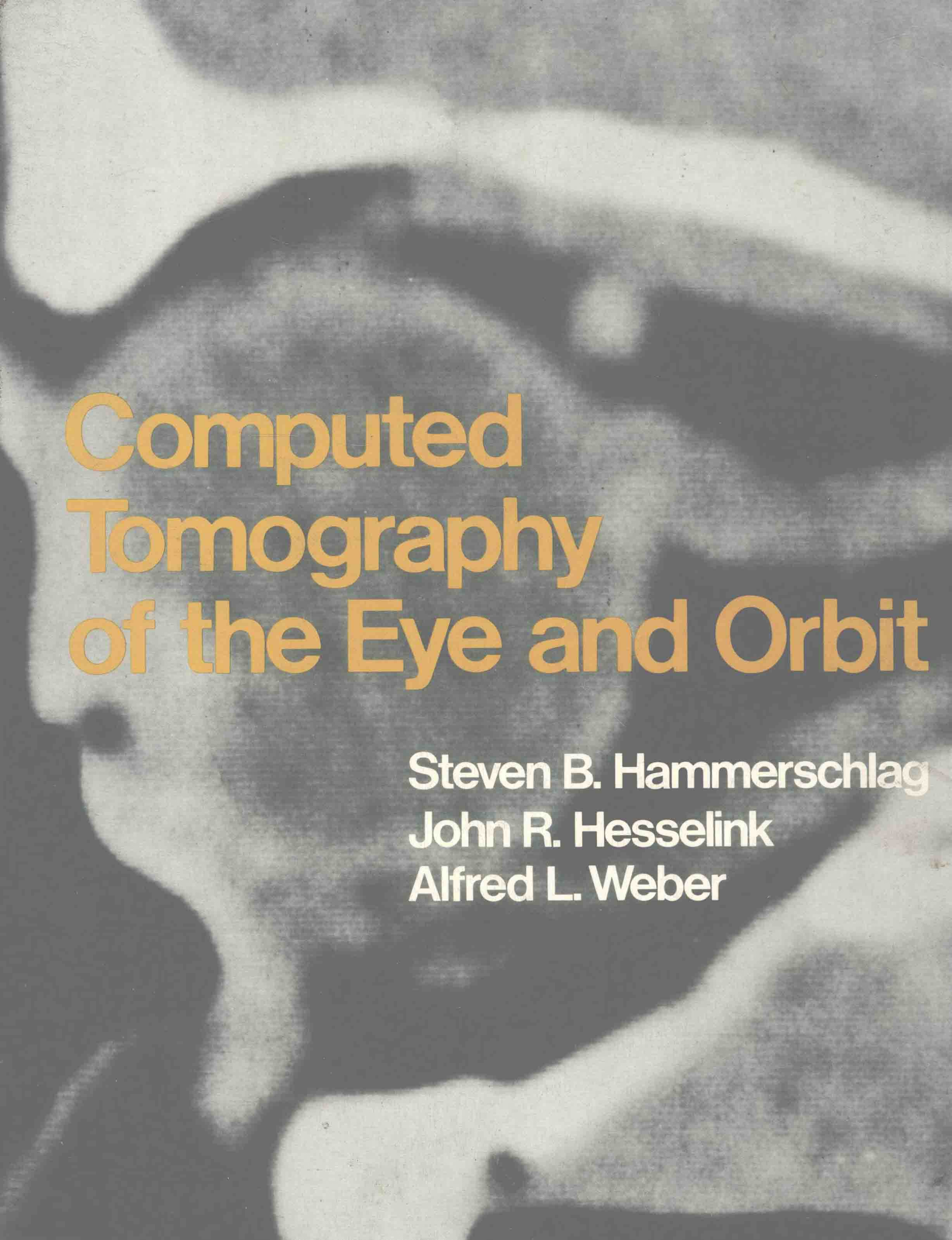

Computed Tomography of the Eye and Orbit

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Notice: Our knowledge in the clinical sciences is constantly changing. As new information becomes available, changes in treatment and in the use of drugs become necessary. The authors and the publisher of this volume have taken care to make certain that the doses of drugs and schedules of treatment are correct and compatible with the standards generally accepted at the time of publication. The reader is advised to consult carefully the instruction and information material included in the package insert of each drug or therapeutic agent before administration. This advice is especially important when using new or infrequently used drugs.

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To Debra, Ilse, and Patricia
Kay and André
Gloria and Rachael

Foreword

It was not long after the discovery of x-rays by Roentgen in 1895 that they were used to obtain images of the skull. I am sure that Arthur Schüller of Vienna was one of the first to become involved in the radiography of the orbit in view of his interest in radiography of the skull and facial structures. He published a book on radiology of the skull in 1906, which was translated into English and published in 1912. Some time in the late 1920s or early 1930s, radiography of the orbits was employed to study traumatic and neoplastic lesions. A method was also described to accurately localize radiopaque foreign bodies in their relationship to the globe. There was no other method to visualize the soft tissues of the orbit until the introduction of orbital pneumography. The combination of tomography with orbital pneumography yielded fairly good detail of the anatomy of the orbit. It was, however, technically difficult to control the exact placement of the air and this modality did not become generally or frequently utilized. Surgeons preferred orbital exploration for removal of tumors, determining the relationship of the lesion to the normal structures at the operating table.

The visualization of the eye and other orbital structures was achieved in the late 1950s with the introduction of orbital ultrasound. For the first time it was possible to see the soft tissues within the eye as well as the area around the eye up to the bony walls. The high-resolution ultrasound beam yielded excellent detail in many conditions and still has some advantages over computed tomography. However, it was not until the development and technical improvements of the latter technique that exploration of the orbit by means of cross-sectional imaging techniques reached its present state of development.

With this work the authors hope to present a state-of-the-art approach to the diagnosis of orbital lesions by cross-sectional imaging techniques. This book is intended for students and specialists in both imaging diagnosis and ophthalmology. This I believe the authors have achieved.

Juan M. Taveras, M.D.

Preface

The successful application of computed tomography is exemplified by the major role it has assumed in the diagnosis of orbital pathology. Except for vascular diseases, it has virtually replaced invasive diagnostic modalities such as angiography and venography. The clarity of presentation of orbital structures by computed tomography (CT) has prompted investigations into detailed multiplanar anatomy of the orbit. Tumor margins and inflammatory processes are so clearly defined that one can place the lesions in specific compartments and accurately determine the extent of the disease processes. Orbital involvement by extra-orbital diseases are also well delineated. Specific CT criteria have been established to assist in differential diagnosis.

With the increasing utilization of CT in orbital diagnosis, radiologists have been confronted with a new spectrum of disorders, many of which did not enter the radiology department prior to the advent of CT. The situation is compounded by the fact that orbital disease accounts for a small part of the average CT scanner load and therefore provides little opportunity for one to gain expertise in this area.

It was our aim, therefore, to consolidate our accumulated experience in a concise book which would serve as a reference for the occasional diagnostic dilemma and also provide a general review of all the major disease entities affecting the orbit. We have introduced each chapter with a brief text describing pathology, salient clinical features and the CT findings of each disease. We have also included references for more in-depth reading. The case history format provides a clinical bias to the illustrated material, including follow-up and surgical findings in many cases. It is our hope that this aspect will purvey a broader perspective to the disorders discussed, and will be particularly useful to ophthalmologists.

Acknowledgments

We could not have undertaken this project without the support of our many colleagues and assistants. We are especially indebted to Dr. Roy Strand of the Children's Hospital Medical Center in Boston, who generously provided us with numerous pediatric cases. A special acknowledgment is also made to Karen Easter, research assistant at the Massachusetts Eye and Ear Infirmary for her invaluable contribution.

We are grateful to all of our colleagues, both radiologists and ophthalmologists, who sent us cases either as patients for scanning or as completed images. In this regard we wish to thank the following: Drs. Reed Altemus, Richard Baker, Donald Bienfang, Richard Dallow, Arthur Grove, Susan Hughes, Thornton Kell, Gregory Krohel, Simmons Lessell, Glyn Lloyd, Dan O'Leary, Gerald O'Reilly, Keith Richards, David Walton, and Charles Wright. In addition, we obtained valuable advice from Dr. Richard Dallow, especially in regard to the chapter on Inflammatory Disease.

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Finally we are indebted to our publisher, Appleton-Century-Crofts and especially to their executive medical editor, Doreen Berne, who supervised the project, Jody Thum, the production editor, and Jean Sabato, the art director.

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Contents

CHAPTER ONE
Anatomy
Discussion

THE BONY ORBIT

The orbital cavities are located in a parasagittal plane of the skull between the facial skeleton and cranium. Each orbit is roughly pyramidal in shape, with seven bones contributing to the walls: frontal, maxilla, sphenoid, zygoma, ethmoid, lacrimal, and palatine. Above each orbit is the anterior cranial fossa; medially, the ethmoid sinus; below, the maxillary sinus; posteromedially, the middle cranial fossa, and posterolaterally, the temporal fossa. The medial walls of the orbits are almost parallel, whereas the lateral walls subtend an angle of approximately 90° with each other. The orbital roof is formed largely by the orbital plate of the frontal bone anteriorly, with a smaller contribution posteriorly by the lesser wing of the sphenoid. The medial wall is formed mainly by the orbital plate of the ethmoid, with a contribution anteriorly by the lacrimal bone and posteriorly by the body of the sphenoid. The ethmoid plate (lamina papyryacea) separating the orbit from the ethmoid air cells is very thin and is perforated by small foramina allowing vascular communications. The orbital floor is formed mainly by the orbital plate of the maxilla, with lesser contributions by the orbital surface of the zygomatic bone anterolaterally and the orbital process of the palatine bone at the apex. The infraorbital groove runs forward from about the middle of the inferior orbital fissure and soon becomes roofed over as the infraorbital canal. The lateral orbital wall is formed by the greater wing of the sphenoid posteriorly and the zygomatic bone anteriorly. The sphenoidal portion of the lateral wall is separated from the roof by the superior orbital fissure and from the floor by the inferior orbital fissure. The lateral wall separates the orbit anteriorly from the temporal fossa containing the temporalis muscle and posteriorly from the middle cranial fossa and middle lobe of the brain. The superior orbital fissure separates the greater and lesser wings of the sphenoid and lies between the roof and the lateral wall of the orbit. It is separated from the optic canal at its medial aspect by the posterior root of the lesser wing of the sphenoid.

THE OPTIC CANAL

The optic canal provides a communication between the middle cranial fossa and orbital apex. The canal is formed by the two roots of the lesser sphenoid wing and is directed anteriorly, laterally, and inferiorly, the axis forming an angle of approximately 37° with the midsagittal plane and 30° with Reid's baseline.[1] The canal is roughly cylindrical and is funneled in one plane at both ends, i.e., the intracranial end of the canal is oval with its long axis horizontal, whereas the orbital end of the canal is oval with the long axis vertical. The midportion of the canal is round. The measurements are: orbital end, 5 × 6 mm; middle, 5 × 5 mm; and intracranial end, 4.5 × 6 mm. The roof of the canal is 8 to 10 mm long, whereas the floor and lateral walls are 6 to 8 mm long. The medial wall of the optic canal is rather regularly adjacent to the sphenoid sinus, occasionally actually projecting into it.[2] The optic canal transmits the optic nerve and its coverings of dura, arachnoid, and pia. The ophthalmic artery lies below and is embedded in the dural sheath. Sympathetic nerve branches accompany the artery. The ophthalmic artery crosses below the nerve from medial at the posterior end of the canal to exit inferolaterally to the nerve at the orbital end. The pia forms a sheath closely adherent to the nerve. The dura serves as a periosteal lining of the canal and splits at the orbital end to become continuous with the periobita, as well as continuing as the dural sheath of the intraorbital optic nerve.

THE OPTIC NERVE

Developmentally, the optic nerve is a fiber tract joining two portions of the brain,[3] its fibers containing glial and not Schwann cells, and it is surrounded by meninges, unlike any peripheral nerves. The total length of the optic nerve is about 4 to 5 cm, and it has four sections: an intracranial prechiasmal part, about 10 mm in length; an intracanalicular part 6 mm in length; an intraorbital part of about 25 to 30 mm (which has a slightly sinuous course, with the length of the optic nerve being about 6 mm greater than the distance from the optic canal to the ocular bulb); and intraocular section, where the optic nerve penetrates the sclera, measuring approximately 0.7 to 1.5 mm in length. The intraorbital optic nerve is enclosed in three sheaths that are continuous with the membranes of the brain and extend along the optic nerve up to the eyeball. The outer sheath, derived from the dura mater is thick and fibrous and blends anteriorly with the sclera. Posteriorly, at the optic canal, it splits to blend with the periosteum of the optic canal and the periosteum (periorbita) of the orbit. The fibrous annulus of Zinn, formed by the convergence of the origins of the rectus muscles, also fuses to the dura of the optic nerve at the optic canal. The intermediate sheath of the optic nerve is derived from the arachnoid mater and is thin and delicate. The subarachnoid space is continuous with the intracranial subarachnoid space, and cerebrospinal fluid (CSF) surrounds the optic nerve up to the lamina cribrosa (papilla) of the eye ball.[4] The inner sheath derived from pia is vascular and invests the nerve. From its deep surface, septa pass into the nerve and subdivide it into bundles.

THE OPTIC CHIASM

The optic chiasm is a flattened quadrilateral bundle of nerve fibers situated at the junction of the anterior wall and the floor of the third ventricle, forming the floor of the chiasmatic recess. It measures about 12 mm in transverse diameter and about 8 mm in sagittal diameter. Anterolaterally it is continuous with the intracranial optic nerves, and posterolaterally with the optic tracts. It lies obliquely, with the posterior border higher than the anterior border, suspended and surrounded by CSF.

ORBITAL VESSELS

Ophthalmic Artery

The ophthalmic artery arises intracranially from the medial side of the internal carotid artery just after this vessel has traversed the cavernous sinus and pierced the dura. Within the optic canal the ophthalmic artery lies inferolateral to the optic nerve contained with the dural sheath of the nerve. It enters the orbit in the muscle cone running inferolateral to the optic nerve for a short distance but soon crosses over the nerve between the nerve and superior rectus muscle (in 15 percent it crosses beneath the nerve) and continues anteriorly to reach the medial orbital wall. Further forward, it lies between the medial rectus and superior oblique muscles up to the maxillary process of the frontal bone. Beyond the orbit the ophthalmic artery supplies the forehead and lateral wall of the nose. Within the orbit it gives off a number of variable branches, about 14 in number,[3] the most important of which is the central retinal artery. Other branches include the ciliary, ethmoidal, lacrimal, muscular, and supratrochlear arteries.

Orbital Veins

The orbital venous drainage occurs mostly via a superior ophthalmic vein and to a lesser extent by an inferior ophthalmic vein. These are tortuous, with many plexiform anastomoses, and like most facial veins they are valveless. The superior ophthalmic vein is formed near the root of the nose by anastomosis of the angular, nasofrontal, and supraorbital veins. It then travels posterolaterally through the orbit, penetrating the muscle cone in midorbit. It then runs deep to the superior rectus muscle and leaves the orbit near the annulus of Zinn via the superior orbital fissure and drains into the cavernous sinus. The inferior ophthalmic vein commences as a plexus near the front of the orbit and extends posteriorly on the inferior rectus, communicating with the superior ophthalmic vein and draining into the pterygoid plexus via the inferior orbital fissure.

Lymphatics

The orbit contains no lymphatic capillaries or lymphoid tissue. The eyelids, conjunctiva, and lacrimal glands do contain a lymphatic system.

EXTRAOCULAR MUSCLES

There are six extrinsic (striated) muscles that move the ocular globe: superior, inferior, medial, and lateral rectus; and superior and inferior oblique muscles. An additional muscle, the levator palpebrae superioris, arises from the lesser wing of the sphenoid, passes forward immediately above the superior rectus, and inserts into the upper eyelid. The sheath of the levator attaches below to that of the superior rectus. The four rectus muscles have a common origin at the apex in the annulus of Zinn, which is a short tendinous ring encircling the optic foramen and medial end of the superior orbital fissure. The muscle extends forwards as separate bundles but is joined together by an intermuscular fascial membrane, providing an inner or intraconal space and an extraconal or peripheral space. Each rectus muscle inserts separately into the sclera of the globe. The superior oblique is the longest and thinnest eye muscle. It arises superomedially to the optic foramen and passes anteriorly between the roof and medial wall to the trochlea. About 1 cm posterior to the trochlea, the muscle is replaced by a rounded tendon that passes through the pulley, turning sharply medially to insert into the globe below the superior rectus. The trochlea consists of a U-shaped piece of fibrocartilage. The inferior oblique is the only extrinsic muscle to take origin from the front of the orbit, arising on the orbital plate of the maxilla just lateral to the orifice of the nasolacrimal duct. It passes laterally and posteriorly (roughly parallel with the tendon of the superior oblique) between the inferior rectus and the orbital floor to insert in the posterolateral aspect of the globe.

ORBITAL FASCIA

There are several components to the orbital fascia.

Tenon's Capsule

Tenon's capsule (the fascia bulbi) is a thin fibrous membrane that envelops the globe from the margin of the cornea to the optic nerve. It is separated from the sclera, providing a potential space—the episcleral space. This space is traversed by delicate bands of connective tissue that extend between the sclera and fascia[5] and can be involved in inflammatory conditions. Tenon's capsule is related by various reflections to the aponeuroses and check ligaments of the extraocular muscles, conjunctiva, and globe. This network of interconnections facilitates the extension of tenonitis to the orbital tissues.[6] The intermuscular fascial membrane and trabeculae of the orbital fat are part of this extensive fascial connective tissue system of the globe and orbit.

Intermuscular Membrane

The intermuscular membrane is an aponeurotic sheath derived from the sheaths of the four rectus muscles. In some individuals it may be a poorly defined structure.[7] Together with the rectus muscles, it separates the intra- and extraconal spaces.

Orbital Septum

The orbital septum is a thin connective tissue membrane that attaches around the orbital margin, where it is continuous with the periosteum. This circumferential structure extends centrally to become attached to the tarsal plates of the eyelids. It is perforated by vessels and nerves that pass from the orbital cavity to the face and scalp, by the palpebral part of the lacrimal gland, and by the aponeurosis of the levator palpebrae superioris.[5] The soft-tissue space anterior to the orbital septum is the preseptal space. The soft tissues confined within the periorbita deep to the orbital septum constitutes the orbit proper. The orbital septum is an important barrier to the spread of preseptal or eyelid inflammation to the posterior compartment.

ORBITAL FAT

The orbital contents are invested by adipose tissue subdivided into lobules by fine fibrous septa. The orbital fat extends from the apex to the orbital septum anteriorly, sometimes bulging it forwards as it slackens with age. The consistency of the fat and the amount of connective tissue between the fat lobules vary in different parts of the orbit. The intermuscular membrane separates the fat into a central or intramuscular portion and a peripheral fat compartment. The central fat is loose, allowing for movements of the optic nerve; and is finely lobulated with thin septa. At the back of the globe the septa insert into Tenon's capsule. The peripheral fat is situated between the rectus muscles and the periorbita, and limited anteriorly by the septum. The peripheral layer of fat is subdivided into four discreet lobules[3] situated mainly in the intermuscular spaces.

LACRIMAL GLAND

The lacrimal gland is about the size of an almond and occupies the lacrimal gland fossa on the medial surface of the zygomatic process of the frontal bone, extending down almost to the lateral angle of the globe. The gland is divided into a larger upper or orbital lobe and a smaller lower or palpebral lobe. The two lobes are separated from each other by the expanded insertion of the levator palpebrae superioris.

COMPUTED TOMOGRAPHIC (CT) MANIFESTATIONS

By virtue of the large amount of orbital fat surrounding the various components of the orbit, visualization of the small structures is exceptional. In different CT planes, the extraocular muscles, vessels, and nerves can be clearly identified. However, the delineation of these structures in their part or whole depends on several factors, including section thickness, angle of the plane of scan relative to the orbit, and the resolution of the scanner. For example, an early-generation CT scanner resolving only 3.5 line pairs/cm could identify the ophthalmic artery in less than 1 percent of the cases, whereas a new high-resolution scanner resolving 10 line pairs/cm could identify this artery in all cases.[8] The orbital fat has a CT value of approximately −100 Hounsfield (H) units. Without contrast enhancement, the arteries, veins, nerves, and muscles of the orbit measure 30 to 35 H units, providing a difference of about 130 H units. Because of this large difference in absorption values without contrast material, utilization of contrast enhancement does not significantly increase visualization of these structures. Detail is dependent on spatial rather than added contrast resolution.[8]

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Illustrations

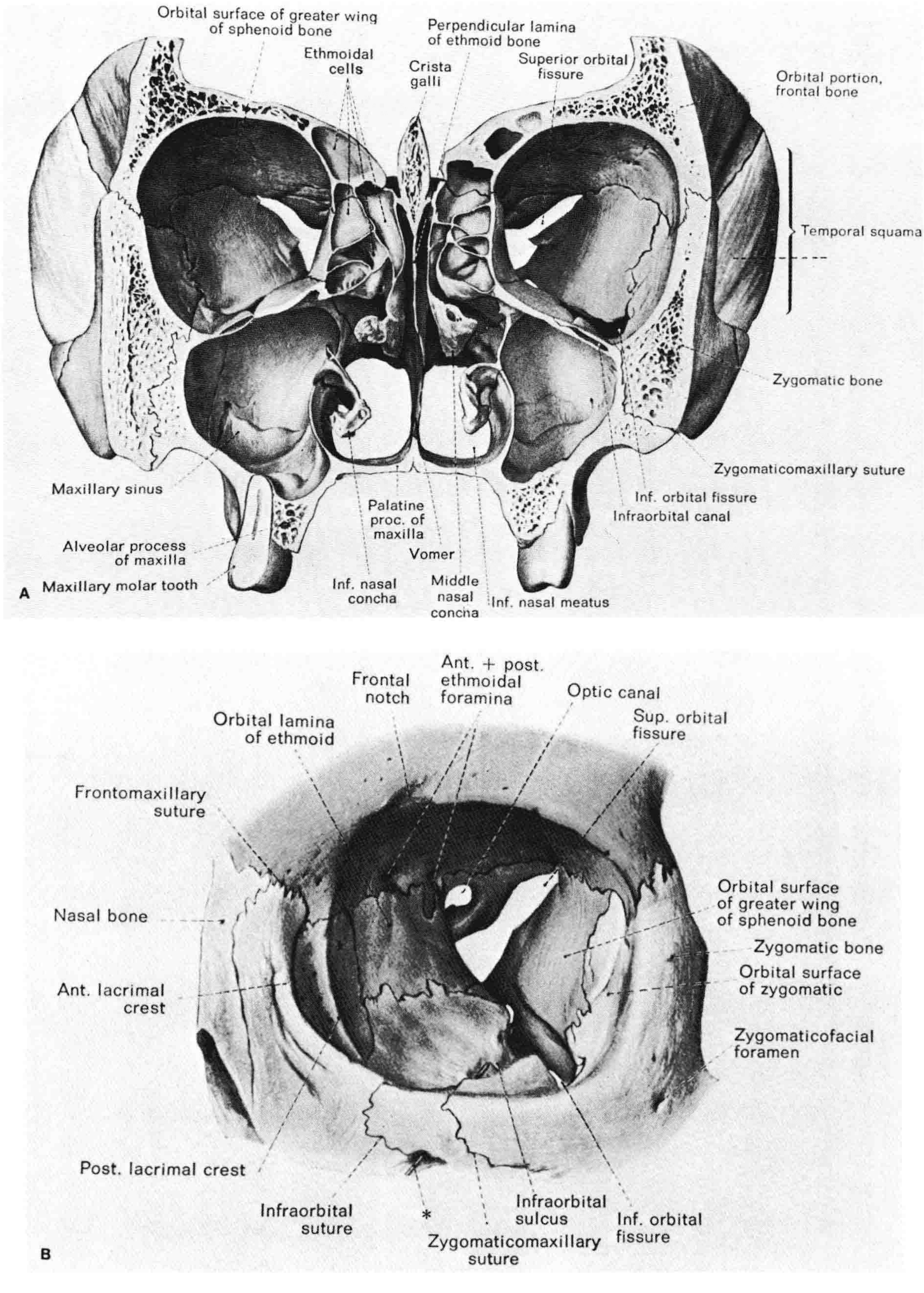

Figure 1.A. Coronal section through orbits. **B.** Apical view of orbit, demonstrating bony relationships.*

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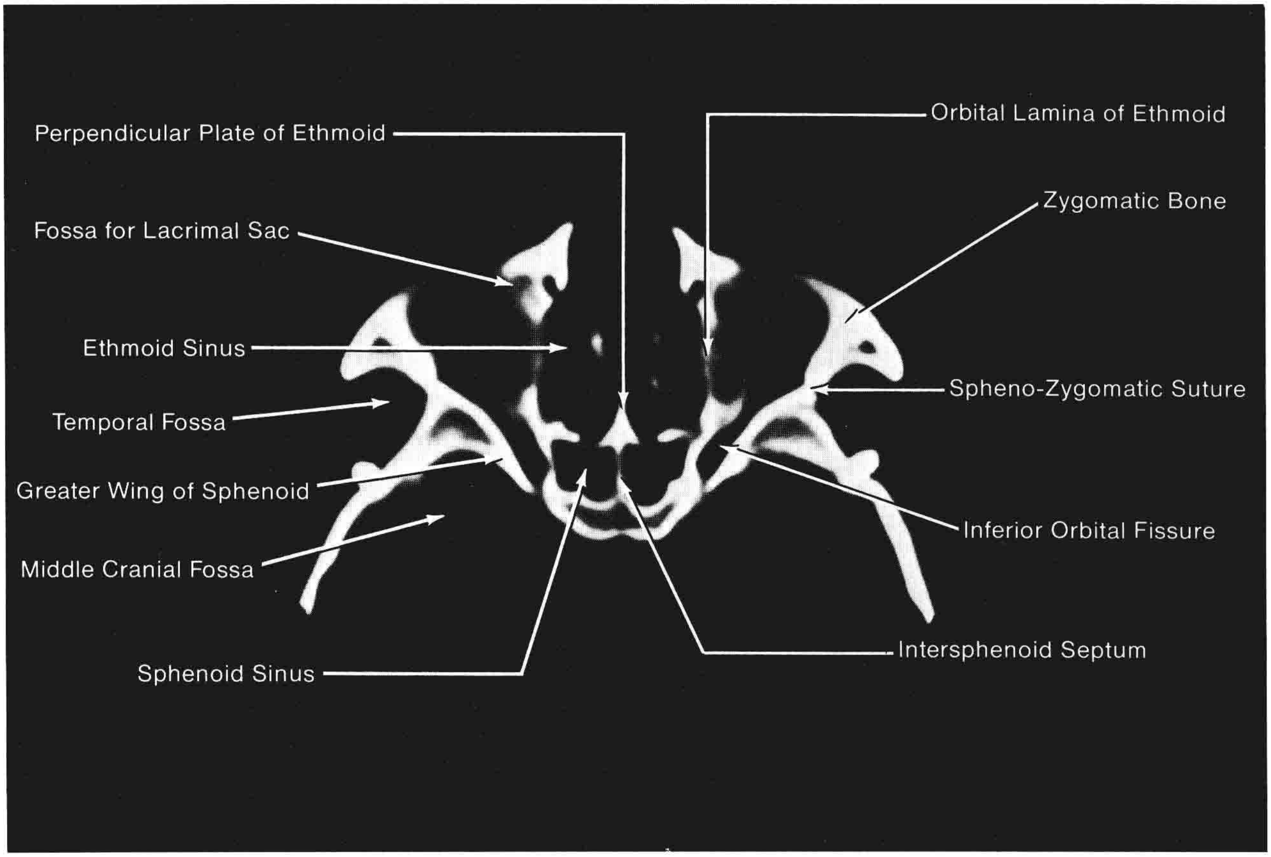

Figure 2. CT through inferior orbit of a skull.

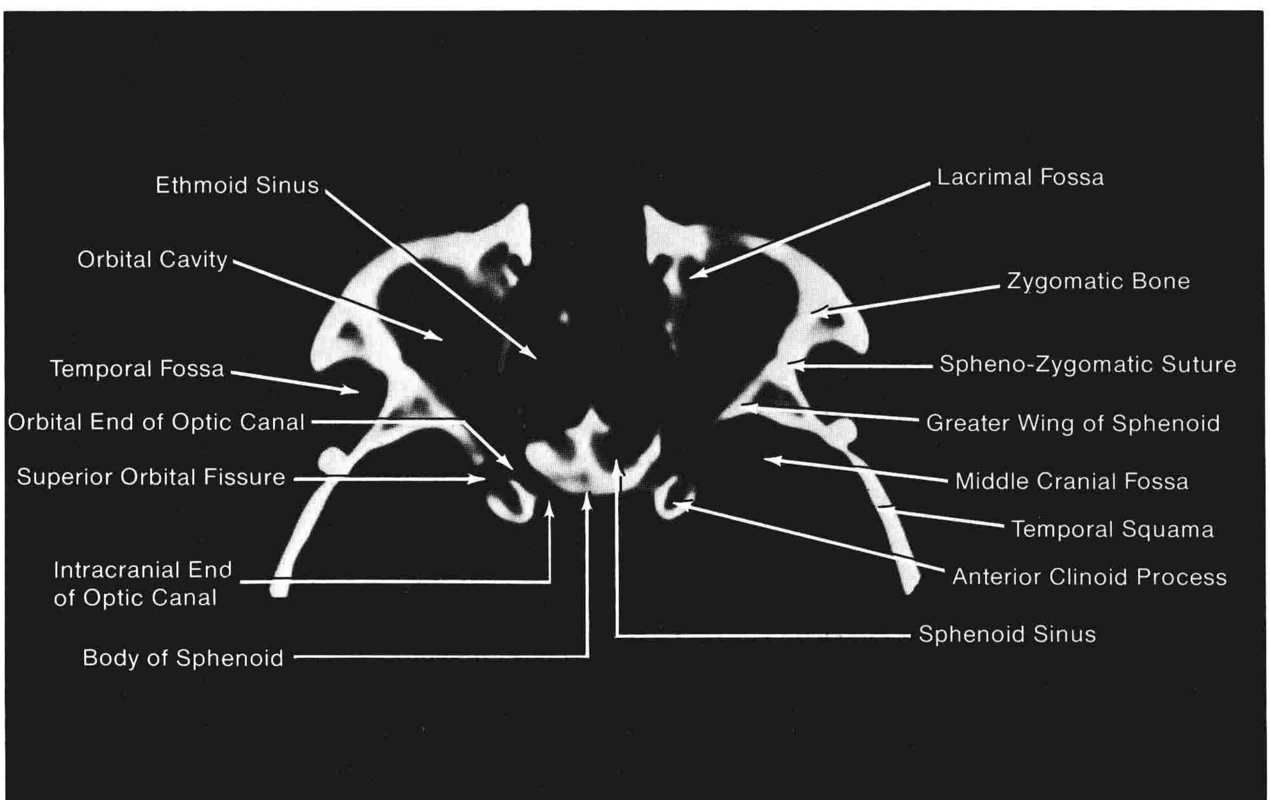

Figure 3. CT through optic canals of a skull.

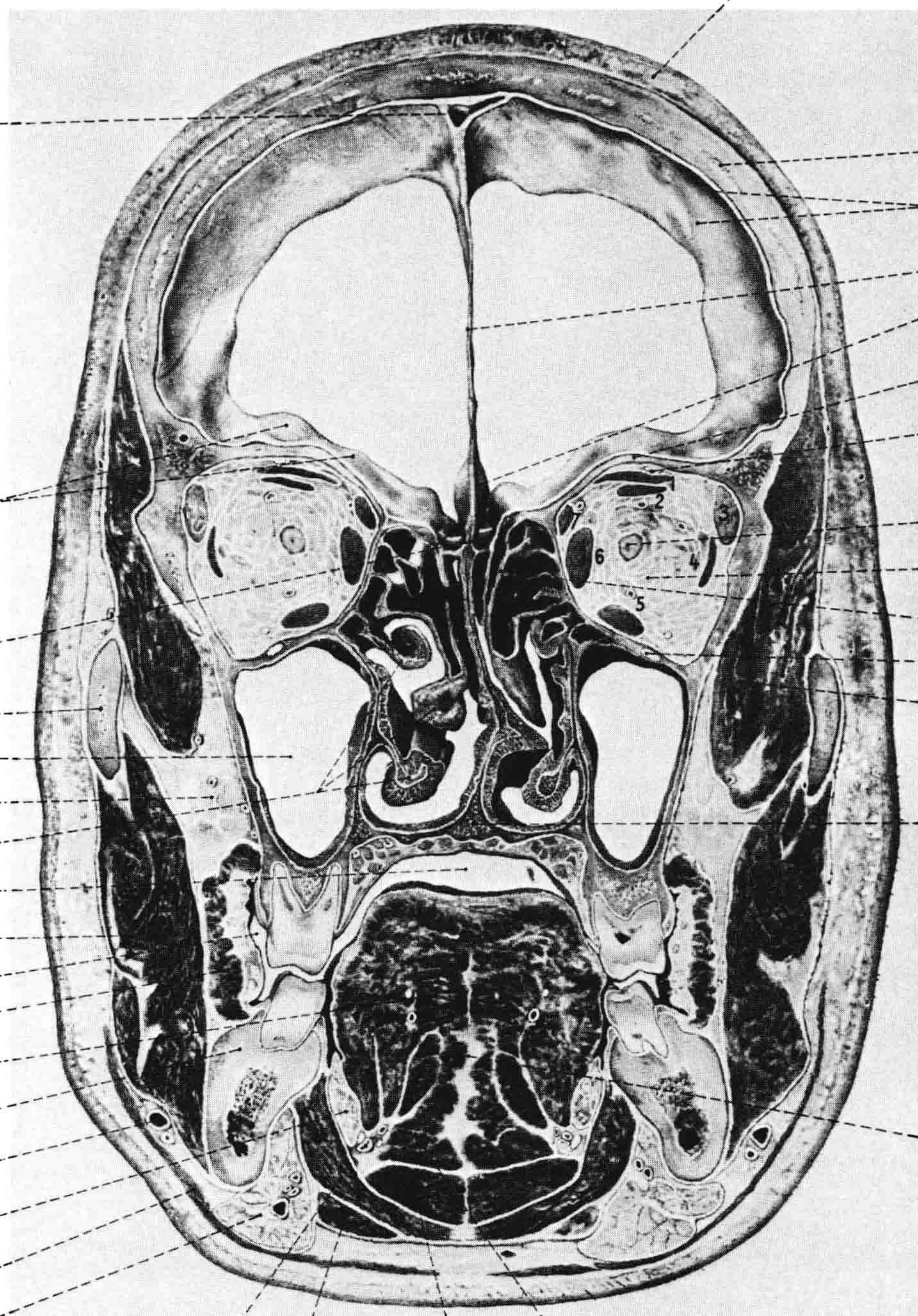

Figure 4. Retrobulbar coronal section through head. 1 = levator palpebrae superioris muscle; 2 = superior rectus; 3 = lacrimal gland; 4 = lateral rectus; 5 = inferior rectus. 6 = medial rectus; 7 = superior oblique.*

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