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2.2.3: Peripheral Electrodes

SELECTIVE RECORDING WITH A MULTI-CONTACT NERVE CUFF ELECTRODE

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***Abstract*— A multi-contact cylindrical nerve cuff electrode was evaluated for its ability to record neural signals selectively in an *in vitro* preparation. Three branches of a Beagle hypoglossal nerve are stimulated sequentially while compound action potentials (CAP) are recorded from its trunk with the multi-contact cuff electrode. A selectivity index (SI) is defined and applied to the CAP recorded from the 4 sets of tripolar contacts (12 contacts in total) that are equally spaced around the cuff. The results show that the cuff can record selectively from different fascicles, but these effects are small. Connecting the contacts of the opposite set together while recording from a tripole improved the *selectivity*. The signal amplitudes from various contacts are consistent with the location of the fascicles relative to the contacts.**

INTRODUCTION

Cuff electrodes with circumferencial metal contacts have been used for whole nerve recordings in acute and chronic animal studies, and recently in humans [1,2]. The drawback of this design is that it provides only a single channel of information about the neural activity. A simple method of increasing the number of channels is to place several contacts around the nerve. In this study, we evaluated the recording selectivity of a multi-contact cuff in an *in vitro* preparation. A selectivity index (SI) was defined, and used to determine the *selectivity* of various sets of contacts for different fiber sub-populations within the nerve trunk. Histology sections were taken to verify the results.

METHODS

Experimental Set-up: The experiments were conducted on two hypoglossal nerves from Beagles (11kg). The nerve sections included 4-5 cm of the main branch and several centimeters of the medial and lateral branches. Three branches with different sizes were dissected under a microscope and each was fitted into a stimulation cuff (Figure 1). A multi-contact recording cuff was placed on the main branch near the bifurcation point of the branches. All cuffs had longitudinal slits to allow the placement of the nerves. The preparation was bathed into a 2 liter tank filled with Krebs solution. The temperature was kept at 37±0.25 °C. The multi-contact cuff was tied with sutures to hold the nerve tightly, hence minimize the amount of solution inside the cuff. Vaseline® was applied over the slits and at the ends of the cuffs for better electrical isolation.

The cuffs were made of silicone tubing and Platinum contacts, welded to lead wires for electrical connection. Three stimulation cuffs, 8 mm in length and 1 mm in diameter, were placed on the branches. The multi-contact cuff was 20 mm long and 2.5 mm in diameter. Four sets of contacts were placed around the circumference and each set consisted of 3 Platinum contacts (4x1 mm) positioned longitudinally with 3 mm gaps between each (A, B, and C in Figure 1). Each set could be configured individually either in tripolar mode or left open, or all three contacts in a set could be connected together using a switch-box employed the multi-contact cuff and the recording amplifier. The nerve signals were amplified (x1000), filtered (100Hz-3KHz), digitized, and stored in a computer.

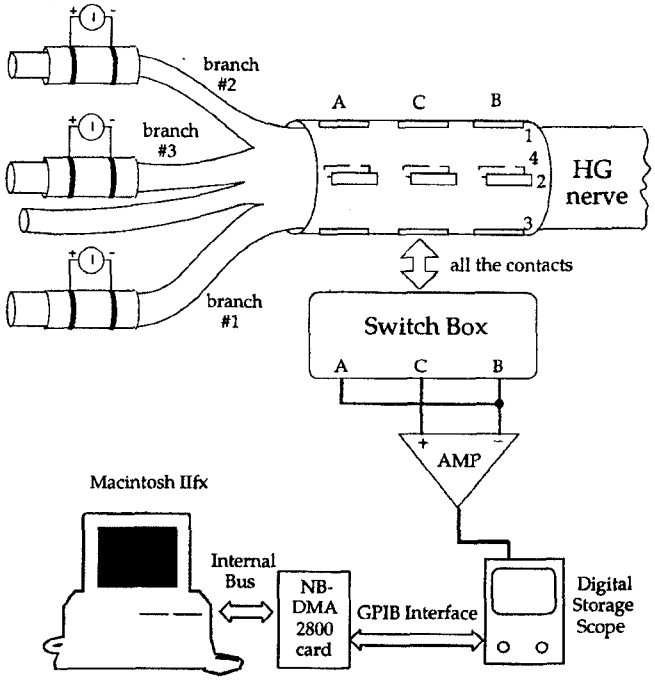

FIGURE 1: The experimental set-up. See the text for details.

Procedure: Two different procedures were performed. In the first procedure, the branches (b1-b3) were stimulated sequentially using a supra-maximal rectangular current pulse (10 μsec, 0.3-1 mA) and compound action potentials (CAP) were recorded in tripolar configuration from each of the four contact sets (c1-c4), while leaving the unused sets open. Thus, a set of twelve CAP traces were collected (3 branches by 4 sets of contacts) within 5-10 minutes. Each procedure is repeated five times for statistical calculations. In the second procedure, the same steps were followed except that the contacts of the 180° opposite set were connected together (shorted) while recording from one set. The selectivity indexes (see below) were calculated and plotted for each procedure. Histology sections were made along the nerve at the locations of the contacts.

Selectivity Index: The selectivity index (SI) is computed in two steps: 1) the CAP amplitudes resulting from stimulation of a branch are normalized (denoted by superscript n) using the following equation

$$V_{bc}{}^{n} = \frac{V_{bc}}{\sum_{j} V_{bj}} \qquad \text{for all } b \text{ and } c \qquad (1)$$

where V_{bc} denotes the CAP amplitude recorded from the contact set c while the branch b being stimulated. 2) the SIs of each contact set are computed in percentages for each fiber sub-population being activated by stimulation of the branches using the following equation

$$SI_{bc} = \frac{V_{bc}{}^{n}}{\sum_{i} V_{ic}{}^{n}} x100 \qquad \text{for all } b \text{ and } c \qquad (2)$$

The term *selectivity* is used to refer to the differences in the amplitudes of the SIs of a contact for various fiber sub-populations.

RESULTS

A typical set of CAP waveforms is shown in Figure 2. Three groups of waveforms corresponding to the three branches are plotted. Each group contains four waveforms from the four contacts.

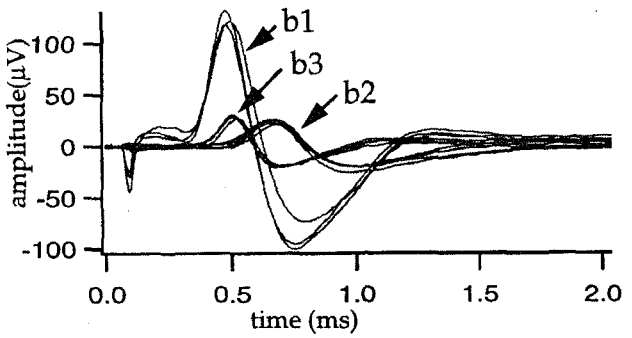

FIGURE 2: A set of CAP traces recorded from the multi-contact cuff.

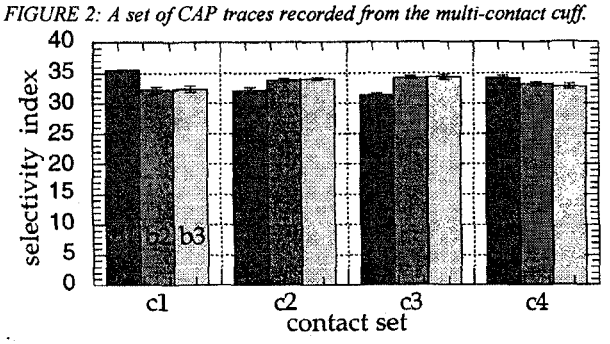

FIGURE 3: The mean SIs of the contact sets (c1-c4) for each fiber sub-population (b1-b3) from the first procedure. The left, middle, and right columns correspond to sub-populations b1, b2, and b3, respectively.

The mean SIs and the ±standard deviations from the first (open circuit) and the second (short circuit) procedures are shown in Figures 3 and 4, respectively. Small but significant *selectivities* are observed. Contacts c1 and c4 record preferentially from branch b1, but record equally from branches b2 and b3. The SI values for b1 and b2 are significantly different (p=0.01) in all contacts and procedures. The SI values obtained for the second procedure are shown in Figure 4. The relative recording order is maintained but the *selectivity* is improved; e.g. the *selectivities* for b1-b2 couple are significantly different (p=0.025) in procedure 2 for all contacts. The plots correlate well with the relative location of the sub-populations being activated and the contacts as shown in Figure 5. From the figure, one would expect to get a larger signal from b1 through contacts c1 and c4 compared to c2 and c3. Similarly, b2 and b3 should give larger signals through contacts c2 and c3.

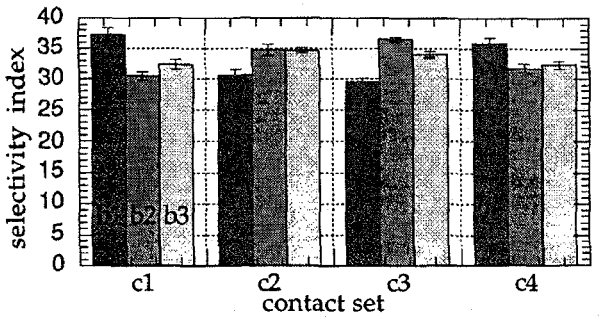

FIGURE 4: The mean SIs of the contact sets (c1-c4) for each fiber sub-population (b1-b3) from the second procedure.

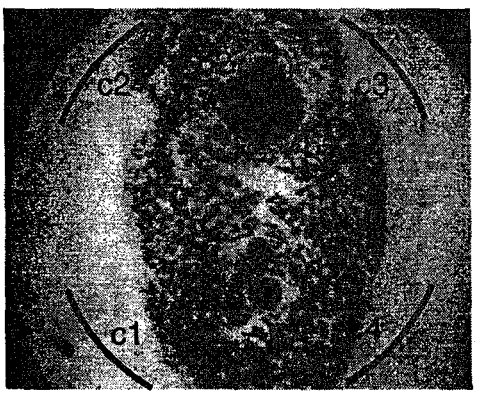

FIGURE 5: Histology section taken at the middle of the multi-contact cuff. The estimated radial locations of the contacts (c1-c4) and the fiber sub-populations (b1-b3) being stimulated are shown.

CONCLUSIONS

Selective recordings can be obtained from multi-contact electrodes but the effects are small. Short circuiting the opposite set of contacts significantly improves the *selectivity* of the multi-contact cuff. A possible method for improving the *selectivity* is to use an external anodic current source to amplify the signals only from a given fascicle [3]. Another potential method is to place the contacts onto an element that is penetrating into the nerve [4].

REFERENCES

[1] T. Sinkjaer, M. Haugland, J. Haase, and J.A. Hoffer, "Whole sensory nerve recordings in human," in *Proc. 13th IEEE Conf. on EMBS*, pp. 900-901, 1991.

[2] D. Popovic and V. Raspopovic, "Afferent recording in digital palmar nerves," in the *Proc. 4th Vienna Intern. Workshop on FES*, pp. 104-7, 1992.

[3] Sahin, M., and D.M. Durand, "Improved nerve cuff electrode recordings by sub-threshold anodic currents," *IEEE/17th Annual Conference of the Eng. in Med. and Biol. Soc.*, 1995.

[4] Tyler, D.J. and D.M. Durand, "Interfascicular Electrical Stimulation for Selectively Activating Axons," *IEEE-EMB Mag.*, 13, 5:575-583, 1994.