56. Lilly, John C. 1958. "Electrode and Carmulae Implantation in the Brain by a Simple Percutaneous Method." Science. 127:1181-1182

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Reprinted from SCIENCE, May 16, 1958, Vol. 127, No. 3307, pages 1181–1182.

Electrode and Cannulae Implantation in the Brain by a Simple Percutaneous Method

John C. Lilly
Laboratory of Neurophysiology, National Institute of Mental Health, Bethesda, Maryland

Electrode and Cannulae Implantation in the Brain by a Simple Percutaneous Method

In an investigation of the psychologically active motivational (reward and punishment) systems of the brain stimulated by electrical means, we have utilized "roving" electrodes implanted in the unanesthetized monkey's brain (*1–4*). The technique of implantation by hammering sleeve-shaped guides into the skull for these movable electrodes apparently has not been used before and simplifies the problem in chronic preparations (*2, 3, 5, 6*). The stereotaxic instrument (*7*) can be used to place the guides. During times when experiments are not being carried out on the animal, all electrodes and cannulae can be removed, leaving inconspicuous self-closing and self-healing skin lesions.

The method consists of implanting in the skull (but beneath the skin and outside the dura) a hollow tube (sleeve) which guides the electrode (or electrode array or cannula)through the skull in a definite direction into the brain. An electrode (*8*) is pushed through the skin and subcutaneous tissues, into the outer end of the sleeve in the skull, through the barrel, and thence into the brain.

The sleeves are made from stainless steel (type No. 316) hypodermic needle tubing (No. 20, 0.90 mm outside diameter, 0.57 mm inside diameter, in one case—a macaque implantation) as is shown in Fig. 1c.

In the spot desired for the implantation, a small indentation is made in the soft tissues and bone with a hardened steel spear-shaped tool (Fig. 1*a*), which is guided through a long tube-shaped rigid bearing in a director used in place of the electrode carrier in the stereotaxic instrument. The director has a cone-shaped lower end which is pressed into the skin; the spear is lightly pounded into the bone (for a distance of about ½ mm) and then is withdrawn. The sleeve is placed on the mandrel (as in Fig. 1*b*); the mandrel is inserted in the director; the mandrel and the sleeve are driven into the bone by light hammering on the outer end of the mandrel. After each

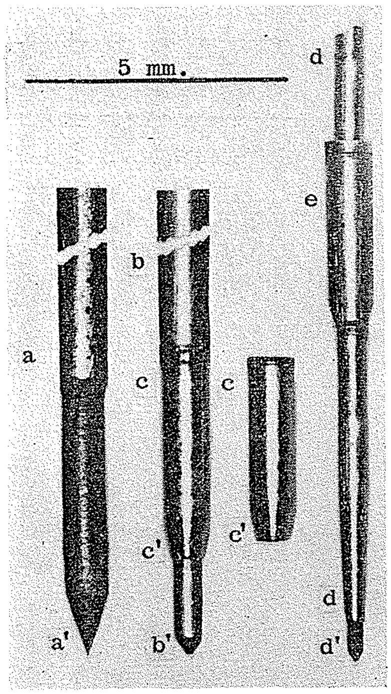

Fig. 1. Parts used in method of electrode implantation described in this report: *a,a'*, the lower end of the spear-shaped hardened steel tool (41 mm over-all length) used for starting the hole in the bone; *b,b'*, the lower part of the mandrel (41 mm over-all length), with a sleeve on the small cylindrical lower end (made of tungsten wire, 0.56 mm in diameter) (*b'*); *c,c'*, sleeves (one on mandrel and one by itself); *d,d'*, electrode; *e*, a sleeve guide on the electrode, showing a tight fit at the tapered inner end.

one-half millimeter or so of the guide is driven into the bone, the mandrel is manually tugged lightly upwards; if it comes out of the sleeve easily, the lower end of the guide (Fig. 1*c'*) has passed the inner table of the skull (but not the dura).

After the sleeve is in place in the skull, the skin and the subcutaneous tissues are allowed to pull together over the upper end and to heal. The sleeves are placed in definite patterns in the skull by means of the stereotaxic instrument and allowed to protrude above the skull about 2 mm. The operator palpates these ends through

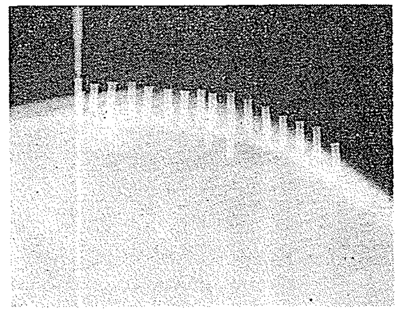

Fig. 2. X-ray photograph of monkey's skull (No. 230857, Horatio) containing 20 sleeves and one electrode; 16 sleeves are in the midplane and two are on each side, 10 mm lateral to the midplane. The latter four sleeves are displaced downward because of skull curvature, not because of deeper penetration. Careful inspection of stereo x-ray pairs shows that none of the sleeves penetrates more than a small fraction of a millimeter beneath the inside surface of the skull. Some angulation of those sleeves which were started on sloping parts of the skull can be seen; this "angulation error" has been reduced by modifications in the size of the sleeve and in the fit of the director on the sleeve (see text).

the soft tissues and finds the opening in the sleeve with the spear's sharp tip. By pressing the cone end of the spear into the guide's outer end, the skin and subcutaneous tissues are pierced. The skin is held in place with a forceps, the spear is withdrawn, and a sharp needle is inserted far enough to puncture the dura. The needle is withdrawn, and the electrode or cannula is inserted into the sleeve and lowered into the brain. To measure the depth of penetration of electrode or cannula, a pointed scale is used to measure the distance from the outer end of the sleeve to the outer end of the inserted cylinder of the electrode or cannula. The length of the sleeve varies with the animal and the loci in the skull. For the top of the skull of a macaque of 6 kg (13.2 lb) weight, for example, suitable lengths are 3½ to 4½ mm; for the skull of a porpoise, 20 to 50 mm.

After 5 to 6 weeks, a thin plate of bone grows over the ends of guides which are flush with the skull's surface. This is easily drilled out with two beveled hypodermic needles—first with one smaller than and then with one the same size as the electrode. Five months after an implantation the bone has not grown over the outer ends of guides which protrude 1.0 to 2.0 mm above the periosteum.

From 20 to 60 zones with 1 to 2 mm resolution have been explored along each track, running from pial cortex through the brain to the base of the skull. Previously, with a stereotaxic button and roving electrodes (*4*), we explored about 500 zones in two monkeys, with no problems assignable to either intracranial bleeding or infection. Currently, two monkeys are being investigated, with sleeves in their skulls at interguide intervals of 2 mm (one with four and one with 20 sleeves, to date). Figure 2 shows an x-ray of the skull of the animal with 20 implanted sleeves (3½ to 4½ mm long) and one electrode in place.

The animal is restrained to avoid pulling out the electrodes or cannulae (*9*). Self-limited amounts of bleeding from penetration of veins does occur but does not cause detectable signs in an upright monkey nor in a floating porpoise with a closed calvarium. Using roving electrodes, we have not yet seen (in exploration of about 30 tracks, in four animals, over a period of 18 months) any signs of tearing of an artery or signs of increased intracranial pressure from any cause. Infections are avoided by the liberal use of 70-percent alcohol on skin and on all of the aforementioned parts. Recently reductions in the hammering force required and in "angulation error" (Fig. 2) have been effected by reducing the diameter of the sleeve guide from No. 20 hypodermic needle tubing to No. 22 and by improving the fit of the director's channel on the sleeve's outside surface. The outside diameter of the roving electrodes and cannulae is reduced by use of No. 27 tubing in place of No. 24, decreasing their stiffness and, possibly, increasing the danger of arterial puncture.

Recently, sleeves made of No. 15 hypodermic needle tubing were manually hammered into the skulls of two restrained porpoises under only local anesthesia; electrodes in No. 18 needles were passed into the brain and used to find intracerebral motivational systems in experiments lasting up to 7 days.

JOHN C. LILLY

Laboratory of Neurophysiology, National Institute of Mental Health, Bethesda, Maryland

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12 December 1957