

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

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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. 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 recorded 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 from a New Zealand White rabbit immediately after euthanasia. The sciatic nerve and its 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 $\mathbf{d}$. The loading force of the tungsten needle $\mathbf{F}$ are related to the spring constant $\mathbf{k}$ by Hooke's law:

$$\mathbf{F}_{\text{LOADING}} = -\mathbf{k}_{\text{SPRING}} \cdot \mathbf{d}_{\text{CORE}}$$

The device (core, attached needle and spring) was calibrated on a regular laboratory scale to determine the spring constant. The spring constant was estimated to 30 N/m. 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.

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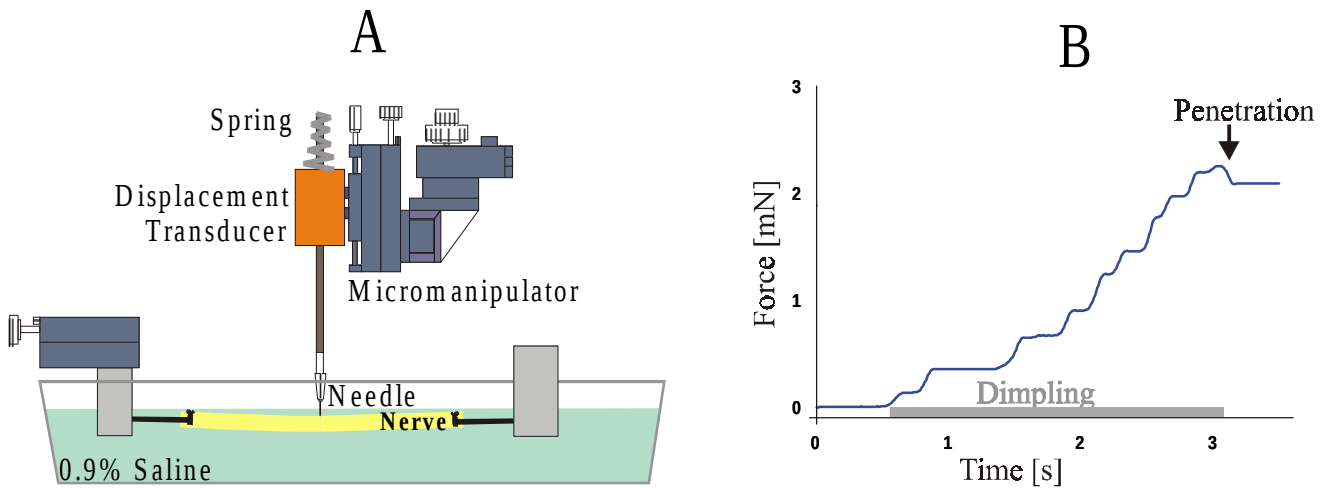


Figure 1. (A) The experimental set-up. The peripheral nerve tissue was kept immersed in 0.9% saline solution. The custom build force measurement device consisted of a linear displacement transducer and a steel core moving in its center. (B) The force applied to the tungsten needle at contact and insertion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

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