Surgical resection has been the preferred treatment for meningiomas since the era of the pioneering neurosurgeon, Harvey Cushing. The great majority of these tumors are histologically benign, circumscribed lesions that grow slowly and tend to compress and displace, rather than invade, the surrounding intracranial structures. In contrast to the intrinsic brain tumors of glial origin, most meningiomas have well-defined borders, enabling the surgeon to dissect the tumor capsule from the arachnoid lining of the adjacent brain, blood vessels, and cranial nerves. Consequently, complete removal can be accomplished without needing to sacrifice functional tissue. In these cases, surgery is often curative, and associated with the preservation of, if not improvements in, the neurological condition.

The size and location of some meningiomas at the time of original discovery sometimes precludes the possibility of complete removal. Four decades ago, Simpson recognized that the extent of surgical resection was an important determinant of the recurrence rate for meningiomas [1]. Since then, numerous groups have retrospectively analyzed the outcome of meningioma patients treated with surgery, to confirm Simpson's observation that the rate of recurrence following surgery was increased in cases where a limited resection was performed [2-4]. Others have subsequently demonstrated that the regrowth of incompletely resected tumors is associated with decreased life expectancy [5]. Unfortunately, meningiomas can recur after a seemingly complete removal [6]. The lifelong threat of recurrence was a topic that Cushing discussed in his classic monograph on meningiomas published in 1938 [7], and this problem continues to plague afflicted patients and their treating physicians. A cause for concern in these cases is that, at the time of recurrence, a previously benign meningioma is sometimes found to be malignant, although this is not a common occurrence [8,9]. While most meningiomas are believed to have a clonal origin from a single cell [10], there is increasing evidence from neuroradiographic [11,12] and pathological [13] studies that patients with these tumors have abnormalities throughout the dura that may actually represent early meningioma foci. It is apparent that surgery, while sometimes curative, is not always successful in ridding the patient of tumor, and even when it does, cannot always ensure freedom from recurrence and protection from future malignancy.

The Rationale for Prompt Treatment

When the diagnosis of a meningioma is made, surgery is the therapy favored by most physicians. The reasons given to support a recommendation for prompt treatment include the desire to confirm the clinical suspicions; to establish a tissue diagnosis on which the need for future therapy will be based; to offer a better chance of maintaining neurological function with early treatment rather than delaying therapy until the tumor has grown in size; and the likelihood that if the tumor proves to be a benign meningioma, the procedure will often prove curative. The goal of surgery is straightforward: The removal of as much of the tumor as possible while minimizing the chance of neurological injury. The technical demands for a given operation are determined by the size, location, and vascularity of the tumor, a history of previous surgery or
radiotherapy, and involvement of critical structures such as dural venous sinuses, major arteries, and cranial nerves. In complex cases, the preoperative neurological condition is an important consideration in deciding upon the extent of resection to be undertaken, as existing deficits may become worse after surgery, delaying postoperative recovery, or be made a permanent cause of long-term morbidity.

**The Surgical Approach**

For the most part, the general principles of meningioma surgery remain unchanged from the early days of the specialty: An approach is chosen to ensure an adequate exposure of the margins of the tumor; an attempt is made to interrupt the blood supply to the tumor early in the procedure to minimize blood loss; and, when possible, an internal decompression of the tumor is performed to reduce the need to retract the brain and to ease the dissection of the tumor capsule away from critical structures.

Recently, multidisciplinary surgical teams have utilized new approaches to remove meningiomas from the base of the skull. Reports describing the use of techniques that include the preoperative balloon occlusion of major intracranial arteries encased by tumor [14], arterial bypass procedures [15,16], grafting of transected cranial nerves [17], and the use of autologous tissue flaps to prevent cerebrospinal fluid (CSF) leaks through cranial defects [18] have been published. Ojemann has cautioned against aggressive surgical approaches for skull-base tumors in cases where the risks associated with their use were great and the chance of altering the natural course of the disease uncertain [19].

Undoubtedly, modern neuroimaging technology such as CT and MR scanning has made it easier to detect recurrent meningiomas, and has resulted in the discovery of an increased number of asymptomatic, coincidentally discovered meningiomas. Advances in molecular genetics may soon make available screening tests for neurofibromatosis. The identification of these patients who are predisposed to developing meningiomas at an early age, combined with vigilant monitoring, makes it likely that an ever-increasing number of these tumors will be discovered among those afflicted with neurofibromatosis.

Presently, meningiomas are most commonly diagnosed after 5 decades of life, suggesting that the incidence of these tumors will increase as our population increases and continues to age. To confront the therapeutic challenge posed by these scenarios, the treating physician will become increasingly dependent on adjuvant therapy following surgery to prevent tumor progression. In cases where the removal of tumor is incomplete, radiation therapy is the most effective way to prevent or delay recurrence after surgery.

**The Case for Fractionated Radiotherapy**

At the University of California, San Francisco, fractionated radiotherapy is the recommended treatment for most patients following incomplete resections of intracranial meningiomas. This approach represents an alternative to radical surgery. The management of cavernous sinus meningiomas is a case in point. The resection of tumors from this location is often a formidable challenge; the technical demands are great and the associated risks to the patient considerable. In those cases where surgery is unlikely to be curative, subtotal resection of tumor followed by radiotherapy can minimize operative morbidity and effectively control the growth of these tumors. A recent report from our institution has shown that, in those patients with benign meningiomas treated after 1980, the 5-year progression-free survival rate was 98%--a result comparable to that achieved with complete surgical removal [20].

Lundsford has addressed the topic of adjuvant radiation therapy in the management of meningiomas [21], and together with his colleagues has reported on a series of meningioma patients treated with stereotactic radiosurgery [22]. Their results suggest that this technique may also one day prove to be an effective way to prevent the growth of selected meningiomas. The microsurgical implantation of I-125 sources into recurrent, previously radiated malignant meningiomas, when performed in conjunction with surgical debulking, can lead to long-term remission [23].

Although there is little data to support a role for chemotherapy or hormone therapy in the contemporary management of meningiomas, knowledge of the molecular mechanisms involved in the progression of a microscopic meningioma focus to a frankly malignant tumor may lead to new therapeutic insights. Identification of genetic mutations common to meningiomas provides reason for optimism that corrective gene therapy may one day play a role in the management of these tumors.
Words of Caution

The allure of surgery as a cure for intracranial meningiomas must be tempered by the realization that these tumors recur even after they have been completely removed, that incompletely removed tumors tend to regrow, and that the threat of malignant transformation surfaces at the time of recurrence. Always keen to cure, the surgeon must remain aware of the insidious behavior of so many of these meningiomas, and be prepared to resort to adjuvant therapies to prevent the progression of this disease. Future breakthroughs will undoubtedly depend upon a combination of continued improvements in surgical technique, new methods to increase the therapeutic ratio of irradiation, and insights into the molecular alterations that underlie tumorigenesis in the meninges.

References:
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