原　　著

A three dimensional microdrive for recording neural activity in the cerebral cortex.

Kosei Taira
Department of Oral Physiology, School of Dentistry, Iwate Medical University
(Chief : Prof. T. A. Suzuki)

〔Accepted : Nov. 25, 1988〕

抄録：大脳皮質内ニューロン活動を記録する微小電極の位置を，高精度でかつ3次元的に遠隔操作できる装置を製作した。装置は油圧制御による3次元微小駆動部分と，脳表面の拍動を抑えるための金属チャンバ部分から構成された。微小電極の移動および位置設定範囲は，X-Y平面内，10mm×10mm，深さZ方向，10mmであり，その駆動精度はX-Y平面で約20μm，深さZ方向で約5μmであった。脳表面の拍動は，チャンバ内をパラフィンオイルで満して密封することにより50μm以下に抑えられた。本装置を用いて，ネコの大脳皮質口腔領域へ微小電極を刺入した結果，脳内標的位置における単一ニューロン活動を2－3時間にわたって安定に記録できることが確認された。

Key words : microdrive, hydraulic control, three dimensions, neural activity, cerebral cortex.

Introduction

In order to postion and shift an electrode accurately and to record stable neural activity in the cerebral cortex of animals, several types of microdrives have been developed[1~4]. In the Davies type drive, an electrode is driven vertically by the precise rotation of gears and horizontally by the sliding of the electrode holder[1]. In the Evarts type drive, an electrode is moved horizontally by eccentric rotations of the electrode holder and vertically by the hydraulic positioner[2]. These devices are manipulated by hand. Recently, three dimensional microdrive was developed, in which hydraulic remote control was adopted only in the vertical direction[4]. In the present study, a new microdrive was developed to make an accurate and rapid positioning of a recording microelectrode not only in the vertical direction but also in the horizontal direction by hydraulic remote control in the cerebral cortex of an animal[5~6].

A three dimensional microdrive for recording neural activity in the cerebral cortex.
Kosei Taira
(Department of Oral Physiology, School of Dentistry, Iwate Medical University, Morioka 020, Japan)
岩手県盛岡市中央通1丁目3－27（〒020）

Construction and performance

Fig. 1 shows schematic diagrams of the apparatus (A. frontal view, B. lateral view). The apparatus consisited of a hydraulic drive (MICROMANIPULATOR; MO-103, Narishige) and cortical chambers. The hydraulic drive consisited of block-X, Y, and Z, each containing a hydraulic cylinder so that its displacement could be controlled by the remote hydraulic drives via the oil tube in the direction of, respectively the X, Y, and Z axis of the coordinate system. The cortical chambers consisited of outer and inner stainless steel chambers which were filled with paraffin oil to reduce the pulsations of the cortical surface. A movable transparent plastic disk of diameter 32 mm and thickness 1.5mm served to seal the outer chamber, with the electrode passing through a minute pore of diameter 1.5mm in the center of this disk. Fig. 1C shows the top view of the disk and the outer chamber.

After performing a craniotomy, the cortical chamber was fixed to the animal's skull with dental cement and filleed with paraffin oil through a minute pore in the disk. The chambers were kept liquid-tight by 1) adjusting the pressure of an O-shaped

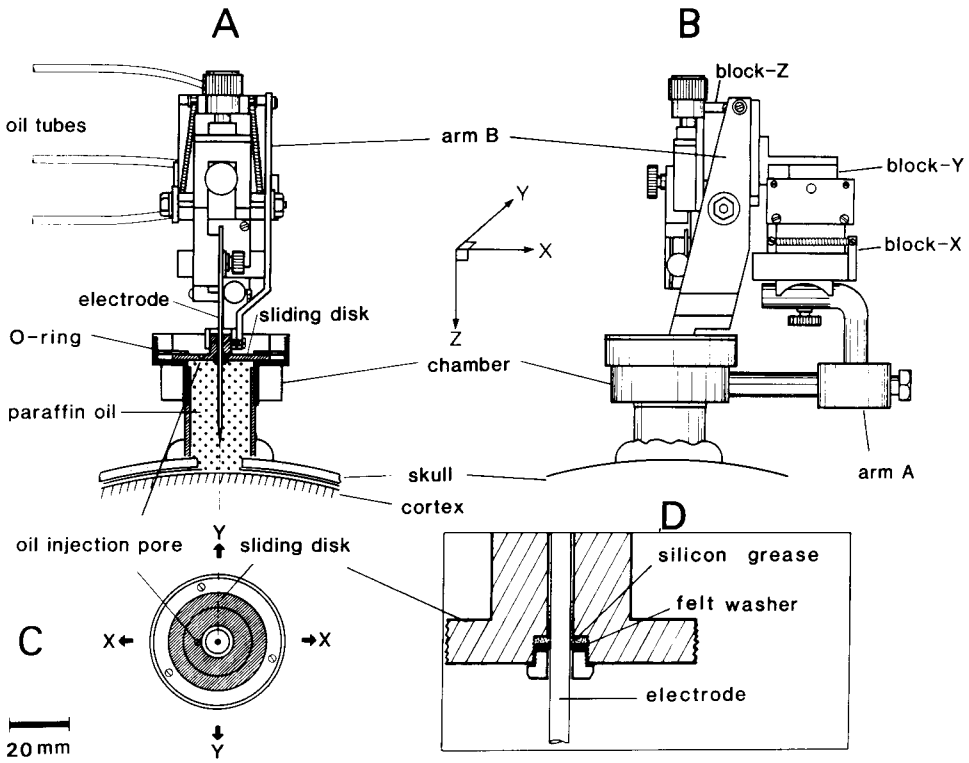

Fig.1 Three dimensional microdrive. A and B show frontal and lateral views of the microdrive. C shows the top view of the chamber part and the plastic disk (indicated by hatched lines) consisting of the driver. D shows an enlarged figure of the center of the plastic disk. An electrode is inserted into the central pore of the plastic disk which slides on the chamber and is hydraulically driven in the directions of the X, Y, and Z axis of the coordinate system.

stainless steel ring with three screws, 2) enclosing silicon grease in the space between the electrode and the plastic disk with a felt washer and a hollow screw (Fig. 1 D), 3) sealing the oil injection pore of the disk with a fine screw. It was possible to reduce the pulsations on the cortical surface to less than 50 μm. The outer chamber and the bottom of the hydraulic driver were fixed to the metallic arm A, and the plastic disk and the driving block-Y were fixed to the metallic arm B. The hydraulic driving block-Z was connected to the recording electrode. As block-X and Y moved in the directions of the X and Y axis, the plastic disk also moved in these directions sliding over the top of the outer chamber, and as block-Z moved in the direction of the Z axis, the recording electrode moved up and down. The movable range of an electrode was 10 mm $\times$ 10mm on the X-Y plane, and 10mm in the direction of the Z axis. Fig.2 shows the photograph of the microdrive.

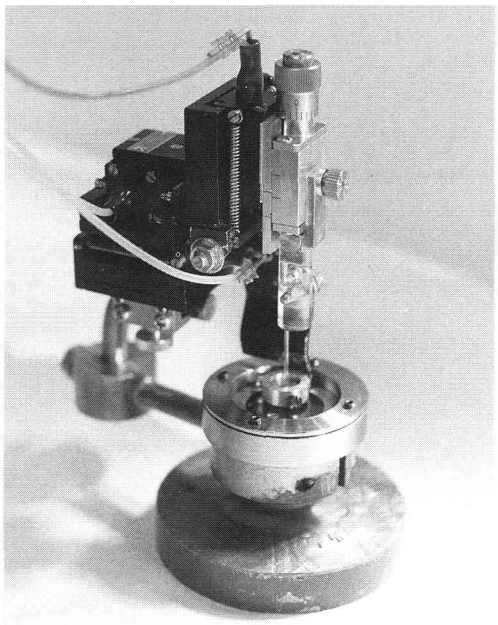

Fig.2 Photograph of the microdrive.

By injectiong the dye through the tip of the glass electrode at the target points, and by examining the locations of these dye spots in serial sections of the cerebral cortex, the error between the desired value and the

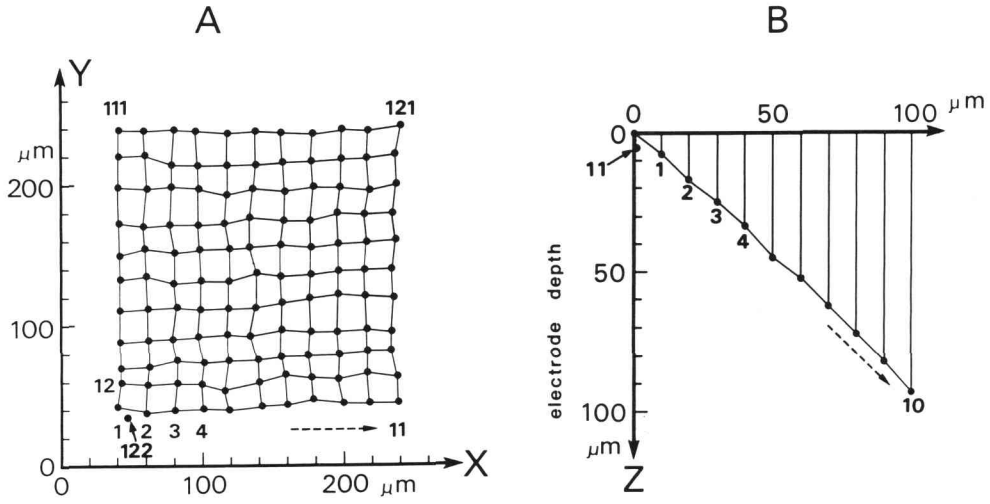

Fig.3 Control accuracy of the microdrive. A shows actual positions and locus of the electrode tip assinged in 20 μm steps in the direction of the X axis (the abscissa) and Y axis (the ordinate). B shows actual positions and locus of the electrode tip assigned in 10 μm steps in the direction of Z axis.

actual value of the electrode movement was measured. Fig. 3 A shows actual positions and locus of the electrode tip in the direction of the X axis (the abscissa) and Y axis (the ordinate). They were assigned in 20 μm steps. Serial numbers of filled points indicate the order of electrode setting. Point 122 is an actual position assigned to the point 1 after positioning the point 121 to see the repeatability. Fig. 3B shows actual positions and locus of the electrode tip in the direction of axis Z (the ordinate). They were assigned in 10 μm steps (the abscissa). Point 11 is an actual position assigned to the point 0 after positioning the point 10. Because of the sliding friction, the repeatability was approximately 20 μm on the X-Y plane, and 5 μm in the direction of the Z axis.

The remote control of the microdrive was accomplished by the rotation of the stepping motors via key board operation of the computer system, which was reported in the previous paper[6].

Application and Discussion

As a practical application of the microdrive, it was mounted on the somatosensory cerebral cortex of the cat, and a tungsten microelectrode was positioned. At each target point in the cortical oral area, the single-unit activity was recorded extracellularly and could be held at least for 2 −3 hours[5]. Utilizing the microdrive, it has been easy to position rapidly and accurately a microelectrode on the surface or in the depths of the brain of animals[6]. Though slight errors were seen in the horizontal direction, which might be due to partial friction of the sliding disk, the driving accuracy of the electrode, particularly in the horizontal direction, was higher than that of conventional instruments[1~4]. The liquid-tightness within the chamber and ability to suppress the pulsation of cortical surface was of the same order as a conventional chamber. However, if an intracellular recording is intended using this microdrive, it will probably be necessary to control the electrode positions more accurately by a feedback control technique.

Acknowledgements

The author wishes to thank Drs. K. Okuda, T. Sato and T. A. Suzuki for critical reading of the manuscript. This study was supported in part by Grant-in-Aid 577728 for Scientific Research from the Ministry of Education, Science, and Culture of Japan.

Abstract : A hydraulic microdrive of a recording microelectrode was developed for rapid positioning of a recording microelectrode both in the vertical and horizontal direction with a range of 10 ×10 ×10mm in the cerebral cortex of a conscious or an anesthetized animal. The apparatus consisted of a three dimensional, remotoly-controlled microdrive unit and metallic chambers to suppress the cortical pulsations. The repeatability range of the apparatus was 5 μm in the vertical direction and 20 μm in the horizontal direction. Using the three dimensional microdrive, stable single-unit activity could be recorded for at least 2−3 hours at a target point in the cerebral cortex of a cat.

Refernces

1) Davies, P. W.:Chamber for microelectrode studies in the cerebral cortex. *Science* 142 : 179-180, 1956.
2) Evarts, E. V. : A technique for recording activity of subcortical neurons in moving animals. *Electroencephalogr. Clin. Neurophysiol.* 24 : 83-86, 1968.
3) Jernberg, N. and Brooks, V. B. : A differential screw drive for microelectrodes. *Electroencephalogr. Clin. Neurophysiol.* 14 : 931-933, 1962.
4) Lemon, R. : Methods for Neuronal Recording in Conscious Animals. pp. 71-87, Jonh Wiley and Sons, Chichester, 1984.
5) Taira, K. : Characteristics of periodontal mechanosensitive neurons in the first somatosensory cortex of the cat. *Brain Res.* 409 : 52-61, 1987.
6) Taira, K. and Suzuki, T. : A computer system for measurement of neural activity in the cerebral cortex. *Jap. J. Oral Biol.* 30 : 683-690, 1988.