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2.2.3: Peripheral Electrodes

FASCICLE SELECTIVE RECORDING WITH A NERVE CUFF ELECTRODE

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ABSTRACT

A multipolar split cuff electrode is used for fascicle selective recording of the electroneurogram (ENG) of the sciatic nerve of the rabbit. Several electrode configurations were evaluated with regarding to selectivity: the peroneal and tibial nerves were stimulated alternately and the ENG was recorded at different sides of the sciatic nerve. The results for two electrode configurations are presented.

INTRODUCTION

It is well established that whole nerve cuff recordings from peripheral sensory nerves can provide tactile information. This was shown in animal studies [1] and in humans as well [2]. In the latter work the recorded nerve signals from the sural nerve were used for the detection of heel strike in drop-foot patients.

Since different parts of the foot-sole are innervated by three different branches of the posterior tibial nerve, more information about foot-floor contact and pressure distributions on the foot-sole could be obtained if signals from these branches could be recorded separately. Preferably, this should be done with only one cuff around the posterior tibial nerve, at a position where the different branches are contained in the posterior tibial nerve as separate fascicles.

In this work we present an experimental animal model for fascicle selective recording. We used a multipolar cuff, similar to those that have been used for selective stimulation [3] to record from the sciatic nerve in the rabbit.

METHODS

Experiments were carried out on 6 New Zealand White rabbits, which were anaesthetized with dormicum 2 mg/kg and hypnorm 0.3 ml/kg subcutaneously. During anaestesia supplementary doses hypnorm and muscle relaxant were administered.

The sciatic nerve and its peroneal and tibial branches were exposed. A twelve contact split cuff electrode was put around the sciatic nerve and bipolar tungsten hook electrodes were used for stimulation of either the tibial or the peroneal nerves (see figure 1).

The silicone cuff electrode had a total length of 25 mm. It had an oval cross section with inner diameters of 4x2 mm. This shape was used because of the flat shape of the sciatic nerve, which has typically a 3x1 mm cross section. The platinum contacts were 2x1 mm, ordered in 4 tripolar rows with a longitudinal contact separation of 10 mm.

Figure 2 shows the two most successful contact configurations that were used for recording from the peroneal and tibial sides of the nerve

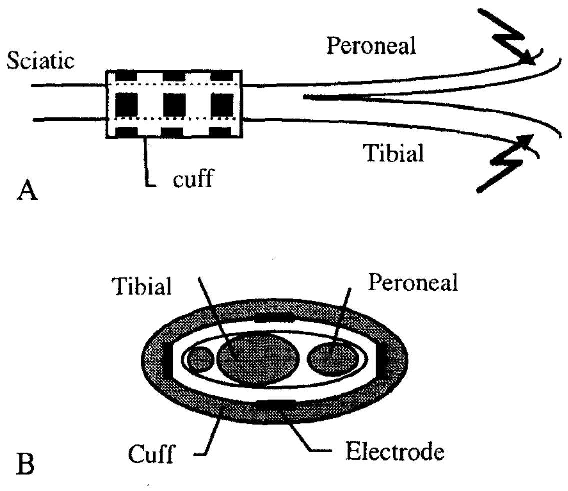

Figure 1 *A) Schematic drawing of the nerves and electrodes: Stimulation of the peroneal and tibial nerves (the sural nerve is not shown), and recording with a cuff around the sciatic nerve; B) Schematic drawing of the positions of the peroneal and tibial fascicles in the sciatic nerve; the small sural fascicle is also shown in this figure.*

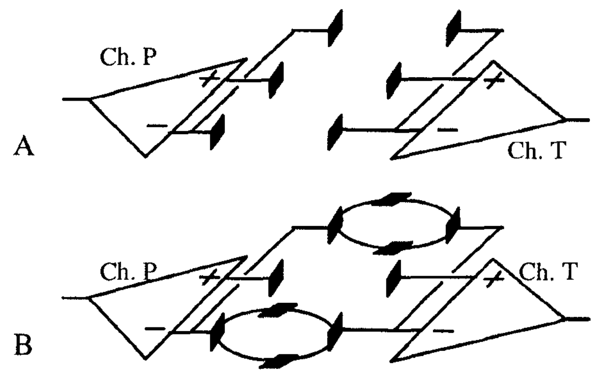

Figure 2 *Two recording configurations. A) A tripolar configuration at each side of the nerve. B) Outer contacts connected to form a shared reference for the central contacts. Ch.P is the recording channel at the peroneal side of the sciatic nerve, Ch.T is at the tibial side.*

To compare the different configurations we defined a selectivity product (alternatively a measure for mutual cross-talk could be used). Suppose P_p and T_p are the rms amplitudes of the CAPs recorded at the peroneal side and the tibial side of the sciatic when stimulating the peroneal nerve. Similarly, T_t and P_t are the rms amplitudes at the tibial side and the peroneal side when stimulating the tibial nerve. Peroneal selectivity S_p can then be defined as $S_p=P_p/T_p$, and tibial selectivity as $S_t=T_t/P_t$. Both selectivities should be as high as possible. Now, an intuitively meaningful single descriptor for the mutual selectivity is the square root of the product of the peroneal and tibial selectivies:

$$S = \sqrt{S_p S_t}$$

which gives a combined single indicator of the ratio of the signal strength at the peroneal (tibial) side when the peroneal (tibial) nerve is active and the signal strength at the tibial (peroneal) side when the peroneal (tibial) nerve is active. Preferably, the value of S should be as high as possible. A value of 1 would mean that there is no selectivity. A value below unity is not expected to occur.

RESULTS

Both at the tibial and at the peroneal side of the sciatic nerve recordings were made while stimulating either the tibial or the peroneal nerve (pulsewidth 20 µs). An example is shown in figure 3. The recordings were taken as recruitment curves. In figure 3A the Compound Action Potentials recorded at both the tibial (solid) and the peroneal sides (dotted) of the sciatic while the peroneal nerve was stimulated are shown

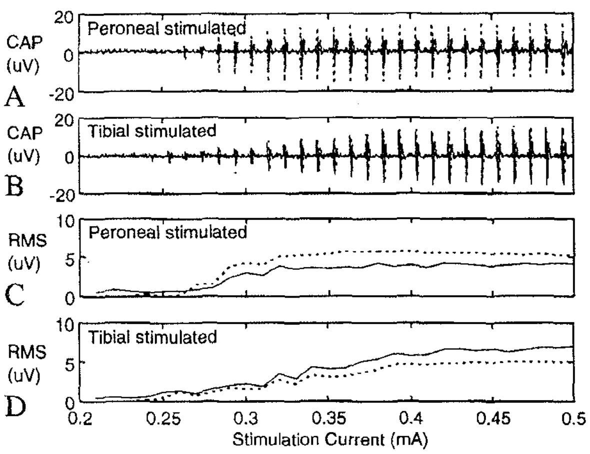

Figure 3 Recruitment curves. Solid: recorded from the tibial side of the sciatic nerve. Dotted: recorded from the peroneal side. A) and B): Compound action potentials shown for increasing stimulus amplitude; C) and D): RMS amplitudes of the CAPs where the peroneal and tibial nerves are stimulated respectively.

In 3B the same is shown for tibial stimulation. The rms amplitudes of the CAPs are shown in figures 3C and 3D.

For the six experiments the average value of the selectivity indicator S was S=1.4 (ranging from 1.1 to 1.6) for the configuration in fig. 2A. For configuration B the average value was 1.3, the difference with configuration A not being statistically significant. Other configurations gave clearly lower selectivities.

DISCUSSION

We have shown that fascicle selective recordings of the electroneurogram can be obtained with multipolar whole nerve cuff electrodes. However, we feel that for reliable selective recordings of more than two fascicles and in the presence of noise (e.g., muscle signal) the selectivity has to be further improved.

An important disadvantage of the presence of the cuff around the nerve may be that the cuff restricts the extracellular space, making the field inside the cuff more homogeneous [4] than when there would be no cuff, thus diminishing the selectivity. Therefore we expect that with an intimately fitting cuff around the nerve selectivity will be lower.

When low noise recordings from both sides of the nerve can be made, low selectivity recordings can still be used to calculate how much of the signal arises from the tibial and how much from the peroneal fascicles, as long as S>1 and if S_p and S_t are known (measured). If there is activity in both the tibial and peroneal fascicles, and the measured ENG amplitudes are T and P at the tibial side and at the peroneal side of the sciatic nerve, respectively, then P_p, P_t, T_t, and T_p can be calculated because $S_p=P_p/T_p$, $S_t=T_t/P_t$., $T=T_t+T_p$, and $P=P_p+P_t$ form a set of four independent equations with four unknowns, yielding $P_p=(S_pT-S_pS_tP)/(1-S_pS_t)$, etc. If SNR is low, then noise terms have to be added to T and P. Thus, for low noise the results obtained with the CAP signals can be extrapolated to the situation of ongoing neural activity.

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