STEREOTAXIC NEUROSURGERY

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Approximately 50 years ago R. H. Clarke, working with Sir Victor Horsley, developed a stereotaxic instrument and laid down the general principles which have been used to this day. In their paper ‘The Structure and Functions of the Cerebellum Examined by a New Method’ (1908) the anatomical, mechanical and electrical problems of producing accurate and discrete electrolytic lesions in the cerebellar nuclei are considered in great detail. They state ‘The first requirement in a research of this kind is the establishment of the relations existing between the exterior of the head in animals and its encephalic contents . . .’ The impossibility, for practical purposes, of projecting measurements of internal structures of the brain on to the irregularly spherical surface of the head was avoided by relating cerebral structures to carefully defined sagittal, horizontal and coronal planes. This conception of ‘rectilinear cranioencephalic topography,’ in fact, replaced attempts at measurement of functions of an irregular sphere by calculations of the three dimensions of a cube. Anatomical material was prepared of the brains of Macacus rhesus and of cats in such a way that post-mortem distortion was reduced to a minimum and sections were cut in the three planes at 1 mm. intervals. Thus anatomical localization of intracerebral structures could be established within the confines of one or more millimetre cubes. The stereotaxic instrument, which is a rigid rectangular frame, attaches firmly to the skull in a constant relationship to the horizontal and sagittal planes. By a graduated, movable needle or electrode holder it is thus possible to transfer measurements from the anatomical sections in terms of the three planes of the instrument and to orient the needle point as desired. In 1920 Clarke and Henderson published a very complete description of the measurements of the skulls of monkeys and cats and their relationships to the brain.

The instrument described incorporated a compensating mechanism to allow for variations from the ‘normal’ in size and shape of skull. However, the variability of skull size and shape in monkeys and particularly in cats is very small when the selection of animals for size and weight is kept within fairly constant limits. Quite the contrary is true in human stereotaxic surgery and further problems arise which will be discussed later. It was suggested in this monograph that some day it would be possible to investigate the deep nuclei of the brain, the action of drugs, the interruption of fibre trunks and the implantation of radium for the treatment of intracranial tumours. All these predictions have now come true in the human being. In the intervening years the method has been applied to further investigations of the anatomy and physiology of the brain, chiefly of cats, notably by Ingram, Ranson and co-workers (1932) and Gerard, Marshall and Saul (1936). During the past ten years there has been a great increase in interest in both stereotaxic neurosurgery and in animal experimentation by this means. It is the purpose of this paper to describe the types of instruments and the methods which are now being used throughout the world in human stereotaxy.

Although human intracranial stereotaxy had been attempted in the past, it was approximately in 1947 that the method really became practicable through the efforts of several independent investigators, the most prolific of whom have been Spiegel and Wycis of Philadelphia, and techniques are constantly being developed for more accurate placement of electrodes. Initially bony landmarks of the skull were used and by correlating width, height and length to the situation of the deep nuclei it was hoped that sufficient accuracy could be obtained. There are still a few investigators in stereotaxy who use modifications of this principle, but a larger group has developed in the last few years employing measurements from the visualized ventricular system. These methods will subsequently be discussed and their merits analysed.

The conventional anthropological method of measuring the skull in determining size and shape is based on the classical Frankfurt plane—an

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imaginary line drawn from the inferior margin of the left orbit to the upper rim of the external auditory meatus. Traditionally such measurements have included the greatest length, breadth and height of the skull. Recently there have been several publications analysing some number of skulls in an attempt to use this method. For example, Delgado and Hamlin (1954) have used orthodontic measurements. The instrument is fixed in position parallel to the floor and at a fixed distance from the X-ray tube. They have then attempted to correlate skull size to intracranial structures and have implanted electrodes into the frontal lobes. Delmas and Pertuiset (1952) analysed ten skulls and made similar correlations. However, there is no report of stereotaxic operations done in this manner. Escolar (1950) has employed a similar technique of investigation. Monnier, in several publications in the Swiss literature (1950, 1951, 1952), described the use of bony fixation of the instrument in relation to Reid's plane.

Of the second group of investigators, using pneumoencephalography and ventriculography, each has developed a different approach to the problem. This technique introduces a further complication due to the divergence of the X-ray beam causing magnification of structures proportional to their distance from the source of radiation and from the centre of the beam. Some workers have disregarded this difficulty, others have made use of only the almost parallel central beam from an unusually long (5 m.) 'tube to plate' distance. A number of ingenious attempts to solve this problem by mechanical and optical means will also be mentioned. Spiegel and Wycis (1947) originally measured from the calcified pineal gland, but they have gradually changed to visualization of the third ventricle, and later of the posterior commissure and the first part of the aqueduct. They are now (1952) also using the angle formed by the pons and the posterior commissure. Leksell (1954) has a very ingenious method of demonstrating the third ventricle, attempting especially to outline the anterior and posterior commissures. He finds that there is a relatively constant distance between the commissures, and by super-imposing the brow-up and the brow-down views of the ventriculogram it is possible to obtain a master outline including the commissures. Measurements are then made from these structures. Talairach (1949) visualizes the third ventricle and by means of an overlaying grid network, with a series of perforations, has been able to make the necessary measurements and to place his electrode accurately. Riechert (1951) has also used visualization of the third ventricle and especially of the pillars of the fornix where these make a small angle with the anterior commissure. In the past few years Bailey and Amador have been employing ventriculography, paying special attention to that part of the system closest to the structure to be investigated, as, for example, the third ventricle in surgery involving the thalamus and the temporal horns when working in the amygdala, etc. Narabayashi (1950) uses a special system of filling the ventricular system, with emphasis on the third ventricle, and measures from that region.

Spiegel and Wycis in 1947 considerably modified the stereotaxic instrument. Fixation is obtained by loose scalp attachment with multiple tattoo marks for re-application of the instrument; there is no penetration of the skull or attachment to bone. Radiograms are taken by placing the instrument against an X-ray table at a fixed distance, usually 36 in., but there is no mechanical or optical control except a sliding bar along the top of the instrument. Such an instrument is light and there is convenient access to the patient's head, but this type of fixation lacks rigidity and the inaccuracy caused by spread of the X-ray beam is appreciable. It has been stated by these authors that they calculate 10 per cent. enlargement of the image, but this only applies to the area round the central beam. Operations have been multiple and have included dorsemedian thalamotomy for pain and in certain psychoses. Destruction of the spinothalamic tract in the mid-brain has been performed for intractable pain of the head and face as well as the rest of the body. The globus pallidus has been cauterized for chorea and explorations have been carried out along the area near the third ventricle, especially around the middle commissure in cases of minor epilepsy. The ansa lenticularis has been divided in the treatment of paralysis agitans. Narabayashi (1950) has used a similar instrument fixed to the scalp, with standard X-ray control. Also in 1947, Bailey's pupils, including Belinson, Green and Hayne, together with Gibbs (1948) used an instrument with skull fixation similar to Crutchfield tongs. Standard X-rays were taken after electrodes had been implanted into the head, but not during the operative procedure. An exploration was carried out of the subcortical areas in epileptic patients, and recently Hayne and Meyers (1950) have performed pre-frontal leucotomies using accurate control of this area with the stereotaxic instrument.

Monnier, in 1950, reported an instrument with skull fixation employing a system of metal inserts rather than the small perforations of the skull previously used. He made a series of measurements of the skull including the sella turcica and feels that measurements made from the central...
portion of the sella can be correlated with the type of skull in which the operation is carried out. This instrument has excellent fixation but the disadvantage that accurate X-ray control cannot be obtained. A few patients have been treated for intractable pain and for severe trigeminal neuralgia by cauterizing the nucleus ventralis posterior lateralis of the thalamus. Talairach and his co-workers, in 1949, described an instrument which attaches to the skull. By means of a dual perforated grid on either side of the head they are able to measure any point from the ventricular system. This system is quite rigid and allows a good deal of accuracy. The X-ray control includes a telescopic sight and a 'tube to plate' distance of approximately 5 m., providing parallel X-ray beams. These workers have studied the E.E.G. effects in the different nuclei of the thalamus, especially those of the dorsalis and medialis. They have also done extensive thalamic stimulation and have coagulated the ventralis posterior medialis in trigeminal neuralgia. Baudoin, Puech and Remond (1949) have used a lightweight instrument with scalp fixation only. Their idea of correcting X-ray distortion is brilliant. These authors use a fixed tube from the X-ray machine to the stereotaxic instrument. After the X-rays are obtained, a light is placed in the same position as the anode so that the distortion of light resembles that of the X-ray beam. The electrode is then positioned in the instrument until its shadow, now falling on the developed X-ray plate, is in the required location. The electrode readings are noted and subsequently used in the actual operation on the patient. This instrument is well designed but the electrode has a limited range of motion. There is no report in the literature of its use in patients.

Mark, McPherson and Sweet (1954) make use of an effective and simple method of calculating X-ray distortion. The X-ray source to the skull, fixed in the stereotaxic instrument, and to the film is always at the same fixed distance. Two sets of printed charts have been prepared to full scale with diverging lines representing the X-ray beams, one for the lateral and the other for the antero-posterior projection. Points taken from the radiograms are projected along the prepared lines and true measurements for electrode settings are made where these lines intersect in the three planes.

The circular type of instrument has recently been utilized by Leksell (1949) and by Riechert and Wolff (1951). Leksell, since 1947, has been using an instrument which consists of a double semi-circular ring in which the central axis is centred over the structure to be coagulated. The instrument is then locked in place and a semi-circular arc carrying the electrode placed on it. Leksell uses X-rays at a fixed distance, held by means of a plastic tube and the instrument is fixed to the patient's skull by three small steel pins. Three advantages of such an instrument are that it is light, that the arc can always be centred on the structure to be investigated and that it does not require repeated calculations as does the square type of instrument. Furthermore the burrhole can be placed at any convenient point on the skull in relation to the arc. However, it has a limited range because not all parts of the head can be reached by it. The other circular type of instrument which is light and easy to handle has been described by Riechert and Wolff (1951). These authors used scalp fixation in their original instrument but now use skull fixation. In recent years they have done a great deal of work in prefrontal leucotomy as well as investigations into the different thalamic nuclei, using extensive E.E.G. recording and stimulation. Patients with intractable pain and phantom limb have been investigated. Pituitary tumours have been approached by this means and cauterization performed.

In recent years Bailey and Amador have used an instrument with a firm, rigid frame attached to the outer table of the skull. Two systems of X-ray technique have been used. (1) The orthodiagnostic method originally conceived by Schaltenbrand (1952) which consists of a 'moving slit' source of X-rays producing a beam giving a true image on the plate in one plane only. This has the disadvantage, however, that many X-ray exposures must be made at 90 degrees to each other in the two types of pictures to be taken. (2) The other system is to use a marked X-ray grid at either side of the head so that distortion may be calculated from the plain films at a certain distance from the central beam. This stereotaxic instrument is large and heavy and is attached to the operating table. Although this is a disadvantage, experience suggests that it is necessary for accuracy. Implanted electrodes or cannulae are inserted into the brain at the proper position and are sealed in plastic in the burrhole. These workers have made E.E.G. surveys of the thalamus and the deeper structures and have often implanted radon seeds for the treatment of intractable pain. E.E.G. recordings and stimulations have also been made in the temporal lobe and the amygdala. Standard X-ray views of the ventriculograms and pneumoencephalograms are used to give the correct location of the electrodes.

Lister and Sherwood have just described a lightweight instrument employing some interesting engineering features, the only disadvantage being the inadequate fixation to the head.

Treatment of a number of diseases is now being
attempts by neurosurgical stereotaxic methods. Psychosurgery has been thoroughly investigated by Spiegel and Wycis, who have performed a large number of dorsomedian thalamotomies for psychosis and have reported rewarding results. However, in the effect of duplicating leucotomy it has been apparent that dorsomedian thalamotomy alone is not sufficient and that it is necessary to coagulate the area lying directly beneath. Pre-frontal leucotomies have been carried out by Hayne and Meyers (1950) and by Riechert and Wolff (1951). It is certainly possible to make a more accurate and discrete, and therefore less damaging, lesion by stereotaxic surgery.

Recently Heath and his associates (1954), using the Bailey and Stein type of instrument, have investigated the septal nuclei and by means of implant electrodes and multiple stimulations have achieved considerable success in the handling of psychotic patients. In the treatment of pain the dorsomedian thalamotomy by Spiegel and Wycis has been prominent. Leksell and Monnier (1951) have reported coagulation of the nucleus ventralis posterior medialis for facial pain. Leksell (1951) has also described a stereotaxic technique of irradiation of a small area in the brain using a source of radiation attached to the semi-circular arc of his instrument. The points of entry of the beams are distributed over the convexity of the skull and by 'cross-firing' a circumscribed lesion is produced in the brain. Mesencephalic tractotomy by electrocoagulation has been used by Spiegel and Wycis (1950) in the treatment of tabetic crises and in other types of intractable pain involving the whole side of the body or rather extensive regions on one side. Bailey and Amador have implanted radon seeds into the dorsomedian nucleus of the thalamus in patients with intractable pain, especially in cases of the thalamic syndrome, with considerable relief of pain and discomfort. In the treatment of athetosis and Parkinsonian tremor two methods have been used. The globus pallidus or the ansa lenticularis has been coagulated, and Narabayashi (1950) reported the injection of procaine in oil with apparent improvement of the condition.

Investigation of the origin of abnormal epileptic discharges has been extensive. Spiegel and Wycis have made recordings from the region around the middle commissures in cases of minor epilepsy, but the origin of the spike and wave has not been localized to this area. Amador, since 1951, has been using implant electrodes scattered throughout the temporal lobe and the amygdaloid nucleus in psychomotor epilepsy patients, and has carried out electroencephalographic and stimulation studies.

The treatment of brain tumours has included the injection of radioactive isotopes in cranio-pharyngioma cavities by Leksell and later by Spiegel and Wycis. Riechert, in 1953 and 1954, coagulated the pituitary for adenomas.

Anatomical considerations in stereotaxic neurosurgery have been the important limiting factor. Unfortunately, adequate anatomical material is not yet available to most workers. Two groups have a large amount of anatomical data. First, Spiegel and Wycis (1952) published an atlas of the brain using 30 specimens, which were perfused, sectioned and measured. During the past four years Bailey, Schaltenbrand and Amador have been compiling material for an anatomical atlas of the brain using 95 perfused specimens. It has become apparent to the latter investigators that the skull cannot be used satisfactorily in the correlation of intracranial nuclei to the external topographical landmarks, in spite of the rough groupings which are present in small numbers of skulls. In investigating large numbers of skulls and brains accurate measurement of the position of subcortical structures could not be consistently achieved in this way. From such anatomical studies it is also evident that a single landmark, such as the pineal body or the posterior commissure, is not accurate for all points in the subcortical areas. Rather it appears that continuous areas or outlines are the most valuable, such as the third ventricle when dealing with the thalamus, the lateral ventricles for the prefrontal and septal areas, and the temporal horns in connection with the temporal lobe and the amygdala. It is on this basis that the authors of this paper have come to believe that the most accurate stereotaxy can be performed. In addition the nuclei themselves vary in size, even though their position may be constant in relation to the above-mentioned continuous structures. Therefore we must always consider two zones of anatomical correlation, one being the zone of the least common denominator of distribution, i.e. an area having a measurement common to the structure in all examined specimens. This, of course, will not include all of the nucleus; for example, the red nucleus may vary in size by several millimetres. However, there is a central area in which part of all the red nuclei in anatomical variations will fall into one place. The other zone to be considered is the overall zone, i.e. a large area which will include the entire nucleus in all cases and in some will, of course, include portions of neighbouring structures. These two zones must be kept in mind depending on the desired area of investigation or destruction of a particular nucleus, and especially as regards the nature of side effects which may be produced by too large a destruction of tissue. At present there are several means of causing discrete lesions in the
brain. The standard electrocoagulation is unsatisfactory in many respects. As has been noted previously by many investigators, the destruction due to electrocoagulation may be asymmetrical, following the path of least resistance, such as fibre pathways and blood vessels rather than creating a concentric lesion of uniform size and diameter. Radon seeds have been used but have disadvantages in that gamma rays may cause damage farther away than is anticipated. In this respect radioactive gold with its beta emission is preferable in producing measurable local destruction. In the future there is the possibility that ultrasound as well as X-ray radiation may be utilized for this purpose.

The future applications of stereotaxic surgery appear to be very considerable. It can be predicted that it will be possible to explore the brain extensively and to acquire a far better understanding of the anatomical pathways in the deep, and at present inaccessible, structures of the brain. In the field of extrapyramidal disorders, in athetosis, chorea and Parkinsonism, therapeutic measures and exploration by stimulation and recording have been commenced and will certainly develop. In cases of epilepsy, it is possible to implant electrodes throughout areas of the cortex and sub-cortex and to gain a better understanding of intractable epilepsy, which may some day shed light on the origin and spread of abnormal discharges. Similarly in cerebral palsy it may be possible to investigate the mechanisms of the motor disturbances as well as those of epileptogenic foci. In the study of mental disease several strids have been taken already and it is theoretically feasible to undertake a more extensive exploration of the frontal and prefrontal areas to determine some of the basic mechanisms in disturbances of behaviour. By means of fine tubes inserted into the brain by stereotaxic technique it is possible to obtain samples of brain tissue from very selective and comparable regions for biochemical analysis and study. In the same way direct injection of chemical and pharmacological preparations may be undertaken.

Thus the use of stereotaxic methods of neurosurgery has much to offer in the investigation of the basic neurophysiological mechanisms and in the treatment of pain, extrapyramidal disturbances, epilepsy and mental disorders. The possibility of using this technique for the irradiation of inoperable brain tumours, by implanting radioactive substances or by more accurate direction of X-ray beams, should also be considered.

Acknowledgment

We wish to express our gratitude to Dr. Percival Bailey for his encouragement and guidance in the preparation of this paper.

BIBLIOGRAPHY


HORSLEY, V., and CLARKE, R. H. (1908), Brain, 31, 45.


LEKSELL, LARS (1954), personal communication.


PEARSON, KARL (1933), Biometerska, 25, 217.


SCHALTENBRAND, G. (1953), Amer. J. Roentgen., 70, 1.


Continued on page 39.
SPONTANEOUS RUPTURE OF UMBILICAL HERNIA IN AN INFANT

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Umbilical hernia in infants is remarkable both for its frequent occurrence and the rarity of any dangerous complications. In a recent paper, Grace Woods (1953) emphasized these points and stated that no case of strangulation has been recorded. A dangerous complication that has been recorded is spontaneous rupture and a further case of this is reported here. This complication is exceedingly rare even though the coverings of the sac are frequently very thin.

Case Report

On the afternoon of March 23, 1948, a male Chinese child, aged three months, was brought into the English Presbyterian Mission Hospital, Swatow, South China, with coils of small intestine lying on its anterior abdominal wall.

Three weeks previously he had been given away as an unwanted child and his foster-mother brought him to hospital. She stated that the umbilicus had looked normal until two days previously (March 21) when it first protruded about 1 in. on crying. The hernia was not treated by native medicine or other device. On the morning of March 23, when at the breast and ‘taking the milk too fast,’ according to his foster-mother, the hernia ruptured and intestine came out. He vomited several times and was in poor condition when brought to hospital about eight hours later, but there was no gross malnutrition. Coils of small intestine were protruding through the ruptured umbilicus and the skin tags and other hernial coverings were seen around the edge of the umbilical orifice. There were no signs of inflammation or ulceration.

Operation was done under ether anaesthesia. The coils of intestine were washed with saline, the umbilical orifice enlarged, the intestine replaced and the wound closed. Though the infant survived the operation he died three days later.

Discussion

The only other similar case in an infant found in the literature is that reported by MacLean (1950) in which spontaneous rupture also occurred at the age of three months in a male infant, but operation was followed by recovery.

Two cases have been reported in children. Von Arnold (1860) reported spontaneous rupture of an umbilical hernia in a child aged four when extrusion of intestine occurred through the very wide umbilical ring. The child died. Porcher (1883), quoted by Johnson (1902), recorded the other case in a Negro girl aged 13. After spontaneous rupture of her umbilical hernia, omentum was extruded but operation was followed by recovery.

Summary

1. A case is described of spontaneous rupture of an umbilical hernia in a male infant aged three months.
2. Only one other similar case could be traced in the literature.

BIBLIOGRAPHY

WOODS, G. E. (1953), Archives of Disease in Childhood, 28, 459.
Stereotaxic Neurosurgery

John Hankinson and Luis V. Amador

doi: 10.1136/pgmj.32.363.28

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