

OPHTHALMOLOGY SERIES

VOLUME 1

CLINICAL GLAUCOMA

GEORGE GORIN

CLINICAL GLAUCOMA

GEORGE GORIN, M.D., F.A.C.S.

**Associate Clinical Professor
of Ophthalmology
Albert Einstein College of Medicine
at Yeshiva University**

**Attending Ophthalmic Surgeon
and Director of Glaucoma Clinic
Manhattan Eye, Ear and Throat Hospital
New York, New York**

MARCEL DEKKER, INC. New York and Basel

Library of Congress Cataloging in Publication Data

Gorin, George.
Clinical glaucoma.

(Ophthalmology series ; v. 1)

Includes bibliographical references and index.

1. Glaucoma. I. Title. II. Series. DNLM:

1. Glaucoma. W1 OP373 v. 1 / W290 G669c;

RE871.G67 617.7141 76-56700

ISBN 0-8247-6456-0

OPHTHALMOLOGY SERIES

Editor: Paul Henkind, M.D., Ph.D.

Professor and Chairman

Department of Ophthalmology

Albert Einstein College of Medicine

Montefiore Hospital

New York, New York

Volume 1 CLINICAL GLAUCOMA George Gorin

Other volumes in preparation

COPYRIGHT © 1977 by MARCEL DEKKER, INC. ALL RIGHTS RESERVED

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming, and recording, or by any information storage and retrieval system, without permission in writing from the publisher.

MARCEL DEKKER, INC.

270 Madison Avenue, New York, New York 10016

Current printing (last digit):

10 9 8 7 6 5 4 3 2 1

PRINTED IN THE UNITED STATES OF AMERICA

FOREWORD

Glaucoma is in many ways a mysterious disease process. It is more than merely the reflection of an intraocular pressure, or a field defect, or a change in the optic nervehead. It is a congerie of conditions and a variety of pathologic features which, when somehow fitted together, fall under the broad heading of glaucoma.

The ophthalmologist faced with a patient who has the constellation of an elevated ocular pressure, a typical field defect, and cupping of the optic nervehead has no problem in making a diagnosis of the condition. Very often medical management will suffice and the patient's treatment will be effective. Not infrequently, particularly in an advanced society such as ours, it is only a borderline intraocular pressure that is found by the clinician and the field may show only the smallest of defects, or the disc the faintest of cupping. What to do in this instance? What about the patient with anatomically narrow angles, whose ocular pressure is only elevated to a modest degree by provocative testing, and how does one manage such a patient? What about the new entities in glaucoma that have been described within the past decade; conditions such as plateau iris, ciliary block, and a host of pigmentary glaucomas? How is one to diagnose and manage this wide variety of conditions all falling under the broad heading of glaucoma?

Fortunately, George Gorin, who has for many years provided a continuing and ever-expanding series of lectures and clinical demonstrations on the various aspects of glaucoma to the ophthalmology staffs of the Albert Einstein College of Medicine and the Manhattan Eye and Ear Hospital, has provided us with this volume. It is the distillate of more than three decades of clinical experience in the area of glaucoma. Here we have a wise and expert clinician who blends his practical experience with modern scientific knowledge concerning this complex subject.

Readers of this volume, be they novice or expert, cannot fail to gain insight into what is one of the most important conditions in all of ophthalmology. Furthermore, they will appreciate the very detailed and up-to-date bibliography which adds such a valuable perspective to our understanding.

Most of all, this is a practical book which will help practitioners to properly treat their patients who have glaucoma.

Paul Henkind, M.D., Ph.D.

PREFACE

The purpose of this book is to describe the pathophysiologic basis of the major entities of glaucoma in adults.

My teaching experience in the Albert Einstein College of Medicine, Manhattan Eye, Ear and Throat Hospital, and at the Academy of Ophthalmology and Otolaryngology made me aware of the difficulties encountered by many ophthalmologists in mastering the intricacies of glaucoma. In addition, my experience with glaucoma consultations gave me an opportunity to deal with many difficult clinical problems.

No attempt is made in this book to offer a comprehensive classification of the glaucomas, as this is not possible at the present state of our knowledge. The pathophysiology of the angle-closure glaucomas and of the secondary glaucomas is described in detail. The pathophysiology of the most commonly encountered form of glaucoma, that of chronic simple glaucoma, remains, however, unknown in spite of major research efforts.

A large volume of work was done during the past twenty years in electron microscopy of the outflow channels in an effort to elicit the cause of open-angle glaucoma. I am aware that many of the findings described are controversial, such as the numerous theories of outflow mechanisms of aqueous, but they are included in the book in order to give the clinically oriented ophthalmologist a general picture of the problems encountered by researchers.

Much of our knowledge of the pathophysiology of glaucoma is based on research in rabbits and monkeys, the findings of which are presumed to apply to the human eye. However, as is seen from a detailed description of the anatomic, circulatory, and neuro-humoral differences between these species and man, this may be a source of gross error.

A detailed description is given of aqueous formation and of the blood-aqueous barrier because it is deemed important in the treatment of one of the most severe forms of glaucoma, that of glaucoma secondary to uveitis.

This book also includes discussions on recent topics of interest, including the role of alpha and beta receptors, chemical sympathectomy, role of prostaglandins in uveitis, radial peripapillary capillaries, axoplasmic transport, laser iridectomy, panretinal photocoagulation in neovascular glaucoma, and the armamentarium for handling vitreous in malignant glaucoma.

Techniques of tonometry, tonography, gonioscopy, and perimetry are described only in connection with their clinical application.

I wish to thank Doctor Paul Henkind, Professor and Chairman of the Department of Ophthalmology at the Montefiore-Albert Einstein Medical School, for his encouragement to undertake the preparation of this volume and for going over and critically evaluating the manuscript. I am also grateful to the authors who graciously permitted me to use their illustrations. I am thankful to Mr. Henrick Malpica for the photographic work.

And finally, my deep appreciation to my wife for her unfailing support and patience during the writing of this book:

George Gorin, M.D., F.A.C.S.
New York

CONTENTS

Foreword	Paul Henkind	v
Preface		vii

SECTION ONE

Physiology, Chemistry, and Anatomy of Aqueous and Aqueous Pathways 1

1	THE AQUEOUS AND AQUEOUS DYNAMICS	3
	Physiologic Chemistry of Aqueous	3
	Inhibition of Fibroblast Growth by Aqueous	5
	Formation of Aqueous	5
	The Blood-Aqueous Barrier	7
	<i>Glossary of intercellular junctions</i>	
	Breakdown of Blood-Aqueous Barrier	13
	<i>Reflux of blood into the canal of Schlemm</i>	
	References	15

2	HISTOLOGY AND PATHOPHYSIOLOGY OF THE AQUEOUS PATHWAYS	19
	Introduction	19
	Site of Resistance to Outflow of Aqueous	19
	<i>The inner wall of the canal of Schlemm / The juxtacanalicular tissue /</i>	
	<i>The canal of Schlemm / Role of acid mucopolysaccharides in outflow of aqueous</i>	
	Mechanisms of Outflow of Aqueous	25
	References	37

3	CHEMICAL AND NEUROHUMORAL CONTROL OF AQUEOUS DYNAMICS	41
	Introduction	41
	Effect of Drugs on Cell Membranes	41
	Chemical and Neurohumoral Control of Intraocular Pressure	42
	<i>Parasympathetic or cholinergic agents / Sympathomimetic or adrenergic agents</i>	
	References	51
4	AQUEOUS DYNAMICS AND AQUEOUS PATHWAYS IN EXPERIMENTAL ANIMALS	53
	Anatomy and Physiology of Aqueous and Aqueous Pathways	53
	<i>Rabbit eyes / Monkey eyes / Prostaglandins</i>	
	Adrenergic Effects on Aqueous Dynamics in Animals	62
	Cholinergic Effects on Aqueous Dynamics	64
	References	65
	SECTION TWO	
	Open-Angle Glaucoma	69
5	DIAGNOSIS OF OPEN-ANGLE GLAUCOMA	71
	Incidence of Open-Angle Glaucoma	72
	Tonometry	73
	Ocular Hypertension	73
	Low-Tension Glaucoma	74
	Technique of Applanation Tonometry	76
	Family History	77
	Diurnal Curve of Intraocular Pressure	78
	<i>Home monitoring of intraocular pressure / Asymmetric levels of intraocular pressure</i>	
	Tonography	80
	Water-Drinking Test	82
	References	86
6	GLAUCOMATOUS CUPPING OF THE DISC	87
	Inherited and Acquired Cupping	88
	Pallor of the Disc	94
	Splinter Hemorrhages on the Disc	97
	Cupping in Myopic Eyes	97
	Pathophysiology of Acquired Cupping	99
	<i>Mechanical theory / Cavernous atrophy of the optic nerve / Ischemic damage to the glial and neuroretinal elements of the disc as a result</i>	

	<i>of compression of the blood supply to the disc / Blockage of axoplasmic transport at the disc</i>	
	References	107
7	FIELD DEFECTS IN OPEN-ANGLE GLAUCOMA	111
	Visual Field Defects in Glaucoma	112
	<i>Circumscribed paracentral defects / Arcuate scotoma / Ring scotoma</i>	
	Atypical Field Defects in Open-Angle Glaucoma	119
	<i>Field changes due to age</i>	
	Pathogenesis of Field Defects	122
	References	123
8	HISTOPATHOLOGIC FINDINGS IN OPEN-ANGLE GLAUCOMA	125
	References	127
9	SYSTEMIC FACTORS AND OPEN-ANGLE GLAUCOMA	129
	Diabetes	129
	Thyroid Disease	130
	Topical Corticosteroid Response and Steroid Glaucoma	130
	<i>Plasma cortisol suppression / Inhibition of lymphocyte transformation</i>	
	References	135
10	MEDICAL TREATMENT OF OPEN-ANGLE GLAUCOMA	139
	Indications	139
	Topical Drugs	139
	<i>Cholinergic drugs / Anticholinesterase drugs / Sympathomimetic drugs / Effect of oral anticholinergic drugs in open-angle glaucoma / Effect of mydriatics in open-angle glaucoma</i>	
	Oral Antiglaucoma Drugs	148
	<i>Carbonic anhydrase inhibitors / Hyperosmotic agents</i>	
	Routine of Medical Treatment	151
	Marihuana in Open-Angle Glaucoma	152
	References	153
11	PATHOPHYSIOLOGY OF FILTERING OPERATIONS	157
	Indications for Surgical Treatment	157
	Pathophysiology of Filtering Operations	158
	<i>Postoperative management / Causes of bleb failure / New operations</i>	
	Surgery on the Ciliary Body	166
	Surgery in Late Cases of Open-Angle Glaucoma	166
	References	167

SECTION THREE	
Angle-Closure Glaucoma	169
12 DIAGNOSIS AND CLASSIFICATION OF ANGLE-CLOSURE GLAUCOMA	171
Introduction	171
Classification of Angles	171
<i>Wide angle / Intermediate angle / Narrow angle / Incidence of narrow angles</i>	
Characteristics of the Eye in Angle-Closure Glaucoma	175
<i>Lens in angle-closure glaucoma / Cornea in angle-closure glaucoma / Ciliary body and iris / Incidence in various population groups / Factors triggering angle closure / Closure sequence of angle</i>	
Mechanisms of Closure of the Angle	178
<i>Angle-closure glaucoma due to pupillary block</i>	
Gonioscopy in Angle-Closure Glaucoma	179
<i>Indirect gonioscopy (Goldmann) / Manipulative gonioscopy (Gorin) / Indentation gonioscopy (Forbes) / Direct gonioscopy</i>	
Relationship Between Depth of Anterior Chamber and Width of the Angle	181
Classification of Forms of Angle-Closure Glaucoma	182
<i>Acute congestive angle-closure glaucoma / Chronic congestive angle-closure glaucoma / Chronic noncongestive angle-closure glaucoma / Angle-closure glaucoma—interval phase / Angle-closure glaucoma due to plateau iris or shortening of the angle / Atypical findings in angle-closure glaucoma</i>	
Provocative Tests in Diagnosis of Angle-Closure Glaucoma	201
<i>Dark room test / Mydriasis test / Reading and prone-position test / Effect of strong miotics in elderly patients</i>	
References	205
13 TREATMENT OF ANGLE-CLOSURE GLAUCOMA	209
Treatment of Acute Congestive Angle-Closure Glaucoma	209
<i>Osmotic agents / Indications for iridectomy</i>	
Treatment of Chronic Congestive Angle-Closure Glaucoma	215
Treatment of Angle-Closure Glaucoma in Plateau Iris	216
<i>Complications of iridectomy / Effect of mydriatics following iridectomy</i>	
Mixed Glaucoma	218
References	220
14 MALIGNANT GLAUCOMA	223
Premalignant Stage	223
Malignant Glaucoma	225
<i>Pathophysiologic concepts: Old and new / Treatment of malignant glaucoma</i>	
References	231

SECTION FOUR

Secondary Glaucomas	233
15 EXFOLIATION SYNDROME	235
Pathophysiologic Considerations of Obstructive Glaucomas	235
<i>Introduction</i>	
Exfoliation Syndrome	238
<i>Origin of exfoliated material / Incidence / Gonioscopic findings in exfoliation syndrome / Glaucoma in exfoliation</i>	
References	244
16 PIGMENT-DISPERSION SYNDROME	247
Gonioscopic Findings	247
Dispersion of Pigment and Krukenberg's Spindle	248
<i>Iris processes in pigmentary glaucoma / Iris in pigment-dispersio-</i>	
<i>syndrome / Sex differences in pigmentary glaucoma / Myopia and</i>	
<i>pigment-dispersion syndrome / Cause of glaucoma in pigment-</i>	
<i>dispersion syndrome / Treatment / Relationship between open-angle</i>	
<i>glaucoma and pigment-dispersion syndrome</i>	
Summary	252
References	255
17 PROGRESSIVE ESSENTIAL ATROPHY OF THE IRIS, CHANDLER'S SYNDROME, AND IRIS-NEVUS (COGAN-REESE) SYNDROME	257
Progressive Essential Atrophy of the Iris	257
<i>Treatment</i>	
Chandler's Syndrome	262
Iris-Nevus (Cogan-Reese) Syndrome	263
References	265
18 GLAUCOMA DUE TO TUMORS OF THE CHOROID, THE CILIARY BODY, AND THE IRIS	267
Glaucoma in Malignant Melanoma of the Choroid	267
Glaucoma due to Oculodermal Melanocytosis	268
Glaucoma in Malignant Melanoma of the Ciliary Body and Iris	269
Glaucoma in Benign and Malignant Lymphoma of the Uvea	272
Glaucoma due to Pigmented Lesions and Cysts of the Iris	
and Ciliary Body	272
References	275
19 THE LENS AND GLAUCOMA	277
The Lens and Open-Angle Glaucoma	277
The Lens and Angle-Closure Glaucoma	278

Glaucoma Associated with an Abnormal Position of the Lens	279
<i>Traumatic dislocation of the lens</i>	
Glaucoma Associated with Spontaneous Dislocation of the Lens	281
<i>Marfan's syndrome / Homocystinuria / Weill-Marchesani syndrome: Spherophakia</i>	
Phacolytic Glaucoma	287
References	290
20 GLAUCOMA IN APHAKIA	293
Glaucoma due to Angle Closure	293
<i>Closure of the angle due to pupillary block / Closure of the angle without pupillary block "shortening of the angle"</i>	
Glaucoma due to Blockage of an Open Angle	
by Particulate Matter	300
<i>Enzyme glaucoma / Treatment of open-angle glaucoma in aphakia</i>	
Glaucoma due to Synechial Closure and Blockage of the Angle	
by Particulate Matter	305
<i>Glaucoma in endophthalmitis phacoanaphylactica / Glaucoma following extraction of a hypermature cataract / Glaucoma following extraction of a congenital cataract</i>	
Miscellaneous Factors Causing Glaucoma	
Following Cataract Extraction	307
<i>Loss of vitreous / Prolapse of the iris / Epithelial invasion of the anterior chamber / Hypotony after cataract extraction</i>	
References	309
21 GLAUCOMA SECONDARY TO UVEITIS	313
Pathogenetic Mechanisms in Glaucoma Secondary to Uveitis	313
<i>Angle closure due to iris bombé / Obstruction of outflow by particulate matter / Angle closure by peripheral anterior synechiae</i>	
Glaucoma in Acute Iritis and Iridocyclitis	317
<i>Effect of inflammation on blood-aqueous barrier and uveovascular permeability</i>	
Glaucoma in Acute Iridocyclitis	318
<i>Keratic precipitates</i>	
Glaucoma in Recurrent and Chronic Cyclitis	
and Peripheral Uveitis	320
<i>Treatment of chronic cyclitis and peripheral uveitis / Heterochromic cyclitis of Fuchs</i>	
Glaucoma in Anterior Uveitis Associated	
with Juvenile Rheumatoid Arthritis (Still's Disease)	322
Acute Open-Angle Glaucoma due to Latent Iridocyclitis	324
Glaucomatocyclitic Crisis (Posner-Schlossman Syndrome)	325
Glaucoma in Uveitis due to Sarcoidosis	326
Glaucoma in Interstitial Luetic Keratitis and Uveitis	327
<i>Treatment of glaucoma secondary to uveitis</i>	
References	332

22	GLAUCOMA DUE TO ABNORMALITIES OF THE BLOOD, INTRAOCULAR HEMORRHAGE, AND NEOVASCULAR FORMATIONS	337
	Glaucoma due to Abnormalities of the Blood	337
	Glaucoma due to Intraocular Hemorrhage	338
	<i>Hemolytic glaucoma</i>	
	HypHEMA	339
	<i>Mechanisms of elimination of blood from the eye / Medical treatment / Complications of hypHEMA / Chemical treatment of hypHEMA / Surgical treatment of hypHEMA / Summary of treatment</i>	
	Neovascular Glaucoma	342
	<i>Neovascular glaucoma caused by diabetic proliferant retinopathy / Neovascular glaucoma following central retinal vein thrombosis / Neovascular glaucoma following closure of central retinal artery / Neovascular glaucoma following cranial arteritis, occlusion of carotid artery, and carotid-cavernous fistula / Neovascular glaucoma due to miscellaneous causes</i>	
	References	349
23	GLAUCOMA DUE TO PERFORATING AND CONTUSION INJURIES OF THE EYE	353
	Glaucoma due to Perforating Injuries	353
	Glaucoma due to Contusion of the Eye	354
	<i>Recession of the angle of the anterior chamber / Pathophysiology of glaucoma after contusion</i>	
	References	363
24	GLAUCOMA SECONDARY TO RETINAL DETACHMENT	365
	Introduction	365
	Incidence	365
	Angle-Closure Glaucoma and Retinal Detachment Surgery	366
	<i>Annular uveal effusion</i>	
	Glaucoma Following Cure of Long-Standing Retinal Detachment	367
	Miotics and Retinal Detachment	368
	Retinal Detachment in Glaucoma due to Angle Recession	368
	Nonrhegmatogenous Detachment and Aphakic Glaucoma	368
	Rhegmatogenous Detachment and Open-Angle Glaucoma	368
	Pigmentary Glaucoma in Rhegmatogenous Detachment	369
	Treatment of Glaucoma Associated with Retinal Detachment	369
	References	370
25	GLAUCOMA SECONDARY TO KERATOPLASTY	371
	References	373
	AUTHOR INDEX	375
	SUBJECT INDEX	385

SECTION ONE

**PHYSIOLOGY, CHEMISTRY, AND ANATOMY
OF AQUEOUS AND AQUEOUS PATHWAYS**

CHAPTER 1

THE AQUEOUS AND AQUEOUS DYNAMICS

Glaucoma constitutes a group of disorders characterized, in general, by increased intra-ocular pressure, alterations in the optic nervehead, and abnormalities in the visual field (National Advisory Eye Council).*

Physiologic Chemistry of Aqueous

The aqueous is a clear fluid formed in the ciliary body at the rate of $3 \mu\text{l}/\text{min}$, or 1% of the volume of the anterior chamber. It circulates from the posterior chamber through the pupil into the anterior chamber, trabecular meshwork, canal of Schlemm, and external collector channels into the intrascleral venous circulation. The flow of aqueous refers to bulk flow and does not include the turnover of water and ions by diffusional exchange through the iris capillaries, between the anterior chamber and the systemic circulation. According to Kinsey (1955), the volume of fluid turnover per minute in the rabbit eye is $50 \mu\text{l}$, out of which only $4 \mu\text{l}$ are aqueous. Goldmann (1970) found the same in the human eye.

The parent fluid of aqueous is blood plasma, which supplies the constituents of aqueous through the blood vessels of the 70 to 80 ciliary processes. The region of the ciliary processes is one of the most richly vascularized parts of the body. The break-up of the small arterioles into wide, thin-walled capillaries is abrupt, causing high capillary pressure in the region. However, aqueous is not a simple dialysate of plasma, produced by the high hydrostatic pressure of the capillary bed of the ciliary processes. There are some differences between the composition of aqueous and plasma.

In the normal human eye the protein content in the aqueous is $5 \text{ mg}/100 \text{ ml}$. In the rabbit, a commonly used experimental animal, the protein content of the aqueous is 10 times higher, $50 \text{ mg}/100 \text{ ml}$. The concentration of glucose is lower in aqueous than in plasma. This could be accounted for partly by the utilization of glucose in the metab-

*Report of the National Advisory Eye Council, Vision Research Planning Committee, Vol. 1 and 2, Research Program Analysis, 1975.

olism of the lens and cornea, and partly by its slow diffusion into the aqueous. There is a high concentration of lactic acid as a result of glucose metabolism, and possibly through the activity of the ciliary epithelium

Normal human aqueous contains 25 times as much ascorbic acid as plasma, 25 mg/100 ml in the aqueous compared with 1 mg/100 ml in plasma. In the human fetus ascorbic acid rises during the last 3 months of gestation. This rise seems to coincide with the greater reliance of lens metabolism on aqueous, instead of oxygen, supplied by the perilental vascular circulation. It was shown, in electronmicrographic preparations, that in this period of fetal life the outflow channels undergo a transformation, tending to facilitate outflow of aqueous. This consists of a decrease in the thickness of the internal wall of the canal of Schlemm, which becomes reduced to a single layer of very thin endothelial cells, a feature absent in the 4-month-old fetus (Wulle 1968). The high content of ascorbic acid in the posterior chamber is due to come active process of secretion, the exact nature of which is still unknown. Ascorbic acid was considered, by Friedenwald, the substance that presumably supplied energy for the production of aqueous, but this theory was not proved.

The content of sodium in aqueous is slightly higher than that in plasma in all species, including man, as shown in both chemical and isotopic studies. According to Davson (1969), aqueous is slightly hypertonic to plasma in the order of 3 to 5 mOsm/liter. That an excess of sodium exists in aqueous was demonstrated by animal experiments in which aqueous was dialyzed against plasma, resulting in a sodium loss from aqueous and a gain by plasma. The excess of sodium is possibly responsible for the small osmotic excess of aqueous over plasma. However, Langham (1958) suggests that the bulk of aqueous is in osmotic equilibrium with blood, and that the difference found is to be attributed to methodologic error. Similarly, Levene (1958) established that the excess of sodium is balanced by a deficiency of other substances, so that there is no great difference between the osmolality of aqueous and plasma.

There is a constant exchange of fluid and ions by diffusion between the anterior chamber and blood plasma through the iris capillaries. The only structure separating aqueous from the iris circulation is the endothelium of the capillaries. Lipid-soluble substances cross the iris barrier rapidly, water penetrates even more rapidly, as shown by experiments with heavy water. If the aqueous in the anterior chamber is in equilibrium with plasma, no diffusional exchanges between anterior chamber and plasma will occur. If the concentration of ions in the aqueous is higher than in plasma, as is the case with sodium in all species and bicarbonate in the rabbit, these ions will diffuse into the plasma. On the other hand, glucose, the concentration of which is higher in plasma, will diffuse into the anterior chamber through vessels in the iris but is constantly utilized in cornea and lens metabolism. As a result, the posterior chamber has a higher content of glucose than the anterior chamber. In the aqueous of the anterior chamber, there is a net gain of chloride through diffusion but a loss of bicarbonate which is replaced by chloride. Sodium diffuses back and forth constantly across the iris capillaries. Because substances are lost to the vitreous and lens, a knowledge of the concentration in the posterior chamber aqueous is very important. Without knowledge of the posterior chamber data, it is difficult to compare concentrations in aqueous with those in plasma. However, posterior chamber data cannot be obtained in human eyes and our knowledge is based on findings in animal eyes.