Microsurgery

EDITED BY
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Preface

Sherman J. Silber, M.D.

Microsurgery is basically a technique for expanding the visual horizon of the surgeon so that he can deal with smaller structures successfully. The only limit to our manipulative skill is what the eye can see, providing that the hand is willing to practice. There should be no mystery to microsurgery. The microscope simply opens up an exciting new universe in which the general surgeon, urologist, gynecologist, neurosurgeon, plastic surgeon, or orthopaedist can deal with small structures that were previously unmanageable. To the clinical surgeon there is a vast expansion of what he can offer his patients in whatever surgical specialty he resides. To the academic surgeon there is a new array of animal models for studying physiological processes that never seemed possible before the days of transplantation in isogeneic inbred animals. To the basic researcher, not necessarily interested in surgery, microsurgical expertise will also provide new avenues for experimentation. Surgeons in every specialty and most biologists will thus have to develop some microsurgical expertise to remain in the 20th century.

With microsurgical animal models now readily available, extraordinarily complicated research projects can be undertaken by the academic surgeon at relatively little cost. Perhaps the greatest value of microsurgery is the ease with which we can now set up experimental surgical protocols. However, to the clinical surgeon, the benefits of microsurgery have been equally dramatic. Not only have new operations been made possible that were never before dreamed of, but the older operations are being performed better by use of microscopic techniques. The use of the microscope for intracranial aneurysms has reduced the death rate from approximately 30 to 4%. Pregnancy rates after tubal reconstruction and vas deferens reconstruction have more than doubled. Peripheral nerve repairs have resulted in quicker and better functional recovery. Even simple operations like varicocoelectomy are finally becoming better understood by the use of the microscope. Surgery such as free skin flap transfer and autotransplantation of the testicle to the scrotum for intra-abdominal cryptorchidism (which were once considered pure dreams) are now being performed routinely. Large defects in the cervical esophagus are being replaced by autotransplanted segments of bowel and higher survival rates are being achieved in infants with biliary atresia.

The premise upon which this book is written is that practice in basic microsurgical techniques and intercommunication between surgical specialists utilizing microsurgery will allow each of us to more seriously and more effectively utilize this surgical discipline, both in our research and in our clinical practice. The urologist who is wrestling with some of the difficult microsurgical problems of his male infertility patients will find striking similarities as well as differences to the microsurgical problems that his gynecological consultant is dealing with in the patient's wife. Vascular surgeons confronted with lesions involving the renal artery will require microsurgical techniques similar to those used by his urological colleagues in testicular autotransplants and varicocoelectomies. The first successful penile reimplantation with microvascular technique was actually performed by plastic surgeons who were very experienced in digit reimplants. The technical considerations for penile or digit reimplantation are very similar, although there are, of course, some interesting differences.

Thus, all surgical disciplines have a common interest in developing microsurgical expertise. The microsurgical problems in the different fields of surgery are sufficiently related that this comprehensive book was necessary. Only the fields of otolaryngology and ophthalmology have been left out (quite intentionally) because although these surgical specialties were among the first to utilize the microscope, their problems are so strikingly different that we felt their inclusion would not be beneficial.

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Foreword

Microsurgery: Its Evolution

Rollin K. Daniel, M.D.

The microscope was first utilized in clinical surgery by Nylen in 1921 for drainage of a middle ear infection. Immediately thereafter, Holmgren realized that increased magnification and illumination would open the confines of the middle ear to a wide variety of surgical procedures. In the next three decades, Otolaryngology developed numerous new microsurgical techniques. In 1953, Carl Zeiss introduced the modern operating microscope, which was widely accepted because of its coaxial illumination, variable magnification, and adjustability for various types of surgery. Ophthalmology quickly accepted the operating microscope with early emphasis on perfection of conventional techniques and only later evolving new procedures to correct deficiencies of the anterior and posterior segment. In the 1960's three specialties became firmly committed to the operating microscope. Neurosurgeons employed the microscope for dissection deep within the cranial vault thereby rendering accessible an increasing number of cerebral aneurysms and tumors. The emphasis was on painstakingly difficult dissections deep within the confines of the brain while preserving critical cerebral blood supply. Concurrently, plastic surgeons initiated experimental studies and clinical attempts at free tissue transfers, peripheral nerve repairs, and reimplantation surgery. These pioneering reconstructive microsurgeons extrapolated the original work of Jacobson and Buncke in microvascular surgery as well as Smith and Millesi in microneural surgery. These procedures have now been perfected and are used on a routine basis by hand surgeons and plastic surgeons.

In the early 1970's urology and gynecology began their preliminary investigations of microsurgical techniques and its clinical applications. The challenge to these specialties is both in perfection of conventional techniques and the development of new procedures to correct problems previously considered irreparable. Success in achieving these objectives will depend upon new research into the pathophysiological processes which specifically afflict these organ systems as well as development of new surgical techniques. A comparable situation existed in reimplantation surgery where clinical attempts at digital reimplantation consistently failed due to the twin problems of technical limitations (inadequate microsutures) and a failure to appreciate basic hemodynamics within the injured finger. It was Chen Chung-wei who realized the need for adequate venous drainage (two veins for each arterial anastomosis), and who instituted the routine utilization of heparin to protect microvascular anastomoses in traumatized vessels. These observations plus development of new microsutures resulted in successful digital reimplantations on a world-wide scale. Similarly with free flap transfers, it was necessary to review the blood supply to the skin and to design skin flaps which were capable of surviving on a single artery and vein. Thus, as in plastic and orthopaedic microsurgery, the objective in urological and gynecological microsurgery is not simply the perfection of conventional techniques, but rather a more fundamental reappraisal of normal physiology of critical luminal structures and basic pathophysiology. Emphasis must be placed on fundamental research which will provide the foundation upon which new surgical techniques can be perfected.

Microsurgery must be performed by surgical specialists who have training in microsurgical techniques as well as their own specialty. Just as it would be foolish for the urologist trained in microsurgery to perform a digital reimplant where final function is dependent upon the quality of the tendon repairs and neural anastomoses, it would be equally foolish for the reconstructive microsurgeon to repair the divided vas deferens or traumatized Fallopian tube. Microsurgical techniques must become a part of every surgeon's training with clinical proficiency the ultimate objective. In urology it is necessary that this training be both in microvascular surgery and vas surgery. As emphasized by Silber, these goals can be achieved from laboratory practice utilizing rat renal transplantation models. One must be able to achieve both end-to-end and end-to-side anastomoses of 1-mm vessels. The progression into clinical surgery is a difficult one. The opportunity to perform a large number of 1-mm arterial anastomoses in reimplantation surgery is obviously not available to the urologist, but clinical microsurgical experience can be gained from vas surgery. Vasovasostomies can be practiced initially on surgical specimens removed at the time of vasectomies as well as increasingly at reversal of vasectomy as required. Fallopian tube surgery can be practiced in the rabbit utilizing the models outlined by Gomel and Winston. In the final analysis, one must achieve proficiency in the laboratory before attempting clinical cases.

The future of microsurgery in urology as well as obstetrics and gynecology is presently an ever expanding one with unlimited opportunities. Neurosurgeons, plastic surgeons, and orthopaedists have already found the microscope indispensible for their most demanding surgical problems. One of the greatest challenges remains the acquisition of microsurgical skills by general surgeons and pediatric surgeons who have yet to make a strong commitment to microsurgery. Despite pathology in these fields afflicting critical luminal structures (biliary ducts, pancreatic ducts) and numerous congenital anomalies (esophageal atresia, biliary atresia), these two specialties have not yet emulated the precedence set by their peritoneal colleagues, the urologists and gynecologists. Ultimately, we may witness a total commitment to microsurgery by all surgeons, thus confirming that microsurgery is indeed a "surgical technique clinically applicable in every surgical specialty."

Introduction

Julius H. Jacobson II, M.D.

It is indeed an honor to be asked to contribute the introduction to this outstanding book. To comment on the contents of the book would serve no purpose, because the individual authors are experts in their particular areas. Of greater interest would be to give a brief history of microsurgery and some perspective on its current use and future horizons.

The microscope for use in surgery was initially developed for surgery of the eye and ear. Its use along with finer suture materials and instruments dramatically allowed many of the blind to see and the deaf to hear.

While people in the basic science laboratories were using binocular microscopes to aid in their dissection, its use had never been applied in the field of vascular surgery. In 1958, while a resident at Presbyterian Hospital in New York City, I was waiting between operations one day and wandered into a room where a stapes mobilization procedure was going on. I was allowed to look through the microscope and was intrigued by the tiny anatomical details that were made visible—but no gong sounded in regard to its implications in other surgical fields.

Fresh out of a seven-year residency I was appointed Associate Professor of Surgery and Director of Surgical Research at The University of Vermont. Its superbly equipped laboratories, loads of animal space, and a National Institute of Health which then had money for any project considered worthwhile made it a grand milieu for new ideas.

I was asked, shortly after my arrival, to help the Department of Pharmacology with a project in which they were trying to denervate the canine carotid artery. No matter how well the artery was skeletonized, there was still evidence of sympathetic activity in its wall. It appeared that the only way to effectively denervate the artery was to divide and reanastomose it. Although the general teaching in the newly developing field of vascular surgery was that one should not attempt anastomoses on vessels that small, the patency rate achieved in these studies was approximately 70%. We became intrigued with the reason for the failures, inasmuch as the technique was the same as that used for canine aortic anastomoses in which patency is consistently achieved.

In assessing the reasons for poor results in small vessel anastomoses, it was reasoned that the technique was at fault. Thus a 1-mm error in placement in a 1-cm artery is of no practical significance, whereas it would cause failure in a 2- or 3-mm vessel. One has only to examine the relationship expressed in Poiseuille's Law, which states: other factors aside, the flow through a vessel is a function of the fourth power of its radius. In an exponential function of this type, minute changes in diameter have a profound effect on flow.

In analyzing the situation further, it became apparent that the major defect in technique was the inability of the eye to see, rather than the hand to do. After attempts with the use of magnifying spectacles and a magnifying glass placed over the operative field, the ear operation I had observed years earlier was finally remembered. A microscope was borrowed from the ENT operating room.

The first experience using the microscope for a vascular anastomosis can be compared to the first time the moon was seen through a powerful telescope; a welter of previously unrecognized detail was seen. What was considered innocuous—holding the intima with a forceps—was seen as the cause of a major trauma. A tag of intima intruding into the lumen could be seen as the nidus formation for clot and the reason for failure.

Once the problem of adequate vision was solved, the existing surgical instruments and suture materials proved to be unsatisfactory. At a local jewelry store, forceps were found which were superior to anything in the surgical armamentarium. The jeweler's forceps are still satisfactory for most applications, and much cheaper than those which can be brought from a surgical supply house. Quite incidentally, a test of forceps adequacy that we have come to rely upon is the ability to pick a single hair from the back of a hand without slippage or cutting the hair.

The assistants were unable to hold the clamp steadily enough so various adjustable arm devices were developed to circumvent that problem. The vascular clamps themselves slipped and were not hemostatic when used on small thin-walled arteries and veins. The problem was easily solved by slipping lengths of shoelace around the clamp jaws to increase their thickness. Thus new microvascular clamps were first produced.

Fine finger motion was an essential to properly manipulate needle holders and scissors; however the ordinary ring-handled instruments available were predominantly controlled by the wrist. The Castro-Viejo handle design, which has been developed for doing precision eye surgery, proved to be the answer. Ethicon, Inc., developed a needle with a diameter of 0.005 inches with a 0.001-inch monofilament nylon suture swaged to it; although slightly finer suture products are now made, there is still a greater need for still finer ones for working on very small vessels. The fundamental problem is that the ratio of needle diameter to suture diameter cannot be made smaller than 3 to 1 and still give a strong enough swage joint. Some attempts have been made at metalizing the end of a suture and then sharpening the point. It is in this direction that future advances lie.

The next problem encountered was that the surgical assistant could not be a proper help because he was unable to see the surgical field in magnified form. The two largest American manufacturers of surgical microscopes were contacted in regard to producing a double binocular microscope. As so often happens when contacting large corporations, the middle management people were enthusiastic and said it could be done, but top management did not see any future potential and the projects were scrapped. Finally, Carl Zeiss, Inc. of West Germany was asked to help and they sent over the engineer who designed the original microscope for eye work. The Zeiss approach was in sharp contrast to that of the American firms. They agreed to build one double binocular microscope (to be named the Diploscope) at no cost. The philosophy behind this decision was interesting and probably accounts for their preeminent position in the field of optics. Carl Zeiss was a mechanic who, with the help of a Mr. Abbé of Abbé condenser fame, designed one of the early microscopes which was the best then available. Their firm had an immediate success and they elected to put 50% of all profits into a foundation to support research and development.

Some months later I was told that the microscope was ready, but that they wished me to come to Oberkochen, Germany to examine the new microscope before it was shipped. Therein lies another tale. When Germany was divided into its present East-West segments, Zeiss was in the East. The American occupation forces had many of their key technicians and engineers on hand and decided to build a new factory in the West. An American occupation officer stuck a pin in the map and the location ended up being Oberkochen, which is situated 2 hours from Frankfurt—with no commercial airline or passenger railroad connecting the two cities. At the time of the visit to inspect the microscope in 1961 there were 24,000 people employed. A car had to be sent to fetch me.

For the next year and a half our laboratory, with the very capable aid of Dr. Ernesto Suarez, spent its time dividing virtually every small tubular structure in the body and rejoining it. Success was achieved in arteries down to 0.8 mm and veins as small as 1 mm in diameter. Kidneys were transplanted in rats, the Fallopian tube divided and reanastomosed—with several clinical cases being done, portacaval shunts and Blalock anastomoses were performed in newborn puppies, and canine ureters were divided and rejoined without the use of a stent. The advantages of being able to realign nerves in proper fasicular pattern was appreciated. Coronary arteries were divided and reanastomosed but we were told by our medical cardiologist friends that the utility of this procedure was essentially nonexistent. Nevertheless, it was presented at a meeting held in 1960. Dr. Carl Kosse came in and did a whole series of canine vas deferens divisions and reanastomoses.

Clinically, the most exciting single development was the performance of four middle cerebral embolectomies with marked improvement shown by several of the patients. Dr. R. M. P. Donaghy, a neurosurgeon, aided in this work, and has helped the entire field of neuromicrosurgery. In 1962, I moved to The Mount Sinai Hospital in New York, and a young neurosurgeon by the name of Gazi Yasargil spent some time with us but was sent up to Burlington because his interests in neurosurgery were akin to Dr. Donaghy's, not mine. Dr. Yasargil has gone on to pioneer the entire field of neuromicrosurgery.

Dr. Donaghy has just founded The Journal of Microsurgery which by its multidisciplinary activities will promote a cross-fertilization of ideas between workers in the multitude of surgical specialties.

The first paper on anastomosis of small vessels was presented at the surgical forum of The American College of Surgeons, 1961. It was greeted with a combination of great interest by the non-vascular surgeons and disdain by those doing vascular surgery. It was just not practical according to the critics. There were exceptions such as Dr. Donald Effler, who took time out from his cardiothoracic directorship at the Cleveland Clinic to come to Vermont to learn the technique for cine arteriography of the coronary arteries. The work of him and his colleagues in developing the field of coronary artery surgery is legendary, and has fostered a major segment of the present health industry.

It has been said that man loves new ideas but rejects new experiences. The medical profession is no exception to this. It is gratifying to see, although many years later, the profession has widely accepted the value of microsurgery, and this book serves as a confirmation of their ability to make it useful.

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Chapter 1

Microsurgical Technique

By Sherman J. Silber, M.D.

Microsurgery should be learned in the laboratory and not on patients. The techniques are very exacting and at first may seem extraordinarily difficult. However, with a reasonable amount of practice one can develop a great deal of facility with the basic techniques. Then when approaching the more involved problems of clinical microsurgery, confidence, which comes from a good laboratory background, will allow the operation to proceed much more smoothly. A clinical microvascular case should not be attempted until the surgeon feels quite confident from his laboratory practice that he will have no difficulty anastomosing almost any vessel down to 0.5 mm in diameter. If one does not have access to a small animal laboratory in his hospital or medical center, and is only interested in doing non-vascular microsurgery such as tuboplasty or vasovasostomy, he can at least practice on segments of vas deferens or fallopian tube removed from patients at the time of hysterectomy, tubal ligation, or vasectomy. The fact that this tissue is not living and there is no bleeding to contend with or seepage of seminal fluid to cloud one's view of the lumen makes such practice unrealistically easy; but at least the basic manipulations can be practiced before a live patient is subjected to a procedure whose success depends upon the precision of the surgeon. For microvascular work no clinical undertaking should be considered until adequate practice in the small animal laboratory has been obtained.

The basic finding upon which all microsurgery is based is the observation that the hand can perform remarkably intricate micromanipulations as long as the eye can see a magnified field and guide it properly. A simple experiment with a micron gauge for measuring finger movement demonstrates unbelieveably fine control is possible if the movements can be visualized precisely. One can move such a gauge almost one micron at a time as long as his eye is viewing it and feeding the information back to the brain. In a similar vein, studies on basketball players who have demonstrated great shooting accuracy have demonstrated that part of their prowess lies in an extraordinary degree of visual acuity and distance perception.[1,2] Optical magnification expands the horizon of what the hands can do simply because we can see better.

There are small structures in every area of the body, and microsurgery therefore has its application in all surgical specialties. Even in the experimental laboratory where rats and mice have always been ideal models because of their convenience in handling and the availability of inbred strains, use of the microscope is outmoding larger animals as experimental models for most surgical research. Operations of incredible complexity can be performed very easily with minimal instrumentation in the rat simply because of the expanded vision afforded by surgical microscopes. The principle of this chapter is that as long as one can see the structure well, he can manipulate it adequately to perform a reliable anastomosis.

OPTICAL LOUPES AND THE OPERATING MICROSCOPE

The most convenient operating loupes provide 2.5 × magnification. Loupes can be obtained at considerable expense that go all the way up to 6 × magnification, but they tend to be very awkward to use. Since they are worn on the head, they move with the head, and cannot be held stationary. With magnification greater than 2.5 ×, these movements become very distracting and irritating. In addition, loupes simply do not have the ability to obtain the same depth of focus at 6 × magnification that can be achieved with a microscope. The field of view is extremely narrow with 6 × magnification and such loupes are totally useless unless they are worn in conjunction with a headlight. Despite the first impression that 6 × loupes with a headlight might have some convenience over a fixed microscope, they usually become rather cumbersome to deal with. Therefore loupe magnification is generally most useful when minor degrees of magnification are all that is needed. One can obtain loupes from Keeler, or Designs For Vision, which have relatively long focal lengths and therefore give one a comfortable working distance. For anastomosis of tubular structures greater than 2 mm in internal diameter, loupes can be used advantageously, but for structures smaller than that a microscope is necessary for a reliable anastomosis. Loupes find their greatest use in microsurgery during the process of freeing up and dissecting the specimen prior to the actual anastomosis. Most microanastomoses are better performed under the microscope.

There are a variety of microscopes available. The Zeiss Opmi-One provides magnification settings of 6 ×, 10 ×, 16 ×, 25 ×, and 40 ×. Focusing and magnification settings are controlled by hand with this model (Figs. 1.1, 1.2). This is the classical Zeiss operating microscope and still is my favorite. The only difficulty with it previously had been the inability of one's assistant to look down his own set of binoculars and observe exactly what the surgeon observes. However, an Urban quadroscope (Burbank, California) can be attached to the Opmi-One to solve this problem (Fig. 1.3). This is a beam splitter which fits onto the Zeiss Opmi-One microscope and allows an ideal arrangement for the surgeon and the assistant to look down binoculars seeing the exact same operative field at a 180° position from each other (Fig. 1.4). In addition, there are two ports on either side of the quadroscope to which movie cameras, still cameras, or TV cameras can be attached for photography or video monitoring. The view one obtains is of course three-dimensional

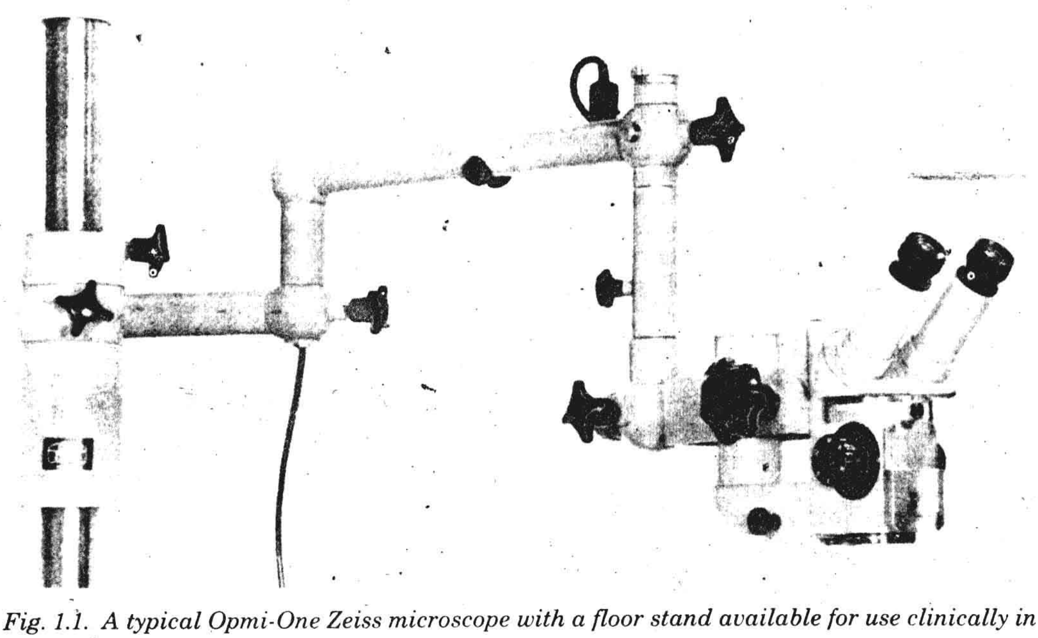

Fig. 1.1. A typical Opmi-One Zeiss microscope with a floor stand available for use clinically in the operating room.