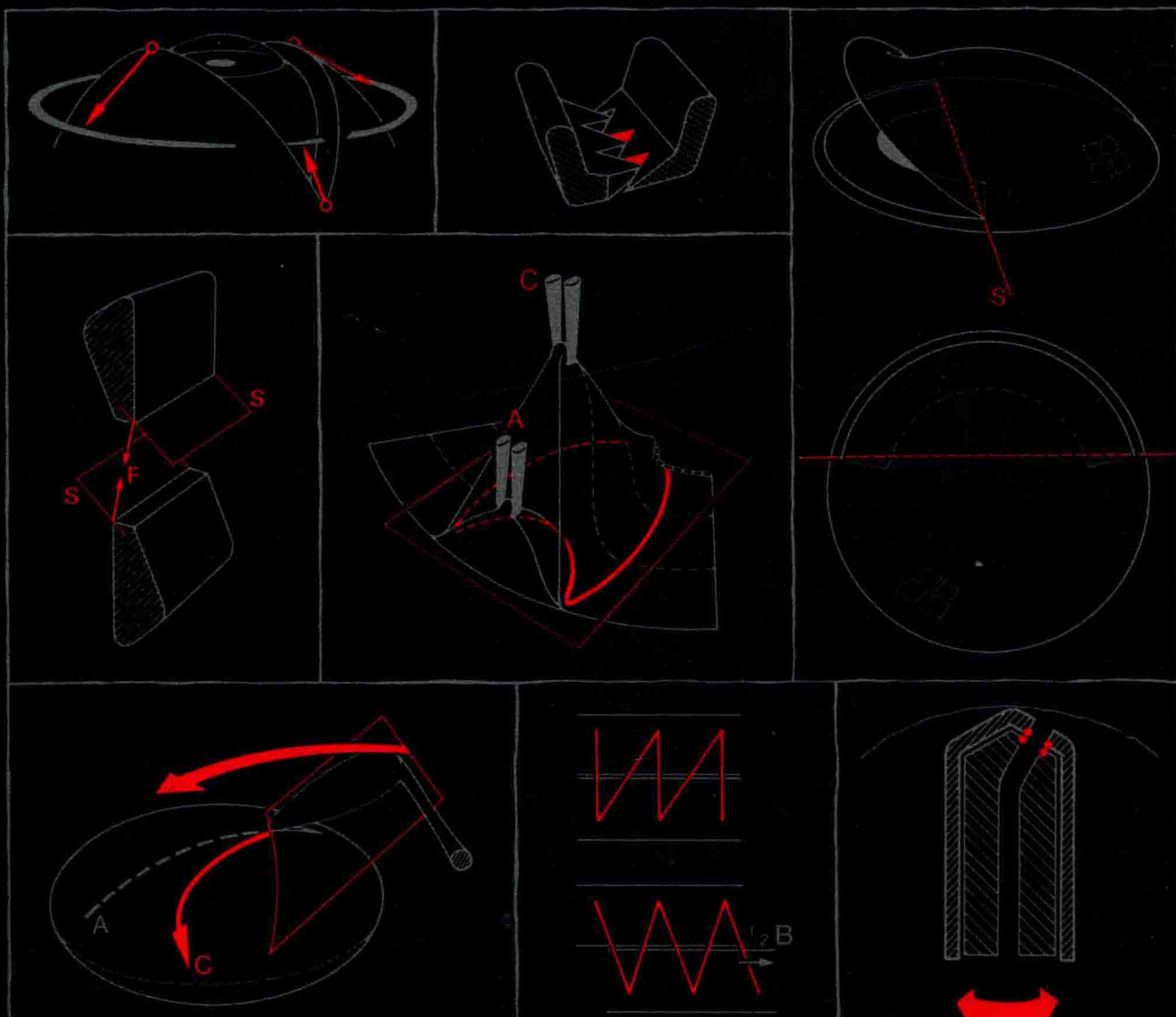
Georg Eisner

Eye Surgery

An Introduction to Operative Technique

Second, Fully Revised, and Expanded Edition



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Translated by Terry C. Telger

With 546 Figures, Mostly in Color
Drawings by Peter Schneider

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Hans Goldmann:

"... I am not manually skilled by nature,
so when it came to surgery I had to carefully ponder,
and try to understand rationally,
each step of the procedure ..."

(From a casual conversation)

Peter Niesel:

Purely intuitive skills are difficult to analyze.
The underlying causes of success or failure remain obscure.
This may be why the operative methods
described by one author are often less successful in other hands:
While the method has been learned, the craftmanship has not.
Experience, dexterity and intuition are not conscious processes
and are thus difficult to transfer to others.
The present book is concerned with finding a rational basis
for specific surgical manipulations.

(From the introduction to the first edition of Eye Surgery 1978)

Preface

The second English-language edition of my book *Eye Surgery* is almost a new book. This reflects the developments during the ten years since the first manuscript was completed. Indeed, the changes have been so far-reaching that a fundamental different ophthalmic surgery has evolved. In the process, a new "way of surgical thinking" has emerged, calling for extensive revisions even in a book that is concerned with the elucidation of basic principles rather than with individual methods.

In keeping with modern developments, it has been necessary to add new chapters to this book and revise the old ones. The revisions took the author, working in his spare time, several years to complete.

While a book by one author has the advantage of being uniform in its style and presentation, it also has shortcomings due to the limitations inherent in a single-author work. It is my hope that, on the whole, the advantages will outweigh the shortcomings.

Though singly authored, the book would not have been possible without the help of others. It has thrived on the friendly exchange of ideas at our University Eye Hospital in Bern – an interchange that was already lively when the first edition was created, while Prof. Hans Goldmann was still clinical director, and which has been carried on by his successors. I am indebted to Prof. Peter Niesel, who based on his tireless research into causes and approaches offered important suggestions for the first edition and continued to offer helpful comments during the development of this second edition. Besides his daily support, he critically reviewed the first chapter on spatial tactics and helped to present the material with greater clarity and precision. I am grateful to Prof. Franz Fankhauser for reviewing the chapter on laser surgery. I also express thanks to the staff physicians and residents at our clinic, who by their useful questions and comments contributed many good ideas.

The number of illustrations has been expanded to 546. I was pleased to rely once more on the help of our university illustrator, Mr. Peter Schneider, who, in addition to his technical competence as an artist, displayed an insight and critical ability which clarified and enhanced my ideas. Although the new illustrations took a great amount of time and effort to complete, Mr. Schneider accomplished the job with patience and uncompromising accuracy. The reader will readily appreciate the quality of his work, a quality attested to by the fact that many of his drawings have since been reproduced in other books. I am very grateful to him.

I also wish to thank the translator of the German text, Mr. T.C. Telger. After his outstanding work on the first edition, I was greatly relieved to learn that he could undertake the job – a job made more difficult by the fact that the novel approach and new terminology in this book made it necessary to incorporate terms from other technical fields. Anyone familiar with the difficulty of reformulating complicated German syntax into readable English will appreciate his achievement.

Introduction

Eye Surgery is intended as a "grammar" of intraocular surgery. However, is such a grammar really necessary? Is it not better to learn by practice than by theory?

What is the role of grammar in learning a language? Indeed, there are people who learn by practice alone. However, while practice may be a fine way to acquire language skills rapidly for everyday use, it is a laborious way to acquire more sophisticated language skills. It is difficult to recognize and correct errors without a knowledge of the basic structure of the language. Furthermore, grammar makes it easier to acquire new knowledge because it facilitates the integration of newly learned material into a whole. Actually, grammar shortens the path to perfection.

In the same way, it is possible to learn surgery by practice alone. But the road to experience is long, and if this is true of routine procedures, it is even more true when it comes to dealing with complications, i.e., finding optimum solutions in unexpected situations. I do not believe that the trial-and-error quest for experience is compatible with the interests of the patient. A knowledge of surgical "grammar" shortens the learning process. Furthermore, it helps in comparing different methods and weighing their advantages and disadvantages. Finally, a mastery of grammar makes it easier to develop new methods, because the basic principles, once learned, can be applied to novel situations in which experience is necessarily lacking.

The present book is tailored to this "grammatical" way of thinking. It describes basic principles of operating technique rather than specific methods. Like a language grammar that is concerned less with what is said in the language than with how well it is expressed, *Eye Surgery* focuses not on *what* is done but on *how* something is done.

And just as the length of the paragraphs in a grammar book does not necessarily reflect the frequency of the problems ("the rules are usually shorter than the exceptions"), the lengths of the sections in this book do not correlate with the practical frequency of surgical situations. If selected problems are presented, they are merely examples intended for training the reader in a surgical way of thinking that will prove valuable in entirely different and perhaps unexpected situations.

Our grammatical approach is appropriate for the standard procedures in the anterior segment of the eye, which usually are performed on normal tissue in a normal anatomic position. For such tissues whose properties are reasonably predictable, the surgeon can rely on geometrical and physical principles. This applies much less in surgery of the posterior segment, however, where we are dealing with pathologically altered tissue that has been displaced from its original position. The primary concerns of the surgeon are the careful clinical evaluation of the pathology and the development of a strategy appropriate for that pathology. The "grammatical" aspects in this type of surgery play a minor role. Therefore, posterior segment surgery is not specifically treated in this book. However, a structured approach can be derived by analogy with the rules for surgery of the anterior segment, i.e., space-tactical requirements, instrumentation, the treatment of lamellar and elastic tissues, etc. When faced with pathology, it is the surgeon's task to recognize which of the respective rules are applicable and to find the best solution.

One point must be emphasized: Just as a grammar cannot replace a language textbook, this book is not meant to replace textbooks on ocular surgery. Here we tend to assume that the reader is already familiar with standard operative goals and methods; and when we do detail the steps in a specific procedure, it is only for the purpose of illustrating essential technical principles. A clinical evaluation of specific operations is outside our present scope.

Every learning process poses a dilemma: The whole cannot be known without understanding its parts, and the parts cannot be grasped without understanding the whole. A "grammar book" can be a helpful roadmap on this complicated path.

Contents

The Paradox of High Success

Our goal in studying principles of surgical technique is to achieve the highest possible rate of success. Yet the closer we come to this goal, the more difficult it becomes to perceive the result of our efforts. The reason for this is what I call the "paradox of high success" – the curious fact that, as success rates improve, it becomes increasingly difficult to substantiate further improvements, because they become

- increasingly less apparent
- and increasingly difficult to prove.

The reason for the poor *perceptibility* of increments at high success levels stems from the practice of expressing success rates as percentages. However, the significance of a percentage change depends on whether it occurs at the middle or extreme end of the percentage scale. For example, a 10% improvement from 45% to 55% means very little, because both rates imply that there is roughly one success for every failure. Thus, the success rate (about 1:2) remains essentially unchanged despite the percentage improvement. In contrast, an improvement from 80% to 90% means that, where formerly we could expect about 5 successes for every failure, we can now expect about 10. In this case, then, the 10% improvement has led to a doubling of the success rate. Following this trend toward the extreme end of the scale, we will find that percentage improvements that appear negligibly small have a profound effect on the success rate. Thus, a rise of only 1% from 98% to 99% means that, where formerly we could expect 50 successes per failure, we can now expect about 100. A further improvement of only 0.5% beyond this point, from 99% to 99.5%, would be a tremendous advance, implying that only 1 in 200 patients would be at risk for failure.[1]

As the percentages rise, of course, there is a corresponding increase in the intellectual and material investment necessary to effect the improvement. Whereas little effort is needed to boost the rate from 45% to 55%, an increase from 80% to 90% calls for considerably greater know-how and technical expertise, while an increase from 99% to 99.5% demands a tremendous investment indeed. The basic problem is that, as success rates climb, it becomes increasingly difficult to justify the expense necessary for further improvements, since the improvement may not be amenable to statistical proof.

This brings us to part two of the "paradox of high success": the *unprovability* of extremely high success rates. The case numbers necessary for statistical proof increase dramatically with the success rate. For example, proof ($p<0.01$) that a success rate of 80% has been raised to 90% by a new technique would require a data base of 250 cases. Proof of improvement from 98% to 99% would require about 2900 cases, and proof of a 99% to 99.5% increase would require about 5800 cases. Clearly, the case numbers necessary for a valid statistical study (one involving comparable patient populations, the same operator using a constant, standardized technique over the course of the study, and standardized follow-up procedures) cannot be achieved in practice. This implies that extremely high success rates cannot be proved.

I address this problem at the start of the book in the hope that the reader who seeks to optimize his surgical technique through intensive study will not become discouraged. Even though the results of his efforts may not be obvious or provable, the certainty of having done his best for the individual patient – *always the primary concern* – will still bring him satisfaction and will motivate him toward further refinements of his technique.[2]

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[1] It follows that success rates are more easily appreciated when they are expressed as fractions.

[2] It is important for the surgeon to understand the paradox of high success not just for his own motivation, but also so that he can discuss the problem intelligently with political and administrative authorities who make funding decisions. Obviously it is difficult to justify the enormous costs of increasing a high success rate when the improvement is neither numerically impressive nor provable.

Tactics in Ophthalmic Surgery

Modern microsurgery has revolutionized the conduct of eye operations. Above all, it has changed the mode of *feedback* on which the surgeon relies to guide his manipulations. The classic concept of *tactile feedback*, in which the operator is guided by tissue resistance, has been largely superseded by a *visual feedback* that relies on the evaluation of spatial relationships. With tissue resistance no longer a critical factor in guiding the application of forces, it has been possible to develop finer instruments that are more in line with the demands of atraumatic technique.

But modern ophthalmologic microsurgery implies more than improved visualization and finer instrumentation. It embodies an entirely new approach to *surgical tactics* in general. The way of "classical" surgery is to accomplish a given task in a minimum number of steps, with each step achieving as many individual goals as possible. The success of this "synthetic" approach requires extremely high skill and dexterity on the part of the operator.[1]

This contrasts with the "analytical" approach of the microsurgical technique, which permits every surgical action to be broken down into its individual components. The advantage of this approach is that each step can be adapted to a specific situation, making it easier for the surgeon to deal with any complications that arise.[2]

Microsurgical technique, then, is characterized by an *increased number of individual manipulations*. While this has advantages, it also increases the potential for tissue lesions caused by inadvertent movements of instruments or tissues. Consequently, modern microsurgery is concerned not just with the intended effects of a surgical action (*offensive tactics*) but also with the

Table 1. **Surgical tactics in ophthalmology**

	Tactical goals	Targets of surgical action	Instruments
Tissue tactics	Division, Removal, Uniting } of tissue	Cornea Iris Lens Vitreous Retina	– Knives – Forceps – Sutures
Surface tactics	Protection of surfaces	Endothelium Lens capsule Anterior hyaloid Inner limiting membrane	– Viscous materials – Plastic sheeting
Spatial tactics	– Maintenance or expansion of intraocular compartments – Blockade of connecting pathways	Intraocular chambers and subcompartments	– Hydrodynamic flow systems – Viscoelastic materials – Bubbles with surface "membranes" (gas, oil)

[1] Examples of "synthetic" manipulations:

- The anterior chamber is opened in a single maneuver with a cataract knife or keratome. The incision requires simultaneous rotational movements about various points and thrusting movements of extreme precision (see Fig. 5.48). The slightest error will jeopardize the procedure by allowing premature collapse of the anterior chamber. The result is a unique type of incision profile; modifications and corrections are nearly impossible.
- Anterior capsulotomy with a forceps (see Fig. 8.44) excises and removes a piece of the anterior capsule whose size and shape are difficult to control. The slightest error may result in an inadequate capsulotomy, rupture of the posterior capsule, damage to the zonule, or unintended extraction of the whole lens.

[2] Examples of the "analytical" approach:

- By opening the anterior chamber with step incisions made on multiple planes, the surgeon can accurately control the shape and profile of the incisions (see Fig. 5.62) and modify them as needed. Each step requires special manipulations, but errors in previous steps can be corrected in subsequent steps, providing an increased margin of safety.
- Anterior capsulotomies can be performed in multiple "ministeps" (see Fig. 8.38) to create an opening of any desired shape and size. With each new step the surgeon is able to correct errors made in previous steps.

avoidance of undesired side-effects on the surrounding tissues (*defensive tactics*).

Offensive tactics, also referred to as **tissue tactics**, include such actions as the grasping, division, removal, and uniting of tissues. The instruments used for these actions are forceps, knives, sutures, etc.

Defensive tactics may be subdivided into surface tactics and spatial tactics. **Surface tactics** are *passive* defensive measures in which protective materials such as plastic film or viscous substances are used to keep tissue surfaces from coming in contact with instruments, implants, or other tissues. **Spatial tactics** are *active* defensive measures in which surrounding tissues are protected by *maintaining or augmenting tissue spaces* to create sufficient room for the numerous micromanipulations. This can be accomplished by the use of hydrodynamic systems, viscoelastic materials, or "membranous implants" (Table 1).

1 Spatial Tactics

Spatial tactics in ophthalmic surgery are concerned with the shape and volume of the globe and its interior compartments (Fig. 1.1). The objective is to alter these parameters or maintain them in a controlled way during the application of external forces. Spatial tactics provide the immediate context within which the cutting, removing, and uniting of tissues are performed.

The **shape of an intraocular chamber**, and thus its volume, is a function of its *wall tension.* This tension results from the physical properties of the wall tissue and/or from the pressure inside the chamber. For a given tissue, then, a change in the volume of the chamber is associated with a change in its internal pressure.

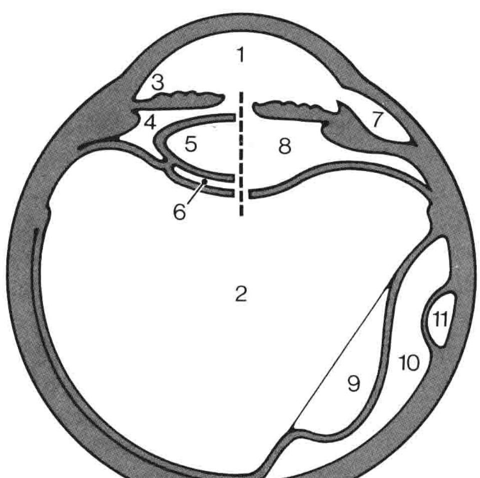

Fig. 1.1. **The globe and its compartments**
Left side: Normal anatomy
Right side: Pathologic spaces

Closed chamber systems:
1 Anterior chamber
2 Vitreous chamber

Open subcompartments:
3 Iridocorneal sinus
4 Iridocapsular interspace
5 Intercapsular sinus
6 Hyalocapsular interspace
7 Cilioscleral interspace (after cyclodialysis)
8 Iridohyaloid interspace (after intracapsular cataract extraction)
9 Vitreoretinal interspace (after posterior vitreous detachment)
10 Chorioretinal interspace (after retinal detachment)
11 Sclerochoroidal interspace (after choroidal detachment)

1.1 Pressure Systems for Regulating Chamber Volume

A *pressure system* is illustrated in Fig. 1.2. The pressure in a chamber P_{ch} is determined by the relation between the inflow volume (V_{in}) and the outflow volume (V_{out}). The pressure in the chamber will remain constant as long as the inflow and outflow volumes are equal (formula 4). However, the pressure cannot be set to a predetermined level just by stipulating the flow-through parameters because it is a ratio and, as such, P cannot be expressed in isolation from the other parameters in formula 5. A given pressure can be established and maintained only by a regulating system which measures the chamber pressure and uses the measured pressure as feedback to make appropriate adjustments.[1]

Of practical importance are the *extreme values* that can develop in a pressure system and the conditions under which they occur (formula 6): The highest pressure is the initial pressure (P_{start}), and the pressure inside the chamber approaches that value when the inflow resistance tends toward zero or the outflow resistance tends toward infinity.[2] The lowest pressure is the ter-

[1] In the absence of such a measuring system, one must rely on an "adequate" pressure as determined by visual observation of the chamber volume.

[2] As a practical example, the occlusion of a tightly inserted outflow cannula would produce an infinite outflow resistance.

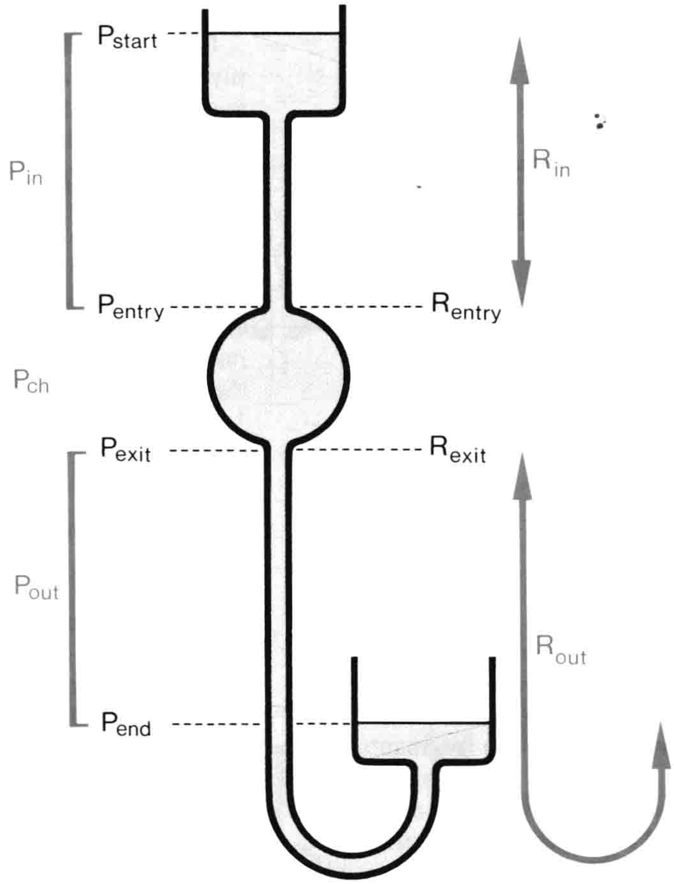

Fig. 1.2. **Schematic diagram of a system for regulating pressure in a chamber**. *Top*: inflow line. *Center*: chamber. *Bottom*: outflow line

[1] Inflow pressure $P_{in} = P_{start} - P_{entry}$
Outflow pressure $P_{out} = P_{exit} - P_{end}$

[2] Chamber pressure $P_{ch} = \frac{P_{entry} + P_{exit}}{2}$

for small differences between P_{entry} and P_{exit}: $P_{ch} = P_{entry} = P_{exit}$

[3] Volume of inflow $V_{in} = \frac{P_{in}}{R_{in}}$

Volume of outflow $V_{out} = \frac{P_{out}}{R_{out}}$

[4] $V_{in} = V_{out}$ when $\frac{P_{in}}{R_{in}} = \frac{P_{out}}{R_{out}}$

or $\frac{P_{in}}{P_{out}} = \frac{R_{in}}{R_{out}}$

[5] Inserting [1] and [2] into [4]:
$$\frac{P_{start} - P_{ch}}{P_{ch} - P_{end}} = \frac{R_{in}}{R_{out}}$$

[6] Therefore:
when $R_{in} \to 0$, then $P_{ch} \to P_{start}$
when $R_{in} \to \infty$, then $P_{ch} \to P_{end}$
when $R_{out} \to 0$, then $P_{ch} \to P_{end}$
when $R_{out} \to \infty$, then $P_{ch} \to P_{start}$

minimal pressure (P_{end}). It develops in the chamber when the inflow resistance tends toward infinity or the outflow resistance tends toward zero.[3]

When values are selected for the **initial pressure** and **terminal pressure**, it must be considered that these extreme values can indeed develop in the chamber under extreme conditions, so they should remain within limits that can be tolerated by the chamber.

In selecting the **inflow resistance**, very low values are advantageous because they permit the selection of a low initial pressure.[4] On the other hand, a high value is advantageous for the **outflow resistance**, as this makes it easier to stabilize the chamber volume. Free selection of the outflow resistance is limited by the fact that surgical goals prescribe minimal widths for openings. Thus, when planning the pressure system for a particular procedure, the surgeon should first define the outflow resistance and then adapt the other parameters to that value.

In surgical practice, then, the various types of **space-tactical system** that are utilized to control the shape and volume of intraocular spaces are classified according to their outflow resistance:

- systems in which the outflow resistance is so high that, under ordinary conditions, there is no drainage of the chamber contents, and no inflow is needed to maintain the chamber pressure (*no-outflow systems*, Fig. 1.3a);
- systems in which the outflow resistance is within limits that allow the pressure to be controlled by regulating the inflow and outflow (*controlled-outflow systems*, Fig. 1.3b);
- systems in which the outflow resistance is so low that a given inflow system is incapable of pressurizing the chamber (*uncontrolled-outflow systems*, Fig. 1.3c).

[3] As practical examples, the inflow resistance approaches infinity when the inflow tubing is inadvertently bent; the outflow resistance tends toward zero when an outflow orifice is widely opened.

[4] As we will see later, however, low values are problematic when external forces act on the chamber. Limits are imposed as well by topographic factors (the size of the cannula).

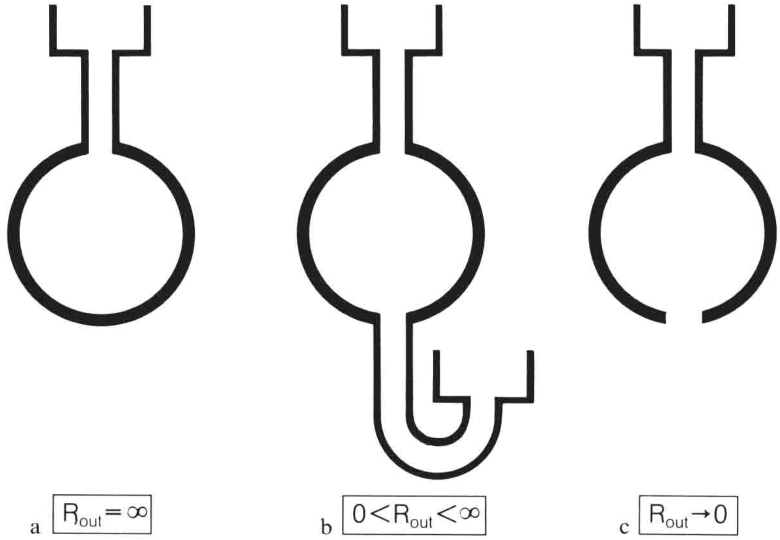

Fig. 1.3. **Space-tactical systems**

a No-outflow system: As outflow resistance tends toward infinity, no drainage occurs, so there is no need for inflow.

b Controlled-outflow system: The outflow resistance is finite and greater than zero. The available inflow capacity can compensate for the outflow.

c Uncontrolled-outflow system: As outflow resistance tends toward zero, the pressure in chambers open to the outside approaches atmospheric (= 0)

1.1.1 No-Outflow Systems

No-outflow systems are technically straightforward. **Primary no-outflow systems** are those in which the contents of the chamber remain unchanged (Fig. 1.4.a, b). It is necessary only to introduce instruments into the chamber in such a way that the access opening remains *watertight*. Surgical options are limited, however, since no material may be removed from the eye, and such systems are suitable only for procedures involving the division of tissues. [5] Absolute no-outflow systems are procedures performed with lasers.

In **secondary no-outflow systems** the chamber is filled with a highly *viscous material* (Fig. 1.4c). Since the size of the outflow opening is not a critical concern in this system, bulky instruments and implants may be introduced into the chamber, and tissue fragments may be removed. Actually, uncontrolled-outflow systems can be converted to secondary no-outflow systems by filling the chamber with viscous material.

1.1.2 Controlled-Outflow Systems

The controlled-outflow system is a **regulating system** that uses a feedback mechanism to coordinate inflow and outflow. Theoretically it would be ideal to have an inflow capacity large enough to compensate for any outflow that might occur. In practice, however, there are constraints: Once the inflow limit is reached it becomes necessary to reverse the control mechanism and regulate the outflow so that it does not outstrip the available inflow capacity. With resistance-modulated outflow, the inflow capacity limits the permissible size of the outflow opening (Fig. 1.5a). With pressure-modulated outflow, this capacity limits the permissible level of the suction (Fig. 1.5b).

Controlled outflow systems imply that inflow ceases when outflow is obstructed. If continuous flow is required because the infusion must perform functions in addition to volume control (e.g., cooling an ultrasonic vibrator or a coagulator), it is essential to avoid total obstruction of outflow. This danger can be eliminated by providing a second, reserve outflow path in addition to the controlled-outflow path (Fig. 1.5c). [6]

1.1.3 Uncontrolled-Outflow Systems

If the inflow capacity is not adequate for a given outflow, the chamber volume can no longer be pressure-modulated. This is the case when there is a large chamber opening, whose lack of outflow resistance would require an inflow capacity of infinite size (Fig. 1.6a). In a chamber that has no inflow system, even the slightest leak will produce a state of uncontrolled outflow (Fig. 1.6b).

[5] Such as capsulotomies, iridotomies, and synechiotomies.

[6] This is the case in phacoemulsification, where a deliberate "leak" is left in the corneoscleral opening next to the irrigating tube to ensure an uninterrupted flow of cooling liquid.