STEREOTACTIC SURGERY: A NOTE ON INSTRUMENTATION

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Stereotactic surgical instruments have developed along two lines. The more traditional and accurate machines were devised by Spiegel and Wycis (1952), Spiegel, Wycis, Marks, and Lee (1947), Bailey and Stein (1951), Talairach, Hécaen, David, Monnier, and Ajuriaguerra (1949), Leksell (1949), Riechert, and Mundinger (1954), and others. Most of these machines are fixed to the skull for stability, and they employ a variety of geometric methods for correcting the distortion and head rotation occurring in cranial radiographs. A stereotactic surgeon, utilizing one of these traditional machines with its accompanying method for correcting radiological distortion, is able to hit a radiologically visualized intracranial target with a high degree of accuracy. (This leaves out entirely the question of geographic variation of the anatomical target structures within the intracranial cavity in their relation to points that can be visualized by air or opaque ventriculography.) Unfortunately, most of the traditional stereotactic machines are complicated and time consuming to use. On the other hand, Parera and Cooper (1960) devised needle guiding machines, used principally in the treatment of Parkinson's disease. These machines can be applied quickly and easily and some of them are fixed to the skull. Their accuracy, however, is not as great as the traditional stereotactic machines, and they are often used in conjunction with uncorrected measurements taken directly from cranial radiographs.

A stereotactic machine, like any other surgical tool, requires constant refinement. It was felt that a stereotactic machine that combined the accuracy of the traditional, skull-fixed radiologically orientated machines with the simplicity and flexibility of the needle guides would be a welcome addition to the neurosurgical armamentarium.

In 1954, our group described a new method for correcting distortion in cranial radiographs with special reference to the type I McPherson stereotactic machine (Mark, McPherson, and Sweet, 1954). This method employs a skull-fixed tubular aluminum stereotactic machine with attachable lead grids. When the distances between the x-ray tube, the lead

grid lines, and the x-ray plate are fixed, one can use a geometric method to plot the position of any desired target point between the grids, *i.e.*, intracranial point. With this method, it is possible to correct the magnification error inherent in all cranial radiographs with relatively short tube-film distances and, in addition, compensate for the degree of rotation or tilt of the head. By means of the geometric plots, it is thus possible to translate radiological measurements into settings for the stereotactic machine that will hit a given intracranial point with an error of less than one half millimetre.

Although this method is easy to use, the type I McPherson stereotactic machine itself is cumbersome. The surgical procedure with this machine has to be done in two stages: one stage for the drilling of tiny openings in the outer table of the skull and the performance of a ventriculogram, and the second stage for the insertion of the electrodes into the target areas (Mark, Ervin, and Hackett, 1960). The halo, utilized as the base of the stereotactic machine, completely surrounds the head in a wide band and, therefore, limits the possible positions and angles at which an electrode can enter the cranial vaults to reach an intracranial target. We decided, then, to design a new stereotactic machine which would overcome the defects of the first model without sacrificing its potential accuracy.

THE APPARATUS

Our new stereotactic machine¹ is essentially a tripod support for the centre post (C₁) (Fig. 1). The machine can be applied to the skull within three minutes without the use of incisions. Sharply pointed skull supports are tapped into the bone at the lined temporalis just above the superolateral corner of each orbit anteriorly and in the midsagittal plane posteriorly. The machine is sturdily fixed to the skull at these three points. Grids (G) indicating the horizontal and vertical plane on each side of the head fit on the centre post (C₁) (Fig. 2) and correspond in their geometric relationships to each other in exactly the same way as the grids used with our previous plotting

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FIG. 1

FIG. 1. The stereotactic machine is fixed to the skull.

FIG. 2

FIG. 2. A pair of plastic grids with vertical and horizontal grids have been fitted to the stereotactic machine. C_1 points to the centre post.

FIG. 3

FIG. 3. The phantom is shown with its centre post (C_2). This centre post has exactly the same geometric relations as C_1 of the stereotactic machine. The intersecting lines on the base of the machine duplicate the lines on plotting chart 1.

FIG. 4

FIG. 4. Plotting chart 1 is at the left with its plastic straight-edge. Plotting chart 2, at the right, is used to determine the distance of the target point above the zero plane.

FIG. 5. C_2 points to the centre post of the phantom, and Q indicates a leaded caliper used to determine the distance of the target point above the zero plane. T indicates a theoretical target point with a lever arm and electrode carrier locked in place so that the tip of the electrode reaches the target point in the desired geometric plane.

FIG. 6. The lever arm and electrode carrier have been transferred from the centre post of the phantom (C_2) to the centre post of the stereotactic machine (C_1). The geometric relations of the target point T remain unchanged. When an appropriate burr hole has been placed in the skull, the electrode can be inserted to the desired intracranial target point.

chart method and type I McPherson stereotactic machine (Mark *et al.*, 1954). The ventriculogram is then done with the grids and x-ray film in a fixed relationship to the head. We use a 36 in. target-film distance. Measurements of the grid line separations and distance to the target point are taken from the ventriculographic radiographs and transferred to the plotting charts. These measurements are used to define the desired intracranial target point in three planes in relation to the zero plane of the plotting charts. Now the geometric relationships of the centre post of the stereotactic machine (C_1) are identical with the geometric relationships of the centre post of the phantom¹ (C_2) (Fig. 3). Furthermore, the base of the

¹The word 'phantom' denotes the mechanical setup simulating instrumentation on the patient's head but without an obscuring skull.

phantom is an exact duplicate of plotting chart I (Fig. 4). Plotting chart II, which is used to determine the height or distance of the target point above the zero plane, is represented by a leaded caliper Q which is positioned on the base of the phantom (Fig. 4). Thus, when the three intersecting planes of the target point (T) are determined on the plotting charts, they can immediately be transferred to the corresponding precise position in the phantom (Fig. 5). A lever arm, which fits onto the centre post (C_2) of the phantom and holds the electrode carrier, is positioned so that the electrode going through the carrier touches the target point (T). The lever arm is completely flexible. There are no measurements to be read or translated into the lever arm, which consists merely of revolving and rotating parts to provide complete flexibility for the electrode carrier. Once the desired point is hit in the desired plane, the various components of the lever arm are locked. It is then a simple matter to transfer the lever arm from the centre post of the phantom (C_2) to the centre post of the stereotactic machine (C_1) (Fig. 6), drill a burr hole, and sink the electrode to the desired intracranial target area. Post-implantation films can then be taken with the machine still fixed to the skull by re-applying the grids to the centre post in the sagittal and lateral directions.

This machine has many advantages. It is light, flexible, and easy to apply. It cuts down the time of the stereotactic operation and has allowed us, in 12 patients, to do a one- instead of a two-stage surgical procedure. Strategic placing of a minimal number of supporting members enables us to bring an electrode into the cranial cavity from any conceivable angle (even through the nose should that be desirable). Measurements are taken exclusively from the geometric plotting chart and transferred to the reproduction of this chart on the base of the phantom. Once the electrode carrier is locked in position, no extra measurements have to be taken and, thus, errors in calculation and angulation are avoided. This machine utilizes the grids and geometric plotting method of the earlier McPherson stereotactic machine and has the same degree of accuracy as the earlier machine. Because of the ease of application and flexibility of this machine, we have been able to do stereotactic surgical procedures under local anesthesia on patients with difficult abnormalities of movement.

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ADDENDUM

Since the submission of the paper for publication, two important modifications have been made in the stereotactic machine as seen in Fig. 7. The plastic grids have been replaced by a thin aluminium ring containing the lead cross hairs (A). The cross hairs in the aluminium ring are identical in position to the cross hairs in the plastic grids. A universal joint (B) has been substituted for the multiple jointed lever arms as shown in Figs. 5 and 6.

FIG. 7. The stereotactic machine showing the two new modifications: A, the aluminium ring with its four lead cross hairs; B, the new universal joint of the electrode carrier.