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CONTENTS

VOLUME XII

CHAPTER ONE

THE BRAIN

WALTER E. DANDY, M.D.

SYNOPSIS

I. Introduction and Historical Background
II. Examinations Used for the Diagnosis of Lesions of the Brain
    1. The head { inspection, palpation, percussion, auscultation }
    2. The eyegrounds (ophthalmoscopic examination)
    3. Neurological examinations of
        A. The cranial nerves
        B. The regions of the brain
        C. The reflexes
    4. Roentgenography of the skull and intracranial contents
    5. Lumbar and cisternal punctures
    6. Ventricular puncture
    7. Diagnostic punctures of the brain
    8. Studies of the blood and cerebrospinal fluid
    9. Rhinorrhea
    10. Cerebral pneumography—ventriculography and subarachnoidography (encephalography)
    11. Ventricular estimation
    12. Encephalography with iodized oils (lipiodol and iodipin)
    13. Arterial encephalography
    14. Electroencephalography
III. General Considerations Concerning Intracranial Surgery
    1. Anesthesia
    2. Routine operative exposures
    3. Operations in stages
    4. Control of hemorrhage
    5. Control of intracranial pressure
    6. Electrocautery
    7. Use of "sucker" in bleeding
    8. Immediate postoperative care
    9. Postoperative complications
IV. Lesions of the Cranial Nerves
    1. Trigeminal neuralgia and tic douloureux
    2. Glossopharyngeal neuralgia and tic douloureux
    3. Relief of pain from carcinoma of the mouth, pharynx and tongue
    4. Geniculate neuralgia
    5. Ménière's disease
    6. Spastic torticollis

4461

V. Hydrocephalus
1. Normal circulation of cerebrospinal fluid
2. Functions of the cerebrospinal fluid—space compensation
3. Experimental production of various types of hydrocephalus
4. Role of obstruction in hydrocephalus
5. Lesions causing hydrocephalus
6. Other pathologic changes in brain
7. External hydrocephalus—its cause
8. Clinical features
9. Diagnosis
10. Differential diagnosis
11. Localization of cause by clinical tests
12. Types of hydrocephalus { with communication / without communication
13. Two obstructions
14. Operative treatment

VI. Encephalocele and Meningocele

VII. Cranial Injuries and Their Effects
1. Acute injuries of the head
A. Of the skull
Concerning classification of fractures
Construction of the skull
Lines of fracture
B. Of the brain
Cerebral hemorrhage
Extradural hemorrhage
Cerebral edema
Cerebral contusion and laceration
C. Signs of acute intracranial disturbances
Intracranial pressure
Localized injury to the brain
Injury to the cranial nerves
Injury to the meninges
Infection
D. Treatment of the effects of acute injuries endangering life
Shock
Extradural hemorrhage
Intracranial hemorrhage
E. Treatment of the effects of acute injuries chiefly endangering function
Compound fractures and foreign bodies
Simple fractures
Convulsions
2. Late effects of cranial injuries and their treatment
A. Posttraumatic neurosis
B. Old depressed fractures
C. Foreign bodies
D. Epilepsy
E. Subdural hematoma
F. Subdural hygroma
G. Pneumatocele (external)
H. Pneumocephalus
I. Arteriovenous (carotid-cavernous) aneurysm

VIII. Epilepsy
1. Experimental convulsions
2. Character of seizures in epilepsy
3. Etiology and pathology of epilepsy
4. Lesions causing epilepsy
Congenital malformations and maldevelopment
Tumors
Abscesses
Tubercles
Gummas
Aneurysms
Syphilis
Areas of cerebral calcification
Depressed fractures
Hematomas
Foreign bodies
Old cerebral injuries, including birth injuries
Thrombosis and embolism
Obscure inflammatory lesions
5. Diagnosis and localization of cause and treatment of epilepsy
6. Surgical observations on certain epileptic brains

IX. Infections of the Brain, Meninges and Skull
1. Pyogenic meningitis
Source
Pathology
Prognosis
Diagnosis
Treatment
Cisternal drainage
Irrigations of the spinal canal
2. Gradenigo's syndrome
3. Tuberculous meningitis
4. Acute and chronic nonpurulent meningitis
5. Pyogenic abscesses of the brain
Etiology
Location and number
Pathology
Diagnosis and differential diagnosis
Treatment of brain abscess { acute / chronic / multiple / extradural / subdural
6. Aerogenic abscess
7. Tuberculomas
8. Gummas
9. Encephalitis and meningitis from pathogenic fungi
A. Blastomycosis and coccidioidal granuloma
B. Torula
C. Actinomycosis and streptothricosis
10. Animal parasites
A. Cysticercus cellulosae

2. Dural endothelioma (dural meningioma)
   A. General facts
   B. Symptomatology as a whole and from tumors in specific locations
   C. Treatment
3. Cerebellopontine (acoustic) tumors
   A. General facts
   B. Diagnosis in various stages
   C. Exceptional findings
   D. Differential diagnosis
   E. Removal—operative procedure
   F. Results
   G. Spinofacial anastomosis and fascial grafting to correct postoperative facial paralysis
4. Hypophysial tumors
   A. The normal hypophysis
      Origin
      Structure, gross and microscopic
      Functions
         Relation to maintenance of life
         Functions of posterior lobe
         Functions of anterior lobe
         Relation to gigantism, acromegalia, ateleiosis and progeria
   B. Tumors of the hypophysis
      Acromegalia
      Types of hypophysial tumor
      Diagnosis of primary hypophysial tumors
   C. Operative treatment
      Nasal approach
      Intracranial approach
      Nasal versus intracranial operation
      Author's hypophysial operations (Procedures I, II and III)
      Comparison of intradural and extradural approach
5. Hypophysial duct tumors
   A. Function of the hypothalamic region—diabetes insipidus
   B. Hypophysial duct tumors
      Diagnosis
      Removal
6. Pineal body and pineal tumors
   A. Function of the pineal body
   B. Pineal tumors
      Diagnosis
      Removal
      Results
7. Tumors of the third ventricle
   A. Gross characteristics
   B. Signs and symptoms
   C. Ventricular changes and ventriculographic findings
   D. Operative treatment
      Pineal approach

SECTION I

INTRODUCTION AND HISTORICAL BACKGROUND

Surgery of the brain is the outgrowth of three discoveries of the nineteenth century, namely, anesthesia, asepsis and cerebral localization. Without asepsis or antisepsis, surgery of the brain would never be possible. With asepsis and without cerebral localization, it could be of but little value. With both asepsis and cerebral localization and without anesthesia, it would be possible but greatly limited. Although

anesthesia had been in use nearly a quarter of a century before Lister's great discovery, surgery of the brain made no advance. And 17 additional years were required before the three combined discoveries were sufficiently secure and adequately correlated to permit this field of surgery to be fairly launched.

Cerebral Localization.—It is the prevailing belief that localization of cerebral function dates from the great discoveries by Broca (1861) of a center for motor speech, and by Fritsch and Hitzig (1870) of motor centers in the cerebral cortex. Such a statement, however, must be qualified in fairness to a great line of distinguished investigators who preceded. Unquestionably these crucial observations were the first to determine *precise* localization of cerebral function, and being well timed with the advent of antiseptic and aseptic surgery, their importance cannot be overestimated. They provide the necessary foundation for intracranial surgery, but it is by no means certain that, had not surgery quickly added the absolute proof, skepticism would not still have denied their acceptance, as had been true of other discoveries almost equally great. Indeed as late as 1876 an authority of no less renown in the fields of experimental and clinical neurology than Brown-Séquard not only protested the significance of either contribution but introduced what he thought to be decisive proof of the impossibility of cerebral localization. Had not a most perfect scheme of cerebral localization been wrought from careful observations by Gall and Spurzheim, had its day and been found to be incorrect? Did not the decerebrate dogs of Goltz walk without evidence of motor weakness? And did not the 200 cases which he assembled demonstrate that hemiplegia occurred on either the homolateral or contralateral side of the brain, and apparently indiscriminately? And did not clinical evidence also demonstrate that aphasia occurred with lesions on either side of the brain? Certainly there was ample evidence that areas of the brain did not have special function but that the brain worked "as a whole." To quote from Brown-Séquard's publication of the above date: "Clinical observation teaches that paralysis, as an effect of brain disease, as regards its place, its extent, its degree, its duration and its association with other symptoms, has no absolute relation" with the seat, the degree and extent, the kind and the rapidity or slowness of appearance of disease in or injury to the brain!

Differences of opinion no less pronounced existed on most physiologic beliefs. There were always missing links of scientific facts. For centuries the missing links comprised most of the chain and were for the most part readily supplied by the speculations of philosophers and metaphysicians. Nor could the results of the laboratory be accepted unhesitatingly. Poorly controlled and imperfectly executed experiments, or even accurately performed experiments carrying undue significance when transferred to man, were links destined, sooner or later, to break. It was, therefore, only fair to demand that before acceptance of the doctrine of cerebral localization predictions based upon neurological examinations should be accurately fulfilled. This could result only by an intensive study of material observed at the bedside and later checked at necropsy and operation. The final proof resulted when predicted lesions were the basis for operative procedure and were found at operation.

The belief in some degree of localization of functions in the cere-

bral hemisphere goes back to the earliest medical records. Usually the references are made in a manner so casual as to indicate that the fact was well known and generally accepted. It was known to Hippocrates and Galen that hemiplegia resulted from a lesion in the opposite side of the brain and that convulsions, disturbances of speech and of mental function and loss of consciousness were caused by affections of the brain. Recently Professor Breasted in his remarkable translation of case reports of an unknown Egyptian physician living about 3500 B.C. has unearthed much older evidence of this character. Among these records is the description of a cranial injury from which hemiplegia resulted, curiously on the side of the cerebral trauma. In another patient speech was lost from a blow in the temporal region.

After a lapse of many centuries the broken thread of medical literature is again picked up, during the Renaissance. In his delightful little book on the history of surgery of the brain, Ballance mentions the fact that Massa (1533) and Valsalva (about 1700) describe contralateral paralysis from lesions of the brain such as trauma, apoplexy and cerebral abscess. Pierre Marchettis (1666), referred to in Alfred Brown's *Old Masterpieces in Surgery,* cured a case of contralateral hemiplegia by removing a depressed fragment of the skull. Motor power began to return in half an hour! He also cured a case of traumatic epilepsy by a similar operation.

About this time Mistichelli (1709) and Petit (1710) independently discovered the decussation of the pyramidal tracts in the medulla. For the first time an anatomic explanation was offered for the cause of crossed paralysis. Arataeus, a Roman physician of the second century, is usually given credit for having postulated a decussation of the motor fibers. The slow progress of science is again in evidence, for 100 years later this easily proved point was still disputed. In a remarkable report (1809) by six prominent French anatomists upon their impressions concerning the superior anatomic claims of the phrenologists Gall and Spurzheim, the following frank statement is made: "How has it happened that a point of structure so evident [decussation of the motor tracts in the medulla], adopted by Winslow, Lieutaud, Portal and distinctly described by Santorini, should have been doubted by the great Haller, recently denied by very skillful men, and confounded by others, even by Vicq d'Azyr himself. There is certainly some merit in having reviewed the general knowledge of an important point of doctrine, which the doubt or denial of able men had caused to fall into oblivion."

During the first half of the nineteenth century there are many references in support of localization of motor function in the cerebral hemispheres and there are even suspicions that this function was more sharply defined. Percival Pott, Charles and John Bell, Astley Cooper, Larrey, Brodie and Abernethy casually mention the fact that hemiplegia results from a lesion in the opposite side of the brain. But quotations from two great masters of that time, Richard Bright and Bouillard, show how emphatically localization of function in the cerebral hemispheres was regarded as proved, even though controversy continued.

The firm belief of Bright in paralysis from lesions on the contralateral side of the brain and its evidence of cerebral localization is expressed as follows (1827): "Together with other authorities we have

the name of Morgagni in support of such occurrences [homolateral paralysis], but having been once or twice nearly deceived, myself, by the imperfect accounts of friends in such cases, I am not willing to admit them hastily. . . . I have in several cases observed that the speech has been affected when the hand and arm have been affected."

Bright's interpretation of focal convulsions as indicative of cerebral localization was hardly less advanced: "My reason then for supposing that the epileptic attacks in this case depended rather on a local affection than on a more general state of cerebral circulation or excitement, was the *degree of consciousness which was observed to be retained during the fits:* for although we meet with great variety in this respect, yet in two cases which have occurred to me, the fact of the patient's generally remaining conscious has been a remarkable feature, while in each the injury on which the fits depended was of a local rather than a constitutional or general character."

The following excerpt from Bouillard (1830) is not unlike one from the great Hughlings Jackson: "Even though we should admit certain errors have been made as to the localization of the seat of the lesions causing paralysis, yet it remains an established fact that there exist in the cerebrum *several motor centers.* The plurality of motor centers is, in fact, proved by the occurrence of limited paralysis, corresponding to a local alteration in the brain; for it is evident that if this organ did not contain different centers or conductors of motor impulses, it would be impossible to conceive how a limited lesion could produce a limited paralysis, leaving all other movements intact. I am well aware that the preceding propositions appear at variance with the results of experiments on animals. It is certain that after the ablation of the cerebral hemispheres, an animal may walk, run, move its jaws, eyelids, eyes, etc.; and it is not less certain that an alteration of the cerebral hemispheres in man gives rise to a paralysis more or less complete of voluntary motion on the *opposite side of the body.* Can we refute the one set of facts by the other? No, certainly not, for facts equally positive are not susceptible of refutation. A time will come when new light will dispel the apparent contradiction which exists between them."

From an extensive experience in military surgery during the Napoleonic Wars, Dr. J. Thomson made the following unequivocal statement concerning cerebral localization: "In every instance in which it distinctly appeared that the injury existed on one side of the head, the paralysis uniformly manifested itself upon the other; but we were unable to perceive any other fixed relation between the part of the brain which had been injured and the part of the body affected with palsy." He mentions the fact that monoplegia may result from certain cranial injuries and stresses the fact that injuries associated with paralysis are over the parietal bone.

That localization of cerebral lesions was at times, at least, correctly made on the basis of crossed motor paralysis is shown by the following case: Cruveilhier (1829) suspected a right frontal tumor in a patient whose symptoms were frontal headache, enfeeblement of mind, slow speech, involuntary micturition and *weakness of the left leg.* This patient was shown to the students, and after death a right frontal dural endothelioma was found, corroborating the clinical diagnosis.

Early in the nineteenth century new additions were made to neurological localization by the revival, under Magendie and his illustrious

pupil Claude Bernard, of experimental physiology which, except for occasional sporadic outbursts, had been dormant since Galen's time. Charles Bell in 1811 found that there were separate nerves for sensation and for motor power. Arriving at this opinion from clinical observation he clinched the discovery by a few crucial experiments on animals, a test which he always adopted reluctantly. Magendie arrived at the same conclusion so nearly simultaneously that an acrimonious dispute arose concerning priority. Claude Bernard discovered in the floor of the fourth ventricle a tiny point, the puncture of which produced glycosuria. Flourens (1830), experimenting upon pigeons, discovered the grosser functions of the cerebellum, particularly the relationship to equilibrium.

But the experimental method was not without its compensatory disadvantages. Indeed it was in large part responsible for the state of chaos that existed in localization of functions in the cerebral hemispheres. The ablation experiments of Flourens, of Longet on lower animals and eventually of Goltz on dogs showed entire absence of effect on motor function when both cerebral hemispheres were entirely removed. It was not realized that the results on animals could not be transferred in their entirety to human beings. The solution of this mysterious conflict between the negative results of canine experiments and well known positive clinical facts (contralateral hemiplegia from cerebral lesions) developed at a historic meeting of the Physiological Section of the International Congress of Medicine in London in 1881. Ballance, who attended, gives a most vivid description of this occasion at which the great Charcot presided. Goltz, who exhibited his decerebrated dogs, spoke of the utter folly of the view that special parts of the brain are peculiarly associated with certain functional departments. At this meeting Ferrier demonstrated a monkey made hemiplegic by removal of the cerebral cortex of the contralateral side of the brain. As the monkey limped upon the stage the full significance of the experiment was instantly recognized and was most aptly expressed in the words of Charcot: "It is a patient." This event silenced a minority who had persistently refused to accept the two great discoveries in cerebral localization by Broca (1861) and by Fritsch and Hitzig (1870).

Broca had reported the findings at necropsy of a patient afflicted with pure motor aphasia whom he had kept under observation for many years. A small well circumscribed lesion (softening) occupied the third and part of the second left frontal convolution. Although the association of motor aphasia with a right hemiplegia had long been recognized, the *precise* localization of the cerebral area involved had never been suggested. Broca's original definition of the area for motor speech remains essentially unchanged, except that the center is transferred to the right hemisphere in left-handed persons.

The *exact* localization of motor function in the cerebral hemispheres of dogs was first demonstrated by Fritsch and Hitzig in 1870. Their results were substantiated in 1873 by Ferrier in monkeys. He not only amplified their findings but added cortical representation for sensation. By stimulating certain well defined areas in the cerebral cortex with an electrode, using both galvanic and faradic currents, not only were Fritsch and Hitzig, and Ferrier able to set off contractions of contralateral groups of muscles but, with an increased stimulus, they were able to produce typical jacksonian convulsions. Aside from this

restricted motor area, the remainder of the cerebral cortex was insensitive to electrical stimuli. But the discovery of cerebral localization in no small part belongs to Hughlings Jackson, the greatest neurologist of all time, for he predicted from carefully studied cases of the "march" in the type of convulsions which now bear his name, that cortical representation of motor function was absolutely necessary and that the varied centers of control must be in juxtaposition. This faultless reasoning antedated the experiments of Fritsch and Hitzig and was responsible for those of Ferrier.

The above experimental results were first reproduced on a human being by Bartholow of Cincinnati in 1874. The opportunity for this remarkable experiment was afforded in a patient whose parietal bones had been destroyed by carcinoma. Puncturing the dura with the electrode, he stimulated the rolandic areas of the brain and induced contralateral, local and spreading muscular contractions, even convulsions. It was another decade before Victor Horsley applied mild electrical stimulation with a unipolar electrode to brains exposed at operation, in order accurately to define the component parts of the motor zone.

In 1874 Wernicke localized the area of receptive speech (sensory aphasia) to the posterior part of the first temporal convolution of the left side. Kussmaul shortly afterward added an area for word blindness in the left supramarginal and angular gyri. He thought Wernicke's area was restricted to word deafness, a view that is still usually accepted though not without challengers. These discoveries, scarcely less important than those of Broca, and Fritsch and Hitzig, now formed in combination with theirs a most impressive nucleus of cerebral localization.

Other so-called centers of cerebral localization were gradually disclosed. Ferrier, from pathologic studies, localized centers for taste and smell in the uncinate lobe of each side. A center for writing has also been postulated alongside Broca's area.

Development of Other Aids in Cerebral Diagnosis and Localization.—In 1850 Helmholtz invented the ophthalmoscope, which 10 years later was introduced into neurology by von Graefe, who first recognized papilledema and its relationship to intracranial tumors. The application of this great discovery was scarcely less important in neurological diagnosis than in cerebral localization, for it afforded a most valuable objective means of diagnosing that great group of tumors causing intracranial pressure without signs of localization; and it also added much needed support to the diagnosis of brain tumors when signs of localization were inadequate.

Additional assistance in localization developed in the last decade of the nineteenth century from two unexpected sources: (1) glandular disturbances, (2) the x-ray. Pierre Marie (1890), four years after first describing acromegalia, traced its cause to a tumor of the hypophysis. Much additional information concerning the normal and disturbed functions of the hypophysis has since been added. The x-ray was first successfully used to disclose an intracranial tumor in 1897, when Oppenheim detected the absence of the landmarks of the sella turcica and correctly diagnosed a tumor of the pituitary body. Improvement in the quality of the x-rays and increasing experience in the interpretation have made this an invaluable aid in the diagnosis of neurological lesions.