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QUANTIFICATION OF SIMILARITIES IN RECRUITMENT PROPERTIES OF MONOPOLAR AND TRIPOLAR CONFIGURATIONS

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ABSTRACT

Nerve cuff electrodes have been shown to be safe and capable of effecting selective and controlled activation of select segments of a peripheral nerve. This selectivity has been shown using a cuff with four equally spaced tripole electrodes employing twelve contacts and twelve lead wires. With present technology, constructing a twelve contact, twelve lead wire nerve cuff is not feasible for safe chronic implementation in a human. In the study presented here, we evaluate the monopolar configuration for its simplified and reduced number of contacts and lead wires. Based on the similarity of current flow patterns between monopolar and tripolar configurations, the recruitment characteristics should be similar. Both the overlap between monopolar and tripolar configurations and the repeatability of each configuration was measured. A statistical difference was not found between monopolar and tripolar configurations nor was a statistical difference found for the repeatability of each configuration. Based on these findings we conclude that a four contact monopolar cuff electrode can be used in place of a twelve contact tripolar cuff electrode.

INTRODUCTION

Motor function in paralyzed persons may be restored by electrically activating the motor nerves serving paralyzed muscles. Present motor prostheses employ surface electrodes, epimysial electrodes or intramuscular electrodes. Surface electrodes, although the least invasive, suffer from lack of selectivity and poor repeatability. Both epimysial electrodes and intramuscular electrodes require at least one electrode for each muscle desired. These muscle-based electrodes are also subject to material fatigue, failure and displacement due to repeated muscle contraction. Nerve cuff electrodes, however, can be implanted in areas of low mechanical stress, and activate selectively different regions of the nerve trunk to recruit individual muscles [1]. This technique of selective activation is promising for controlling many muscles, as is required by a functional motor prostheses, with one electrode.

Excellent results have been found utilizing the twelve contact (four tripolar) cuff electrode. Present technology, however, lacks the ability to fabricate a lead cable and connector for this twelve contact cuff that is suitable for human implantation. To explore the potential of using the multicontact configuration in humans, we have conducted experiments with a simplified cuff. This simplified cuff contains four equally spaced monopoles [2].

METHODS

A twelve contact spiral nerve cuff electrode was implanted on the sciatic nerve of a cat. This cuff was used to produce both monopolar and tripolar stimulation.

Monophasic 10μsec cathodic current pulses were applied between the stimulating contact in the cuff electrode and the return contact. The return contacts for the tripolar configuration were two contacts inside the cuff. The return contact for the monopolar configuration utilized a hypodermic needle placed subcutaneously in the back of the cats neck.

Isometric twitch torque was recorded using a force transducer attached to the cat's paw. The paw and hind limb was oriented in a horizontal plane with 90° flexion in the hip, knee and ankle joints. Torque about the ankle was measured in all three dimensions, plantar/dorsiflexion, internal/external rotation, and inversion/eversion.

Comparison of two recruitment characteristics was performed by calculating the overlap of the output torque vectors produced by each electrode configuration. The overlap value is a representation of what percent of one curve has a point on the second curve that is not significantly different.

A measure of repeatability is found by calculating the overlap value for multiple recruitments using the exact same contacts in the same electrode configuration. This repeatability also represents the maximum overlap we can expect to find between two different electrode configurations. In order to represent the minimum overlap we calculated the overlap between two electrodes positioned at different places around the nerve.

RESULTS

Shown in figure 1 is a typical recruitment curve, showing the magnitude of plantar flexion and lateral rotation torque vs. current amplitude. The tripolar recruitment curve (squares) is shifted to the right of the monopolar recruitment curve (circles) indicating that monopolar stimulation has a lower threshold for activation. Both monopolar and tripolar configurations plateau at full plantar flexion but activation of different muscles occur during the recruitment. In both electrode configurations, this spill-over to different nerve fibers is evidenced by the change from increasing medial rotational torque to decreasing medial rotational and eventually lateral rotational torque. This spill-over is evident in torque space (figure 2) by the sharp change in the 0° trace from a leftward progression to a rightward progression.

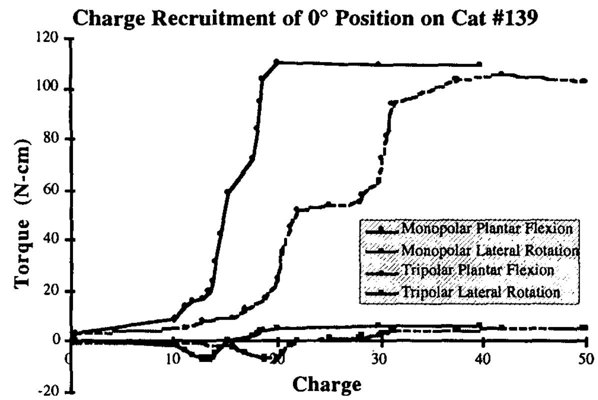

Figure 1 - Charge recruitment curve for monopolar and tripolar configurations at position 0° in Cat #139.

At each of the four positions around the nerve, the monopolar and tripolar configurations were found to generate very similar torque vector magnitudes and directions. This similarity was further quantified by calculating the corresponding overlap values. The output from the 0^{0} and 90^{0} positions are shown in figure 2 with their corresponding overlap values of 83.0 and 83.7% respectively.

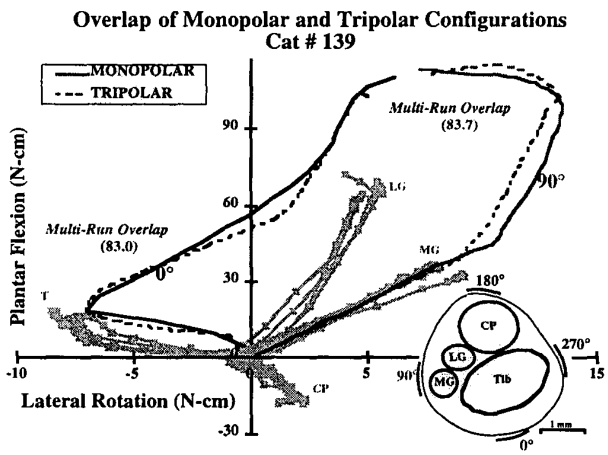

Figure 2 - Recruitment curves for monopolar and tripolar configurations shown in torque space for the 0° and 90° positions in Cat #139. The mean overlap values for the comparison between the monopolar and tripolar configurations are also given next to each curve.

A measure of overlap for each configuration was calculated from a set of 12 different monopoles and tripoles and summarized in figure 3. The average repeatability of the monopolar and tripolar configurations were found to be 79.2% and 79.0% respectively. At a 95% confidence interval these were not found to be statistically different. The average overlap of two different positions around the nerve trunk was found to be 16.4%. The average overlap for all

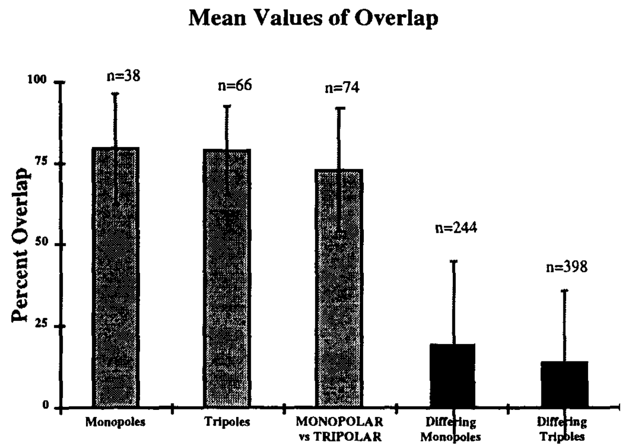

Figure 3 - Mean values of overlap for the repeatability of the monopolar and tripolar configurations, for the monopolar and tripolar comparison and for comparing two different contacts.

monopole vs. tripole configurations was found to be 72.8%. This was found to be statistically different than the overlap value found for two different positions around the nerve but not statistically different than either of the repeatability values found for monopolar or tripolar configurations.

CONCLUSIONS

In this study, we quantified the differences in the recruitment characteristics produced by monopolar and tripolar configurations. The monopolar and tripolar configurations were found to produce very similar output torque vector magnitudes and directions. Further, our measurements indicated that the repeatability of both the monopolar and tripolar configurations was not significantly different. Our measurements also indicated that the monopolar and tripolar configurations was not significantly different. Based on these results we believe that a monopolar configuration can be used to progress this nerve cuff technology into human studies.

REFERENCES

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ACKNOWLEDGMENTS

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