The Anatomic Foundation of Neuroradiology of the Brain

2nd Edition

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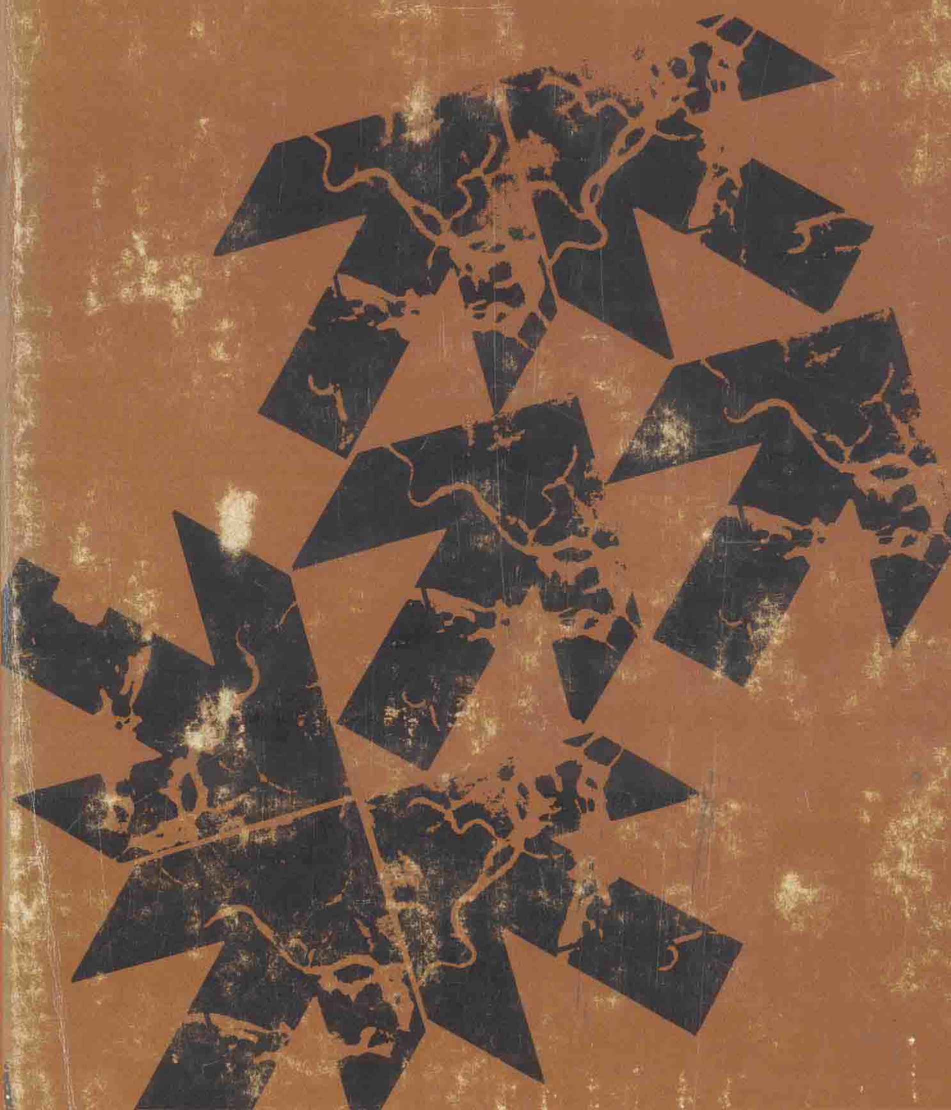

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Preface

FOR MANY YEARS, I have been teaching and practicing neuroradiology at The University of Texas Medical Branch at Galveston and its associated hospitals. When I first became interested in this subject, I discovered that a *detailed* knowledge of neuroanatomy was indispensable; after fifteen years' experience, I am even more impressed with its importance.

The first edition of this book grew out of my effort to learn and to teach neuroanatomy and neuroradiology. Since that book was first published, a great deal of new material has appeared in the literature. Therefore, to my dismay, this new edition is much longer than the first; however, it is as short as I could make it. I hope the book will be of help to young radiologists in their efforts to learn and understand this extremely difficult subject.

I make no claim to originality. This book is based on the work of a large number of investigators, past and present. To name them all is impossible. Any mistakes are my own.

All references mentioned in the text are listed in the Bibliography. The Bibliography, however, also contains many titles not directly cited in the book, but which helped me a great deal. The information so obtained is incorporated into almost every paragraph. These uncited sources may be of assistance to those who wish to delve more deeply into certain subjects.

Many anatomic and radiologic observations are repeated in different sections of the book and in different contexts. This was done on purpose for the sake of clarity and continuity and to reduce the need for cross-references to other sections. Repetition also reinforces the learning process.

Normal anatomic variation in the brain, as elsewhere in the body, is the rule rather than the exception. Occasionally, normal variations, as seen radiologically, closely mimic changes due to disease. In most diagnostic studies of the central nervous system, the first and most important issue that faces the radiologist is not the precise location of a lesion. The really critical question is whether a lesion is or is not actually present.

Since the radiologic borderline between normal variation and early pathologic change is so vague, numerical measurements of the size and position of various anatomic structures are not really useful. Many workers have published such measurements as determined both anatomically and radiologically. Only a few such measurements are quoted in this book. The practice of neuroradiology would be much easier if one could draw lines connecting certain points on an x-ray film, measure these lines with a ruler, and thereby decide whether an abnormality is or is not present. In my experience, such measurements have not been very helpful in arriving at a decision in borderline cases.

As competence is gained in neuroradiology, the problem of normal variation becomes less troublesome. Even the most experienced examiner, however, has difficulty if the site of an unusual variation corresponds to the clinical localization of a suspected lesion. In this situation, it may be impossible to arrive at a definite diagnosis from the radiographs alone. Therefore, all clinical information pertinent to the diagnostic problem should be made available to the radiologist. Only then is he equipped to render the best decision in *any* neuroradiologic investigation.

McC. W.

Galveston

Acknowledgments

A NUMBER OF PEOPLE HELPED ME in preparing the second edition of this book. They have my sincere thanks.

Mrs. Laurentina Gourley typed the manuscript many times. Her skill, speed, and enthusiasm made my task much easier. The legends for the illustrations were typed by Mrs. Dolores Alvarez, who also did a superb job.

The drawings were made from the author's sketches by Mr. Edmond S. Alexander, Mrs. Kay Byrd, Dr. L. B. Morettin, Mr. George Newman, and Mrs. Carol Ann Ratisseau. Their talents are apparent.

All photographs new for the second edition were prepared by Mr. Milan Autengruber. His work also speaks for itself, and he never missed a deadline.

Of the new radiographs, the great majority were produced by Miss Sandy Blume. Her technical competence and dedication are deeply appreciated.

My good friend and colleague Dr. Glenn V. Russell, Professor of Neuroanatomy at The University of Texas Medical Branch at Galveston, made the anatomic preparations shown in Figures 16, 28, 50, and 122. For years, Dr. Russell has supplied abundant anatomic material for my teaching efforts.

Dr. Dorcas H. Padget very graciously rescued me when I was beyond my depth in writing about the embryology of the cerebrovascular system.

I also wish to thank my publisher, Little, Brown and Company, for their cooperation and encouragement. Mrs. Nancy Megley was especially helpful. With competence and dispatch, she took my manuscript and made it into a book.

Some of the drawings are based on illustrations appearing in previously published works. All the authors and publishers involved have kindly granted permission for use of their material. In each instance, the author and source are indicated in the legend accompanying the illustration.

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Contents

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Neuroanatomy

Embryology

The anatomic parts of the brain and their detailed relationships to each other are easier to comprehend if one understands the overall "plan of construction" of the mammalian brain. This basic plan is best understood by referring to embryology. A sound knowledge of the manner in which the central nervous system develops is like a map to which the student can refer whenever he becomes lost amid the intricacies of such structures as the basal ganglia and fornix.

The timing of events in embryologic development is not too important from a practical standpoint. Therefore, in the following discussion, little attention has been paid to the timing of the various morphologic changes. This was done for the sake of clarity and brevity and does not affect the essential truth and usefulness of the information.

Development of the Brain

The embryologic approach follows the central nervous system from its simple beginning as a tube, through its gradual development, to its final form. The final form is enormously complex; basically, however, it is still a tube.

All embryologic transformations are due to a combination of several growth processes occurring in an orderly sequence. These processes, when considered separately, are simple; the end result of a series of these changes is not at all simple. The important embryologic processes are as follows:

1. Fusion of two masses of tissue
2. Splitting of a mass of tissue to form an intervening space or two separate masses
3. Folding of sheets or elongated masses of tissue
4. Differential rates of growth in adjacent groups of cells, resulting in:
   a. Invagination
   b. Evagination
   c. Thinning and thickening
   d. Gradual disappearance or atrophy of masses of tissue

By the use of these basic devices, a simple tube of tissue is transformed into the adult human brain.

The long hollow tube, which at a certain early stage is the central nervous system, is covered by mesenchyme that will become the meninges. Its central cavity is lined by a sheet of cells which will become the ependyma. (True ependyma does not appear until the fifth or sixth fetal month. Even in the adult, true ependyma may be absent over some parts of the ventricular system.) With minor modifications, this arrangement is maintained throughout development in that part of the neural tube which will form the spinal cord. However, at the cephalic end of the neural tube extensive changes take place (Hamilton et al.). By the end of the fourth week of embryonic life, the cephalic end of the neural tube has closed and three rostral swellings have appeared. These swellings are named the rhombencephalon or hindbrain, the mesencephalon or midbrain, and the prosencephalon or forebrain. The medulla oblongata, cerebellum, and pons develop from the hindbrain; the central cavity of the hindbrain becomes the adult fourth ventricle. From a morphologic standpoint, the midbrain remains relatively unchanged during later development. It will form the adult midbrain, and its central cavity becomes the cerebral aqueduct. The forebrain undergoes the most extensive modification of any of the three primary subdivisions of the developing brain. All cerebral structures rostral to the midbrain (cerebral hemispheres, corpus striatum, thalamus, etc.) develop from the forebrain; the central canal of the forebrain will form the adult third ventricle and the lateral ventricles.

As the primitive divisions of the central nervous system are developing, the ventral part of the neural tube becomes much thicker than the dorsal portions and three kinks or flexures appear. These are named the cervical flexure, the pontine flexure, and the cephalic flexure. The cephalic and cervical flexures appear first (in the third or fourth week). Both of these kinks point in a dorsal direction. A week or so later, the pontine flexure appears between the cervical and cephalic flexure. The pontine flexure folds forward in the opposite direction toward the ventral side. Of these three flexures, only the cephalic flexure between the midbrain and the thalamus is recognizable in the adult brain.

At the level of the pontine flexure, the central canal becomes widened transversely and assumes a diamond shape. This diamond-shaped cavity will become the fourth ventricle. The roof of the neural tube covering the diamond-shaped cavity becomes very thin. The two rostral lips of the diamond then enlarge tremendously and merge in the midline, forming the primitive cerebellum. Later, the lateral margins of the cerebellar mass enlarge to form the lateral lobes. The part remaining in the midline becomes the midline lobe, named the vermis. Differentiation into lobules and folia occurs at a later time, thereby markedly increasing the surface area (and therefore the total mass) of the cerebellar cortex.

Immediately caudal to the cerebellar swellings, blood vessels invaginate into the thin roof of the primitive fourth ventricle. This tuft of vessels will become the choroid plexus of the fourth ventricle. Openings appear later in each lateral extremity of the diamond-shaped fourth ventricle and also in the midline at its caudal end. The two lateral openings are the lateral apertures (of Luschka). The midline opening is the median aperture (of Magendie). These three foramina afford the only communication between the ventricular system (derived from the central canal) and the outer surface of the central nervous system. While these events are occurring in the hindbrain, the midbrain undergoes relatively little change.

This is not true in the forebrain, where many extensive changes are proceeding. Two hollow cerebral vesicles begin to evaginate from either side of the lateral walls of the forebrain. These cerebral vesicles are named the telencephalon, and the rest of the forebrain is now termed the diencephalon (Fig. 1). The optic nerves grow out of the lateral walls of the diencephalon, and the pineal and pituitary evaginations appear in its roof and floor, respectively. The right and left thalamus develop from the two lateral walls of the diencephalon, while its floor will form the hypothalamus. The cerebral vesicles (telencephalon) enlarge very rapidly, developing three main subdivisions (to be considered shortly). These are the corpus striatum, rhinencephalon, and neopallium. The central cavities of the cerebral vesicles will become the lateral ventricles.

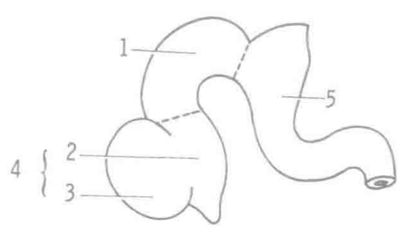

Figure 1. Major subdivisions of the cephalic end of the neural tube.

1. Midbrain
2. Diencephalon
3. Telencephalon
4. Forebrain
5. Hindbrain

The primitive choroid arteries are on the dorsal side of the diencephalon, medial to the expanding cerebral vesicles. They lie just behind and above the interventricular foramina, which connect each lateral ventricle to the third ventricle. Tufts of blood vessels, accompanied by stroma from the brain wall, grow out from the choroid arteries into the lateral ventricles (Fig. 2). The line of invagination is the primitive choroid fis-

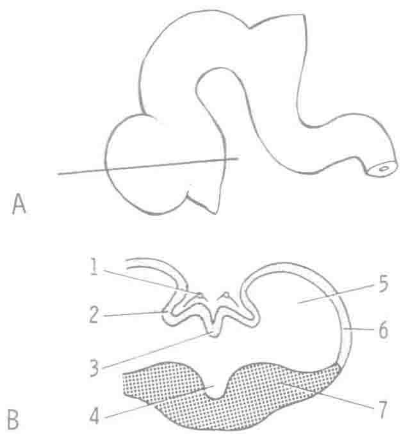

Figure 2. Cross section through forebrain shortly after the cerebral vesicles have appeared. (A) Line indicates level of section. (B) The cross section.

1. Choroid artery
2. Invagination of the brain wall ahead of the choroid plexus of the lateral ventricle
3. Invagination of the roof of the diencephalon ahead of the choroid plexus of the third ventricle
4. Third ventricle
5. Lateral ventricle
6. Wall of the telencephalon
7. Thickened ventral wall of the forebrain, from which the basal ganglia will develop

(After illustration in *Human Embryology* by Hamilton, Boyd, and Mossman. W. Heffer and Sons Ltd., Cambridge, Eng.)