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Reconstructive Microsurgery

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With Sections by 24 Contributors

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Foreword

RECONSTRUCTIVE MICROSURGERY is a vitally needed text written for a new generation of microsurgeons. The clinical successes of the past few years have confirmed the value of replantation surgery and free tissue transfers as well as the microsurgical approach to peripheral nerve lesions. The animal laboratory is no longer a place reserved solely for esoteric research and shunned by all but a few residents. Rather, it has become the training field or practice green for a new breed of clinical surgeons wishing to develop this special skill. Unfortunately, time and patience are required and there are no shortcuts. Those of us who have been working in microsurgery for the past fifteen years learned by trial and error. Progress was slow and hampered by poor equipment, poor planning, and poor results. Those who read this text will be spared much of this wasted motion and will be able to start with successes rather than failures.

Due to the diversity of its subject material, *Reconstructive Microsurgery* will undoubtedly prove of value to a wide variety of surgeons including plastic surgeons, hand surgeons, neurosurgeons, and orthopedic surgeons as well as to house officers, students, and laboratory technicians. The reviews of basic surgical maneuvers and the inclusion of graded exercises provide essential information for beginning microsurgeons to develop their own techniques. Progression to clinical cases must be carefully considered by each individual and the decision influenced by results of laboratory experience. Dr. Rollin Daniel and Dr. Julia Terzis have reflected this progression from research laboratory to clinical application in their own training, in their significant publications, and in this text. The surgical procedures described are a current summary of work being done on a worldwide scale. The scope of microsurgery already extends beyond the grasp of any single author, and the important contributions by an impressive list of international authorities have been included in the text. In future years, microsurgery will continue to expand and to provide surgeons with new techniques for solving their patients' complex problems.

Harry J. Buncke, Jr.

Preface

RECONSTRUCTIVE MICROSURGERY may be defined as the functional restoration of body structures by direct union of parts or transfer of tissue utilizing microsurgical techniques. Its practitioners are drawn from many surgical specialties but especially from plastic surgery, hand surgery, neurosurgery, and orthopedic surgery.

In the past decade microsurgery has progressed from research curiosity to clinical reality on a scale far beyond anyone's expectations. We have had the opportunity to participate in and to witness this evolution firsthand—from San Mateo to Sydney to Shanghai, from Tokyo to Louisville to Vienna, and many places in between. This text is an attempt to summarize the rapid growth and basic principles of reconstructive microsurgery. It is hoped that it will serve as a stimulus for neophytes wishing to learn more about microsurgery, as a primer for novice microsurgeons seeking to perfect their microsurgical skills, as a resource book for clinical surgeons facing difficult cases, and as a reference point for the investigators pursuing related research.

In selecting a format we have tried to combine the cohesiveness and readability of a single-author text with the expertise and divergent views of a multiauthored text. Rather than providing a microsurgical smorgasbord (obligating the reader to try every method), we have presented the advantages and disadvantages of each technique, followed by a statement as to our own preference. In addition, we have adopted an integrated, programmed approach so that the reader can follow the natural progression from research laboratory to clinical application. Skipping around within the various divisions of the text will only result in confusion for the casual browser. For example, in this text the act of surgical coagulation always refers to bipolar coagulation. Similarly, in-depth understanding of microvascular techniques, which is provided in the experimental portion, is necessary to permit selection of the "appropriate anastomotic technique" required in clinical digital replantation or free tissue transfers. Thus, this text must be read sequentially and completely before embarking on clinical reconstructive microsurgery.

Part I deals with the "3 M's" of microsurgery: microscopes, microinstruments, and microsutures. The component parts of the operating microscope and details of the specific magnification systems available to the surgeon are reviewed, and the various microinstruments are described with our preferences listed. Part I concludes with a summary of the evolution of microsutures, with particular emphasis on their physical characteristics. This stress on fundamentals will, it is hoped, eradicate the inherent mysticism of microsurgery.

Part II is devoted to microvascular surgery. An in-depth, step-by-step discussion of microvascular techniques is followed by a series of graded exercises that will permit the reader to master basic microvascular surgery. Then a discussion of replantation surgery of the upper extremity with particular emphasis on digital replantation is presented. Finally, the fundamental principles and most recent developments in free tissue transfers are discussed. Each chapter contains contributions from noted microsurgeons who are either the originators or masters of each technique.

Part III is organized to provide a review of the knowledge basic to the management of peripheral nerve injuries, including the anatomy and physiology of peripheral nerves and their intricate organization. Specific topics considered to be of critical importance, including sensory cutaneous receptors, the microcirculation within a nerve trunk, and the response of peripheral nerves to injury, have been contributed by expert colleagues. The basic microsurgical techniques that must be mastered in the experimental laboratory prior to clinical application are then discussed and supplemented by exercises illustrating the various types of nerve repairs and nerve grafting in an experimental model. Next the factors influencing nerve repairs, the techniques available, the effect of tension at the nerve anastomosis, and the indications for nerve grafting are considered. The applications of autologous nerve grafting in lesions of peripheral nerves, including the brachial plexus, and in cranial nerve lesions are then presented.

The reader must always bear in mind that reconstructive microsurgery is an evolving discipline. The procedures described are based on past experiences for present application, subject to future revision. Thus, healthy doses of surgical objectivity and common sense are mandatory when using this text as a guide.

R. K. D.
J. K. T.

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THIS TEXT was written despite the demands of our busy residencies, our ongoing research projects, and the inconvenience of a 2000-mile separation. That *Reconstructive Microsurgery* was ever finished is a tribute to many people without whose support and encouragement we would not have endured.

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In addition, we are deeply indebted to our colleagues in reconstructive microsurgery, both for their contributions to this text and for their pioneering efforts in microsurgery which will provide the necessary stimulus for the next generation of microsurgeons.

Finally, both of us are indebted to Mr. Fred Belliveau and Mr. Robert M. Davis of Little, Brown and Company for their encouragement, forebearance, and assistance.

R. K. D.
J. K. T.

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Introduction

MICROSURGERY is surgery performed under the magnification of an operating microscope. It originated in 1921 with the work of Nylen, who first used the magnifying power of the microscope lens to improve the precision of surgical techniques. Its advantages were quickly recognized by Holmgren and other otolaryngologists who, as a result, developed many new otolaryngological procedures including stapedectomy, reconstruction of the middle ear, and, eventually, acoustic neuroma resection. In 1953, Carl Zeiss Inc. began mass production of the modern operating microscope. The first beneficiaries were ophthalmologists who initially concentrated on improving conventional procedures and only later devised new ways to repair and reconstruct the anterior segment of the eye. By 1965, plastic surgeons had utilized microsurgical techniques for peripheral nerve repairs and digital replantation. Simultaneously, neurosurgeons began to clip cerebral aneurysms located deep within the brain recesses and to attempt cerebral revascularization.

Now, in the 1970's, urologists, obstetricians, and orthopedic surgeons are beginning to reap the rewards of microsurgery as demonstrated by successful vas deferens repair, fallopian tube anastomoses, and free bone transfers. In each instance microsurgery has led to improved results with conventional operative procedures and to the introduction of new techniques for conditions previously considered irreparable.

Microsurgery is a surgical technique clinically applicable in every surgical specialty. Thus, there is no need to develop a separate microsurgery subspecialty comprising master technicians available on demand. Rather, microsurgery must become an integral part of every surgical specialty. For it is only when surgeons receive dual training—in their own specialty and in microsurgery—that they will be capable of solving many difficult problems that plague each specialty. The microsurgeon whose expertise is restricted to experimental models is of little value in clinical cases in which the majority of operative time is spent in complex, tedious dissections (free tissue transfers) or in pursuing function (digital replantation). Rather, the surgeon must be trained in microsurgical techniques and must apply them within his or her own area of special expertise.

Who should learn microsurgery, and how should it be taught? Obviously, microsurgeons are not born, nor do they emerge fully trained from most residencies. They must be trained in the laboratory, with experienced surgeons or laboratory technicians serving as teachers. These teaching laboratories may be operated either by an individual specialty or serve as a central laboratory operated by multiple specialties. When these facilities are not available, laboratory manuals and textbooks such as this can provide sufficient information for the determined individual to acquire the fundamentals.

Residents should spend a significant period of time in the teaching laboratory, perfecting microsurgical skills. Currently, our residents have an annual two-week rotation dedicated **exclusively** to microsurgery, with the first week devoted to techniques in neural microsurgery and the second week to microvascular techniques. It is our belief that a concentrated period of intensive learning is far superior to casual, once-a-week exposure. Practicing surgeons must assess the areas of microsurgery that would be of benefit to them. This range of applicability includes exposure to: (1) general microsurgery, (2) microsurgical techniques of tissue handling and dissection, (3) microsurgical techniques for peripheral nerve repair, and (4) microvascular techniques for digital replantation and free tissue transfer. Workshops of several days' duration provide microsurgical exposure but do not produce instant microsurgeons. A one-week rotation at an established microsurgical center will permit one to acquire proficiency in delicate tissue handling and refinement of conventional surgical techniques. The majority of microsurgical teaching laboratories, where one can take a one- to two-week course, have concentrated on microvascular surgery to the exclusion of proficiency in neural microsurgery. However, the majority of clinical reconstructive microsurgery involves peripheral nerve repairs with a minimum 20:1 ratio of digital nerve repairs to digital artery anastomoses being realistic. Therefore, greater emphasis must be placed on teaching techniques of neural microsurgery to all plastic surgeons and hand surgeons.

Those pursuing clinical microvascular surgery with its replantation of amputated parts and free tissue transfers should plan on a six-month fellowship at a center specializing in this type of surgery. With survival rates of over 90 percent now prevailing, casual attempts at digital replantation can no longer be justified, and referral to a major replantation center must be considered with similar consideration in free tissue transfers. For this reason intensive clinical experience must be obtained at the fellowship level.

What are the contraindications to learning microsurgery? The only absolute one is severe astigmatism or other visual limitations that preclude use of the microscope. Age in itself is not a barrier, but a gross tremor, irascible temperament, and impatience will certainly limit one's success. Those who wish to perfect their microsurgical skills need patience, persistence, and curiosity.

What can neophyte microsurgeons hope to achieve in the teaching laboratory? First, they can determine their own degree of interest and ability, as well as their future commitment to learning microsurgery. Certain surgeons will decide that the requisite time is too great and the task too demanding. Others will be satisfied with acquiring basic microsurgical techniques of tissue handling and dissection. The majority, it is hoped, will accept the challenges of microsurgery and pursue a program of graded exercises. The final goal of any training program is for the individual surgeon to develop his or her own reproducible technique that can be implemented clinically. Thus, each surgeon must evolve a personal "disaster-proof" technique in the laboratory, which will permit subsequent successful execution regardless of the clinical situation. The confidence gained from repeated practice in the laboratory enables one to cope with the varied difficulties of clinical cases. Because many microsurgical procedures have an all-or-none result, critical anastomoses must be performed flawlessly.

The transition from experimental laboratory to clinical setting is not easy. The surgeon must question his own technical expertise and be aware of the potential pitfalls and complications intrinsic to each case, as well as the realistic expectations of a successful result. Clinical success depends on acquisition of fundamental techniques in the laboratory, extensive preoperative preparations, precise intraoperative judgment, and meticulous postoperative care. Yet the rewards to the patient and to the surgeon can of course be immense. The patient may benefit from a procedure for which there is virtually no acceptable alternative (replantation) or for which the alternative would require prolonged hospitalization (free flap transfer) or for which the alternative might well produce an inferior result (peripheral nerve surgery). The charges of increased operative time are valid; many cases do exceed eight hours in duration. However, when one considers the forementioned alternatives, the time is insignificant, provided the cases are carefully selected and the anesthetic risk is precisely determined. For the surgeon, months of practice in the experimental laboratory are rewarded by the restoration of blood flow in a replanted digit, the pinking up of a free flap, or the exact alignment of a fascicular nerve graft.

Yet the microsurgical laboratory has a dual function: the training of clinical surgeons (teaching laboratory) and the scientific investigation of factors bearing on microsurgical techniques (research laboratory). During the previous decade these two roles were often combined when surgeons perfected their microsurgical techniques during experimental investigations. All too often the results indicated that the surgeon was "trainable," but that the experiment data were meaningless. However, these pioneering studies did lead to the development of basic principles and techniques which have freed investigators from continually concentrating on 100 percent patency rates. The time has now come for major scientific investigations in the microsurgical laboratory. This progression is evident in recent studies of the healing process of small vessel anastomoses and the fate of denervated nerve endings.

Recent advances in the neurosciences indicate future efforts and rewards are to be expected from research into the surgical disorders of peripheral nerves. Our understanding of the basic biochemical processes and organizations of normal neurons, axons, Schwann cells, myelin, and supportive connective tissue is limited to a mere outline. Axoplasmic flow and its significance in health and disease require further investigation. The phenomena of nerve degeneration and regeneration must be ultimately understood and controlled. Pharmalogical agents stimulating regeneration and retarding scar tissue proliferation will undoubtedly play a significant role in the future management of peripheral nerve lesions. Further understanding of the trophic interrelationships between nerves and target organs is essential as is understanding of the functional anatomy and sensorimotor distribution of fibers within peripheral nerve trunks. One of the most pressing needs is a precise objective method for evaluating sensory and motor loss and predicting the adequacy of repair without a tragic delay. Interdisciplinary research engaging clinicians, neurophysiologists, anatomists, and biochemists holds the key to future breakthroughs.

The future of reconstructive microsurgery is virtually unlimited. We can reasonably expect that replantation surgery will place greater emphasis on patient selection, resulting in higher survival rates and justifying greater emphasis on primary reconstruction. Expanded clinical series will yield information on the role of anticoagulants and the best techniques for achieving optimal function following primary repairs of tendons, nerves, and joints, as well as the selection, timing, and methods for secondary reconstruction. The indications for free tissue transfers will continue to expand with the development of new techniques applied by an increasing number of trained surgeons. Thus far, most free tissue transfers have been done in end-stage cases in which conventional procedures had previously failed or were otherwise impossible. As the collective complication rate decreases and surgical techniques are standardized, free tissue transfers will assume their correct position in the armamentarium of reconstructive surgeons. In peripheral nerve surgery, great emphasis will be placed on perfecting and simplifying histological and electrophysiological techniques for differentiating motor from sensory fascicles. The ability to achieve correct fascicular orientation in primary nerve repairs and in bridging large nerve gaps with autografts will undoubtedly lead to improved results. The optimal timing and technique for clinical nerve repairs will eventually be established by accurate scientific studies on human patients.

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