SIGNAL-TO-NOISE RATIO OF NERVE SIGNALS RECORDED WITH FULL AND OPEN CYLINDER CUFF ELECTRODES

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***Abstract*— In this paper, we compared the signal-to-noise ratios (SNRs) of nerve recordings obtained with an open cuff (a 270° cylinder) and a full cylindrical electrode (simulated by lifting the open electrode outside the solution) using an *in vitro* set-up. The thermal noise was considered as the main source of noise. The SNR with the open cuff was only 52±7% (n=3) less than that of a full cylindrical electrode, although the reduction in signal amplitude was 3.5±0.6 times. One may prefer to use the open cuff geometry to reduce the risk of nerve insult in certain nerve recording applications where this loss in SNR is acceptable.**

***Index Terms*—** electroneurogram, noise, cuff electrodes.

I. INTRODUCTION

Analytical models and simulation studies predict that peripheral nerve signal amplitudes recorded with a cylindrical cuff electrode decrease significantly when a longitudinal conductive pathway is present between inside and outside the electrode [1,2]. In this paper, we evaluate the effect of the longitudinal opening on the signal quality (i.e. the SNR) assuming that the thermal noise is the main source of noise. The electronic noise generated in the recording pre-amplifier can be reduced to a level that is negligible compared the thermal noise generated within the nerve/electrode impedance by employing the concept of noise-matching in the design [3]. Thus, the thermal noise ultimately constitutes the main source of the noise within the frequency band of the nerve signals that deteriorate the signal quality. In this paper, we compare an open cuff (270° cylindrical) electrode with a full cylindrical geometry in terms of the SNRs obtained with each design using an *in vitro* nerve recording preparation.

II. THEORY

Assuming that all the other types of noise except the thermal noise can be eliminated, the signal-to-noise ratio (SNR) of the nerve recordings can be defined as

$$SNR = S / \sqrt{4kTBR} \qquad \text{(Eq. 1)}$$

where S: signal, k: Boltzmann's constant (1.38×10^{-23} joules/°K), T: absolute temperature (°K), B: noise bandwidth (Hz), and R: the resistive part of the nerve/cuff impedance. For the same bandwidth and temperature, the SNR reduction from one electrode (electrode 1) to another (electrode 2) can be estimated using the following equation:

$$\text{Percent SNR Reduction} = 100 \times \left(1 - \left(\frac{S_2}{S_1}\right) \times \left(\sqrt{\frac{R_1}{R_2}}\right)\right) \qquad \text{(Eq. 2)}$$

III. METHODS

In vitro recordings of compound action potentials (CAPs) from sciatic nerves were made using a bath (1 liter, heated to 37°C, 95%O_2 and 5%CO_2 gas bubbled through) filled with modified isotonic Krebs solution whose resistivity was increased to a value that was comparable to that of the vascular tissue (200-300 Ohm.cm at 37°C) by replacing 90-100% of NaCl with glucose. Piglet sciatic nerves (n=3) were stimulated at one end and CAPs were recorded distally with a 270° cylindrical electrode made of silicone tubing (I.D.=2 mm, L=20 mm). The recording electrode had three Platinum-band contacts (width=1 mm) placed at the ends and in the middle. Recordings were made from the middle contact with respect to the shorted end contacts (tripolar connection). First, the evoked CAPs were recorded and the electrode impedance was measured (at 1, 2, and 3 kHz and then averaged) while the electrode was lifted above the surface such that the nerve was touching the solution only at the ends to simulate a full cylindrical cuff electrode. Second, the CAPs and impedance measurements were repeated after immersing the nerve/cuff preparation into the solution. The decrease in the SNR with the open electrode geometry was estimated using Eq. 2.

IV. RESULTS

The CAP amplitude (Fig. 1) and the tripolar nerve/electrode impedance (resistive component) decreased by the amounts (mean±SD) shown in Table 1 when the nerve was immersed into the solution. As a result, the estimated SNR was reduced by 52±7%.

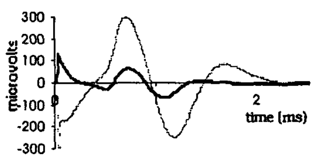

***Figure 1:** Compound action potentials recorded while the 270° cylindrical electrode is outside (dotted line) and inside (bold) the solution.*

	Signal	Contact Resis.	SNR
Reduced by	3.5±0.6 times	2.8±0.4 times	52±7%

***Table 1:** Amount of decrease in the measured parameters when the electrode was immersed into the solution.*

V. CONCLUSIONS

The reduction in SNR when the electrode was immersed into the solution was significantly less than the decrease in the signal amplitude alone. This SNR loss may be acceptable in some chronic implantations to allow one to use electrodes with longitudinal opening for reducing the risk of nerve insult.

REFERENCES

[1] L.N.S. Andreasen and J.J. Struijk, "On the importance of configuration and closure of nerve cuff electrodes for recording", in *Proc. of 20th Annual International Conference of the IEEE/EMBS*, pp. 3004-3007, 1998.

[2] J. J. Struijk, "The extracellular potential of a myelinated nerve fiber in an unbounded medium and in nerve cuff models", *Biophysical J.*, vol. 72, pp. 2457-2469, 1997.

[3] M. Sahin, and D. M. Durand, "An Interface for nerve recording and stimulation with cuff electrodes," in *Proc. of 19th Annual International Conference of the IEEE/EMBS*, pp. 2004-2005, 1997.

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