HFLA signal thus explaining why the noise amplitude is so high.
The second SAECG recording (figure 2) was done in a 57 years old man who also had ventricular tachycardia caused by ARVC and revealed the presence of ventricular late potentials (fQRS = 238 ms, HFLA = 155 ms, RMS40 = 2 \( \mu \text{V} \)) with a noise level of 0.96 \( \mu \text{V} \) after averaging 504 beats. The same comments as for figure 1 apply to this recording which shows a lesser degree of superimposition of noise window on the last part of HFLA resulting in a comparatively lower noise amplitude.

The third SAECG is the most striking of all (figure 3) and was done in a 50 years old male with an old postero-lateral myocardial infarction, dilative cardiomyopathy and severe heart failure but without documented ventricular tachycardia. This recording shows an extremely large ventricular vector with huge ventricular late potentials (fQRS = 293 ms, HFLA = 233 ms, RMS40 = 5 \( \mu \text{V} \)) that engulf the noise window (between arrows) leading to a noise level given by the device of 3.81 \( \mu \text{V} \) after averaging 251 beats. This noise level is in sharp contrast with the smooth appearance of the isoelectric baseline both before and after the ventricular vector.

**Discussion**

These three extreme SAECG cases, with very long HFLAs, indicate that when the noise level is unexpectedly high when using devices which have a fixed noise window that cannot be moved by the operator outside the ventricular signal the first step must be to search for the position of noise window. If this one is superimposed at least in part on the ventricular vector the quality of the recording in terms of noise should be appreciated only visually based on the appearance of the isoelectric baseline at completion of averaging. In such situations, if the averaging is programmed to stop only after reaching a certain target of noise level and not of a target number of beats, the SAECG recording may never end. By keeping all these in mind, the operators can save time by not trying to record SAECG again and again with increasing number of averaged beats or by repeatedly and vigorously rubbing the skin of the patient which might not be very pleasant.

**References**


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