Meningiomas are slow-growing benign tumors that arise at any location where arachnoid cells reside. Although meningiomas account for a sizable proportion of all primary intracranial neoplasms (14.3–19%), only 1.8 to 3.2% arise at the foramen magnum. Their indolent development at the craniospinal junction makes clinical diagnosis complex and often leads to a long interval between onset of symptoms and diagnosis. The sensitivity of this region to surgical manipulation has sparked recent debate as to the most advantageous surgical approach. The intent of this paper is to provide an overview of the relevant surgical anatomy, clinical features, and nuances of the management of foramen magnum meningiomas. We introduce the concept of the “surgical corridor” and discuss its importance in the management of these challenging lesions.

FORAMEN MAGNUM ANATOMY

Several excellent reviews of foramen magnum anatomy have been published. By definition, foramen magnum meningiomas arise from arachnoid at the craniospinal junction. The borders of this zone, as defined by George and George and colleagues range anteriorly from the lower third of the clivus, to upper margin of the body of C-2, laterally from the jugular tubercle to the upper margin of the C-2 laminae, and posteriorly from the anterior edge of the squamous occipital bone to the C-2 spino process.

The foramen magnum contains several critical neuroanatomical and vascular structures of which the surgeon must be aware. The neural structures include the cerebellar tonsils, inferior vermis, fourth ventricle, caudal aspect of the medulla, lower cranial nerves (ninth–12th), rostral aspect of the spinal cord, and upper cervical nerves (C-1 and C-2). The ninth through 11th cranial nerves arise as a series of rootlets along the anterior medulla, with the spinal component of the 11th cranial nerve arising midway between the anterior and posterior spinal rootlets of the spinal cord. The spinal accessory rootlets coalesce and ascend rostral to join the ninth, 10th, and the cranial portion of the 11th nerve. Together, these nerves exit the skull through the jugular foramen. The 12th cranial nerve exits the medulla more anteriorly than the other lower cranial nerves and passes anterior to the ipsilateral VA on its course to the hypoglossal canal, located within the superior and anterior–most portion of the occipital condyle.

Major arterial structures located within the foramen magnum include the VAs, PICAs, anterior and posterior spinal arteries, and the meningeal branches of the vertebral, external, and internal carotid arteries. The VA courses through the foramen transversalis until reaching C-1 where it curves above the lateral aspect of the posterior arch and proceeds rostral to pierce the dura mater just

Abbreviations used in this paper: CSF = cerebrospinal fluid; CT = computerized tomography; GKS = gamma knife surgery; MR = magnetic resonance; PICA = posterior inferior cerebellar artery; QOL = quality of life; VA = vertebral artery.
inferior to the lateral edge of the foramen magnum adjacent to the occipital condyle. Its intradural portion typically gives rise to the posterior spinal artery and PICA, although the origin of the PICA has been reported to vary, arising at, above, or below the foramen magnum.\textsuperscript{13}

**CLASSIFICATION OF FORAMEN MAGNUM MENINGIOMAS**

We describe foramen magnum meningiomas as having originated primarily from within the confines of the foramen magnum or having secondarily invaded the region but originating elsewhere. We also classify the primary tumors according to their anteroposterior and lateromedial orientations. The spinal dentate ligament delineates the anterior and posterior compartments. Most lesions (68–98\%)\textsuperscript{2} arise anterolaterally; a posterolateral origin is the second most frequent, purely posterior lesions the third, and least common are entirely anterior. We also classify these lesions based on their size relative to that of the foramen magnum: small, \(<1\) one third the transverse dimension of the foramen magnum; medium, one third to one half its dimension; large, \(>1\) one half).

Most importantly, when managing these lesions, we define an avenue that we term the “surgical corridor.” This is defined as “the space for surgical access to a lesion.” It describes the space that the surgeon will work through to access the lesion. The surgical corridor can be enlarged naturally by a tumor displacing normal structures like the medulla oblongata in a confined space such as the foramen magnum. Alternatively, one goal of a surgical route such as the transcervical approach would be to enlarge the surgical corridor.

In the management of foramen magnum meningiomas, the surgical corridor involves the space between the lateral margin of the cervicomedullary junction and the medial aspect of the occipital condyle. The corridor can and should be assessed on preoperative imaging. In these lesions, the corridor represents the view of a lesion that a surgeon obtains via a posterolateral approach after removing only the occipital bone and leaving the condyle intact. We define a corridor as “narrow” if it provides a diameter of access to the tumor of less than 1 cm; “adequate” if it is greater than 1 cm but less than 2 cm; and “large” if greater than 2 cm (Fig. 1). Thus, a tumor arising primarily from the posterior lip of the foramen magnum and extending laterally has a large corridor of access, whereas one purely anterior with no displacement of the cervicomedullary junction has a narrow corridor. Most tumors, once advanced enough to produce symptoms, have at least an adequate corridor.

**CLINICAL PRESENTATION**

The clinical presentation of foramen magnum meningiomas is protean, and the mean length of symptoms prior to diagnosis is 30.8 months, even in the era of MR imaging.\textsuperscript{15} The clinical differential diagnosis includes multiple sclerosis, amyotrophic lateral sclerosis, syringomyelia, and cervical spondylosis.\textsuperscript{11,20,36} In a cursory examination the physician may miss subtle findings early in the stage of the progression, but later symptoms are often advanced, undeniable, and lead to significant and often permanent neurological deficit. Early features of foramen magnum meningiomas include occipital headache and upper cervical pain, which is often exacerbated by neck flexion or Valsalva maneuvers. Classic foramen magnum syndrome is defined by development of unilateral arm sensory and motor deficits, which progress to the ipsilateral leg, then the contralateral leg, and finally contralateral upper extremity. Long tract findings characteristic of upper motor lesions are found paradoxically in the presence of atrophy in the intrinsic muscles of the hands. Later findings include spastic quadripareisis and lower cranial nerve palsies. Slowly progressive lesions such as these allow the development of accessory muscles to replace trapezius and sternocleidomastoid function. We therefore highly recommend that the patient be undressed and the sternocleidomastoid and trapezius muscles be closely inspected for atrophy. Likewise, the tongue should be inspected at rest for atrophy and fasciculation. Close attention to sensory testing of the C-2 dermatome will help establish the diagnosis. Patients attest to initial sensory disturbances such as cold or burning dysesthesias, astereognosis, and anesthesia but often do not seek medical attention until intractable pain, motor deficits, or ataxia ensue. Terminal progression includes quadriplegia, an inability to maintain airway protection with secondary pneumonitis, and ultimately respiratory arrest.

**IMAGING FEATURES**

The role of neuroimaging is to confirm the clinical diagnosis and to allow the planning of a surgical approach. Magnetic resonance imaging is the modality of choice for defining tumors of the foramen magnum because it provides high-resolution images of soft-tissue anatomy that is
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not susceptible to degradation by the surrounding skull base, a pitfall of CT scanning. Although plain T1-weighted MR images demonstrate excellent anatomical detail, they provide little discrimination between tumor and brainstem because the former may appear isointense, mildly hypointense, or hyperintense to surrounding brain. On T2-weighted images meningiomas appear as isointense to slightly hyperintense compared with brain (Fig. 2 left). The T2-weighted images should be carefully inspected for the presence of an arachnoid plane between the tumor, brainstem, and spinal cord. Edema depicted within the presence of an arachnoid plane between the tumor, brainstem, and spinal cord. Edema depicted within the T1-weighted Gd-enhanced contrast imaging is particularly helpful in defining the dural attachment site of the tumor; additionally it provides ready discrimination between tumor and brainstem, with often dramatic demonstration of brainstem distortion (Fig. 2 right). Magnetic resonance angiography should also be performed with an autotriggered elliptic centric-ordered sequence,12 if available, to help demonstrate vascular anatomy, collateral vessels, and the effect of the tumor on the VAs. A VA that is encased and narrowed suggests that the adventitia of the artery has been invaded, and the surgeon needs to assess whether residual tumor will be left in the adventitia or whether reconstruction is necessary. In our experience, subtotal resection is the preferred approach in this instance.

Although MR imaging provides clearly superior soft tissue assessment, CT scanning with osseous algorithms remains the tool of choice for identifying calcification, hyperostosis, and osseous anatomy. Axial CT scanning allows planning of the extent of bone resection required to resect tumor safely because of the sharp contrast between bone and soft tissues. It is sometimes difficult to outline bone margins on MR images, and this technique may overestimate the size of the surgical corridor available for extirpation. It is clearly evident that optimal surgical planning requires both CT and MR imaging to assess appropriately bone and soft tissues, respectively.

An additional imaging modality that may assist surgery is conventional angiography with optional embolization of vessels that supply tumor exclusively. The dural blood supply typically arises as posterior and anterior meningeal branches from the VAs with the support of meningeal branches via ascending pharyngeal and occipital arteries. The tumor may derive its vascular supply from a dominant vessel, which when subjected to contrast injection, is visualized as a “blush.” If the vessel is accessible to endovascular catheterization, one might opt for preoperative embolization to diminish intraoperative bleeding during tumor debulking.33

PREOPERATIVE ASSESSMENT

As is true with all oncology, all neurosurgeons must remember that they are treating people and not just resecting tumors. Sometimes this requires consideration of subtotal resection or monitoring. In initial discussions about surgery one must not assume that patients wish to undergo surgery because they are present at a neurosurgeon’s office. Often patients seek consultation to gather information about their situation, and depending on their age, ethnic background, and personal values, their decision-making process may not coincide with that of a neurosurgeon. It is therefore vital to reach an understanding of the patient’s expectations of surgery as well as his/her philosophy regarding QOL issues. The possibility of residual tumor and subsequent treatment must also be discussed in relation to the risks of surgery.

A careful and detailed history will often demonstrate that symptoms appeared long before the chief complaint. As the lesion progresses in size, the clinical course may seem to accelerate because compensatory mechanisms are exhausted and the neural compromise reaches critical levels. A history in which symptoms are rapidly progressive without a longer prodrome should raise clinical suspicion that lesions such as carcinoma or infectious/inflammatory entities may be present.

Potential surgery-related risks are not insignificant, and a careful assessment will give the astute clinician a better understanding of them in a particular patient. Care should be directed to lower cranial nerve examination. Deficits of any magnitude suggest neural compression and potential vasa nervosum involvement, thereby making the nerves more vulnerable to surgical manipulation. The ninth and 10th cranial nerves represent the afferent and efferent arms of the gag reflex, respectively, and play a pivotal role in protecting from aspiration pneumonia. Patients with unilateral preoperative gag deficits are often able to adapt because of the deficit’s slow growth pattern and its chronic nature, which allow time for compensatory mechanisms to develop. An acute disruption of the gag reflex, however, can be lethal due to aspiration pneumonia. Thus, preoperative and immediate postoperative endoscopic in-
scenario. Because the two posterior approaches to
mas relies heavily on imaging findings and the clinical
and often irreversible signs of 12th cranial nerve palsy.
Ipsilateral tongue deviation and furrowing are late
overlooked if the tongue is not inspected at rest within the
lateral paralysis of the 12th cranial nerve may also be
actively with an acute disturbance of this nerve, and its pres-
foramen magnum meningiomas rarely present preopera-
often the only symptom is shoulder pain. Patients with
11th cranial nerve deficits are sure to be problematic for
patients for vocal cord and swallowing functions. Acute
laryngology and speech pathology consultation to test
cheostomy if necessary. We routinely order an early oto-
by placing a gastric or jejunal feeding tube, and early tra-
be treated using aggressive support measures, primarily
spection of the pharynx should be performed to assess
laryngeal function. New postoperative dysfunction should
surgery in which the cranial nerves and vascular structures are preserved is integral to foramen mag-
management (Fig. 3). Every attempt should be
or, rarely, below, particularly if a transcondylar
a posterior and contralateral direction. It is our opinion
majority of foramen magnum meningiomas are anterolater-
in relation to tumor. Most importantly, an assessment of
the surgical corridor is made at this stage. Because the ma-
that this in situ retraction creates an adequate surgical cor-
dor for resection of most of these lesions. In our ex-
perience, no drilling of the occipital condyle has been ne-
ecessary to achieve resection, and in the cases in which
 residual tumor remained, resection of the condyle would
not have affected the degree of resection.
Imaging also clearly displays the relationship of tumor
to vascular structures. Encasement of the VA is not un-
common and should not be surprising intraoperatively
during tumor debulking. Provided that encasement of the
VA exists, proximal control of the vessel is prudent and
may require mobilization of the VA at the C-1 transverse
foramen or, rarely, below, particularly if a transcondylar
approach is needed. Assessment of the PICA is also of
importance in some cases, particularly those in which one
encounters an encased VA. Magnetic resonance angiogra-
/CT angiography provides the best degree of noninvasive resolution
and should be used to assess for encasement, contralateral
VA, and focal narrowing that could indicate adventitial
invasion. If it is hypoplastic, the surgeon may decide to
leave residual tumor on the vessel if necessary or perform
a bypass, rather than simply resect the affected segment.
Conventional angiography with greater resolution is
sometimes necessary. An additional advantage of preoper-
otive imaging is to determine whether the PICA originates
at above, at, or below the level of the foramen magnum.13
Careful identification of PICA during routine posterior
neck dissection is indicated if the PICA originates extra-
durally.

SURGICAL MANAGEMENT
Surgical dissection in which the cranial nerves and vascular structures are preserved is integral to foramen magnum tumor management (Fig. 3). Every attempt should be made to keep the arachnoid with these structures and to perform surgery on the tumor’s side of the nerves and vessels during dissection. Even in cases involving encasement of the VA, if the dissection is deliberate and selective, an arachnoid cuffing of the artery may often be identified and allow successful dissection of the VA free from tumor. It may be tempting to cauterize small vessels overlaying tumor capsule, in light of the concept that the tumor is parasitizing blood supply from the meninges. If possible, however, these vessels should be left intact in the arachnoid because they may actually mislead the surgeon into moving outside the ideal plane where coagulation could potentially produce brainstem perforator ischemia.

Intraoperative monitoring is intended to aid the neurosurgeon in preserving neurological function. Somatosensory evoked potentials provide a measure of ascending pathways within the surgical field, whereas electromyographic recordings in the sternocleidomastoid muscle and
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tongue reflect 11th and 12th cranial nerve activity, respectively. If either of these modalities demonstrates a change, then the surgeon is alerted to a potentially threatening maneuver and may pursue a different manner of dissection. Although we have found electromyographic monitoring of the 11th cranial nerve useful, stimulation of the 12 cranial nerve occasionally will cause protrusion of the tongue, which, if not returned to position by the anesthesia staff, can lead to postoperative swelling. There is insufficient evidence to support the use of routine evoked potential monitoring in this location. Currently, these modalities have not gained absolute clinical acceptance; their use instead is based on surgeon preference.

**SURGICAL APPROACHES TO FORAMEN MAGNUM MENINGIOMAS**

The foramen magnum can be approached via anterior, lateral, and posterior approaches. Each approach serves an important function and each was developed to deal with specific problems. The anterior transoral approach to the foramen magnum is rarely conducted to reach intradural lesions such as meningiomas because of problems with dural repair, risk of CSF leakage, and meningitis. Debate about foramen magnum meningioma resection primarily involves the suboccipital craniectomy and posteralateral approaches, which necessitate drilling of the occipital condyle (Fig. 4). We limit our discussion to these approaches.

To simplify understanding of approaches to this region, we advocate the use of the terms of suboccipital craniotomy and transcondylar approach. Both require laminectomy, although the transcondylar is more commonly associated with mobilization of the VA from its lateral attachments to widen the surgical corridor.

**Suboccipital Craniotomy**

Suboccipital craniotomy, or craniectomy, with or without cervical laminectomy represents the classic approach to the foramen magnum meningiomas and is familiar to most neurosurgeons. For posteriorly situated lesions we place the patient prone. For lateral or anterolateral lesions, the patient is placed in the lateral decubitus position with the vertex of the head displaced slightly downward to open the space between occiput and the cervical spine. We also turn the head approximately 20 to 30° toward the floor, depending on the extent to which the tumor is laterally situated. The surgical corridor defined on preoperative imaging must be easily within reach of the surgeon. The corridor should not be hidden under a large bulk of paracervical muscles deflected laterally. Sufficient soft-tissue dissection to create access to the corridor is essential. Routine use of computerized neuronavigation helps to demonstrate subtle variations of anatomical distortions caused by these sessile meningiomas.

For midline posterior lesions, we make a midline incision. For posterolateral lesions that require exposure up to the condyle, we make a “hockey-stick” or inverted L-shaped extension laterally at the superior end of our incision just beneath the superior nuchal line. Whichever the incision, cutting of the C-2 nerve branches and the 11th cranial nerve distally in the neck should be avoided.

The VA is easily identifiable as it curves above the arch of the atlas, in the depth of the suboccipital triangle, providing proximal vascular control if required. We use neuronavigation to help determine the extent of the craniotomy needed. Although some authors prefer to conduct a craniectomy, we prefer a craniotomy because the incidence of postoperative occipital pain, we believe, is limited by replacing a firm protective covering over the dura, even if it only covers a fraction of the exposed dura. If the surgical corridor to the tumor cannot be safely accessed by replacing neuronavigation prior to dura opening, more bone can be removed laterally toward the condyle. The craniotomy almost always has to be combined with a laminectomy to the inferior aspect of the tumor. At C-1 the laminectomy should encompass at least the vertebral groove in the lateral aspect of the C-1 lamina. Care should be taken to not injure the thin-walled vertebral plexus of veins that surround the thick-walled VA. Of help in this procedure is bipolar coagulation with constant saline irrigation to avoid sticking of the tips of the instrument.

The advantage of suboccipital craniotomy includes visualization of the VA, brainstem, cranial nerves, and tumor in a safe, simple, and rapid manner. Criticisms of this approach primarily relate to the interposition of brainstem, cranial nerves, and vessels between an anterior tumor and the surgeon. The purely anterior midline tumor without an adequate surgical corridor is completely obscured by these structures. The unmodified suboccipital craniotomy approach necessitates undue retraction of critical neurological structures in cases in which the lesion is purely anterior. Fortunately, these purely ventrally located tumors are the rarest.
Transcondylar Approach

In an attempt to offer effective and safer resections particularly in cases of more anteriorly situated lesions, the transcondylar approach was developed. A number of different names exist for the variations in this approach, and this leads to significant confusion regarding nomenclature. In the literature on foramen magnum meningiomas, two major variations have evolved: 1) the far-lateral approach, which necessitates removal of the foramen magnum rim toward the condyle and excision of the ipsilateral atlantal arch, and 2) the transcondylar approach, in which resection of some or all of the occipital condyle is required. The first of these is ultimately a suboccipital approach involving an appropriate soft-tissue dissection to allow access to the surgical corridor.

The transcondylar approach requires an inverted U-shaped incision with one limb of the U in the midline and the other along the anterior border of the sternocleidomastoid muscle. The sternocleidomastoid muscle is detached from the mastoid process and reflected as laterally as possible to avoid hindering access to the skull base. The superficial splenius capitis, semispinalis capitis, and longissimus capitis muscles are reflected downward to expose the underlying suboccipital triangle. Bordering the superior and inferior oblique muscles are the rectus capitis posterior muscles, the VA courses in the fat of the suboccipital triangle below the occipital condyle. All three muscles are released from their vertebral attachments and reflected toward the midline. The craniotomy should include the bulk of the lesion and often be extended from near the midline, to just medial to the sigmoid sinus, and to just above the rim of the foramen magnum. The residual bone over the sigmoid and foramen magnum is removed using rongeurs or high-speed drill. The C-1 laminectomy is more extensive than the suboccipital craniotomy and extends out into the foramen transversarium. The posteromedial aspect of the occipital condyle and C-1 lateral mass are removed by drilling or careful rongeuring. If necessitated by the anatomy of the lesion, the foramen transversarium and C-2 lamina are also decompressed.

The VA is freed from collagenous tissue at the C-1 foramen transversarium and adjacent to the condyle by using a high-speed drill under surgical magnification. A fine prolene stitch can be used to secure the VA in a medial position. Guided by preoperative planning of the surgical corridor and supplemented intraoperatively, if necessary, by computerized neuronavigation, the condyle is progressively removed in a mediolateral direction. Anterior condylar resection can include liberating the hypoglossal nerve from its canal if necessary to create an adequate surgical corridor. Because bone removal is extended much more laterally than in the suboccipital craniotomy, the ipsilateral VA is situated in the center of or medially in the “surgical corridor” prior to dural opening. The dura is opened by making an incision that parallels the lateral margins of the craniotomy, with the base of the flap located medially. A ring of dura can be left attached to the VA where it is pierced. This maneuver allows the artery to be retracted away from the surgical corridor, thereby providing a clear view of the anterior portion of the brainstem and rostral cord. Occipitocervical fusion is recommended in condylar resections of 50% or greater.

PERSONAL EXPERIENCE

Between 1992 and 2002, 10 (3.4%) of 296 patients with meningiomas underwent resection of the lesion from the foramen magnum at our institution. Six of these arose from the anterior or anterolateral rim, three were predominantly posterior, and one had a lateral origin. Eight of the 10 patients were women, and the mean age was 55 years (range 34–72 years) in the entire series. The most common complaint was occipital pain with progression to hand paresthesias. Typically the mean duration of these symptoms was 10 months (range 3–24 months).

All patients underwent preoperative CT, MR, or both CT and MR imaging. In cases of predominantly anteriorly located lesions, a suboccipital craniotomy and hemilaminectomy were undertaken. An adequate surgical corridor was obtained in all patients, and retraction of neural elements or resection of the occipital condyle was deemed unnecessary in all cases. Total excision of the tumor was achieved in nine patients, and there was no recurrence as of the last follow-up examination. In one patient with MR imaging–documented residual tumor growth GKS was performed 7 years after resection. Subtotal resection was not necessitated by the poor quality of the surgical corridor but rather by the lesion’s adherence of the VA and the perceived risk of damage to the vessel if total excision were attempted.

Cerebrospinal fluid leakage and transient worsening of preoperative symptoms were the only surgery-related complications. In two patients CSF leakage developed, in one of whom meningitis with hydrocephalus was also present. Treatment required antibiotic therapy and placement of a ventriculoperitoneal shunt. To treat the uncomplicated CSF leak duraplasty was conducted. No patient suffered permanently worsened postoperative cranial nerve deficits, but one patient sustained a mild Brown–Séguard syndrome. There was no surgery-induced death. At a mean of follow-up period of 33 months (range 2–70 months, median 30 months) improved functional was evident in seven patients and relatively unchanged status was demonstrated in two. Of the two patients with unchanged status, one continues to experience unilateral leg weakness that was present preoperatively, and in the other follow-up period is too short (2 months) to determine final functional status. The one patient with residual enlarging tumor who underwent GKS is experiencing hand ataxia and subtle neurocognitive difficulty.

NONSURGICAL MANAGEMENT

We have tended to err on the side of recommending resection to patients with reasonably sized tumors in the foramen magnum (even with minimal symptoms in younger patients) because of the lack of space for future tumor growth or swelling during other treatments such as radiotherapy. The ideal treatment of meningiomas is a safe and complete resection. If contraindications to surgery exist or if the patient elects not to undergo surgical resection, then radiotherapy should be considered. Because of the critical anatomy within the foramen magnum and the size of most tumors (< 3 cm in maximum dimension), we usually recommend focused GKS rather than standard conformal radiotherapy. Patients with small residual tumors under-
go monitoring to assess growth rate, and in the event that the residual lesion grows we recommend GKS.\textsuperscript{19,24,26} In patients with multiple recurrent tumors or in whom the aforementioned contraindications exist, we administer hydroxyurea therapy, with or without Cox II inhibitor management.\textsuperscript{7}

### CLINICAL OUTCOMES

Early reports of resection in cases of foramen magnum meningiomas were associated with a surgery-related mortality rate of 5 to 13%\textsuperscript{43,47} and morbidity rate of 36%\textsuperscript{23}. Postoperative complications include intracranial hematomas, CSF leakage, meningitis, lower cranial nerve palsies, hemiparesis, quadriplegia, and aspiration pneumonia.\textsuperscript{40} In the past decade, greater than 75% gross-total resection has been reported in series, and morbidity rates have been lower than previously documented (Table 1). Outcome has been similar in series involving condylar drilling and those in which it has not been an aspect of approaching the lesion. No randomized controlled trial of the two principal approaches has been conducted nor is one likely to be performed. Surgeons will have to continue managing patients as individuals by undertaking careful assessments of critically relevant issues such as the surgical corridor. When the transcondylar approach is considered necessary to create an appropriate surgical corridor, it should to be performed. Otherwise, the suboccipital craniotomy is likely sufficient.

Unfortunately, no authors have reported functional outcomes in terms of multidimensional QOL measures. It behooves all neurosurgeons treating these patients to consider issues of QOL foremost in decision making and in discussion of preoperative planning with patients and their families.\textsuperscript{9}

#### Acknowledgment

We gratefully acknowledge the contribution of the intraoperative photograph from Dr. Paul Muller, St. Michael’s Hospital.

#### References


#### TABLE 1

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Cases (No. of Lesions)</th>
<th>FM location</th>
<th>No. of Condyle Resections</th>
<th>Tumor Resection</th>
<th>Major Morbidity</th>
<th>Mortality Rate (%)</th>
<th>Postop QOL</th>
</tr>
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<tbody>
<tr>
<td>Kratimenos &amp; Crockard, 1993</td>
<td>8 (ant)</td>
<td>none</td>
<td>80% total, 20% subtotal</td>
<td>aspiration pneumonia</td>
<td>none</td>
<td>25</td>
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<td>Akalan, et al., 1994</td>
<td>8</td>
<td>ant, 7 anterolat</td>
<td>none</td>
<td>100% total</td>
<td>NA</td>
<td>0</td>
<td>88% improved, 12% unchanged</td>
</tr>
<tr>
<td>Bertainif, et al., 1996</td>
<td>19</td>
<td>ant &amp; anterolat</td>
<td>19</td>
<td>100% total, 63% total, 37% subtotal</td>
<td>NA</td>
<td>0</td>
<td>NA improved mean performance</td>
</tr>
<tr>
<td>Samii, et al., 1996</td>
<td>38</td>
<td>15 spinocranial, 25 cranio cervical, 11 ant, 12 lat, 2 pst</td>
<td>7</td>
<td>94% total intradural; 50% total extradural</td>
<td>pulmonary embolism, air embolism</td>
<td>7.5</td>
<td>90% improved, 7.5% worsened, 2.5% unchanged</td>
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<td>George, Lot, &amp; Boissonnet, 1997</td>
<td>40</td>
<td>18 ant, 21 lat, 1 pst</td>
<td>yes (NA)</td>
<td>100% total</td>
<td>NA</td>
<td>15</td>
<td>NA for meningiomas</td>
</tr>
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<td>Sharma, et al. 1999</td>
<td>20</td>
<td>5 ant, 5 pst</td>
<td>none</td>
<td>CN palsy, CSF leak, hydro, spinal instability</td>
<td>CN palsy, CSF leak, hydro, spinal instability</td>
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<td>approach dependent, slightly improved</td>
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<td>Salas, et al., 1999</td>
<td>24</td>
<td>24 ant or anterolat</td>
<td>24</td>
<td>66% total, 33% subtotal</td>
<td>hydroc, CSF leak, CN palsy</td>
<td>0</td>
<td>89% improved, 11% unchanged</td>
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<td>Arnautovic, et al., 2000</td>
<td>18</td>
<td>18 ant</td>
<td>18</td>
<td>75% total, 25% subtotal</td>
<td>4 CSF leak, 1 shunt, 10 CN palsies</td>
<td>0</td>
<td>100% improved, 100% active &amp; independent improved mean performance</td>
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<td>2</td>
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<td>Roberti, et al., 2001</td>
<td>21</td>
<td>NA</td>
<td>NA</td>
<td>76% total, 24% subtotal</td>
<td>21.5% (CN palsy, CSF leak, meningitis) tetraparesis, CN palsy</td>
<td>9.5</td>
<td>100% improved, 100% active &amp; independent improved mean performance</td>
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<td>Marin Sanabria, et al., 2002</td>
<td>7</td>
<td>5 ant, 2 pst</td>
<td>2</td>
<td>100% total</td>
<td>NA</td>
<td>14</td>
<td>NA</td>
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<td>Nanda, et al., 2002</td>
<td>6</td>
<td>6 ant</td>
<td>none</td>
<td>100% total</td>
<td>0</td>
<td>100% improved, 10% worsened</td>
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</tr>
<tr>
<td>present experience, 2003</td>
<td>10</td>
<td>6 ant, 3 pst, 1 lat</td>
<td>none</td>
<td>90% total, 10% subtotal</td>
<td>40% (CSF leak, worsened hand ataxia, urinary frequency)</td>
<td>0</td>
<td>100% improved, 20% unchanged, 10% worsened</td>
</tr>
</tbody>
</table>

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* ant = anterior; CN = cranial nerve; FM = foramen magnum; hydro = hydrocephalus; NA = not available for meningioma data; pst = posterior.


Manuscript received April 16, 2003. Accepted in final form May 14, 2003. Address reprint requests to: Michael Cusimano, M.D., Ph.D., Division of Neurosurgery, St. Michael’s Hospital, University of Toronto, 38 Shuter Street, Toronto, ON, M5B 1A6, Canada. email: mountain@smh.toronto.on.ca.