Stereotaxy of the Human Brain

Anatomical, Physiological and Clinical Applications

Edited by
Georges Schaltenbrand and A. Earl Walker
Co-Editors: R. Hassler, H. Narabayashi and T. Riechert

2nd, revised and enlarged Edition
335 partly colored Figures, 76 Tables

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Stereotaxy of the Human Brain

Preface

Almost 20 years have elapsed since Bailey and Schaltenbrand published the first edition of the *Introduction to Stereotaxy with an Atlas of the Human Brain*. The Atlas volume of this publication, containing enlargements of macroscopical sections and myelin sections of the brain, was revised and published in 1977 by Schaltenbrand and Wahren.

Because of the tremendous advances in anatomical and physiological knowledge of the brain and the technical developments in stereotaxic surgery, the first volume of the *Introduction to Stereotaxy* has become outdated. Only a brief introduction from it was incorporated as a pamphlet in the Atlas volume. Accordingly, a second edition to update basic knowledge of stereotaxic procedures, of the anatomy, physiology, and neuropathology of the deep structures of the brain is the purpose of this volume.

This edition has a changed format. A bilingual (German and English) presentation is considered unnecessary and accordingly the text is in English.

The emphasis has shifted from the mechanistic aspects of stereotaxic surgery to the careful clinical study of patients for operation, the neurophysiological data that may be derived during the surgical procedure, and the critical evaluation of the physiological and therapeutic results of subcortical operations. This has been made possible by the development of highly sophisticated methods, often computerized, to localize and guide a trocar or electrode to the target point and of effective stimulation, recording, and destructive techniques. This edition has further explored new fields for the exploitation of stereotaxic procedures. In addition to the time-honored operations for movements and emotional disorders, procedures to alleviate pain, sexual disturbances, epilepsy, and deep-seated lesions are discussed in this volume.

The editors are grateful to the many contributors to this edition who have brought their specialized knowledge to the volume. Acknowledgment is made of permission granted by other authors and publishers for the reproduction of illustrations that have been taken from other works:

Finally, the editors express their appreciation of the friendly cooperation of G. Thieme Verlag in the compilation of this second edition.

GEORGES SCHALTENBRAND A. EARL WALKER

Addendum

After writing this foreword, Professor Schaltenbrand suffered a stroke and died before the second edition of his monumental work went to press. Thus unfortunately, both editors of the first edition did not live to see the fruition of their plans for a second edition.

Professor Percival Bailey in the United States of America and Professor Dr. Georges Schaltenbrand in Germany early realized the potentialities of stereotaxic surgery for man and recognized the necessity of mapping the subcortical structures and of defining their variability. This required that an atlas of the human brain with coordinates based upon internal landmarks be compiled. Accordingly, they proceeded to cut human brains in specific planes, to photograph the sections, and to ascertain the variations in the coordinates of the subcortical nuclei which resulted from differences in the size and configuration of the heads and brains. Their findings related to the basal ganglia and thalamus were beautifully reproduced in the first edition of the atlas. However, stereotaxic surgery shortly spread to the medial temporal structures, the brainstem and cerebellum, so that an enlarged atlas, which demonstrated the relationships of these cerebral nuclei and gave their coordinates, was published in 1977 by Schaltenbrand and Wahren.

The textbook which accompanied the first edition of the atlas was long out of date and quite incomplete by the time the new atlas was published. For this reason, a completely revised text with new chapters was planned. Unfortunately Dr. Bailey did not live beyond the early planning stage, and Dr. Schaltenbrand only sufficiently long to receive the manuscripts of the new edition. Thus, it is appropriate to honor these two pioneers in the field of stereotaxic surgery.

This book is dedicated to

Professor Dr. Georges Schaltenbrand
and
Professor Percival Bailey,

Brilliant Neurologists, Astute Neuroscientists and Pioneering Stereotacticians
for their contributions to the art and science of stereotaxic surgery

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Purpose and General Aims

G. Schaltenbrand, A. E. Walker

It is not by chance that neurologists took a leading part in the development of stereotaxy. In fact, this technique rests on neurological pillars: neuroanatomy, neuropathology, neurophysiology, psychology, neurology, and, not the least, neurosurgery. Moreover, it is desirable that stereotaxy continues to be carried out by a team composed of neuroanatomists, neurophysiologists, neurologists, psychologists, and neurosurgeons who bring to the operating room their specialized skills that make it possible not only to help the patient but through appropriate planning and carefully executed stereotaxic procedures to acquire information about the functions of the human brain that can never be gained from experiments on animals, unable to talk or describe their subjective experiences during and after such procedures.

The eventual neuropathological studies of the brains of patients who have undergone a stereotaxic procedure are of utmost importance to establish the site and extent of the lesions. Unfortunately, neuroanatomy and neuropathology are not held in high regard; in fact, in some institutions they are considered obsolete and practically ignored, but much knowledge may yet be gained from well-controlled clinical studies.

Not every city, or even every university hospital need have a stereotaxic theater. A country like Germany may require about six to eight stereotaxic centers to meet the demand for such operations and to provide enough patients to keep the stereotaxician and his team sufficiently busy to maintain their skills and produce optimum results.

The equipment and instrumentation for stereotaxic surgery, since the first edition of this atlas, has not changed much – they still resemble the original apparatus devised by Horsley and Clark, then adapted by Spiegel and Wycis, Narabayashi, Riechert, Percival Bailey, Schaltenbrand, and many others for use on the human individual. A few innovations have been introduced, and some instruments have not survived the test of time. However, the slightly different instrumentations that have been developed in clinics will give comparable results, provided that the neurosurgeon has acquired basic knowledge of his technique and has sufficient experience.

If possible, stereotaxic procedures should be made under local anesthesia because the cooperation of the patient is needed. This means that the patient must be indoctrinated to have no fear of the stereotaxic operating theater. Through discussions of the operation with other patients who have experienced the procedure, or perhaps, by reviewing movies of the operation, the patient may have his fears and worries assuaged. This may be further achieved by engaging cooperation and interest of the patient and their participation in the clinical work up, which should clearly document the clinical state, if possible, with moving pictures or videotape. Although the mortality of stereotaxic procedures is practically zero in the hands of an experienced operating team, the patient should be appraised of the dangers to life and limb. Moreover, it should be emphasized that he or she can make a contribution to other people by granting an autopsy in case of death. Only through this cooperation of the patient will it be possible to verify the site, extent, and nature of the morbid and iatrogenic lesions and to correlate them with the clinical course of the disorder.

Of course, for children and mentally incompetent or uncooperative people, general anesthesia must be used and administered by a trained neuroanesthesiologist. Even when local anesthesia is used, a competent anesthesiologist is necessary to avoid fatalities. Occasionally unavoidable and undesirable effects occur; some will be discussed in this volume.

Unavoidable damage to the brain, due to the needle track and the lesion, must be kept to a minimum. Since stereotaxy is usually performed in a diseased cerebral hemisphere, fewer clinical deficits may result than would occur with a similar lesion in a normal brain. Still, certain precautions should be taken. First, one should try to select targets for destruction in a line so that they may be reached by one pass of the needle; second, the needle should be stiff so that it is not deflected from the target by tissue resistance; third, the needle point should be blunt, as Cushing taught, in order not to puncture or lacerate large vessels; finally, the needle should be as small as possible, and yet with a lumen through which a thermocouple, a wire electrode, or loop trocar may be passed. In any case, it is necessary to be able to study the physiological responses to electrical stimulation or – in case of the freezing technique – the results of cooling. The injection of drugs has been generally abandoned because of their unpredictable distribution in the tissue of the brain.

The individual variations of the ventricular system of the brain seen by radiopaque or radiolucent ventriculograms are commonly used to correct calculations for target sites. Some authors use a modern abacus, others a computer to make the calculations. The simplest method seems to be the superimposition of a roentgenogram upon an atlas picture with visual adjustments for size and shape of the cerebral structures.

Everybody who has observed on an X-ray amplifier the distortion of the brain made by the insertion of a needle is aware that certain structures, such as the corpus callosum, will be depressed before the needle penetrates, and once perforated, as the needle is withdrawn, it will retract along with the needle a variable distance. Therefore, the presence of the needle tip at the target site in roentgenograms is not proof that the point of the needle is in the anatomical target. It is necessary to make a physiological control to compensate for these individual anatomical and physical variations in the deep structures of the brain.

The Changing Perspective

Stereotaxic surgery is in a fluctuating state. Some conditions for which it was particularly effective have been alleviated by pharmacological discoveries such as L-dopa for parkinsonism. In other disorders, such as pituitary tumors, the stereotaxic approach has proved to be of limited value. True, excellent results can be achieved by stereotaxic methods for the treatment of basophilic adenomas causing Cushing's syndrome and for small eosinophilic adenomas. But in the case of chromophobe adenomas, the transphenoidal procedures have proved superior because they allow a complete removal of the tumor without the danger of edema, which often follows implantation of radioactive seeds.

Stereotaxic procedures have been criticized by psychotherapists who believe that it is an unnecessary invasion of their domain for they maintain that ailments like torticollis, tics, and certain types of dystonias are amenable to standard psychiatric therapy. However, their results are only achieved by psychotherapy after long years of treatment, but more often than not they fail, leaving the patient emotionally and financially destitute. A simple stereotaxic procedure has at least an equal chance of correcting a dyskinesia within days and at a relatively small expense, thus enabling the patient to resume his work and support his family. This economical side should not be depreciated.

In some countries, an emotional appeal has been launched against psychosurgical procedures, particularly in criminals with irresistible sexual compulsions who cannot be helped by psychotherapy or legal restraints. Granted that special precautions are necessary in such cases to insure that informed consent is voluntary and that the rights of the individual are protected; nevertheless, these unfortunate persons should not be deprived of promising stereotaxic treatment.

New possibilities for the stereotaxic treatment of epilepsy and for vegetative disorders are opening. Targets in the hind brain are being explored for the treatment of Meniere's syndrome or intractable tinnitus, and the exciting new concepts of chronic pain may lead to more effective stereotaxic procedures.

The reader of this volume will find that occasionally different authors present divergent or contradictory opinions. In a developing field, this is a healthy sign for it takes some time until a consensus of opinion is reached. For this reason, a certain overlap in the different chapters is considered not only unavoidable but desirable.

History of Human Stereotaxy (Stereoencephalotomy)

E. A. Spiegel

Introduction

It may be astonishing that guided electrodes were used in the human brain less than 30 years ago since they were employed for the study of the vasomotor center in the medulla oblongata as early as 1873 in Ludwig's laboratory by Dittmar (28). The method was perfected by Horsley and Clarke (1908) who devised a stereotaxic apparatus for experiments on cats and monkeys. In patients Kirschner (51) treated trigeminal neuralgia by lesions of the gasserian ganglion using an electrode guide in 1933. It should be emphasized that the gasserian ganglion is adjacent to the skull so that its position can easily be determined on plain roentgenograms of the skull. Such determinations were much more complicated for intracerebral targets due to the great variability of their topic relationships to the human skull and, as has long been known, to the pineal gland.

Appalled by the enormous destructions produced by prefrontal lobotomy and the resulting undesirable side-effects, Spiegel proposed to H. T. Wycis in 1947 that the thalamofrontal circuits involved in the mechanism of emotions might be interrupted by circumscribed lesions of the dorsomedial nuclei of the thalamus using a stereoencephalatome such as shown in figure 1.

Thus, in 1947 Spiegel et al (124) initiated stereotaxic operations on intracerebral structures using intracerebral reference points, initially the pineal gland and the posterior and anterior commissures. Later, the line connecting these commissures was adopted for reference by Hassler and Riechert (38) and by Talairach et al (132). For operations on deep structures of the temporal lobe, e. g., the amygdala, the inferior horn of the cerebral ventricles was a preferable reference structure. (Austin et al [7] and Mundinger et al [78] attempted to use osseous reference points for calculation of the coordinates of intracerebral targets.)

To distinguish their technique from the stereotaxic method of Horsley and Clarke, Spiegel and Wycis named it stereoencephalotomy. Operations on subcortical structures were carried out with minimal injury to overlying cerebral tissue and a considerably reduced mortality. For instance, section of pallidofugal fibers by a transventricular approach (66) resulted in a mortality of 15.7%, so that the author himself considered the risk too great to warrant its general employment in parkinsonism. For stereotaxic pallido-ansotomy, Spiegel and Wycis (117) reported a case mortality of 2.8% and an operative mortality of 2.0%; in Riechert's (97) experience, the mortality was below 1%.

Since the coordinates of subcortical structures in relation to the above-named reference points and reference lines could not be exactly determined by reference to existing atlases of the human brain, Spiegel and Wycis (117) prepared an atlas in which the coordinates of subcortical structures in relation to the pineal gland and to the posterior commissure could be determined. Since the celloidin embedding induced some shrinking of the tissue, the distance of 1 cm was marked by incisions in the preparation before the embedding, and the scale of the atlas indicating millimeters was adjusted accordingly. In a number of tables the variability of the coordinates of the most important subcortical ganglia was documented. Subsequently, atlases and variability studies were published by Talairach et al (132), by

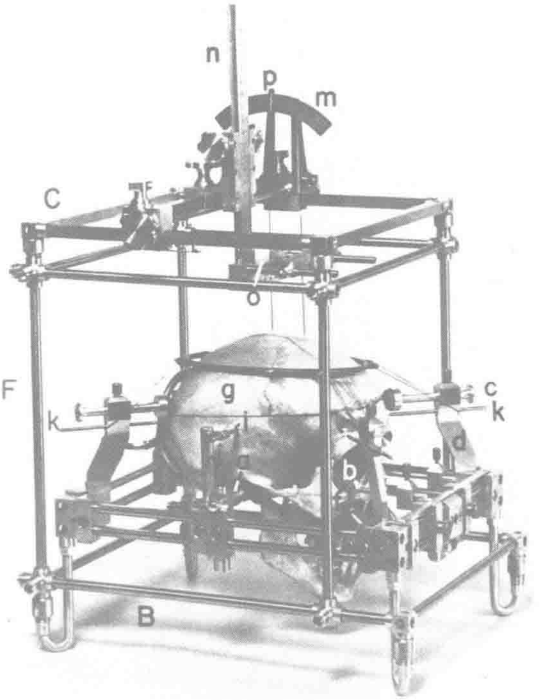

Fig. 1 Stereoencephalotome (model III). a = ear plugs, b = orbital bars, B = base, c = rubber cushioned stops, C = electrode carrier, d = support for c, f = maxillary support, F = frame, g = oval metal ring, l = lateral graduated pins, j = removable upright supports, k = graduated pins, m = protractor, n = upright bar, o = transverse bar, p = pointer (117).

Schaltenbrand and Bailey (108), by van Buren (139, 140), and by Andrew and Watkins (4). Of these Schaltenbrand and Bailey's atlas is the most elaborate.

The first thalamotomy using this method was performed by Spiegel and Wycis in the spring of 1947. The method soon enjoyed worldwide acceptance. Hécaen et al (40), and Guiot et al (35) in Paris, Riechert and Wolff (100), Schaltenbrand and Bailey (108), and others in Germany, Leksell (56) in Sweden, Gillingham (32) and others in Great Britain, Krayenbühl and Yasargil (52) and Siegfried in Switzerland, Kandel and Chebotaryova (50) and Bechtereva et al (11) in Russia, Laitinen and Toivakka (54) in Finland, C. Bertrand and G. Bertrand and H. Jasper (12) in Canada, Velasco-Suárez and Escobedo (141) in Mexico, Narabayashi (80) in Japan, and numerous other surgeons in many countries all adopted the procedure so that Riechert (98) stated that a new era in neurosurgery had been started. In 1965 Spiegel (112) listed over 25000 and in 1969 over 37000 stereotaxic operations that had been performed by various neurosurgeons.

In 1961 the "International Society for Research in Stereoencephalotomy" was founded, and its first symposium was held in Philadelphia. The name of the society was changed in 1975 to "World Society for Stereotaxic and Functional Neurosurgery". Its symposia have been published in the Confinia Neurologica and as special volumes (Advances in Stereoencephalotomy).

Stereotaxic Diagnostic Procedures

The measurement of impedance has been used experimentally for localizing brain structures (101). However, the accuracy of depth electroencephalography exceeded that achieved by impedance measurements of the border and position of deep-seated brain tumors (54). For the identification of thalamic nuclei, e. g., of the cell group responsible for the genesis of Parkinson tremor, microelectrode studies proved valuable (2, 12, 35). Albé-Fessard in a discussion of Bertrand and Jasper's paper (13), however, admitted that recording of unit discharges was rather timeconsuming and recommended for localization of therapeutic lesions in patients, the recording of evoked potentials from groups of cells. Remote telemetered stimulation and recording from depth electrodes implanted in the temporal lobe were used by Mark et al (65) for localization of sei-

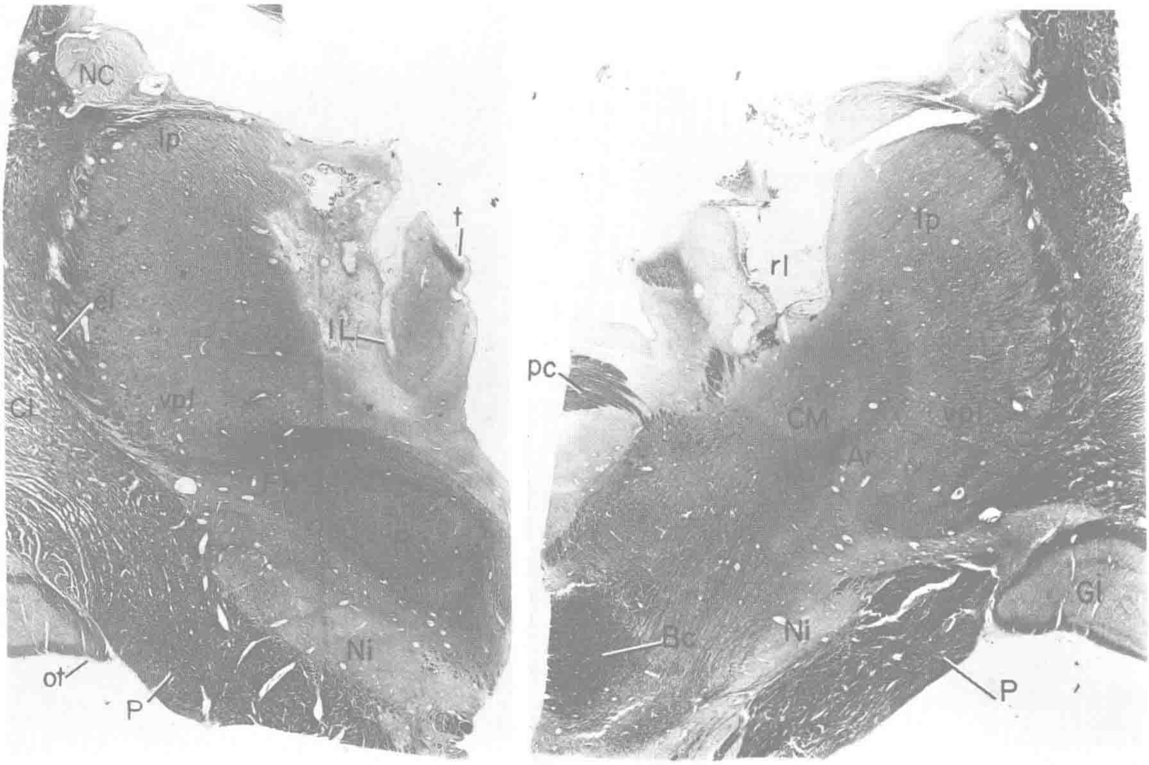

Fig. 2a, b Electrolytic lesions in the dorsomedial nuclei of the thalamus. IL = left lesion, rL = right lesion, Ar = arcuate nucleus, Bc = brachium conjunctivum, Cl = internal capsule, CM = centrum medianum, el = lamina medullaris externa FH = Forel's field H, Gl = lateral geniculate body, lp = nucleus lateralis posterior, Nc = caudate nucleus, Ni = substantia nigra, ot = optic tract, P = cerebral peduncle, pc = posterior commissure, R = nucleus ruber, t = taenia thalami, vpl = nucleus ventralis posterior lateralis.