MEASUREMENT OF INTRAFASCICULAR INSERTION FORCE OF A TUNGSTEN NEEDLE INTO PERIPHERAL NERVE

W. Jensen[1], T. Malina[2], U. Hofmann[2], K. Yoshida[1]
[1]Center for Sensory-Motor Interaction, Aalborg University, Denmark
[2]Med. Universität zu Lübeck, Instiut für Signalverarbeitung und Processrechentechnik, Germany

***Abstract* – Microfabricated silicon array structures, such as those being developed by the VSAMUEL consortium may one day provide inexpensive yet highly selective chronically implanted interfaces to the peripheral nervous system. In the present study we examined the feasibility of implanting such microelectrodes into peripheral nerve tissue by characterizing the mechanical forces required for implantation. We conducted *in-vitro* implantation experiments into excised rabbit peripheral nerve with electrosharpened tungsten needles similar in dimension to the VSAMUEL probes. A needle was manually advanced through the epineurium and perineurium using a micro-manipulator, and the force applied to the needle during the insertion process was measured using a custom built force detection device. We found that a force greater than 2 mN was necessary to insert the needle. Clear dimpling of the nerve surface was also observed prior to penetration.**

***Keywords* - Peripheral nerve, micro-electrodes, tungsten needle, recording, insertion force.**

I. INTRODUCTION

Cuff electrodes have long shown the ability to provide a chronic reliable interface to record peripheral nerve activity. The electrodes have found their way into application in advanced closed-loop functional electrical stimulation (FES) systems, which use signals from natural nerve sensors as feedback [1,2]. However, the success of the FES control is limited by the quality of the information recorded by the electrodes.

Intrafascicular electrodes were developed to provide a more selective interface by penetrating the nerve sheath and placing the recording/stimulating site within the nerve. Using intrafascicular electrodes, Yoshida and Horch successfully extracted joint angle from muscle afferent activity, and demonstrated that linear real-time control of ankle flexion-extension movement was possible [3]. Given electrodes with greater selectivity than the nerve cuff a finer graded control might be achieved.

Microelectrodes (metal, glass micro-pipette or photoengraved types) can potentially register activity from single axons, and these electrodes may therefore be an attractive alternative peripheral nerve interface.

Recordings from individual nerve cells in the brain, has been one of the main techniques used to study how the brain processes information to control body functions [4]. Similarly, recordings from the sensory afferents in peripheral nerves have shown to contain information on body movement and orientation of the body in space [1-3]. Future use of information recoreded from these afferents could broaden the number of possible applications and possible movements to be controlled by FES.

The mechanics of insertion and density of microelectrodes sites have been studied [5], however, similar studies in peripheral nerve do not exist. The objective of the present study was to determine the necessary force to implant a microelectrode through the epineurium and perineurium into peripheral nerve.

II. METHODOLOGY

Peripheral nerve tissue was obtained a from a New Zealand White rabbit immediately after euthanasia. The sciatic nerve and it's distal tibial and peroneal branches were exposed in the rabbit's left leg and removed. The excised nerve was stored in a normal 0.9% saline solution until the measurements were made. During the insertion experiments the peripheral nerve tissue was kept immersed in the saline solution. Sutures were tied to the nerve ends as anchor and to adjust the tension on the nerve (Figure 1A). The insertion force was measured using a custom build force transducer device described in [6]. The force sensor consisted of a DC-DC lateral displacement transducer (LVDT 0200-000, Trans Tek. Inc., Connecticut, USA), a steel core attached to a spiral spring and a coupling junction attached to the probe. In the present experiment, we characterized the insertion force using a 50µm electro-sharpened tungsten needle. The displacement of the steel core reflects the deflection of the spring **d**. The loading force of the tungsten needle **F** are related to the spring constant **k** by Hooke's law:

$$\mathbf{F}_{\mathrm{LOADING}} = -k_{\mathrm{SPRING}} \bullet \mathbf{D}_{\mathrm{CORE}}$$

The device (core, attatched needle and spring) was calibrated on a regular laboratory scale to determine the spring constant. The spring constant was estimated to 3 g/mm. The tungsten needle was advanced manually using a micromanipulator. The insertion speed was not controlled during the experiment. The insertion angle of the tungsten needle was kept normal to the surface of the peripheral nerve. Furthermore, the effect of insertion angle and insertion speed was not studied.

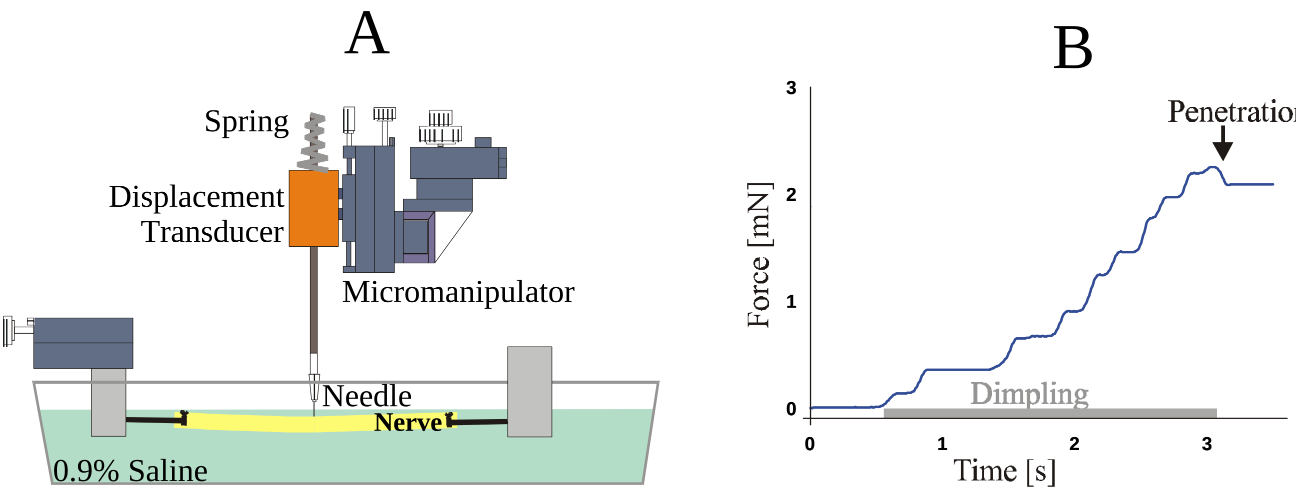

Figure 1. (A) The experimental set-up. During the insertion experiments the peripheral nerve tissue was kept immersed in 0.9% saline saline solution . The custom build force measurement device consisted of a linear displacement transducer and a steel core moving in it's center (B). The force applied to the tungsten needle at contact and insertion plotted as a function of time.

III. Results

The force applied to the tungsten needle at contact and insertion was measured and the results are plotted in Figure 1B. Dimpling started to occur at the point of contact between the nerve and the tungsten needle. The force and the dimpling increased as the needle was advanced further. The dimple in the nerve disappeared as the penetration force of the epineurium was approximately 2 mN. Simultaneously, at this point the dimpling disappeared, and the measured force decreased.

IV. Discussion and Conclusions

It was possible to penetrate the epineurium with the tungsten needle. However, the penetration force in the present experiment was higher than the penetration forces observed during insertion of tungsten needles in rat brain [6]. To provide single unit information in the peripheral nerve, the needle must be able to sustain an axial load of at least 2 mN without breaking or causing other damage to the electrode. In the present experiment a single-shaft needle electrode type was used. It has been reported, that multi-shaft probes can produce a pin cushion effect on the tissue, before the probes penetrate the surface. Furthermore, the insertion force increases with increasing number of shafts of the microelectrode [6]. It can therefore be expected that although a higher overall force is required to insert a multiple-shaft microelectrode into peripheral nerve, each individual shaft would likely require the same amount of force as a single shaft for insertion.

The present work will pave the way for modeling of the insertion mechanics of electrodes into peripheral nerve and towards more efficient design and implantation techniques of intrafascicular electrodes.

Acknowledgment

This project was funded by a grant IST-1999-10073 from the European Commission.

References

[1] M. Haugland and T. Sinkjær, Cutaneous Whole Nerve Recordings Used for Correction of Footdrop in Hemiplegic Man *IEEE Trans Rehab Eng*, vol. 3, pp. 307-317, 1995.

[2] M. Haugland, A. Lickel, J. Haase, and T. Sinkjær, Control of FES Thumb Force Using Slip Information Obtained from the Cutaneous Electroneurogram in Quadriplegic Man. *IEEE Trans Rehab Eng*, vol. 7, pp. 215-227, 1999.

[3] K. Yoshida and K. Horch, Closed-Loop Control of Ankle Position Using Muscle Afferent Feedback with Functional Neuromuscular Stimulation. *IEEE Trans Biomed Eng*, vol. 43, pp. 167-176, 1996.

[4] K. Najafi, Solid-State Microsensors for Cortical Nerve Recordings *IEEE Eng Med Biol Mag*, vol. pp. 375-387, 1994.

[5] D.J. Edell, V. Van Toi, V.M. McNeil, and L.D. Clark, Factors Influencing the Biocompatibility of Insertable Silicon Microshafts in Cerebral Cortex *IEEE Trans Biomed Eng*, vol. 39, pp. 635-643, 1992.

[6] U. Hofmann, D.T. Kewley, and J.M. Bower, Inserting Silicon-based Electrodes in Cerebral Cortex: A Study of Dimpling *J Neurosci Method*, vol. 2000.