Microneurosurgery

ROBERT W. RAND, Ph.D., M.D.

THIRD EDITION

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Preface

The first edition of *Microneurosurgery* was an outgrowth of the 1966 symposium on this subject, presenting successful microsurgical experiences in neurovascular syndromes, rhizotomy of the trigeminal and glossopharyngeal nerves, facial nerve reconstruction, resection of selected brain and spinal cord tumors, and related pathologic conditions from the neurosurgical division of the Department of Surgery at the University of California School of Medicine (Los Angeles). The emphasis was on operative techniques using the surgical microscope and microsurgical instrumentation, and the book was dedicated to Carl W. Rand.

Many individuals have made substantial contributions to the first and second editions of *Microneurosurgery*. These scientists, surgeons, physicians, nurses, and engineers—some of whom are named in the list of contributors—are continuing to add significantly to the discipline of microneurosurgery. It was my opinion that microneurosurgery would continue to expand and bring about a new standard in the art of surgery of the central and peripheral nervous system by the time the second edition was published. However, the growth of the field of microneurosurgery has been even more rapid than expected. Consequently, the third edition includes new material added to many chapters as well as completely new chapters and contributors. Certain chapters from the second edition were omitted because new material was insufficient to justify inclusion; these included the ones on nerve allografting and cerebrospinal fluid leak.

Material for the third edition could not have been compiled and prepared without the assistance and cooperation of a number of people. Among the many helpful individuals I wish to thank specially are Betty Day, medical photographer; Gloria Carugati and Lisa Campbell, neurosurgical research nurses; Mrs. Doris Boyd, secretary and special assistant; Laurel Purinton Rand, medical artist and consultant; Ali Khonsary, M.D.; Barbara Staton, editorial assistant; the UCLA biomedical librarians who helped conduct the literature search for the various chapters; and the entire editorial staff of The C.V. Mosby Company, especially Eugenia Klein, Jean Carey, and Carlotta Seely.

Robert W. Rand, Ph.D., M.D.

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Introduction

Microsurgery continues to be more widely applied in the surgical specialties. The otologists were the first to employ the surgical microscope clinically in the treatment of middle ear diseases because gross dissection, even with magnifying loupes, was not completely satisfactory. Using magnification, Evald[5] and Maier and Lion[17] performed labyrinthine procedures on animals in 1921. In the same year Nylen[18] first used a monocular dissecting microscope for operations on two patients, one suffering from chronic otitis and the other from labyrinthine fistulas. Holmgren,[6] at Nylen's suggestion, performed fenestration under a dissecting microscope.

Improvements in surgical microscopes have led to new and technically improved operative procedures. The current binocular surgical microscopes allow variable magnification with a reasonably stable, rather than static, objective-to-target distance, adequate width of operative field, superior illumination systems, and automatic focusing devices. Accessories have been added, such as observation tubes, 35 mm still and 16 mm motion picture cameras, and closed-circuit color television. Color television, once done on an experimental basis through the surgical microscope using a fiberoptic illuminating system, has now become universally available as a closed-circuit system with audio-video tape capabilities to produce teaching cassettes or to transmit directly to hospital and medical school classrooms. This color television system is currently in use at the UCLA Medical Center, Los Angeles, California.

The otologists have continued to use microsurgical techniques and make further improvements and applications, and in the past 20 years other surgical specialties have begun to utilize the surgical microscope. Jacobson and Suarez[12] reported the use of microsurgery in the anastomosis of small peripheral blood vessels in 1960. In the same year Jacobson's group applied the technique to coronary endarterectomy, middle cerebral artery endarterectomy, and ureteral reconstruction.[11-13] In 1962 Smith[22] used the surgical microscope in peripheral nerve reconstruction. House,[7] in 1961, and Kurze and Doyle,[15] in 1962, reported the development of a subtemporal middle fossa approach to the internal auditory canal for removal of acoustic tumors with microdissections. This operation, together with a translabyrinthine and translabyrinthine-suboccipital approach, has been used by House and associates[7-9] in a large series of operations upon acoustic neurinomas. Kurze, in 1963, discussed his experiences with microsurgical techniques in cordotomy, myelotomy, cerebellopontine angle tumor, en plaque meningioma, rhizotomy, and extracranial nerve anastomosis.[14] Rand and Kurze[3] developed the suboccipital transmeatal operation for acoustic tumor resection in 1964. This operation has received acceptance by otologists for preserving both hearing and the facial nerve during tumor removal. Donaghy[4] reported the use of a binocular surgical microscope in surgery of the spinal cord and in microvascular surgery. Adams and Witt,[1] Pool and Colton,[19] and Rand[20] have used the surgical microscope in the management of intracranial aneurysms for more than 20 years.

Lougheed, Gunton, and Barnett[16] described a case in which an improved technique of microsurgical embolectomy was performed to remove an embolus from the intracranial carotid bifurcation. The Yaşargil-Donaghy operation of microvascular anastomosis of the superficial temporal artery or occipital artery to a branch of the middle cerebral artery or extracranial/intracranial (EC/IC) bypass to improve collateral circulation continues to have wide acceptance in selected cases. Furthermore, Ausman and associates,[2] among others, have expanded the EC/IC procedure to improve the vertebral-basilar circulation using the occipital artery to the posterior inferior cerebellar artery or anterior cerebellar artery and the superficial temporal artery to the superior cerebellar artery.

In addition, recent results in peripheral nerve surgery have shown improvement by more precise epineural and interfascicular suture approximation. Techniques of cable grafting using the sural nerves have been more effectively developed by Samii.[21]

The original Gardner operations of neurovascular decompression of the trigeminal and facial nerves, developed in the late 1950s and early 1960s for treatment of trigeminal neuralgia and hemifacial spasm, have been improved by microneurosurgical techniques developed by Jannetta and Rand and are now widely and successfully employed.

Microsurgical instrumentation is available from most instrument companies. Microlaser systems have been introduced into microneurosurgery in the past 5 years.[10] The CO_2, Nd:YAG, and Argon type of lasers are used, depending upon the particular surgical entity being treated. This allows a no-touch technique for destroying tumor tissue and therefore reduces mechanical manipulation in resecting selected neoplasms such as acoustic neuromas. Size 70 μ microneedles, commonly available with 11-0 monofilament nylon or absorbable suture, are now made in sizes less than 30 μ with correspondingly decreased suture diameters to be used in particularly delicate microvascular and microneural surgery.

Microneurosurgery has come of age since 1961, and it continues to grow and expand as the neurosurgical residents being trained come to realize that it is essential to the proper care of their patients and the development of their professional careers. Most of the major neurosurgical training centers, including the UCLA School of Medicine, now have microsurgical laboratories.

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Part I

GENERAL PRINCIPLES

Chapter 1

General applications of microneurosurgery

ROBERT W. RAND

In this chapter it seems appropriate to outline the general areas in which microsurgical techniques have been immediately applicable to the general field of neurologic surgery. Therefore this chapter has been divided into four general sections. The first deals with brain tumors, the second with cranial and peripheral nerve surgery, the third with neurovascular surgery, and the fourth with spinal cord tumors and diseases.

BRAIN TUMORS

The surgical management of certain benign and even malignant neoplasms in and around the brain can be facilitated by stereoscopic magnification of the surgical field and by the excellent illumination provided by the current binocular surgical microscopes.

Pituitary tumors and craniopharyngiomas

Pituitary tumors are currently treated surgically by transfrontal craniotomy, transsphenoidal resection, and, for certain intrasellar tumors, by stereotactic cryohypophysectomy and stereotactic radiosurgery.[2,8,9] Craniopharyngiomas for the most part are approached by a transfrontal or temporal craniotomy and to a lesser extent by a transsphenoidal approach.

The transfrontal craniotomy has been most widely used by neurosurgeons up through the 1960s. Tumor dissection and resection may be limited, however, by prefixed positions of the optic chiasm and nerves and by the extrachiasm and intrachiasm vessels in relationship to the sella turcica and the direction of tumor growth. These pathoanatomic obstacles have been overcome, as noted in Chapter 9, with greater surgical exposure afforded by diamond-drill resection of the planum sphenoidale, tuberculum sellae, and anterior wall of the sella turcica between the cavernous sinuses performed under the surgical microscope.[8] In addition, direct trauma to the small chiasmatic vessels and optic chiasm, so often a source of postoperative visual loss, can be minimized by this transfrontal transsphenoidal approach. The sphenoid mucosa is preserved or repaired to prevent cerebrospinal rhinorrhea.

The optic nerves and carotid arteries are protected by bone during this high-speed diamond drilling, provided with tuberculum sellae and sella turcica are undercut and the medial walls of the optic foramen are left intact and have not been eroded by tumor. Erosion can be determined preoperatively by optic canal tomography and CT scans with appropriate views and settings to demonstrate bone anatomy and pathologic condition. In pituitary tumors and craniopharyngiomas, microsurgery is of considerable aid during the internal dissection and decompression of the neoplasm in defining the posterior and anterior limits of the tumor, and in the separation of the "tumor capsule" from the optic chiasm and nerves with preservation of their intrinsic vessels. Removal of the planum sphenoidale, tuberculum sellae, and anterior wall of the sella turcica, in addition to allowing more exposure for tumor removal without trauma to the optic chiasm, gives free access to the contents of the sella turcica with direct intrasellar visualization of the pituitary tumor or craniopharyngioma. This is rarely possible in a transfrontal craniotomy alone. The cavernous sinuses are pushed laterally by intrasellar tumors, and therefore there is less risk of vascular damage than with a normal pituitary gland. The exact position of the cavernous sinuses can be determined by preoperative cavernous sinus venograms[10] and by enhanced reconstructed CT scans.

In craniopharyngiomas the enhanced high-resolution CT scan and nuclear magnetic resonance (NMR) imaging can determine whether a transtemporal, bifrontal, or combined craniotomy will give the best basic surgical exposure because the exact relationships to the hypothalamus and brain stem can be determined. This is further discussed in Chapters 9, 10, and 12.

The transnasal transsphenoidal operation to the sella turcica harboring secreting or nonsecreting adenomas of the pituitary gland has been increasingly substituted for the transfrontal craniotomy. This is particularly true for the microadenomas discussed in detail in Chapter 11 by Hardy. The operation can be used for other types of intrasellar tumors, and I strongly recommend it. I have used it extensively for the aforementioned diseases since 1968, as described in Chapter 9.

Cerebellopontine angle tumors

The dissection and removal of acoustic neurinomas, ependymomas, and meningiomas and related tumors about the cerebellopontine angle are distinctly facilitated with a current binocular surgical microscope. Employing a suboccipital craniectomy and transmeatal drill dissection under the microscope, Rand and Kurze[11-14] accomplished total removal of acoustic neurinomas with preservation or intracranial reconstruction of the facial nerve, preservation of the noninvolved cochlear and vestibular nerves. This approach has definite advantages over the subtemporal and translabyrinthine approaches. These advantages, as further discussed in Chapters 17 and 20, include (1) a wide field of action, (2) immediate and direct visualization of the anterior inferior cerebellar artery, (3) identification of the acoustic tumor prior to risk of damage of the facial nerve and the labyrinth and cochlear systems, (4) dissection of the tumor always under direct vision, and (5) direct anastomosis of the facial nerve or reconstruction with nerve graft when necessary.

Sacrifice of the facial nerve has frequently occurred in surgery of acoustic tumors in the past, even in the best of hands, because of the close anatomic relationship of the seventh and eighth cranial nerves in the cerebellopontine angle and especially in the internal auditory canal, where the tumor usually arises from one of the vestibular nerves. The tumor frequently is tightly adherent to a splayed-out, attenuated facial nerve and cannot be separated from it with the usual gross dissection. There is, however, less risk of facial nerve damage during complete removal by use of the Rand-Kurze transmeatal approach and the magnified dissection afforded by the surgical microscope.[12]

The aim of the posterior fossa transmeatal approach to acoustic tumors, especially the small ones, is to preserve what vestibular and cochlear function remains and at the same time remove the tumor completely.[14] In order to do this the vestibular and cochlear nerves, as well as the internal auditory artery, must be saved and the semicircular canals left undisturbed.

Other tumors

The removal of intraventricular tumors, including a meningioma of the lateral ventricle, colloid cyst of the third ventricle, and fourth ventricle ependymoma, is facilitated by the use of the surgical microscope and microdissection. If a pinealoma is to be approached by the method of Dandy[1] or by other surgical exposure,[15] the dangers of dissection around the internal cerebral veins and other mesencephalic structures are lessened with the use of the binocular surgical microscope, as demonstrated in Chapter 22. Total removal of mesial sphenoid wing meningiomas is difficult because of their attachment and close relationship to the cavernous sinus, carotid artery, and superior orbital fissure. This part of the dissection can be aided by the surgical microscope. Stevenson and associates[16] performed near-total removal of clivus chordomas by the transclival approach. Tumors at the skull base, such as glomus jugulare and chordomas, have been successfully resected by others also (Chapters 23 and 24). Such dissection would have been impossible without the surgical microscope and special surgical exposure.

CRANIAL AND PERIPHERAL NERVE SURGERY

Tumors of the lower cranial nerves, although rare, can be removed through a posterior fossa approach. Kurze and Geiger[7] reported removal of two intrapetrous facial neurinomas by a subtemporal middle fossa approach. The fifth, ninth, and tenth nerves, which after the acoustic nerve are the most commonly involved by neoplasm, can be approached either from the middle fossa for the fifth cranial nerve or posterior fossa for the fifth, ninth, tenth, and eleventh cranial nerves. The distortion of the associated structures can be better observed and there is a greater chance of preserving them by the use of a surgical microscope.

Successful use of the subtemporal transtentorial approach to the trigeminal nerve in trigeminal neuralgia was reported by Jannetta and Rand[6] and is further discussed in Chapter 38. Differential section of pain and temperature fibers was possible, as described by Dandy,[6] with fibers subserving touch preserved. The surgical treatment of major trigeminal neuralgia and hemifacial spasm by the Gardner neurovascular decompression of the fifth and seventh cranial nerves has now been firmly established, as described in Chapters 38 and 39.

Microsurgical techniques can be applied to surgical problems about the optic nerves and chiasm other than pituitary adenomas. Craniopharyngioma removal is facilitated, particularly in the circumstance of a prefixed chiasm. Clearer evaluation of the extent and resectability of optic nerve glioma can be obtained. The planum sphenoidale, which is often hyperostotic in meningiomas of the tuberculum sellae, can be drilled away to ensure complete removal of the neoplasm.

The deep location and small size of cranial nerves has made their reconstruction virtually impossible. Facial nerve palsy in particular has received considerable attention because of the subsequent unsightly facial and ophthalmologic consequences. Fascial slings and extracranial nerve (spinal accessory or hypoglossal) anastomosis to the facial nerve have been less than satisfactory. Dott[4] performed reconstruction using intracranial-extracranial nerve grafts. Drake[5] successfully repaired a facial nerve intracranially using an autogenous graft and one direct anastomosis without benefit of magnification. The considerable skill displayed by such a success is worthy of admiration. However, with more extensive exposure of the facial nerve from the brain stem through the internal auditory canal and mastoid, unique types of nerve grafts and relocation of the facial nerve have been possible.[7,14]

Primary intracranial end-to-end anastomosis of the seventh cranial nerve was performed successfully twice in our early series of acoustic tumors with the use of the surgical microscope.[13] Since that time, other cases have been similarly successful, including those involving the use of nerve grafts.[12] The occipital and auricular nerves are available for the graft in acoustic tumor operations.

Kline, Smith and Newman, and Van Beek and Kleinert point out in Chapters 41, 42, and 43 that there is faster and more complete recovery of function after peripheral nerve reconstruction done under the surgical microscope. Similar improvements can be noted in the results of reconstruction by autonerve grafts. Although cadaver nerve grafts have not been successful in the past, with present methods of tissue typing, sterilization, drug suppression of the rejection phenomena, a storage nerve bank may become a reality in the future. Neurolysis is facilitated with the use of the surgical microscope.

NEUROVASCULAR SURGERY

The dissection of any cerebral aneurysm that can be approached surgically can be facilitated and made safer by the use of the surgical microscope, as recommended in Chapters 31 and 32. The perforating arteries so essential to brain function, arising from the circle of Willis, can be identified and preserved. The newer techniques of small vessel anastomosis performed with the use of the surgical microscope, discussed in Chapters 26 and 28, will find application in removal of heretofore unresectable intracranial aneurysms and arteriovenous malformations. The EC/IC bypass techniques for experimental cerebral artery repair in dogs were applied by Donaghy and Yaşargil in a limited manner in man in 1970, as recorded by Chater in Chapter 26 and Rand and Frazee in Chapter 27. This EC/IC (STA-MCA) bypass operation has now been widely adopted and in my experience has been quite successful in improving cerebral circulation in selected cases.

SPINAL CORD PROBLEMS AND DISEASES

A surgeon is always distressed when the patient from whom he or she has apparently removed in toto a benign spinal cord tumor shows postoperative paraplegia, monoplegia, or paresis despite what appeared to be gentle dissection using gross technique. Donaghy[3] described several cases in which the surgical microscope was used with great success in the treatment of spinal cord tumors. Meningioma, neurofibroma, and ependymoma especially lend themselves to microsurgical technique and total removal.

Operation on a patient with an intramedullary lesion without discernible increase in neurologic deficit is possible to a great degree because of the use of a surgical microscope. It is also possible to perform a biopsy of a lesion without sacrificing spinal cord tissue. The myelotomy is placed accurately in an avascular area, since the minute vessels can be seen and avoided. The cyst wall can be biopsied with no sacrifice to neural tissue. If a cleavage plane is found, similar dissection can be carried out, especially with the aid of microcryosurgery. The microcryoprobe developed by Rand with Frigitronics* is an ideal instrument to grasp by ice fusion at the tip of such intramedullary tumors as ependymomas and hemangioblastomas. This allows for the tumor to be gently lifted from its bed within the spinal cord and for development of the necessary cleavage plane to accomplish total resection. The CO_2, Nd:Yag and Argon lasers at very low wattage settings can also be used alone or in combination with the microcryoprobe to perform an internal decompression and dissection of the tumor capsule.

The microscope can be of value in intervertebral disk surgery in both the cervical and lumbar regions. In difficult lumbar disks, the microscope can be used to visualize the anulus fibrosis anteriorly to ensure complete removal of degenerated disk material. In anterior cervical disk excision and interbody fusion, the microscope may be used to advantage in visualizing the posterolateral dissection, as described in Chapters 45 and 46. Kurze performed cordotomy with the use of a surgical microscope and found it of great help in doing a safe and complete anterolateral section. Rhizotomy is facilitated by the use of this instrument in that vascular structures along the

*Frigitronics of Connecticut, Inc., 770 River Road, Shelton, Conn. 06484.