# Clinical Presentation And Surgical Outcome Of Foramen Magnum Meningiomas : A Retrospective Study



*Submitted for MCh Neurosurgery*

By

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# *CERTIFICATE*

*This is certify that the thesis entitled "**Clinical Presentation And Surgical Outcome Of Foramen Magnum Meningiomas : A Retrospective Study**" is a bonafide work of Dr. Manmeet Chhabra and was conducted in the Department of Neurosurgery, Sree Chitra Tirunal Institute for Medical Sciences & Technology, Thiruvananthapuram under my guidance and supervision.*

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# DECLARATION

This thesis titled " **Clinical Presentation And Surgical Outcome Of Foramen Magnum Meningiomas : A Retrospective Study** " is a consolidated report based on a bonafide study done by me during January 2005 to October 2007 in the Department of Neurosurgery, Sree Chitra Tirunal Institute for Medical Sciences & Technology, Thiruvananthapuram.

This thesis is submitted to SCTIMST in partial fulfillment of rules and regulations of MCh Neurosurgery examination.

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# *Introduction*

# INTRODUCTION

Extra-medullary tumors in the region of foramen magnum are of special interest for several reasons. First, many tumors in this location are histologically benign and, if diagnosed early in their course, are amenable to complete surgical removal. Second, they have insidious, often bizarre, and occasionally remitting clinical course simulating cervical spondylosis, multiple sclerosis, and other degenerative diseases. Third, the mechanisms by which tumors in this region produce unexpected effects, such as remote muscular atrophy and a relapsing remitting course, remain unexplained. Fourth, the treacherous location of these tumors and their potential for operative cure makes them of particular interest to the neurosurgeon.[1]

Meningiomas are the most common benign tumor of foramen magnum region.[2] The first case of foramen magnum meningioma was observed by **Hallopeau (1874)** in Lariboisiere Hospital, Paris.[3]

Foramen magnum meningiomas represent 0.3 to 3.2% of all meningiomas, 4.2 to 20% of all posterior fossa meningiomas, and 60 to 77% of all benign extramedullary tumors at the craniospinal junction.[4] 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 present study is a retrospective analysis of 20 patients operated for foramen magnum meningioma at Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum between 1990 and 2007, with a view to study the clinical presentation and surgical management of foramen magnum meningiomas.

# Aims & Objectives

# AIMS AND OBJECTIVES

This study was carried out with the following aims and objectives:

1. To study the epidemiology, clinical presentation, and imaging features of foramen magnum meningiomas.

2. To study the surgical and functional outcome of foramen magnum meningiomas.

# *Historical Landmarks*

# HISTORICAL LANDMARKS

The first report of this entity was probably that of **Hallopeau** in **1874**.[3] He described a 50-year old woman presenting with upper extremity weakness progressing to quadriparesis, bulbar palsy, and, ultimately to death from respiratory failure. An autopsy revealed bilateral degenerative changes in the lateral funiculi of the spinal cord and a tumor “the size of a small chestnut” arising from the basilar groove.[2]

The first systematic evaluation of foramen magnum tumors was by **Elsberg(1925)** [5] and much of the subsequent literature is a confirmation and extension of Elsberg’s observations. Among these later reports, the more important include those by **Elsberg and Strauss (1929)** [6] , **Bailey and Bucy (1930)**[7], **Symonds and Meadows (1937)**[8], **Friedman (1941)**[9] and **Piehl et al (1950)**.[10]

**Elsberg and Strauss (1929)**[6] performed the first successful removal of a foramen magnum meningioma in a 36 year old woman presenting with Brown-Sequard syndrome. Although the patient required pulmonary resuscitation several times intraoperatively, she survived with eventual complete resolution of her symptoms.

Significant contributions to the natural history of foramen magnum tumors were made by **Cushing and Eisenhardt (1938)**[11], who divided these tumors into two anatomical classes: craniospinal and spinocranial. Spinocranial tumors referred to lesions found lying posterior or posterolateral to the spinal cord and projecting upward into the cerebellar cistern. Craniospinal tumors lay within the basilar groove anterior or anterolateral to the medulla, displacing it posteriorly and projecting downward through the foramen magnum. **Cushing and Eisenhardt (1938)**[11] based their classification primarily on clinical symptomatology.

**Love et al (1954)**[12] presented the first extensive review of both benign and malignant tumors of the foramen magnum. They debated the merits of the classification into craniospinal and spinocranial tumors by

Cushing and Eisenhardt. However, **Dandy (1941)**[13] felt the dichotomy important with regard to planning an operative approach.

Analysis of case series by **Broager (1953)**[14] , **Smolik and Sachs (1954)**[15], **Love et al (1954)**[12], **Dodge et al (1956)**[16], **Stein et al (1963)**[17] and **Gautier-Smith (1967)**[18] further documented the varied clinical presentation of such tumors.

# *Review of Literature*

# REVIEW OF LITERATURE

## DEFINITION

It is not possible to provide an accurate estimate of the incidence of tumors in the region of foramen magnum by simple tabulation of surgical or autopsy series. In part, this is so because the boundaries of the 'region' are not precisely defined, and because different criteria for inclusion or exclusion of cases have been variously been employed. [1]

**Bogorodinsky (1936)**[19] included under the caption 'craniospinal tumors' those growths which had entered and partially blocked the foramen, whether arising from the clivus or from the spinal levels.

**Cushing and Eisenhardt (1938)**[11] preferred to maintain a distinction between those meningiomas arising in posterior fossa and extending downward (craniospinal tumors) and those arising from the spinal levels and extending upwards (spinocranial tumors).

**Castellano and Ruggiero (1953)**[20] were much more restrictive in their definition of foramen magnum meningioma. They classified posterior fossa meningiomas with respect to their dural site of attachment alone. They included only those tumors which were attached to the dural margin of the foramen or to the inferior portion of the basilar groove. Thus, tumors passing through the foramen magnum but not actually attached to it were not included in their series.

**Stein et al (1963)**[17] included only those tumors which 'were located about the upper-cervical and foramen magnum region with generally small extensions into the posterior fossa', and excluded tumors which arose in the posterior fossa and extended downward to enter the foramen.

**Guidetti and Spallone (1980)**[21] have advocated that the term foramen magnum meningioma be used to describe neoplasms extending into both the posterior fossa and the cervical canal regardless of their dural point of origin.

**George B et al (1997)**[22] defined the foramen magnum area corresponding to a zone ranging anteriorly from the lower third of the clivus to the upper edge of the body of C2, laterally from the jugular tubercle to the upper aspect of the C2 laminae, and posteriorly from the anterior edge of the squamous occipital bone to the C2 spinous process. The zone of insertion is taken into account only in defining the location of meningiomas. This definition allows one to differentiate between foramen magnum meningioma in which the origin is inside the foramen magnum area and meningiomas in which the origin is mostly outside the foramen magnum area but extends slightly into it.

## EPIDEMIOLOGY

A review of several series totalling 4974 meningiomas throughout the neuraxis yielded 89 cases of foramen magnum meningioma with an overall incidence of 1.8%.[2] They represent 6% to 7% of posterior fossa meningiomas, 8% to 9% of spinal meningiomas, and about 2% of all spinal cord tumors. [2]

**Dodge et al (1956)**[16] analyzed the Mayo Clinic experience with 30 benign tumors at the foramen magnum, which consisted of 26 meningiomas and 4 neurofibromas.

**Scott EW and Rhoton AL (1991)**[2] reported that benign intradural extramedullary tumors account for approximately 30% of neoplasms found in the region of foramen magnum. Meningiomas are by far the most common, comprising almost three-quarters of the total. They occur in a 3:1 ratio to neurinomas, with isolated cases of, cystic teratoma, lipoma, and cavernous malformation [23] also reported.

Most series report female preponderance, ranging from 2:1 to 3.6:1. [17,20,21,24,25] In the **Columbia series(1963)**[17] of 25 foramen magnum meningiomas, the ratio of female to male was 2:1.

The majority of foramen magnum meningiomas become evident in the fourth through sixth decades of life, although patients range in age from 4 to 88 years at presentation.[2]

**Dodge et al (1956)**[16] reported that the age group from 40 to 50 years was the most common period for the occurrence of a benign tumor at the foramen magnum with 14 patients being in this age group in their series of 30 cases of benign tumors at the foramen magnum. **Porras (1963)**[26] reported the occurrence of a meningioma in an 8 year old boy. Although there are occasional reports of pediatric foramen magnum meningiomas, the clinical, radiographic, and histological features of this subgroup and their surgical management are no different from that of the adult population.[26, 27]

Foramen magnum meningioma has occasionally been described in patients with neurofibromatosis[25,28] although schwannomas of the foramen magnum have a much higher rate of association with neurofibromatosis.[2] Reports of multiple meningiomas in the foramen magnum and upper cervical cord[29], simultaneously occurring foramen magnum meningioma and eleventh cranial nerve neurilemmoma[24], and concurrent sphenoid wing meningiomas[30] are exceptional. A case of foramen magnum meningioma which was associated with a pheochromocytoma is also on the record[31].

## CLINICAL FEATURES

**Piehl et al (1950)**[10] noted that "the most vivid impression one gains from reviewing the reported cases of meningiomas located at the foramen magnum is the lucidity of the clinical picture in retrospect, post-operative or post-mortem, and the diagnostic pitfalls preceding such clarification."

**Castellano and Ruggiero (1953)**[20], stated that "the possibility of a meningioma of the foramen magnum should always be considered in the presence of a capricious clinical history with long remissions and 'illogicalness'."

The duration of clinical course depends greatly upon the histological type of the tumor, its site of origin, and its direction and rate of growth. [1].

**Stein et al (1963)**[17] found that of their 25 cases of foramen magnum meningioma, the duration of initial symptoms in 9 patients was less than 1 year, and in the great majority of the patients was less than 5 years.

**Dodge et al (1956)**[16], felt that the "CSF cisterns of the foramen magnum region allow room for steady continued growth and displacement of adjacent neurologic structures to a sometimes marked degree before the limit of this tolerance is reached or before the continued presence of the growing tumor causes impingement of the adjacent neural tissue against some hard unyielding surface." They emphasized that, unless sufficient credence is given to the patient's often bizarre and seemingly functional subjective complaints, one is "likely to deny the patient his ultimate opportunity for cure."

Several authors have reported a significant delay between the onset of the first and second groups of symptoms or hard neurological findings. This ranged from 20 days to 5 years (average 14 months) in **Guidetti and Spallone's series(1988)**[32] and 5 months to 6.5 years (average 2.25 years) in the **Mayo Clinic series(1984)**[25]. **Dodge et al (1956)**[16] record a case in which a 12 year interval elapsed between the onset of cervical pain and the appearance of other symptoms.

**Yasuoka et al (1978)**[24] described two clinical stages in tumor progression. The first consisted of posterior cervical/suboccipital pain and upper extremity dysesthesia. The neurologic examination at this stage was usually normal at this stage and a diagnosis of "cervical spondylosis" often ensued. Subsequent development of weakness and associated sensory/sphincteric disturbances led to the appropriate diagnosis and treatment.

A relapsing and remitting course has been demonstrated in 30% to 50% of patients by various authors.[2] **Cohen and Macrae (1962)**[33] theorized that early vascular compression might transiently compromise blood flow with later augmentation from collateral sources. However, other authors felt that such remissions are more likely related to inappropriate or non-specific therapy such as corticosteroids, physical therapy, or surgical decompression (sans tumor removal) [21,32,34].

**Piehl et al (1950)**[10] reported a case with marked daily variation in signs and symptoms, and **Broager (1953)**[14] reported a patient with a partial remission of over 12 years. Most remissions are of several months to several years duration. [1]

**Meyer et al (1984)**[25] remarked that 40% of patients in their series had initially normal examinations but demonstrated findings on periodic follow-up evaluation. Nearly 20% were neurologically normal at the time of surgery. However, all patients in this series had shown continuous progression of symptoms rather than the relapsing and remitting course.

## PAIN

**Cohen L (1975)**[1] reported that pain in the suboccipital and posterior cervical region on the side of the tumor is either the first symptom or is an early and prominent complaint. The painful area may extend to the parieto-occipital region and may involve the ipsilateral shoulder and upper extremity.

**Elsberg(1925)** [5] noted that "pain in the neck and occipital region is an important symptom. The patient is therefore apt to hold his head stiffly."

**Elsberg and Strauss(1929)**[6] added complaints of cold dysesthesia and atrophy of the intrinsic hand muscles to the clinical picture.

A "classical triad" of symptoms emerged [6, 8, 12, 16, 35] consisting of: (1) occipital headache and posterior cervical pain; (2) progression of motor and sensory deficits starting in one arm and eventually involving all the extremities; and (3) atrophy of the intrinsic hand muscles.

**Abott (1950)**[35] suggested that the severity of occipital and suboccipital pain was greater in cases of spinocranial meningiomas than in craniospinal meningiomas, presumably because the second cervical root is more likely to be stretched by a posteriorly situated intraspinal lesion, but the clinical value of this distinction is limited.[1]

Suboccipital headache and upper cervical pain are the most frequent presenting complaints and may precede other developments by months or years. [16,17,24,25,32] Characteristically, the pain is aggravated by postural changes or neck movements with the patient resisting such movements and holding the neck stiffly. Coughing, straining, or a Valsalva maneuver may also exacerbate the pain.[2]. **Stein et al (1963)**[17] reported unilateral neck pain in the majority of their cases and occasional symptomatic relief with traction or a cervical collar. Hyperesthesia in the C2 distribution may accompany pain and, when present, is an important finding suggestive of a foramen magnum tumor. [2]

The lateral margin of the foramen magnum and the floor of the lateral posterior fossa are supplied by the meningeal branch of the twelfth cranial nerve, which enters the hypoglossal canal with the posterior marginal branch of the ascending pharyngeal artery. Its fibers actually originate from the upper two cervical dorsal root ganglia. The dura lining the anterior floor of the posterior fossa, clivus, and ventral craniospinal junction is supplied by ascending branches of meningeal rami from the upper three cervical nerves. Most of the fibers originate from the second cervical level. Interconnections between branches from opposite sides of the body occur within the ventral dura near the midline.[36,37] These structures are frequently noted to be directly involved with tumor or markedly stretched at the time of surgery. [2]

**Krayenbuhl (1973)**[38] offered an alternative anatomical hypothesis for the occipital pain seen with tumors confined to the foramen magnum. He demonstrated a sensory component of the first cervical nerve root and postulated that occipital pain from an anterolateral tumor of the foramen magnum originates either in the first cervical nerve root below the vertebral artery or in the dura near the entrance point of the vertebral artery. This may account for the occasional patient complaining of posterior cervical pain but without sensory changes in the C2 distribution.

**Dodge et al (1956)**[16] found that low back pain of a sciatic character was 'not infrequent' in their 30 cases of meningioma and neurofibroma in the region of foramen magnum.

## SENSORY DISTURBANCES

Every variety of sensory defect has appeared at some time in the course of foramen magnum tumors. [1] **Elsberg (1925)**[5], **Symonds and Meadows (1937)**[8] and **Craig and Shelden (1940)**[39] have stressed that pain and temperature sensibility are relatively more involved than tactile sensation. However, defects in vibratory and position sensibility may be particularly prominent in the upper extremities. [16, 35]

**Guidetti and Spallone (1980)**[21] have grouped the sensory disturbances caused by foramen magnum meningioma into three major categories: (1) cold dysesthesia; (2) burning dysesthesia; and (3) astereognosis / stereoanaesthesia.

**Elsberg and Strauss(1929)**[6] noted that patients complained of a feeling of intense cold in one or both lower limbs, a symptom not present in any tumors except those high in the cervical cord.

**Haymaker (1969)**[40] has written that a "common complaint" of patients with extramedullary tumors in the region of the foramen magnum is a sensation of intense cold in one or more limbs.

In a review of this phenomenon, **Beatty RA (1970)**[30] cited a case in which the patient experienced waves of intense cold over the entire body and another case in which pilo-erection was observed in association with the complaint of cold. In the latter case, cold stimuli were experienced as abnormally painful. These pathological sensations occurred most frequently if the tumor site was anterior or antero-lateral to the cord.

The frequency of cold dysesthesia ranges in major series ranges from less than 10% **(Meyer FB, 1984)**[25] to approximately 30% **(Guidetti and Spallone, 1988)**. [32]

**Stein et al (1963)**[17] noted that ventrolateral tumors caused only ipsilateral arm paresthesia, but that more dorsally placed lesions typically produced bilateral paresthesia / hypalgesia.

**Beatty RA (1970)**[30] proposed that pressure on the spinal cord is the stimulus and that the relative mobility of the cervical spine is a significant factor. They postulated that the subarachnoid space which is already compromised by a ventrally placed tumor, is further compromised by movement of the neck, resulting in pressure on, or ischemia of, the spinal cord, which produces dysesthesia.

**Guidetti and Spallone (1980)**[21] attributed these sensations to temporary impairment in microcirculation and / or cerebrospinal fluid dynamics.

Burning dysesthesia of the arms has also been described and may precede the onset of hypesthesia. [24,32] Lhermitte's sign is occasionally reported.[32] Dissociated sensory loss is reported in approximately 25% of patients with a 'cape distribution' sensory loss demonstrated in 7% by various authors suggesting an intramedullary process [6,25,32]

Astereognosis is defined as an inability to identify an object by palpation in the presence of intact primary sensory modalities of touch pain, temperature and vibration.[41] It is most often described with lesions of contralateral primary sensory cortex or its afferent thalamo-cortical pathways.[2]

**Cushing (1923)**[42] was the first to note astereognosis associated with a tumor in the "posterior cerebellum". Although this met with some initial skepticism, a series of subsequent reports confirmed his findings. [43,44]

**Riley HA (1940)**[45], proposed the term *stereoanaesthesia* to be used to describe the clinical picture associated with foramen magnum lesions and *astereognosis* be reserved for lesions involving the sensory cortex.

**Dodge et al (1956)**[16] and **Stein et al (1963)**[17] found loss of proprioception in the hands, with relative preservation in the lower extremities.

**Blom and Ekbom (1962)**[46], described two cases of foramen magnum meningioma ventral to the cord with loss of proprioception in the upper extremities. Their patients displayed 'pseudoathetotic' movements of the fingers and hands when the arms were outstretched, which they colorfully referred to as "pseudoathetose tabétique" or "piano-playing fingers phenomenon".

**Halpern(1968)**[47], demonstrated that astereognosis may occur not only with lesions of the parietal cortex but also as a result of interruption of the sensory pathways in the medial lemniscus, the posterior columns of the cervical spinal cord, the posterior roots of the spinal nerves, or in the peripheral nerves.

**Krayenbuhl (1973)**[38] felt that all of the sensory complaints and deficits in the ipsilateral upper extremity, characterized by loss of tactile, positional, and vibration sense as well as hyperesthesia / anaesthesia and diminished temperature sensation, could be explained by involvement of the lateral upper funiculus cuneatus and substantia gelatinosa.

In a review of patients with brain-stem vascular syndromes, **Endtz and Frenay (1980)**[48] showed that simultaneous occurrence of astereognosis and amyotrophy of the hand frequently encountered with foramen magnum tumors could *not* result from a single ischemic lesion.

**Weidenfeld et al (1988)**[49] postulated that stereoanesthesia was due to a lesion of the nucleus cervicalis lateralis, a specialized sensory system within the medial lemniscus. The afferent pathway consists of a band of fibers from the hand to the third and fifth layers of the dorsal horn where the cell bodies are located. They form monosynaptic connections to the nucleus cervicalis lateralis. Efferent fibers from this nucleus run within the medial lemniscus to its decussation within the upper brainstem, synapsing on the third order neurons in the VPL nucleus of the thalamus. This pathway ultimately terminates in the parietal sensory cortex.

Sensory symptoms often begin in the limb which is first affected by weakness and follow the same order as that of the progression of motor signs, but cases of defective pain and temperature sensibility on one side in association with weakness of the contralateral side, as in the classical Brown-Sequard syndrome, are frequently seen.[1]

**Symonds and Meadows (1937)**[8] suggested that on occasion, patches of apparently normal sensation may be preserved over segments of trunk leading to an erroneous clinical diagnosis of multiple sites of spinal cord involvement.

**Dodge et al (1956)**[16] mention one case in which the sensory defect only involved the saddle area. **Stookey (1924)**[50] observed that 'bands of hyperesthesia may be found below the level of the tumors in areas remote from the segment directly involved'.

From a diagnostic point of view, the relatively isolated or prominent alteration of sensation over the back of the head is a particularly valuable finding since it suggests involvement of the second cervical posterior root by a postero-lateral lesion. [1]

Another frequent sensory complaint in high cervical cord lesions is that of sudden transient electrical sensations which are experienced during neck flexion and which are felt to spread to the upper or lower limbs.[1] Although originally regarded as a symptom of multiple sclerosis [51], identical complaints have since been observed in cases of high cervical cord compression or intrinsic spinal cord disease of any etiology. [1]

In view of the variable, multiple and frequently bizarre character and distribution of sensory complaints, it is not surprising to find that hysteria or some other functional disorder is often suspected early in the course of the disease. [1].

## MOTOR DISTURBANCES

Weakness, clumsiness, or stiffness which is limited to one shoulder and upper limb, is frequently an early complaint. [1]

**Elsberg (1925)**[5] observed that the most characteristic progression was initial involvement of one upper limb followed by involvement of the ipsilateral lower limb, then involvement of the contralateral lower limb and finally involvement of the contralateral upper limb. **Symonds and Meadows (1937)** [8]later confirmed this observation.

This pattern of progression is common but by no means universal. Initial motor deficits in both upper limbs have been observed [1], and **Bogorodinsky (1936)**[19] has described paraplegic and mixed forms. **Abbott (1950)**[35] observed a case of crossed upper and lower limb weakness. **Stein et al (1963)** [17] described an "asymmetrical pyramidal quadriparesis" predominantly ipsilateral to the tumor, with greatest involvement of the arms. **Meyer FB (1984)**[25] reported that occasionally motor symptoms may appear first in the legs, leading to a search for peripheral vascular disease or lumbar stenosis.

**Elsberg (1925)**[5] described a "modified Brown-Sequard syndrome" with *predominant* ipsilateral corticospinal tract involvement and *predominant* contralateral spinothalamic tract involvement seen in approximately 30% of patients with benign foramen magnum tumors. When weakness is asymmetric, it is always more pronounced on the side of the tumor. [16]

**Blom and Ekbom (1962)**[46] noted that the motor disturbances will depend on the degree of involvement of the pyramidal tracts. They stated that marked motor signs occur when the lesion is situated ventrally and above the decussation of the pyramids, or laterally and below it ; the motor symptoms will be less pronounced in cases in which the lesion is lateral and above the decussation or ventral and below it.

**Oppenheim (1913)**[52], was the first to describe wasting of the distal upper extremity musculature and, in particular, the intrinsic hand muscles associated with compression of the upper cervical spinal cord. This relatively common finding with foramen magnum meningioma is reported in approximately 20% to 50% of patients in larger series. [17,25, 32]

**Liveson et al (1973)**[53] demonstrated fibrillation potentials and positive sharp waves in both arms but normal lower extremity recordings in a patient with atrophy and a confirmed foramen magnum meningioma. They concluded that the neurophysiological evidence favored anterior horn cell dysfunction of the lower cervical cord, rather than upper motor neuron disease or disuse atrophy.

**Bailey and Bucy (1930)**[7] and later **Symonds and Meadows (1937)**[8] advanced the hypothesis of interference by tumor with the descending arterial supply to the lower cervical cord. **Love et al (1954)**[12] and **Dodge et al (1956)**[16] also stressed this possibility and cited cases in which the vertebral and basilar arteries were directly compressed by, or incorporated within, tumors of the foramen magnum.

Subsequent anatomic and angiographic studies have shown, however, that the major blood supply to the lower cervical spinal cord is via the large radicular arteries of the neck (particularly C6) with minimal contribution from the vertebral artery components [54,55].

The atrophic changes were occasionally so pronounced as to lead to theories of central hydromyelia or cystic degeneration in the lower cervical cord secondary to compression at a higher level.[2] However, concurrent syringomyelia and foramen magnum meningioma have only been documented once. [56]

**Cohen and Macrae (1962)**[33] postulated another theory entailing a stretching mechanism with cord displacement/rotation by the tumor and contralateral traction produced by the anchoring dentate ligaments.

The most widely accepted hypothesis proposed by **Taylor and Byrnes (1974)**[57], surmises venous outflow obstruction by the high cervical lesions with subsequent infarction and necrosis at lower levels. The authors implanted hygroscopic plastic spheres in the high cervical subarachnoid space of rhesus monkeys, producing progressive upper extremity weakness.

Histopathological examination disclosed progressive downward dilatation of the paracentral veins with hypoxic changes in the anterior horn cells and small perivascular hemorrhages in the posterior horns, but normal white matter tracts. They concluded that the false localizing signs in foramen magnum compression are due to venous distension and stagnant hypoxia in the grey matter of the lower cervical cord secondary to interruption of venous channels by the high cervical lesions.

The intrinsic hand muscles are characteristically the most atrophied. However, **Bogorodinsky (1936)**[19] noted that "the degenerative atrophies are not limited to the level of compression but involve the cervical, the thoracic and sometimes the lumbar segments of the cord." **Cushing and Eisenhardt (1938)**[11] illustrated a patient with intercostal muscle wasting, while **Stein et al (1963)**[17] reported severe *unilateral* atrophy of cervical musculature in three of their patients.

## CRANIAL NERVE INVOLVEMENT

Cranial nerve palsies are uncommon with foramen magnum meningioma except for spinal accessory nerve involvement, reported in 27.8% to 44% of patients in larger series [17, 20,25, 32]. Ipsilateral and bilateral involvement occurs with approximately equal frequency [17] and may be associated with atrophy of the trapezius and sternocleidomastoid muscles[20]. **Meyer et al (1984)**[25] noted that "spinal accessory nerve involvement is highly suggestive of foramen magnum tumor, especially if vagus nerve function is normal thereby eliminating the possibility of jugular foramen lesions."

**Cohen L (1975)**[1] suggested that there remains ambiguity regarding the frequency with which the nerve itself is directly compressed or incorporated by the tumor because the weakness and atrophy of the sternocleidomastoid and upper trapezius muscles, which is frequently noted, may represent a remote effect of compression more rostrally and need not be due to involvement of the XI$^{th}$ nerve in its extramedullary course.

Trigeminal nerve involvement is variably reported in different series. **Stein et al (1963)**[17] found facial hypesthesia in only one of their 25 cases, although **Guidetti and Spallone (1988)**[32] reported a 15.4% rate. Onion-skin distribution of sensory loss,[58] hyperesthesia,[20] and occasional trigeminal neuralgia [20] has also been described.

Unilateral or bilateral facial weakness has been reported by various authors. [5,11,15,16] Scattered references to glossopharyngeal and vagal involvement have also appeared but are less well-documented.[16]

Hypoglossal nerve involvement is noted in more than 7%.[25,32] Isolated cases of involvement of seventh and eighth cranial nerves [16,25,28] and the ninth and tenth cranial nerves [16,20] are reported.

**Stein et al (1963)**[17] have reported unusual combinations of cranial nerve lesions, e.g., a dorsally placed tumor presenting with bilateral impairment of hearing and vestibular functions, facial nerve palsy, and papilledema.

## OTHER FEATURES

Nystagmus, usually mild, has been reported in 25% to 50% of patients.[16,17,20,25] **Stein (1985)**[59] attributes this finding to "pressure on the sulcomarginal fibers which are an extension of the medial longitudinal fasciculus." Most often the movement is horizontal, but isolated cases of upbeat and downbeat nystagmus have been reported. [25]

Papilledema is unusual with foramen magnum meningioma unless there is a large posterior fossa component to the tumor.[20,25] **Dodge et al (1956)**[16] noted a much higher incidence of papilledema in intramedullary and malignant tumors of the foramen magnum.

The incidence of Horner's syndrome varies widely, from 3.9% [25] to 20%.[17] When present, it is usually incomplete, consisting only of a mild ptosis and miosis.[2] **Stein et al (1963)**[17] could not find the complete syndrome in any of their 25 cases of foramen magnum meningioma.

**Haymaker (1969)**[40] observed that in lesions of the upper spinal cord there may occasionally be hyperhidrosis rather than anhidrosis of the face.

Although hiccup has been observed as an early sign [8], respiratory disturbances typically arise late in the clinical course, usually in the setting of quadriparesis.[60] The majority of patients in early reports succumbed to pulmonary complications.[16,61] **Meyer et al (1984)**[25] noted that respiratory failure may result from compression of the medullary respiratory centres, diaphragmatic paralysis from tumor involvement of the C2, C3 and C4 nerve roots, or impairment of the gag reflex and vocal cord paralysis from injury to the vagus and glassopharyngeal nerves.

Sphincteric disturbances, another "late" symptom, are seen in 20% to 40% of patients at the time of admission. [25,32]

Phasic stretch reflexes are typically hyperactive and the plantar responses are extensor at some time in the course of almost all cases. [1]

There is a distinct paucity of cerebellar findings unless the tumor has a large posterior fossa component. [17]

## RADIOGRAPHIC FEATURES

Standard x-ray films of the skull and cervical spine are usually unrevealing.[2] Cervical spondylosis is a common associated radiographic finding and patient's symptoms are frequently attributed to these degenerative changes. [25,32.]

**Love et al (1954)**[12] recommended special views, including stereoscopic skull base and olique Stenver's views of C1 and C2 to delineate the foramen magnum region. **Malis (1958)**[62] noted that bony changes are generally detectable in extradural malignant lesions of the foramen magnum, but that benign intradural tumors usually show no alterations on plain films.

**Guidetti and Spallone(1980)**[21] found plain film abnormalities in 25% to 30% of benign, intradural extramedullary foramen magnum tumors.

Hyperostosis [32] and tumor calcification[12] have been described with foramen magnum meningiomas.

**Malis (1958)**[62] provided the first detailed description of myelographic techniques in the region of foramen magnum and gave several illustrative examples of foramen magnum meningioma.

**Stein et al (1963)**[17] noted myelographic abnormalities in 13 of 25 patients with documented foramen magnum meningioma. Their findings included: (1) increased distance between the dens and anterior margin of cervical subarachnoid space in ventrally placed tumors; (2) lateral displacement of the oil column on anteroposterior (AP) view; (3) complete blockage to dye passage; and (4) a dorsal defect in the contrast column in cases of dorsolateral or dorsally placed tumors.

**Bull (1974)**[63] emphasized the need for supine as well as prone studies to delineate the posterior half of the thecal sac and thus a mass lying dorsal to the spinal cord. **Margolis (1976)**[64] described a "lateral inclination" maneuver to facilitate visualization of the posterior foramen magnum. Pantopaque myelography in both prone and supine positions proved diagnostic in 95% of patients in the **Mayo Clinic series**. [25]

The overall diagnostic accuracy of CT alone, without intrathecal contrast, approached 75% as reported by **Guidetti and Spallone (1988)**.[32] CT with intravenous contrast was shown to be diagnostic in 75% and suggestive in additional 20% of benign intradural extramedullary foramen magnum tumors. [25]

**Spallone et al (1980)**[65] noted that the findings suggestive of a foramen magnum meningioma on CT scan include: (1) absence of bony changes; (2) oval shape and homogeneity of the mass; and (3) marked contrast enhancement.

MRI has replaced CT/myelography as the imaging modality of choice for foramen magnum lesions.[2] T1-weighted imaging demonstrates displacement of the normal soft tissues by the tumor, which may appear isointense, slightly hypointense, or slightly hyperintense relative to normal brain tissue. On T2-weighted images, meningiomas generally show an isointense or hyperintense signal.[66,67] Administration of the paramagnetic contrast agent gadolinium-diethylenetriamine pentacetic acid (Gd-DTPA) markedly enhances the sensitivity of MRI in evaluating meningiomas. [2]

**Boulton MR and Cusimano MD(2003)**[68] suggested that 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 not susceptible to degradation by the surrounding skull base, a pitfall of CT scanning. They further advised that 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 neuroparenchyma on T2-weighted sequences suggests that the pial membrane has been invaded; this should prompt an attempt at function preservation in which a near-total resection leaves a small thin plating of tumor intact.[69] The use of 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.[68] The authors further suggested that magnetic resonance angiography should also be performed with an autotriggered elliptic centric-ordered sequence,[70] if available, to help demonstrate vascular anatomy, collateral vessels, and the effect of the tumor on the vertebral arteries. They found that a vertebral artery 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. [68]

MRI is poor at demonstrating tumor calcification or skull invasion preoperatively.[2] 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 the 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. Optimal surgical planning requires both CT and MR imaging to assess appropriately bone and soft tissues, respectively[68]

Angiography should be considered in all patients with suspected foramen magnum meningioma to (1) demonstrate the vascular supply of the neoplasm; (2) define the position of major vessels with respect to the tumor; (3) determine the venous drainage of the posterior fossa; and (4) eliminate the possibility of an aneurysm of the posterior circulation.[2]

The dura mater around the foramen magnum is supplied by the anterior and posterior meningeal branches of the vertebral artery and the meningeal branches of the ascending pharyngeal and occipital arteries. Occasionally the posterior inferior cerebellar artery (PICA), posterior spinal arteries, and the intradural portion of the vertebral artery give rise to meningeal branches.[71,72] Any of these vessels may show pathological enlargement or give rise to "tumor blush".[21] An extremely hypervascular tumor may prove amenable to preoperative selective embolization, making surgical extirpation markedly less hazardous[2]

Displacement of major vessels by the tumor is a common finding and was evident in five of six cases in the series of **Guidetti and Spallone (1980)**.[21] The anterior spinal artery, PICA, terminal vertebral artery, and the spinal veins are most likely to be affected. Occasionally the vertebral artery (or other major vessel) is encased by the tumor, an important preoperative discovery. Angiography is also helpful to define the venous drainage of the posterior fossa to determine whether the sigmoid sinus or internal jugular vein might be sacrificed in some of the more anterior or lateral surgical approaches. [2]

**Boulton MR and Cusimano MD (2003)**[68] stated that planning for resection of foramen magnum meningiomas relies heavily on imaging findings and the clinical scenario. Because the two posterior approaches to anterior foramen magnum meningiomas require dissection of skin and muscles in anatomically distinct regions, one must decide preoperatively which approach is most suitable for the given tumor. Selection is based on the basic skull base surgery principle of removing bone to provide a corridor of access to the tumor to allow total tumor resection and to preclude retraction of neurological structures. Evaluation of MR imaging data allows one to determine the relationship of the tumor to the brainstem and its possible site of dural attachment. Computerised tomography scans provide data regarding the osseous anatomy in relation to the tumor. Most importantly, an assessment of the surgical corridor is made at this stage.

**Boulton MR and Cusimano MD (2003)**[68] found that encasement of the vertebral artery is not uncommon. They suggested that if encasement of the vertebral artery exists, proximal control of the vessel is prudent and may require mobilization of the vertebral artery at the C-1 transverse foramen or, rarely, below, particularly if a transcondylar approach is needed. They further emphasized that the assessment of the PICA is also of importance in some cases, particularly those in which one encounters an encased vertebral artery. Magnetic resonance angiography/ auto-triggered elliptic centric-ordered or CT angiography provides the best degree of noninvasive resolution and should be used to assess for encasement, contralateral vertebral artery, 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.

## CEREBROSPINAL FLUID ANALYSIS

Early investigators found elevated CSF protein, normal glucose, and a normal to slightly elevated cell count in most patients.[15, 16, 17] A variable incidence of block was noted (35% to 67%) in those undergoing CSF manometrics and Queckenstedt maneuvers. Spinal fluid manometrics and CSF analysis now play a limited role in the diagnosis of foramen magnum lesions.[2]

**Guidetti and Spallone (1980)**[21] found 18% of patients to have entirely normal CSF pressures, which they attributed to the large size of the subarachnoid cisterns at the foramen magnum, allowing considerable tumor growth before a complete / severe block occurred. The CSF protein in their cases was normal, mildly or markedly (upto 1100 mg%) increased, depending upon the extent of the blockage. **Meyer et al (1984)**[25] reported an increased opening pressure in 30%, elevated CSF protein in 50% and a positive Queckenstedt test in 8%.

## NEUROPHYSIOLOGICAL STUDIES

Electromyographic (EMG) studies also have a limited diagnostic role. **Liveson et al (1973)**[53] reported normal EMG studies in a patient with arm weakness, but when atrophy of the intrinsic hand muscles ensued 14 months later, fibrillation potentials and positive sharp waves became evident in the C5-T1 supplied muscles. Lower extremity studies were normal despite bilateral Babinsky signs. They concluded that the neurophysiological evidence favored anterior horn cell dysfunction in the lower cervical cord rather than upper motor neuron disease or disuse atrophy.

**Yasuoka et al (1978)**[24] and **Meyer et al (1984)**[25] found EMG to be of diagnostic value in 40% of the patients they studied. Fibrillation potentials were noted in the intrinsic hand muscles and occasionally in the sternocleidomastoid, trapezius, and upper cervical paraspinous muscles. Signs of upper motor neuron involvement have also occasionally been reported. [24,32]

## SURGICAL PRINCLPLES

**Boulton MR and Cusimano MD (2003)**[68] suggested that surgical dissection in which the cranial nerves and vascular structures are preserved is integral to foramen magnum tumor management. 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 vertebral artery, if the dissection is deliberate and selective, an arachnoid cuffing of the artery may often be identified and allow successful dissection of the vertebral artery free from tumor. They stated that it may be tempting to cauterize small vessels overlying the tumor capsule, in light of the concept that the tumor is parasitizing blood supply from the meninges. They suggested that 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

**Boulton MR and Cusimano MD (2003)**[68] stated that 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 tongue reflect XI$^{th}$ and XII$^{th}$ 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. The authors further stated that, although they found electromyographic monitoring of the XI$^{th}$ cranial nerve useful, stimulation of the XIIth cranial nerve occasionally will cause protrusion of the tongue, which, if not returned to position by the anesthesia staff, can lead to postoperative swelling. They stated that 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

Meningiomas are most commonly located anterolaterally within the foramen magnum. A few arise strictly anterior to the neural structures and present a considerable surgical challenge. Approximately 12% to 20% occur in a posterior or posterolateral location. [17,20,25,32]

**TUMOR LOCATION RELATIVE TO CERVICO-MEDULLARY JUNCTION**

| Series | N | Anterior | Anterolateral | Posterior / Posterolateral |
|---|---|---|---|---|
| **Stein et al (1963)**[17] | 25 | 1 (4%) | 21 (84%) | 3 (12%) |
| **Guidetti and Spallone (1988)**[32] | 17 | 4 (23.5%) | 10 (58.8%) | 3 (17.6%) |
| **Castellano and Ruggiero (1953)**[20] | 24 | 13 (54.2%) | 7 (29.2%) | 4 (16.7%) |
| **Meyer et al (1984)**[25] | *102 | 61 (60%) | 20 (19.5%) | 21 (20.5%) |

* Includes 23 neurofibromas , 1 teratoma.

The choice of a surgical approach is determined by several factors: (1) tumor location with respect the bony ring of the foramen magnum; (2) anterior-posterior relationships to the spinal cord and medulla; (3) rostral-caudal extent; (4) laterality; (5) size of dural attachment; and (6) size of the tumor. [2]

Traditionally, four surgical approaches to foramen magnum meningioma have been described: posterior, posterolateral, and anterior via the transoral or transcervical routes. [2]

## TRANSORAL APPROACH

The transoral (buccopharyngeal) approach is appropriate for most anterior extradural foramen magnum lesions because it provides midline exposure and is the most direct route to the pathology. However, there are serious limitations to its use for anterior foramen magnum meningiomas (and other intradural lesions) due to the high incidence of CSF fistulae and meningitis when the dura is opened through the nasopharynx. [2]

**Mullan et al (1966)**[73] first described the partial resection of an intradural sarcoma via transoral route in a 2-year old child who died later from recurrence,

**Guidetti (1974)**[74] advocated the transoral approach to meningiomas originating from the anterior rim of the foramen magnum, although he did not describe the surgical results and, in a later report, stated that this technique was only suitable for extradural lesions at the craniocervical junction.[21]

**Laine et al (1977)**[75] reported the successful removal of a clival meningioma via a transoral-transclival approach.

**Crockard and Bradford (1985)**[76] utilized this approach to totally resect a 3-cm intradural schwannoma anterior to cervicomedullary junction after an aborted attempt at tumor removal via a posterior approach.

**Miller and Crockard (1987)**[77] reported two cases of subtotal resection of foramen magnum meningiomas via a transoral approach. They averted CSF fistulae by meticulous attention to: (1) water-tight dural closure with dural substitute when necessary; (2) use of biological adhesives over the dura; (3) water-tight closure of pharyngeal wound by use of a biological graft or rotational flap of pharyngeal mucosa; and (4) aggressive CSF drainage and, in some cases, permanent CSF diversion via a lumbo-peritoneal shunt.

Although with this approach, work can proceed intradurally and the neuraxis is not situated between the surgeon and the tumor, the transoral route carries the disadvantages of working at a greater depth from the surface and of working through a contaminated field. [73,78]

**Bonkowski et al (1990)**[79] suggested use of a “bone baffle” to prevent CSF leakage after transoral resection of foramen magnum meningioma.

**Pasztor E et al (1984)**[80] suggested that the transoral-transclival approach seems more suitable in the treatment of extradural lesions.

## TRANSCERVICAL TRANSCLIVAL APPROACH

The trans-cervical approach, first described by **Stevenson et al (1966)**[81], is directed through the anterior fascial planes of the neck to the region of foramen magnum. This approach provides an exposure affording a narrow space that is anterior to the foramen magnum.

To widen the exposure, **Guidetti and Spallone (1988)**[32] modified the approach to include an anterior dislocation of the mandibular condyle. This widens the retropharyngeal exposure and allows for nasotracheal intubation rather than a tracheostomy. CSF diversion via a lumbar catheter is usually employed for 48 hours to minimize the risk of fistula formation. **Guidetti and Spallone (1988)**[32] used this approach in one foramen magnum meningioma that had earlier been partially removed by a posterior approach. They stated that the advantages of this technique include: (1) it allows a more direct exposure of the ventral foramen magnum than posterior approaches (although less so than the transoral approach); (2) the foramen magnum is reached through the deep fascial planes of the neck rather than through the nasopharynx with its attendant risks of CSF fistula and meningitis; and (3) retraction of the brainstem and spinal cord is avoided. This approach is severely limited by the depth of exposure and the lengthy dissection required.

## SUBOCCIPITAL APPROACH

The posterior approach via a cervical laminectomy and suboccipital craniectomy is the most widely used approach [12, 16, 25, 71, 82]

The prone, three-quarter prone (park-bench) or semi-sitting position may be utilized depending upon the preference of the surgeon. The straight prone position is used for most lesions localized at the level of foramen magnum. The semi-sitting or three-quarter prone position would be used if the lesion extends in front of the brain-stem or lower cranial nerves. Turning the head toward the side of the lesion facilitates access to the front of the brain-stem. [2]

Either a vertical midline or a hockey-stick suboccipital incision is used. The vertical midline incision is used for lesions situated in the upper spinal canal and posteriorly / posterolaterally at or above the foramen magnum. The hockey-stick incision is selected if the lesion extends anterior or anterolateral to the brain-stem toward the jugular foramen or the cerebello-pontine angle (CPA). The skin-incision extends from the mastoid process along the superior nuchal line to the inion, and downward in the midline. The incision permits removal of the full posterior rim of the foramen magnum, the posterior elements of the atlas and axis and, in addition, a unilateral suboccipital craniectomy of sufficient size to expose the anterolateral surface of the brainstem and the nerves in the CPA. A vertical paramedian incision with the head turned toward the side of the lesion is used if the tumor is situated predominantly anterolateral to the medulla. [2]

The amount of suboccipital craniectomy and cervical laminectomy varies depending upon the rostral / caudal extent of the tumor and its size. Despite the large bulk of some of the more anteriorly located lesions, they usually arise from a small vascular pedicle off the anterolateral dura and are thus fully resectable via this approach. The laminectomy should be carried out widely and may include the medial margin of the facet joints on the side of the tumor, although it is rarely necessary to sacrifice the stability of the joints themselves. [2]

The dura is opened with a Y-shaped incision. Posterior or posterolateral lesions may separate easily from the surface of the brain-stem and the spinal cord. Occasionally they are firmly attached to the nerve roots or vascular structures and must be microsurgically dissected free.[2]

Anterolaterally situated tumors displace the cord dorsally and rotate it away from the side on which the main tumor mass is located. The ventral rootlets are often pushed dorsally by such lesions. They must be identified and separated from the dorsal rootlets and dentate ligaments. [2]

A useful landmark is the most rostral dentate ligament that lies at the level of the foramen magnum and indicates the point at which the vertebral artery pierces the dura. The upper two or three dentate ligaments may be sectioned to reduce traction on the spinal cord during manipulation. The tumor is next isolated with cottonoid strips. Its capsule is opened and the intracapsular contents are removed in a piece-meal fashion. Extreme care should be utilized when cutting into tumors situated anterolateral to the brain-stem, since they may encase a segment of the vertebral or the posterior inferior cerebellar arteries. Occasionally, a small tab of tumor is tightly adherent to the vertebral artery and will need to be left behind. [2]

While some authors claim that the dural attachment should be radically removed to prevent recurrence,[83] others have demonstrated no clear correlation between the late recurrence and the extent of dura resection.[84] Upon completion of tumor resection, an attempt should be made to excise the involved dura. Failing this, scraping the inner dural surface with a Penfield dissector or curette followed by vigorous bipolar coagulation is usually sufficient to complete elimination of the tumor. [2]

Complications related to this approach include injury to the vertebral artery,[17,32] epidural hematoma,[24] and destabilization of the craniocervical junction leading to atlanto-occipital dislocation.[12]

Lateral modifications of the posterior approach to facilitate removal of more anteriorly placed lesions and to minimize the need for retraction on the medulla, lower cranial nerves, and the spinal cord have been described.[85,86,87]

**Scott (1972)**[85] removed the lamina and pedicle of C1 and C2 as well as the lateral rim of the foramen magnum to afford better anterior exposure. Complications of this technique included formation of an arteriovenous fistula from injury to the vertebral artery during dissection. He recommended leaving the dura open to allow for decompression in cases of very firm anterior foramen magnum meningiomas that were subtotally resected. **Scott and Rhoton (1991)** [2] recommended using a fascia lata or cadaver dural graft when closure of the patient's own dura might constrict the neural structures.

## CONCEPT OF LATERAL APPROACH

The concept of a lateral approach to reach the craniocervical junction was first proposed by **Seeger W (1978)**[88]. This method has since then been refined and called the far lateral retrocondylar approach **(Heros RC, 1991)**[89], the extreme lateral approach (**Sen CN and Sekhar LN, 1990**)[90] and the transcondylar approach (**Bertalanffy H and Seeger W, 1991**)[91]. All these methods approach the dorsal midline clivus through the anterolateral suboccipital craniectomy which extends to the foramen magnum. [92]

**Sen CN and Sekhar LN (1990)**[90] resected five meningiomas and one neurofibroma using the extreme lateral approach. They removed the posterior half of the occipital condyle and mastoid bone with complete unroofing of the sigmoid sinus to obtain a large surgical field that provided sufficient exposure of the tumor – cord / brainstem interface.

**Tange Y et al (2001)**[92] argued that a large craniectomy including the mastoid region was more appropriate to perform a tumor resection, but is so invasive that opening of the mastoid air cells can easily cause complications such as CSF leaks and infections. They suggested that a large craniectomy should only be performed in cases of persistent adhesions to the brainstem, such as in recurrent tumors.

**Heros RC (1991)**[89] described the far lateral retrocondylar approach which provides the fundamentals of the lateral approach, but the jugular tubercle remains an obstacle for viewing the ventral aspect of the brainstem. The mean distance between the two entrances of the bilateral hypoglossal canals is 30.4 mm, whereas that between the inside aspect of the bilateral jugular tubercles, which are located above the hypoglossal canals, is only 19.7mm.[71] Hence, the bone eminences narrow the dorsal region of the clivus.[92]

**Bertalanffy H and Seeger W (1991)**[91] described the transcondylar approach which is a more advanced approach than the far lateral retrocondylar approach regarding the resection of these bone eminences. After removing part of the occipital condyle, the jugular tubercle is drilled out in the extradural space. Generally, the posteromedial one-third of the occipital condyle is removed when using the transcondylar method and no instability to the occipitocervical joint has been reported when removal is limited to less than one - third.[4,93,94] However, some patients demonstrated limitations in head rotatory movement after undergoing this operation [95]

**Tange Y et al (2001)**[92] used the transcondylar fossa approach, first described by **Mutsushima T and Fukui M (1996)**[95], for excision of a ventrolateral foramen magnum meningioma. They observed that the transcondylar fossa approach provides a large surgical field that was virtually equal to that of the transcondylar approach through the condylar fossa, without resection of the occipital condyle. The approach involved a C1 hemilaminectomy and a suboccipital craniectomy after drilling out the condylar fossa. Further expansion of the deeper surgical field was then obtained by removing a part of the jugular tubercle. They stated that the jugular tubercle interrupts the surgical view, and thus resection of the occipital condyle is not always necessary.

The transcondylar fossa approach can be easily converted to a transcondylar approach in the same operative field simply by performing resection of the posteromedial occipital condyle, if drilling out of the condylar fossa is inadequate to enter the ventral portion of the brainstem. The transcondylar approach is preferred in patients with a small condylar fossa or a posterior protrusion of the occipital condyle which markedly interferes with the surgical view. The transcondylar fossa approach should be selected based on a meticulous analysis of the relationship between the occipital condyle, the condylar fossa and the jugular tubercle using three dimensional computer tomography.[92]

## POSTEROLATERAL APPROACH

**George et al (1988)**[86] described two posterolateral approaches. The first, a midline vertical incision from C4 to the occiput curving laterally up to the mastoid process, employed the sitting position. The other, performed in a lateral decubitus position, began with a lateral incision 4 cm below the mastoid tip, followed the anterior border of the sternocleidomastoid muscle up to the mastoid, and then curved towards the midline along the occipital crest. Bone removal in both cases consisted of a C1 hemilaminectomy and suboccipital craniectomy.

The technique requires exposure of the vertebral artery within its periosteal sheath from C2 to its intracranial extension, which allows either: (1) superior and lateral retraction of the vertebral artery, giving access to the tumor between the lateral medulla and vertebral artery; or (2) medial displacement (transposition) of the vertebral artery, requiring resection of the transverse foramen of C1 and giving access to the tumor lateral to the vertebral artery.

In addition, this technique requires exposure of the sigmoid sinus via a posterior mastoidectomy down to the jugular foramen. In those cases in which the tumor extends laterally into the jugular foramen, the sigmoid sinus is sectioned between its vertical and horizontal portions. This "widens access to the anterior portion of the foramen magnum and inferior clivus, thus continuing at a higher level the benefits obtained by vertebral artery exposure".

**George et al (1988)**[86] employed this approach in 14 cases (10 with foramen magnum meningioma) achieving total tumor resection in eight and incomplete resection in six. There were three perioperative deaths: one from air embolism, one from pulmonary sepsis, and one patient whose comatose, quadriplegic preoperative state did not improve. There were no

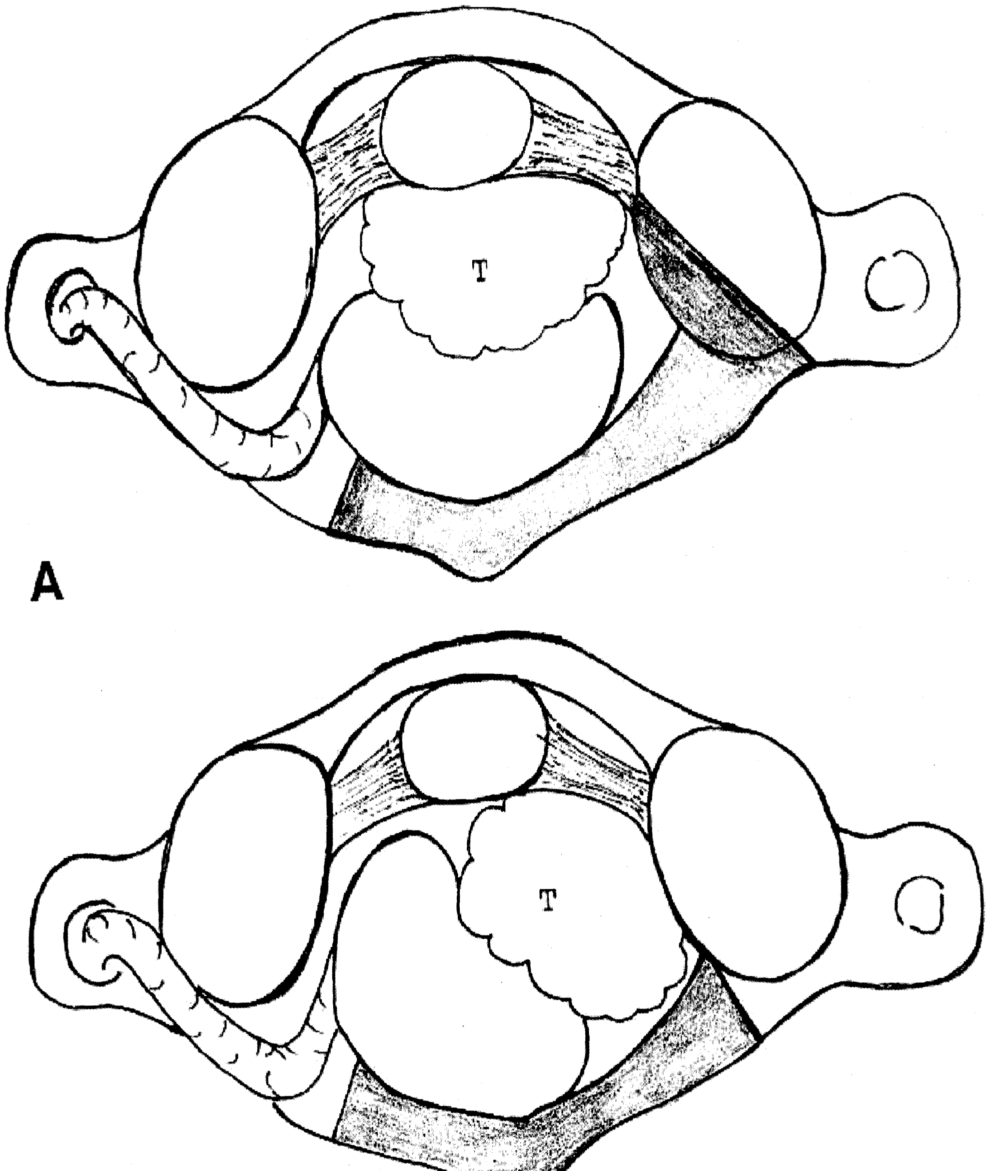


Fig.2: Schematics of the extent of bone drilling (shaded area) in the posterolateral approach in cases of anterior (A) and lateral (B) foramen magnum meningiomas

[From ref. no. 22]

new neurological deficits, and ten of their patients showed excellent recovery neurological function.

## ANTEROLATERAL APPROACH

**George B et al (1997)**[22] used the anterolateral approach on 5 patients with foramen magnum meningiomas with wide zones of attachment and cervical extension. In this exposure, the incision is along the anterior edge of the sternocleidomastoid muscle, the mastoid process, and the occipital crest up to the midline. The transverse processes of C1 and C2 are exposed, passing between the external aspect of the internal jugular vein and the sternocleidomastoid muscle; the spinal accessory nerve is freed and retracted inferiorly before the vertebral artery is exposed with unroofing of the transverse foramen of C1. A laminectomy of C1 and craniectomy of the inferior and lateral parts of the occipital bone, including part of the mastoid process, are then performed.

This approach allows the sigmoid sinus to be exposed down to the jugular foramen and the vertebral artery to be seen from C2 to its intracranial part. The approach is quite lateral to the spinal cord and medulla. The intradural space can be reached, but through a narrow and deep surgical field, unless the occipital condyle and the lateral mass of the atlas are extensively drilled out.

**George B et al (1997)**[22] suggested that the anterolateral approach appears more appropriate to expose any anterolateral extradural lesions, like chordomas, osseous tumors etc. In the case of a tumor with intradural and extradural components, the posterolateral and anterolateral approaches can be associated in the same or in two different stages.

**Boulton MR and Cusimano MD (2003)**[68] introduced the concept of 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 meningiomas that had displaced the neuraxis to one side.[21,28,96] However, this approach has its limits in accessing anterior tumors that displace the neuraxis in a posterior direction. **Heros** [87], in 1986, described the posterolateral retrocondylar approach to target vascular lesions located in front of the brainstem. This approach has been used successfully in the removal of anterior foramen magnum meningiomas.[2,97,98,99,100] To enhance vision of the ventral medulla, **Seeger** [88] resected the jugular tubercle and medial part of the occipital condyle in 1978. Several variations of this approach, usually without resection of the jugular tubercle, have been used to treat ventral foramen magnum meningiomas. These include up to one-third condylectomy, [22,94,101,102,103,104,] up to one-half condylectomy, [4,90,105,106] and up to two-third condylectomy. [107] Most surgeons have dissected and transposed the third part of the vertebral artery to facilitate condylar drilling and to enlarge access to the tumor.[4,90,103,105, 106,107] Other investigators have found mobilization of the vertebral artery not to be necessary.[22,91] Some surgeons have added a partial mastoidectomy.[90,105,106] It has been argued that the retrocondylar approach requires undue retraction of the brainstem, particularly in anteriorly located meningiomas, and some series have reported subtotal tumor resection after performing a suboccipital craniotomy because of inadequate exposure.[22,90,104] These surgical impressions were echoed by several cadaveric studies showing that condylar resection provides a wider angle of exposure when targeting lesions located on the anterior foramen magnum region.[108,109] It should be noted that measurement results obtained from cadaveric studies did not consider the presence of an extraaxial space–occupying lesion, which creates additional working space. **Nanda et al (2002)** [98] concluded from their anatomic study that resection of the occipital condyle was not required for safe and complete removal of intradural foramen magnum tumors.

## RESULTS

Results in the early surgical series were not very encouraging. During manipulation and tumor dissection, the lower cranial nerves and brainstem were often injured, resulting in labile hypertension, aspiration, and not uncommonly, respiratory arrest. Those who survived surgery often had residual brainstem and lower cranial nerve dysfunction necessitating a tracheostomy and / or feeding gastrostomy. [2]

**Love et al (1954)**[12] reported 34 perioperative deaths in their series of 74 foramen magnum tumors, most commonly a result of respiratory failure. Despite these discouraging results, there were occasional reports of remarkable improvement after tumor resection despite an extremely poor preoperative status.[58,110]

**Yasargil et al (1980)**[28] reviewed 114 cases of surgically treated foramen magnum meningiomas from the world literature spanning the years 1924 through 1976. There were seven operative and eight postoperative deaths for an overall mortality rate of 13.2%. Neurological outcome was described as "good" in 79 cases (69.3%), fair in 9 (7.9%), and poor in 11 (9.6%).

**Guidetti and Spallone (1988)**[32] reported an operative mortality rate of 11%. Twenty of their 26 patients were described as "normal" some 2 to 34 years after surgery. There were no tumor recurrences in their series.

On reviewing the Mayo Clinic series of 102 benign intradural extramedullary foramen magnum tumors from 1924 to 1982, **Meyer et al** [25], reported a 5% operative mortality and 5% mortality from recurrence within 3 years. Outcome in survivors was described as "excellent" in 75%, "mildly impaired" in 12%, and "poor" in 13%. Functional recovery was largely determined by the patient's preoperative neurological status and duration of impairment.

**Cohen L (1975)**[1] suggested that many of the signs and symptoms encountered in cases of foramen magnum tumors are due to physiological disturbances of neural function and need not indicate irreversible structural damage. The case reported by **Resnikoff and Cardenas (1964)**[110] is particularly instructive in this regard, documenting complete neurological recovery following surgery in a woman whose spinocranial meningioma had caused complete quadriplegia, respiratory arrest, and a subsequent episode of cardiac arrest.

**Pritz (1991)** [99] evaluated intradural tumors located anterior to the cervicomedullary junction operated by a lateral suboccipital approach. He found that selecting an appropriate surgical corridor between the lower cranial nerves (IX through XII), the vertebral artery, and the posterior inferior cerebellar artery allows satisfactory tumor removal. The author suggested several advantages of this approach. First, a direct view of the anterior surface of the lower brainstem and upper cervical cord is obtained. Second, surgery is undertaken in a sterile field in which the dura can be closed watertight. Third, neither mastoidectomy nor transposition of the vertebral artery is required.

**Babu et al (1994)** [105] reported the use of extreme lateral transcondylar approach in 22 patients with complex lesions. They observed that transcondylar approach is absolutely essential for intradural mass lesions located ventral to the spinomedullary junction, but is not necessary for laterally placed lesions, which can be removed by traditional approaches. The extent of occipital condyle resection can be varied according the needs of the particular case. They also reported the disadvantages of the transcondylar approach, viz., vertebral artery injury, CSF leakage, and cranial nerve injury. They reported that the risk of CSF leakage with the transcondylar approach may be slightly greater for intradurally approached lesions than that with a midline posterior approach because the abnormal dura mater is not resected after a midline approach.

**Salas et al (1999)**[106] described six variations of the extreme-lateral craniocervical approach for anteriorly and anterolaterally located lesions in the craniocervical area: (1) transfacetal approach, (2) retrocondylar approach, (3) partial transcondylar approach, (4) complete transcondylar approach, (5) extreme-lateral transjugular approach, (6) transtubercular approach with or without division of the sigmoid sinus. They concluded that tailoring of the approach to each specific lesion avoids unnecessary surgery while providing the needed exposure.

**Arnautovic et al (2000)**[4] in a retrospective study of 18 patients with ventral foramen magnum meningiomas operated by a trancondylar approach reported frequent but transient morbidity caused by lower cranial nerve deficits. The hypoglossal canal is opened after resection of the medial third of the occipital condyle; this maneuver increases susceptibility of this nerve to damage .[111]

**Goel A et al (2001)**[97] in their study on 17 patients with ventral/ventrolateral foramen magnum meningiomas operated by conventional posterior suboccipital approach concluded that, the time tested, posterior midline conventional approach to most anteriorly placed foramen magnum meningiomas remains a viable and possible better option versus the alternative approaches described in the literature.

**Gupta et al (2004)** [96] studied 27 patients with anterior / anterolateral foramen magnum tumors. Thirteen of these patients were operated via the posterior midline approach. All these 13 patients had large or giant tumors displacing the cervicomedullary region posteriorly and laterally. This allowed adequate access through the posterior midline approach with minimal handling of neural tissue. For small lesions the authors used the far lateral approach. Most of the patients improved significantly neurologically. The authors recommend the standard midline posterior approach for large/giant foramen magnum tumors and the far lateral approach for small lesions.

# *Material & Methods*

# MATERIAL AND METHODS

This study is a retrospective analysis of 20 patients operated for foramen magnum meningioma at Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum between January 1990 and August 2007.

The clinical records, radiological examinations, and follow-up data in each of these 20 patients were retrospectively analyzed.

As suggested by **George B et al (1997)** [22], the foramen magnum area was defined as corresponding to a zone ranging anteriorly from the lower third of the clivus to the upper edge of the body of C2, laterally from the jugular tubercle to the upper aspect of the C2 laminae, and posteriorly from the anterior edge of the squamous occipital bone to the C2 spinous process. The zone of insertion was only taken into account in defining the location of the tumor. This definition allowed differentiating between foramen magnum meningioma in which the origin is inside the foramen magnum area and meningiomas in which the origin is mostly outside the foramen magnum area but extends slightly into it.

The pre-op evaluation of patients included detailed history, neurological examination, routine blood investigations and pulmonary function tests. All patients were examined preoperatively by magnetic resonance imaging (MRI) including contrast-enhanced T1 studies in the sagittal and axial views. Vertebral angiograms were obtained bilaterally in all patients to look for encasement of the vertebral artery by the tumor.

The tumor was defined based on imaging studies in relation to the neuraxis and the dura mater.

As depicted from preoperative MRI scans and confirmed during surgery, foramen magnum meningiomas were classified in the axial plane into three subgroups according to their dural attachment (as suggested by **George B et al, 1997** [22]). Anterior or ventral tumors were defined as those attached to the anterior rim of the foramen magnum on both sides of anterior midline and displaced the neuraxis in a purely posterior direction. Lateral meningiomas were defined as those situated on the ventrolateral rim of the foramen magnum between the anterior midline and the dentate ligament and displaced the neuraxis posterolaterally. Tumors attached posterior to the dentate ligament were classified as posterior or dorsal.

In regard to the dura mater, meningiomas were classified as purely intradural, intradural with extradural extension, or entirely extradural.

## RATIONALE FOR CHOOSING THE APPROACH

All patients were operated by either a midline posterior suboccipital approach or a posterolateral approach, i.e., lateral extension of the standard posterior approach. The choice of approach was determined by the location of the tumor in the axial plane in relation to the neuraxis (i.e. anterior, lateral or posterior), size of the tumor and amount of space provided by displacement of the neuraxis by the tumor as determined by preoperative imaging.

In lateral meningioma, the tumor enlarges the space lateral to the neuraxis. So the surgical opening does not need to be enlarged and the bone resection includes the posterior arch of atlas up to the vertebral artery groove and preserves the lateral mass of atlas and the occipital condyle. In anterior meningioma, the tumor enlarges the space anterior to the neuraxis and the spinal cord and medulla are shifted posteriorly. The standard midline posterior approach has its limits in accessing anterior tumors that displace the neuraxis in a posterior direction. The posterolateral approach (posterior approach with lateral enlargement) provides a lateral extension to the standard posterior approach to gain access to the anterior part of the foramen magnum.[22]

Intradural meningiomas were always treated by the midline posterior approach if posteriorly located or by the posterolateral approach if they were located anteriorly. For laterally located tumors, the choice between midline posterior and posterolateral approaches was determined by the size of the tumor and amount of space provided by displacement of the neuraxis by the tumor as determined by preoperative imaging.

## MIDLINE POSTERIOR APPROACH

The patient was placed in prone position with head fixed on Mayfield head-holder. A midline vertical skin incision was taken from inion to C5 spinous process. The amount of suboccipital craniectomy and cervical laminectomy varied depending upon the rostral / caudal extent of the tumor and its size. The posterior arch of atlas was removed up to the sulcus arteriosus. The dura was opened with a Y-shaped incision. After the dura was opened, the tumor, cranial nerves, and presumed site of the vertebral artery course were identified. Dentate ligament was sectioned whenever necessary. The tumor was next isolated with cottonoid strips. Its capsule was opened and the intracapsular contents were removed in a piece-meal fashion. Upon completion of tumor resection, the site of its attachment was coagulated and the involved layer of dura was resected. No attempts were made to resect the dura widely or to excise the involved bone.

## POSTEROLATERAL APPROACH

The patient was placed in lateral position with head fixed on Mayfield head-holder. An inverted hockey-stick skin incision was used and was initiated at the mastoid process. It was then carried superiorly to the superior nuchal line, curving towards the inion and proceeding from there to the spinous process of C4. After dissecting the suboccipital muscles, a posterolateral retrocondylar suboccipital craniectomy was done, including the rim of foramen magnum and the condylar fossa. The vertebral artery was identified in its sulcus arteriosus on the posterior arch of C1, but it was neither dissected nor transposed. A laminectomy of C1 or of C1 and C2 was tailored to the caudal extent of the tumor in the upper cervical spinal canal. The dura was opened microsurgically just behind the dural entry of the vertebral artery. Whenever possible, the first two processes of the dentate ligament were sectioned before initiating tumor removal to release tension on the neuraxis and to widen surgical access to the tumor. The spinal portion of the accessory nerve, the posterior root of C1 (if present), and the posterior root of C2 lying posterior to the tumor were identified and preserved. Drilling of the posterior one-third of the occipital condyle was required in only one patient to facilitate tumor excision.

Dural closure was done primarily or with fascia lata graft.

## POSTOPERATIVE MANAGEMENT

Postoperatively, the patients were managed in neurosurgical intensive care unit. Aggressive management was instituted postoperatively (for example tracheostomy and placement of nasogastric tubes) for patients with either preop or postop lower cranial nerve deficits. Patients with uneventful recovery were discharged on the $8^{th}$ postoperative day after suture removal.

## MANAGEMENT OF RESIDUAL / RECURRENT TUMOR

We tried to get imaging (CT/ MRI) for all patients postoperatively. However, due to financial constraints, it was not possible in all the patients. If postoperative imaging (CT/ MRI) demonstrates a recurrent meningioma or a tumor remnant, we postpone surgery until neurological signs start to develop. As long as the neurological situation is stable and the patient is asymptomatic, we follow the patient closely with repeated CT / MRI examinations. Surgery for patients with recurrent or residual tumor was advised only for symptomatic patients.

# *Observations*

# OBSERVATIONS

## 1) GENDER

**Table no. 1: Gender distribution**

| Gender | No. of patients (n) | Percentage (%) |
|---|---|---|
| Male | 04 | 20 |
| Female | 16 | 80 |
| Total | 20 | 100 |

There were 16 female and four male patients in the present study, making the female to male ratio of 4:1

## 2) AGE RANGE

Most of the patients in this study aged between 31 to 60 years. The following table shows the distribution of patients in various age-groups.

**Table no. 2: Age distribution**

| Age group (years) | Male (n) | Female (n) |
|---|---|---|
| 11-20 | 02 | 00 |
| 21-30 | 00 | 01 |
| 31-40 | 01 | 04 |
| 41-50 | 01 | 06 |
| 51-60 | 00 | 04 |
| 61-70 | 00 | 01 |
| Total | 04 | 16 |

The age of the patients in the present study ranged from 18 – 68 years with an average age of 42 years.

**3) DURATION OF SYMPTOMS BEFORE PRESENTATION**

The duration of symptoms before presentation ranged from 2 months to 5 years with a mean duration of 20.8 months. The maximum duration was observed in a lady who had occipital headache since 5 years and was previously misdiagnosed as having cluster headache, while another female who had neck pain since 4 years was misdiagnosed as cervical spondylosis, thus leading to delay in correct diagnosis and appropriate management.

**4) FIRST SYMPTOM**

**Table no. 3 : First symptom**

| First Symptom | No. of patients (n) | Percentage (%) |
|---|---|---|
| Neck pain / suboccipital headache | 12 | 60 |
| Weakness | 03 | 15 |
| Numbness / paraesthesia | 03 | 15 |
| Dysphagia | 01 | 5 |
| Dyspnoea | 01 | 5 |
| Total | 20 | 100 |

The most frequent initial symptom in the present study was neck pain or suboccipital headache seen in 12 (60%) patients, while 3(15%) patients presented with limb weakness and another 3(15%) patients presented with sensory complaints like numbness and paresthesias. One patient having lower cranial nerve involvement presented with dysphagia, while another had respiratory dysfunction as the presenting complaint.

## 5) SYMPTOMATOLOGY

**Table no. 4: Symptomatology**

| Symptoms | No. of patients * (n) | Percentage (%) |
|---|---|---|
| Neck pain | 17 | 85 |
| Weakness | 17 | 85 |
| Stiffness | 16 | 80 |
| Gait unsteadiness | 12 | 60 |
| Numbness | 10 | 50 |
| Paresthesias | 11 | 55 |
| Dysesthesia (cold / burning) | 03 | 15 |
| Dysphagia | 05 | 25 |
| Nasal regurgitation | 02 | 10 |
| Dysarthria | 02 | 10 |
| Dyspnoea | 07 | 35 |
| Urinary disturbance | 08 | 40 |
| Clumsiness of limb movement | 02 | 10 |
| Cough headache | 01 | 05 |
| Flexor spasms | 01 | 05 |
| Raised ICP headache | 01 | 05 |

* More than one symptom was present in each patient

Thus the most frequent symptoms in this study were neck pain, weakness and stiffness seen in 17 (85%), 17 (85%) and 16 (80%) patients, respectively. This was followed by gait unsteadiness in 12 (60%), numbness in 10 (50%) and paresthesias in 11 (55%) patients. Urinary disturbances were observed in 8 (40%) patients, while a significant percentage of patients had dysphagia (25%) and dyspnoea (35%). Dysesthesias (cold / burning) were seen in only 15% patients. One patient had raised ICP headache.

## 6) NEUROLOGICAL FINDINGS

**Table no. 5: Neurological findings**

| Neurological findings | No. of patients | Percentage |
|---|---|---|
| **Cranial nerve deficits** | **11** | **55** |
| V | 02 | 10 |
| IX, X | 07 | 35 |
| XI | 07 | 35 |
| XII | 02 | 10 |
| **Motor deficits** | **17** | **85** |
| Tetraparesis/ plegia | 15 | 75 |
| Hemiparesis | 02 | 10 |
| **Muscle wasting** | **16** | **80** |
| Hand | 11 | 55 |
| Generalized | 04 | 20 |
| Suboccipital | 01 | 05 |
| Sensory deficits | 14 | 70 |
| Cerebellar signs | 03 | 15 |
| Gait disturbance | 10 | 50 |
| Nystagmus | 07 | 35 |
| C2 hypoesthesia | 06 | 30 |
| Respiratory dysfunction | 11 | 55 |
| Romberg's sign | 03 | 15 |
| Babinsky's sign | 15 | 75 |
| Papilledema | 01 | 05 |

Cranial nerve deficits were observed in 11 (55%) patients with involvement of IX$^{th}$ and X$^{th}$ cranial nerves in 7 (35%) patients, involvement of XI$^{th}$ cranial nerve in 7 (35%), while V$^{th}$ cranial nerve was involved in 2 (10%) and XII$^{th}$ cranial nerve was also involved in 2 (10%) patients.

Motor deficits were observed in 17 (85%) patients, with 15 (75%) patients having tetraparesis / plegia and 2 (10%) patients having hemiparesis. Muscle wasting was observed in 16 (80%) patients with 11 (55%) patients having wasting of small hand muscles, while 4 (20%) patients had generalized wasting. One patient had wasting of suboccipital muscles. Fifteen patients (75%) with motor deficit had positive Babinsky's sign. Three patients had no motor deficit at presentation.

Sensory deficit in the form of numbness was observed in 14 (70%) patients, while cerebellar signs were found in only 3 (15%) patients. A positive Romberg's sign was found in 3 (15%) patients. Gait disturbances were seen in 10 (50%) patients, while seven (35%) patients were totally bed ridden before surgery.

Eleven (55%) patients had respiratory dysfunction in the form of decreased breath holding time (B.H.T.) and single breath count (S.B.C.) and /or use of accessory muscles of respiration while breathing at rest.

C2 hypoesthesia was present in 6 (30%) patients, while nystagmus was seen in 7 (35%) patients. One patient with raised ICP headache was found to have papilledema on examination.

## 7) LOCATION OF THE TUMOR

**Table no. 6 : Location of tumor**

| Location | No. of patients (n) | Percentage (%) |
|---|---|---|
| Anterior | 06 | 30 |
| Lateral | 13 | 65 |
| Posterior | 01 | 05 |
| Total | 20 | 100 |

The most common location of the tumor in the present study was lateral, i.e. between the anterior midline and the dentate ligament, seen in 13 (65%) patients. The second commonest location was anterior, i.e. having insertion on either sides of anterior midline, seen in 6 (30%) patients.

Only one patient in the present study had a posteriorly located tumor, i.e. tumor located posterior to the dentate ligament.

## 8) RELATIONSHIP OF THE TUMOR TO VERTEBRAL ARTERY

**Table no. 7: Relationship of the tumor to vertebral artery**

| Location of tumor | Vertebral artery encased | Vertebral artery not encased | Total |
|---|---|---|---|
| Anterior | 04 | 02 | 06 |
| Lateral | 01 | 12 | 13 |
| Total | 05 | 14 | 19* |

* One patient with posterior foramen magnum meningioma not included

Out of 6 patients with anteriorly located tumors, vertebral artery was encased in 4 patients and it was not encased in 2 patients. Amongst the 13 patients with laterally located tumors, vertebral artery was encased in only one patient, while it was not encased in the remaining 12 patients. Thus, out of the total 5 patients who had encasement of vertebral artery, four patients had anteriorly located tumor and only one patient had a laterally located tumor.

## 9) RELATIONSHIP TO DURA

**Table no. 8: Relationship to dura**

| Location of tumor | Intradural | Intradural / Extradural | Total |
|---|---|---|---|
| Anterior | 06 | 00 | 06 |
| Lateral | 11 | 02 | 13 |
| Posterior | 01 | 00 | 01 |
| Total | 18 | 02 | 20 |

Out of total 20 patients, 18 (90%) patients had completely intradural tumor, while only two patients (10%) had intradural tumor with extradural extension. None of the patients had purely extradural tumor in the present study.

## 10) PULMONARY FUNCTION TEST (PFT)

**Table no. 9 : Pulmonary function test**

| PFT | No. of patients | Percentage |
|---|---|---|
| No restriction | 08 | 40 |
| Restriction | 12 | 60 |
| Mild | 01 | 05 |
| Moderate | 02 | 10 |
| Severe | 07 | 35 |
| Very severe | 02 | 10 |
| Total | 20 | 100 |

Out of the total 20 patients, 12 (60%) patients had restricted pulmonary function as seen on PFT. Amongst these 12 patients, one had mild, two patients had moderate, seven patients had severe and two patients had very severe restriction of pulmonary function.

## 11) VERTICAL EXTENT OF TUMOR

**Table no. 10: Vertical extent of tumor**

| Vertical extent of tumor | No. of patients (n) | Percentage (%) |
|---|---|---|
| Lower 1/3rd clivus to foramen magnum rim | 02 | 10 |
| Lower 1/3rd clivus to lower border of C1/ upper border of C2 | 06 | 30 |
| Lower 1/3rd clivus to lower border of C2 | 06 | 30 |
| Foramen magnum rim to lower border of C1/ upper border of C2 | 02 | 10 |
| Foramen magnum rim to lower border of C2 | 04 | 20 |
| Total | 20 | 100 |

Most of the patients had medium sized tumor with vertical extension from lower 1/3rd clivus to lower border of C1/ upper border of C2 in 6 (30%) patients and from foramen magnum rim to lower border of C2 in 4 (20%) patients. Six patients (30%) had large tumor extending from lower 1/3rd clivus to lower border of C2 , while 4 (20%) patients had small tumor, extending from lower 1/3rd clivus to foramen magnum rim in 2 patients and from foramen magnum rim to lower border of C1/ upper border of C2 in another 2 patients.

## 12) SURGICAL APPROACH AS PER LOCATION OF TUMOR

**Table no. 11: Surgical approach as per location of tumor**

| Location of tumor | Midline posterior approach (%) | Posterolateral approach | Total |
|---|---|---|---|
| Anterior | 01 (05) | 05 (25) | 06 (30) |
| Lateral | 06 (30) | 07 (35) | 13 (65) |
| Posterior | 01 (05) | 00 (00) | 01 (05) |
| Total | 08 (40) | 12 (60) | 20 (100) |

Almost all the anteriorly located tumors (5 out of 6) were operated by a posterolateral approach. Drilling of the posterior one third of the occipital condyle was required in only one of these anteriorly located tumors. In this case, the tumor was of a small size with minimum in situ retraction of the brainstem. Mobilization of the third part of the vertebral artery was not required in any of the patients in the present study.

In one bed-bound patient with tetraplegia who had severe restriction of pulmonary function, a midline posterior approach was used to remove the anteriorly located tumor to shorten the operative time. The tumor was approached from both sides of medulla and a gross total excision was achieved.

Most of laterally located tumors could also be removed by midline posterior approach. Posterolateral approach was required in 7 out of 13 patients with laterally located tumor. Two of these patients had intradural tumor with extradural extension, while in the remaining 5 patients, a posterolateral approach was required due to small size of the tumor where the space provided by tumor enlargement was relatively less.

One patient with intradural posteriorly located tumor was operated by midline posterior approach.

## 13) EXTENT OF RESECTION

**Table no. 12 : Extent of resection**

| Location of tumor | Gross Total Resection | | Subtotal Resection | | Total |
|---|---|---|---|---|---|
| | Midline posterior | Postero Lateral | Midline posterior | Postero Lateral | |
| Anterior | 01 | 05 | 00 | 00 | 06 |
| Lateral | 06 | 05 | 00 | 02 | 13 |
| Posterior | 01 | -- | -- | -- | 01 |
| Total | 08 | 10 | 00 | 02 | 20 |

Gross total resection could be achieved in 18 (90%) patients. Gross total resection was achieved in all the 6 anteriorly located tumors, while 11 (84.61%) laterally located tumors could be removed gross totally. Gross total resection could also be achieved in one patient with posteriorly located tumor by a midline posterior approach.

The two patients (10%) who underwent subtotal resection had laterally located intradural tumor with extradural extension which rendered complete resection difficult.

## 14) INTRA-OP COMPLICATIONS

Intra-op complications were noted in 4 (20%) patients. In one patient, vertebral artery got injured in the sulcus arteriosus while removing the posterior C1 arch, which was controlled with weck clips. In one patient, $XI^{th}$ nerve was coursing through the tumor and had to be sacrificed. Two patients had bleeding from large marginal venous sinuses which led to transient intra-op hypotension in one.

## 15) POST- OP VENTILATION

Post –op ventilation was required in 10 patients, out of which 8 patients were electively ventilated. One patient had generalized seizure in immediate post operative period and developed respiratory arrest. She was re-intubated and ventilated for one day. Another patient required ventilation due to poor post op respiratory effort.

**Table no. 13 : Post op ventilation**

| Reason for ventilation | No. of patients |
|---|---|
| Elective | 08 |
| Post op seizure and respiratory arrest | 01 |
| Poor respiratory effort | 01 |
| Total | 10 |

The duration of ventilation ranged from 1 day to 8 weeks with a median duration of 3 days.

## 16) TRACHEOSTOMY

Tracheostomy was required in 5 patients. Out of these, three patients underwent tracheostomy for prolonged ventilation (10 days, 36 days and 60 days). In the other two patients, tracheostomy was required because of thick oropharyngeal secretions and lower cranial nerve paresis.

## 17) POST-OPERATIVE NEUROLOGICAL STATUS

**Table no. 14: Post-operative neurological status**

| | Immediate post op | Condition at discharge |
|---|---|---|
| Improved | 04 | 11 |
| Static | 07 | 06 |
| Deteriorated | 09 | 02 |
| Total | 20 | 19 * |

*One patient expired in post –op period

In the immediate post operative period, 4 patients improved in their neurological status, while the neurological status of 7 patients remained same as pre-op. Nine patients had deterioration in their neurological status in the immediate post operative period, out of which six patients improved by the time of discharge and one patient expired on fifth post –op day due to brain stem and thalamic infarct. By the time of discharge, 11 patients had improved in their neurological status as compared to pre op status.

## 18) NEW POST OP DEFICITS

**Table no. 15 : New post op deficits**

| New post op deficits | No. of patients* |
|---|---|
| Cranial nerve paresis | 05 |
| VI$^{th}$ | 01 |
| VII$^{th}$ | 01 |
| IX$^{th}$ - X$^{th}$ | 04 |
| XI$^{th}$ | 02 |
| XII$^{th}$ | 03 |
| Motor deficits | O4 |

* More than one deficit was observed in most patients

New post op deficits were observed in 9 (45%) patients, which included motor deficits in 4 patients and cranial nerve deficits in 5 patients. The most common cranial nerve paresis seen post-operatively included IX$^{th}$ - X$^{th}$ in four patients, XII$^{th}$ nerve in three patients, and XI$^{th}$ nerve in two patients. Post op VI$^{th}$ and VII$^{th}$ cranial nerve paresis were observed in one patient each.

## 19) OTHER POST OP COMPLICATIONS

A total of 8 (40%) patients had the following post op complications.

**Table no. 16: Post op complications**

| Complications | No. of patients |
|---|---|
| Respiratory tract infection | 06 |
| Urinary tract infection | 04 |
| Septicemia | 02 |
| Pseudomeningocele | 04 |
| Wound infection | 00 |
| CSF leak from wound site | 01 |
| CSF otorrhoea | 02 |
| Meningitis | 02 |

Respiratory tract infection was the most frequent complication encountered in 6 patients. Four patients developed pseudomeningocele which was managed with drainage lumbar punctures in three patients and lumboperitoneal shunt in one patient. Two patients developed CSF otorrhoea, which was managed by lumbar drain. One patient developed CSF leak from wound site which was managed by taking additional sutures. Urinary tract infection seen in 4 patients was managed with appropriate antibiotics. One patient who underwent surgery for recurrent tumor expired after fourth surgery due to septicemia and fulminant meningitis.

## 20) DURATION OF HOSPITAL STAY

Duration of hospital stay after surgery ranged from 8 to 70 days with a mean duration of 17 days.

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|---|---|
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| Urinary tract infection | 04 |
| Septicemia | 02 |
| Pseudomeningocele | 04 |
| Wound infection | 00 |
| CSF leak from wound site | 01 |
| CSF otorrhoea | 02 |
| Meningitis | 02 |

Respiratory tract infection was the most frequent complication encountered in 6 patients. Four patients developed pseudomeningocele which was managed with drainage lumbar punctures in three patients and lumboperitoneal shunt in one patient. Two patients developed CSF otorrhoea, which was managed by lumbar drain. One patient developed CSF leak from wound site which was managed by taking additional sutures. Urinary tract infection seen in 4 patients was managed with appropriate antibiotics. One patient who underwent surgery for recurrent tumor expired after fourth surgery due to septicemia and fulminant meningitis.

## 20) DURATION OF HOSPITAL STAY

Duration of hospital stay after surgery ranged from 8 to 70 days with a mean duration of 17 days.

## 21) POST OP IMAGING

Post op imaging was done in 10 patients (CT scan in 9 patients and MRI in one patient), which showed no residual lesion in 6 patients while 4 patients had minimal residual lesion. Due to financial constraints, we could not obtain postoperative imaging for all patients.

## 22) HISTOPATHOLOGICAL TYPE

**Table no. 17 : Histopathological type**

| Histopathological type | No. of patients (n) | Percentage (%) |
|---|---|---|
| Transitional | 09 | 45 |
| Psammomatous | 07 | 35 |
| Meningothelial | 03 | 15 |
| Meningioma with papillary differentiation | 01 | 05 |
| Total | 20 | 100 |

The most common histological subtype was transitional meningioma seen in 9 (45%) patients, followed by psammomatous subtype, seen in 7 (35%) patients. Meningothelial subtype was seen in three patients and one patient had meningioma with papillary differentiation.

## 23) FOLLOW UP

Follow up was obtained in 17 (85%) patients. One patient was not available for follow-up.

The duration of follow up ranged from 2 months to 15 years with a mean follow up of 45 months. At follow-up twelve patients (70.59 %) did not have any deficit, two (11.76%) patients were moderately disabled, (one had persisting lower cranial nerve paresis and the other had quadriparesis same as pre op status). Three (17.65%) were severely disabled and bed bound (all improving from preoperative dense quadriparesis).

## 23a) OUTCOME OF PATIENTS WITH PRE OPERATIVE CRANIAL NERVE DEFICITS

**Table no. 18: Outcome of patients with pre operative cranial nerve deficits**

| Pre op deficit | No. of cases | Complete recovery | Partial recovery | No recovery |
|---|---|---|---|---|
| $V^{th}$ CN | 01 | 01 | 00 | 00 |
| $IX^{th}$-$X^{th}$ CN | 05 | 02 | 01 | 02 |
| $XI^{th}$ CN | 06 | 04 | 02 | 00 |
| $XII^{th}$ CN | 01 | 00 | 00 | 01 |
| Total | 13 | 07 | 03 | 03 |

Data from 17 patients available for follow up

Of the 13 instances of the pre-operative cranial nerve dysfunction, complete or partial recovery occurred in 10, while no recovery was seen in 3 instances.

## 23b) OUTCOME OF PATIENTS WITH PRE OPERATIVE NEUROLOGICAL (EXCLUDING CRANIAL NERVE) DEFICITS

**Table no. 19 : Outcome of patients with pre operative neurological (excluding cranial nerve) deficits**

| Preop Deficit | No. of cases | Improved | Same as pre-op | Worsened |
|---|---|---|---|---|
| Hemiparesis | 02 | 02 | 00 | 00 |
| Tetraparesis | 10 | 07 | 03 | 00 |
| Tetraplegia | 03 | 02 | 01 | 00 |
| Sensory deficit | 12 | 12 | 00 | 00 |
| Cerebellar deficits | 03 | 02 | 01 | 00 |

Data from 17 patients available for follow up

Fifteen patients presented with preoperative motor deficit. Two of these presenting with hemiparesis recovered completely. Of the ten patients presenting with tetraparesis, 7 patients recovered completely and 3 patients had their motor power same as pre-op at the last follow up examination. Out of the 3 patients presenting with tetraplegia, two recovered completely. All the 12 patients presented with pre-op sensory deficits had complete resolution. Cerebellar signs improved in 2 patients, while remained same as preop in one patient.

## 23c) OUTCOME OF PATIENTS WITH NEW POST OPERATIVE NEUROLOGICAL DEFICITS

**Table no. 20: Outcome of patients with new post operative neurological deficits**

| Post - op Deficit | No. of cases | Complete Recovery | Partial Recovery | No Recovery |
|---|---|---|---|---|
| $VI^{th}$ CN | 01 | 01 | 00 | 00 |
| $VII^{th}$ CN | 01 | 01 | 00 | 00 |
| $IX^{th}$-$X^{th}$ CN | 03 | 02 | 01 | 00 |
| $XI^{th}$ CN | 01 | 00 | 00 | 01 |
| $XII^{th}$ CN | 03 | 02 | 01 | 00 |
| Motor deficits | 03 | 03 | 00 | 00 |

Data from 17 patients available for follow up

In the present study, out of the 5 patients who sustained post operative fresh cranial nerve deficits, three patients made complete recovery; one patient had only partial recovery of $IX^{th}$, $X^{th}$ and $XII^{th}$ cranial nerves while one patient in whom the $XI^{th}$ nerve was sacrificed during tumor removal showed no recovery. All the three patients who sustained post operative hemiparesis had complete resolution of their deficits at the last follow up examination.

## 24) OPERATIVE MORTALITY

In the present study, out of the 20 patients who underwent surgery, we had one (5%) operative mortality. This patient was operated for a large anterior foramen magnum meningioma and was electively ventilated after surgery. She developed pupillary asymmetry on first post op day. Her CT scan showed cerebral edema with brainstem and bilateral thalamic infarcts with hydrocephalus. An external ventriculostomy was done and she was continued on ventilation, but she expired fifth post operative day.

## 25) FOLLOW UP IMAGING AND RECURRENCE

Due to financial constraints, follow up imaging could be done in only 6 patients (CT scan in 5 patients and MRI in one patient).

Out of these 6 patients who underwent follow up imaging, two patients had already undergone post op imaging showing small residual lesion. Follow up imaging for both these patients showed no increase in size of the residual lesion.

Amongst the remaining 4 patients who underwent follow up imaging, three patients showed recurrent lesion. Out of these 3 patients with recurrent lesion, two patients were absolutely asymptomatic, while one patient with symptomatic recurrences underwent re-exploration three times, 2 ½, 3 and 10 years after first surgery, expired after fourth surgery due to septicemia and meningitis.

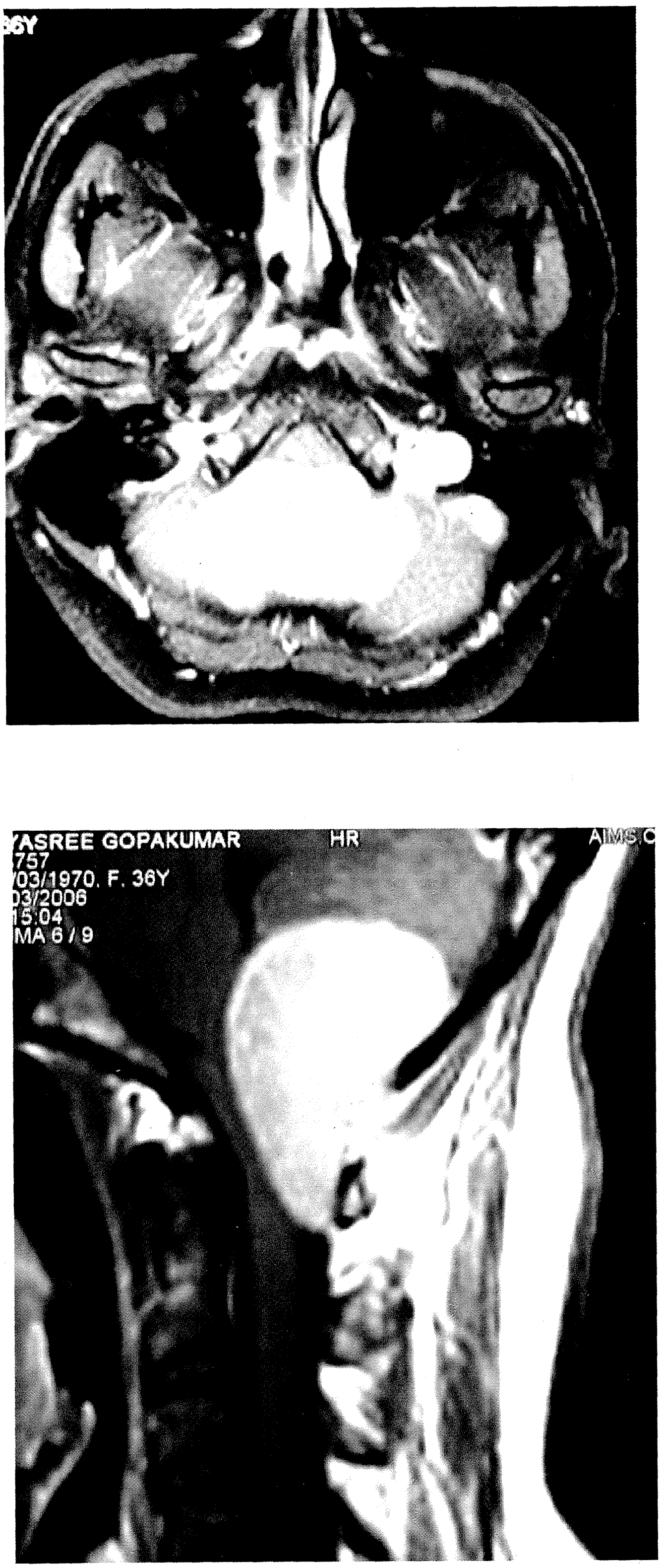



Fig. 13 : Post contrast MRI (Axial and Sagittal) of a patient with posterior foramen magnum meningioma

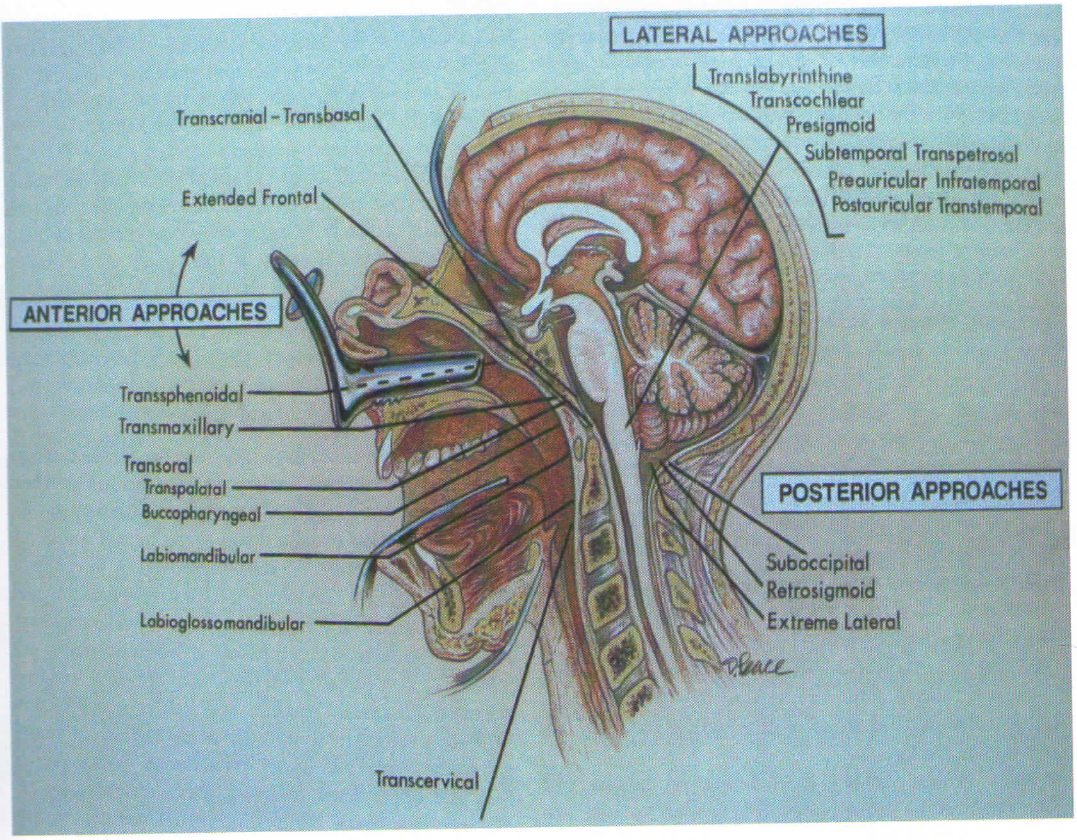
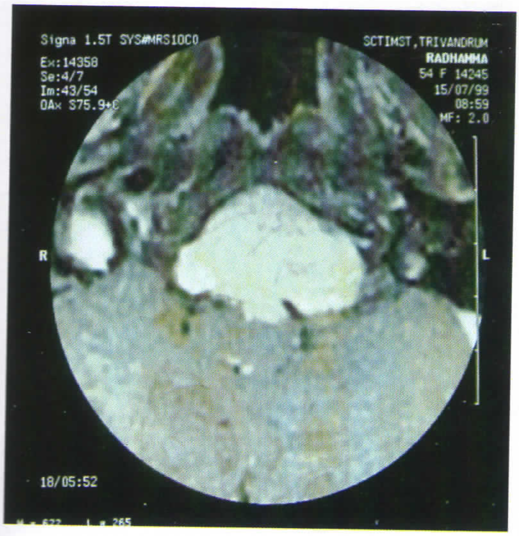



Fig.1: Approaches to foramen magnum

[From ref. no. 71]




Anterior

Lateral

Posterior

Fig. 3 : Post contrast axial MR images showing location of foramen magnum meningiomas in relation to neuraxis

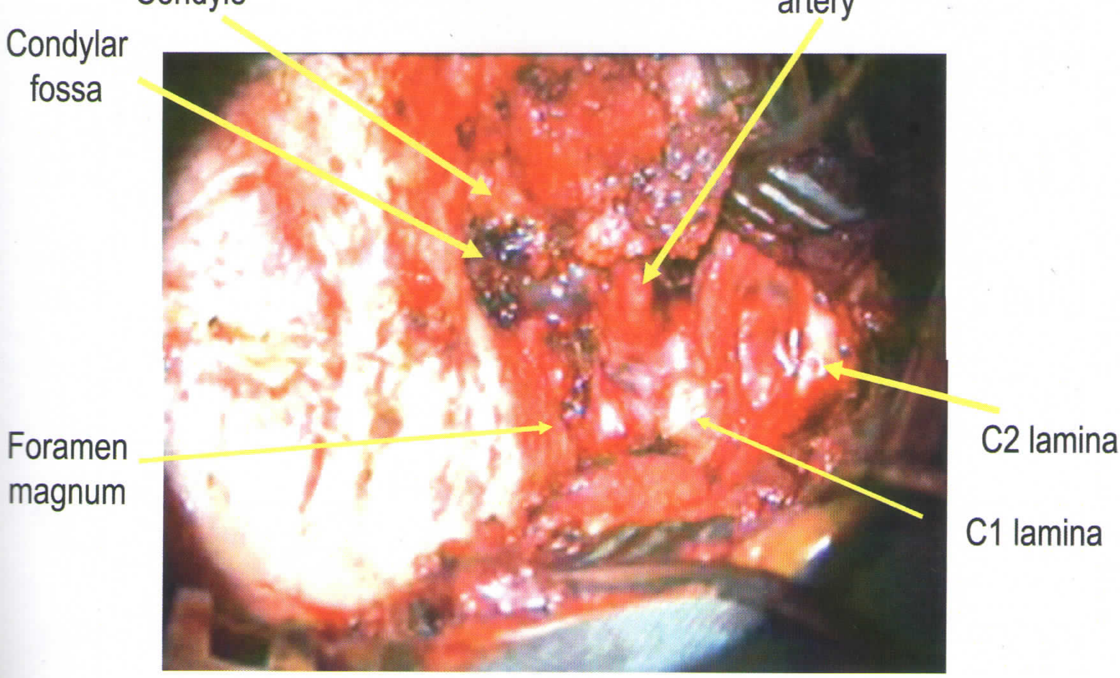



Fig. 4: Intraoperative photograph showing exposure for a posterolateral retrocondylar approach

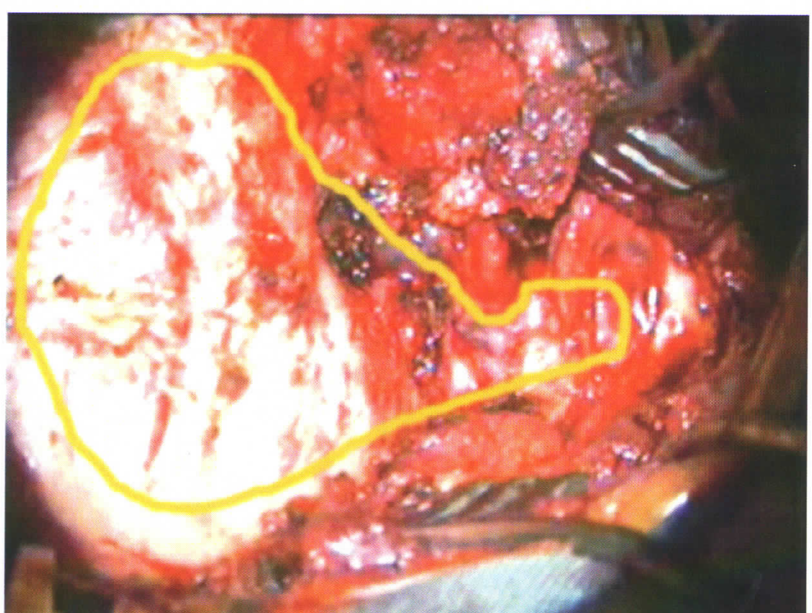


Fig. 5: Intraoperative photograph showing the limits of bone removal for a posterolateral retrocondylar approach.
Bone removal includes condylar fossa and C1 lamina

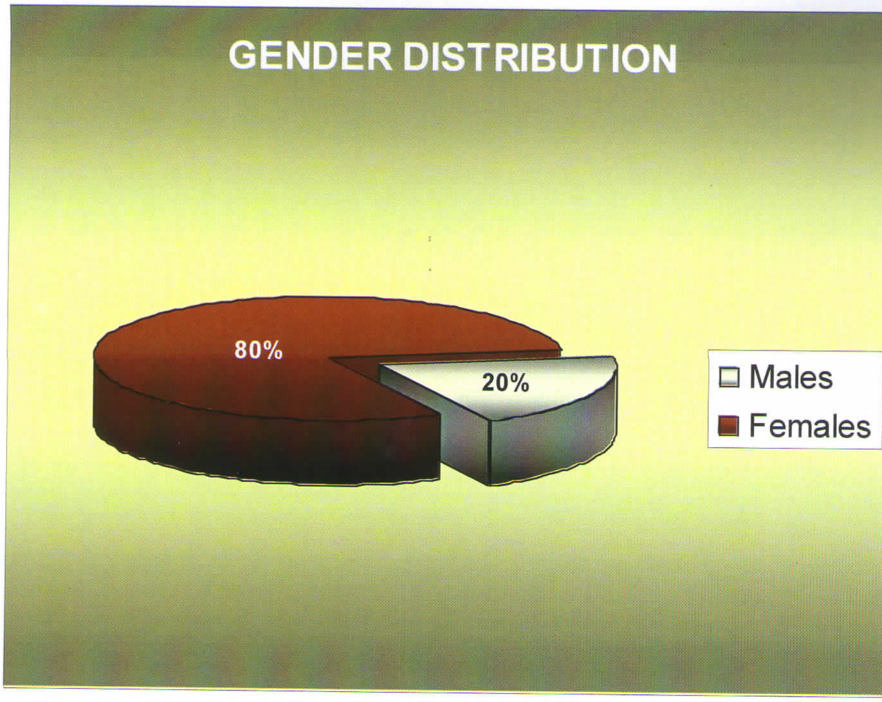



**Fig. 6: Gender distribution of patients**

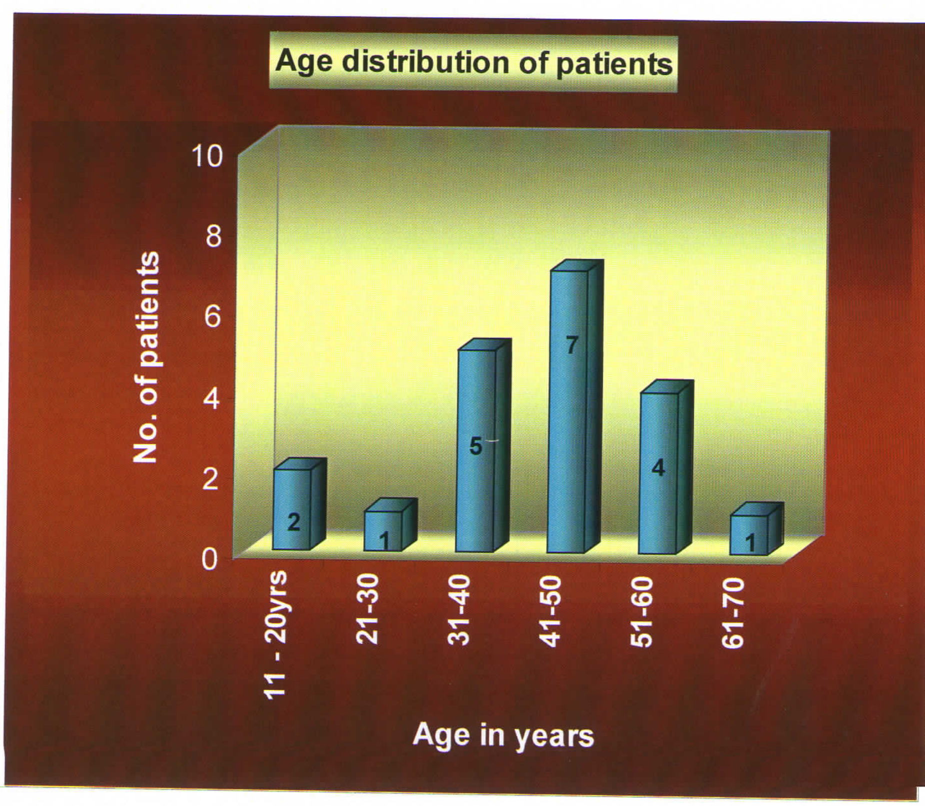



**Fig.7: Age distribution of patients**

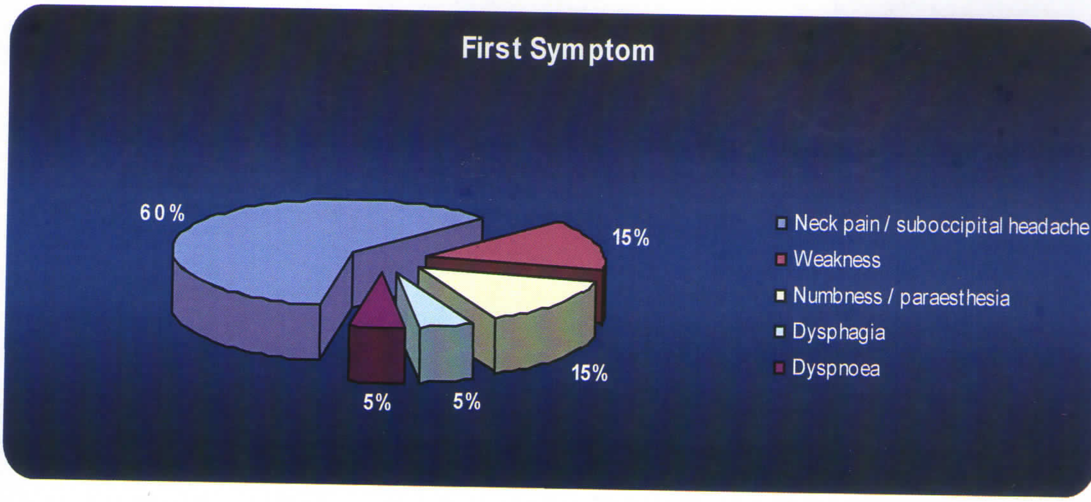



**Fig.8: Frequency of first symptom**

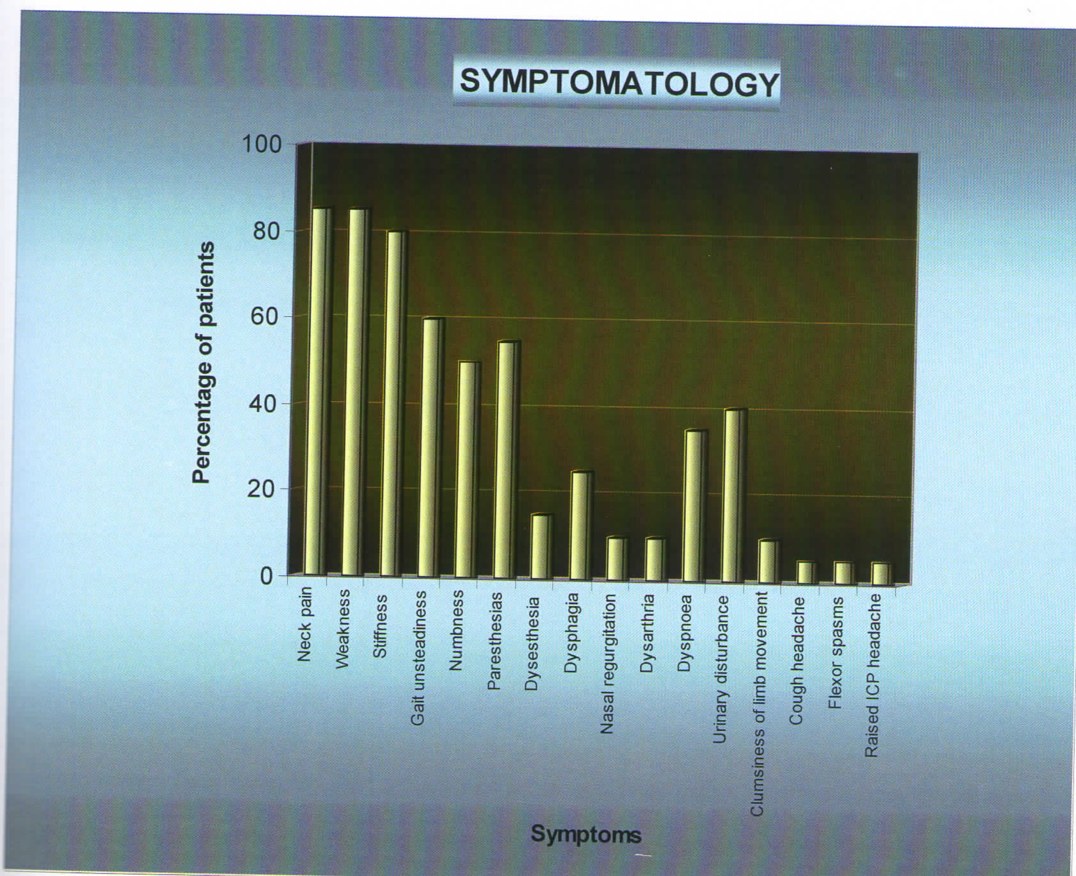



**Fig.9: Incidence of various symptoms**

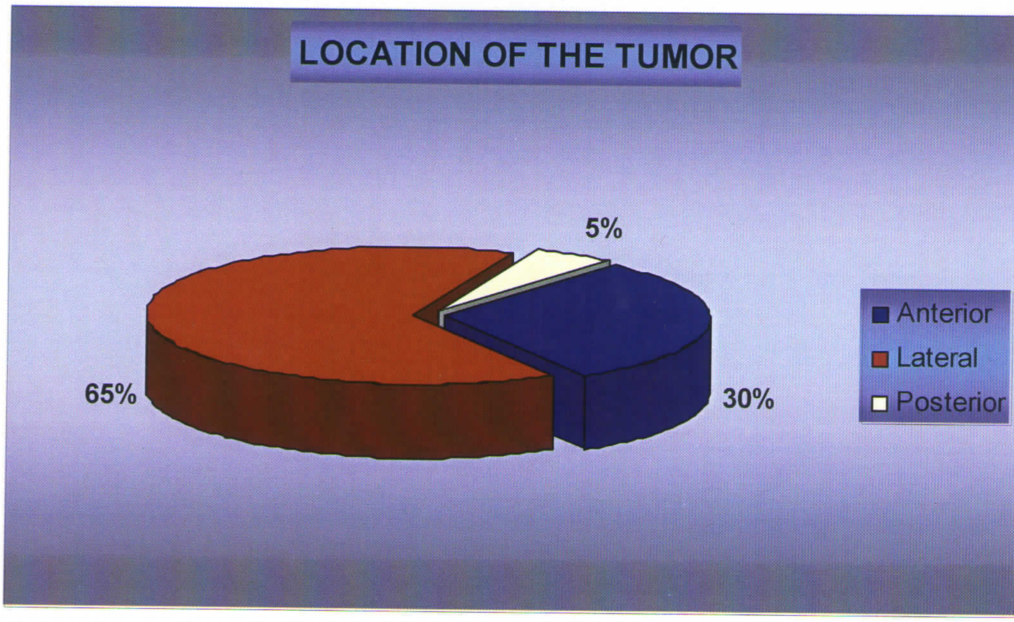



**Fig.10: Tumor location in relation to the neuraxis**

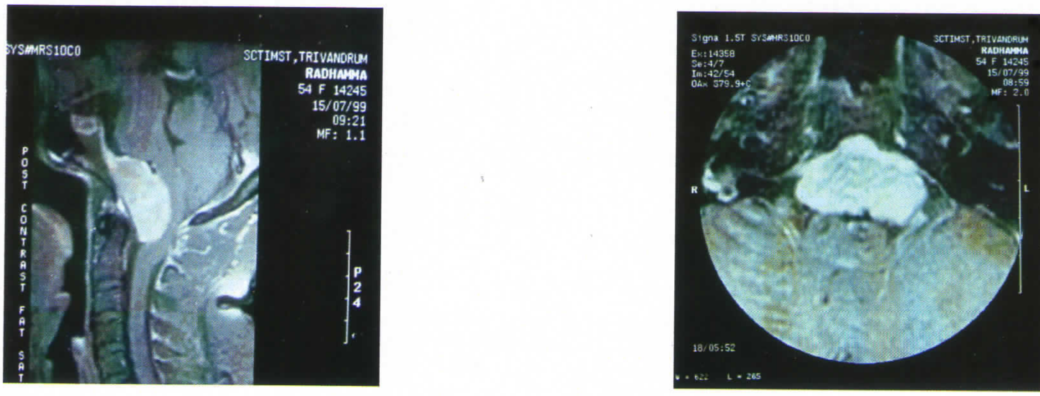



Fig. 11 a : Post contrast MRI of a patient with large anterior foramen magnum meningioma

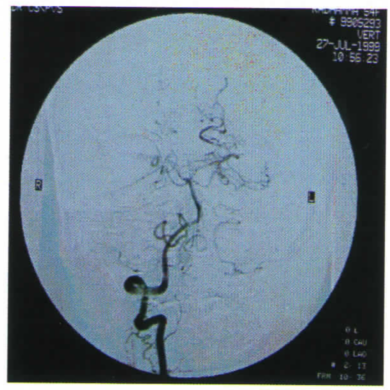


Fig. 11 b : DSA showing the right vertebral artery narrowed due to encasement by tumor

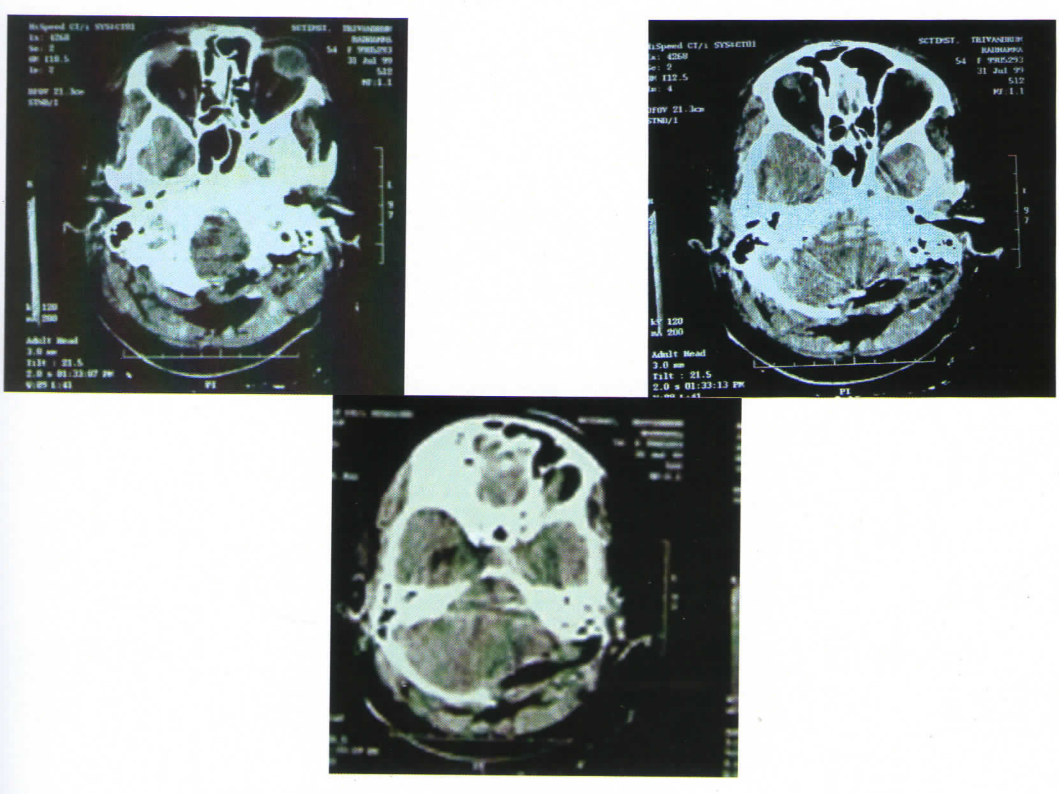


Fig. 11 c : Post op CT scan after left posterolateral retrocondylar approach showing no residual lesion

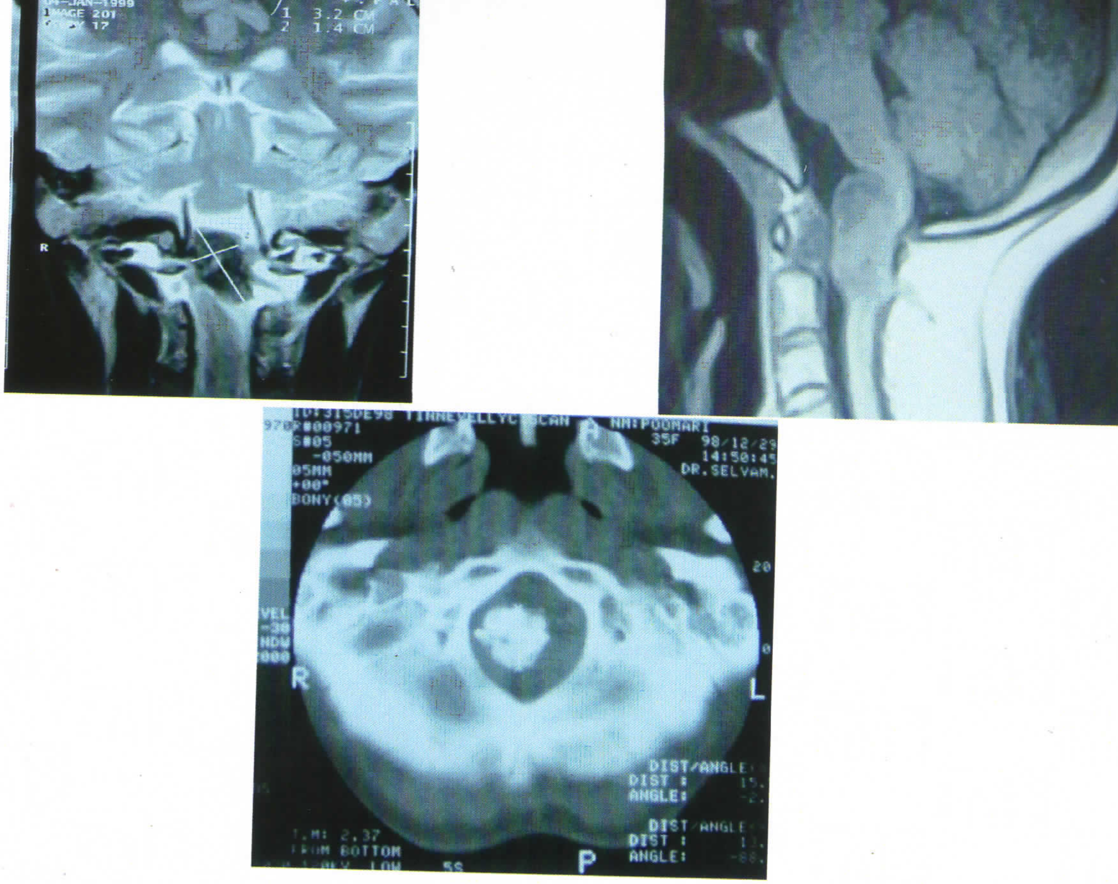



Fig. 12 a : Preop imaging of a patient with right lateral foramen magnum meningioma.

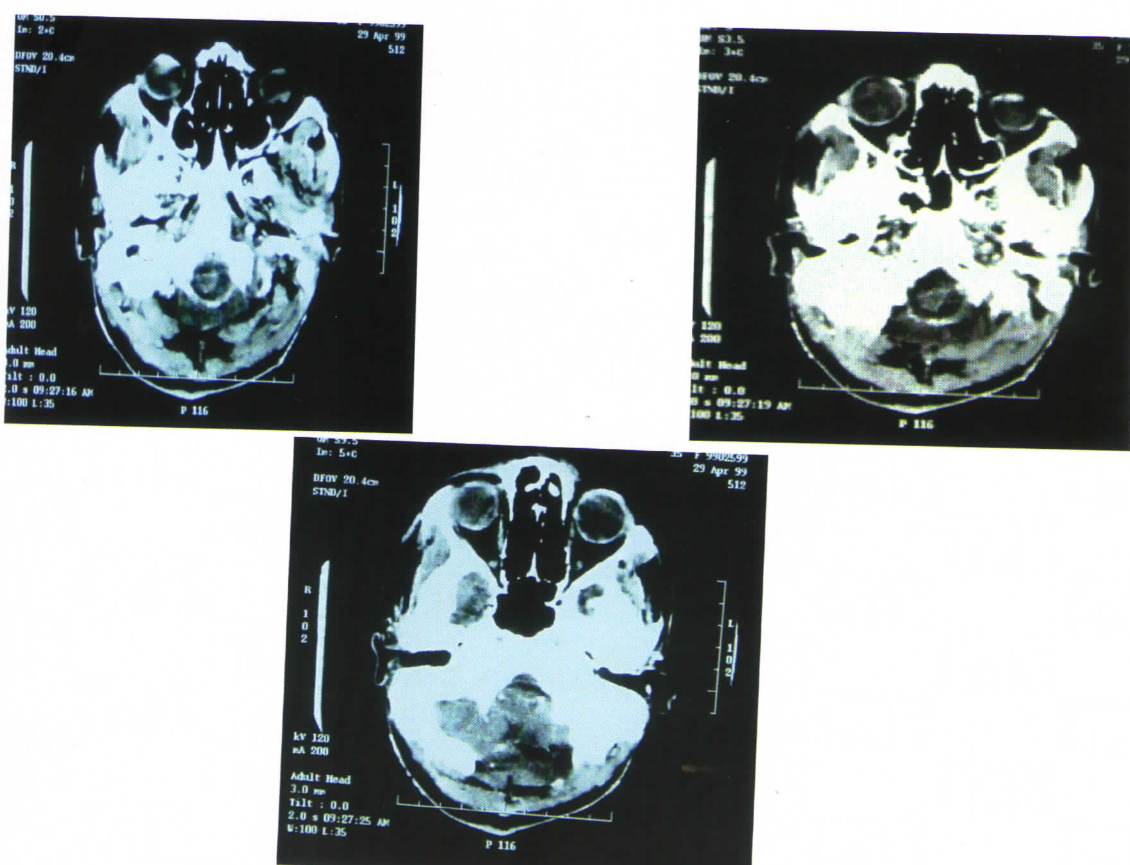



Fig. 12 b : Post op CT scan after midline posterior suboccipital approach showing no residual tumor.

# *Discussion*

# DISCUSSION

## 1. GENDER

**Table no. 1: Gender distribution**

| Gender | Present study (n) | **George B (1997)[22]** |
|---|---|---|
| Male | 04 | 16 |
| Female | 16 | 59 |
| Total | 20 | 75 |

The sex distribution of foramen magnum meningiomas is similar to sex distribution of meningiomas at other locations. [78] The female to male ratio in the present study was 4:1. In the series of **George B (1997)** [22] consisting of 75 foramen magnum meningiomas, there were 59 females and 16 males making the F: M ratio of 3.6: 1.

## 2. AGE RANGE

**Table no. 2: Age distribution**

| | **Age range (years)** | **Average age (years)** |
|---|---|---|
| **Present study** | 18 – 68 | 42 |
| **Meyer et al (1984)[25]** | 12 – 18 | 49 |
| **George B (1997)[22]** | 14 – 76 | 52 |
| **Samii et al (1996)[100]** | 17 – 74 | 49 |

The age of the patients in the present study ranged from 18 – 68 years with an average age of 42 years. This correlates with the observations by **Meyer et al (1984)** [25], **George B (1997)** [22] **and Samii et al (1996)** [100].

Most of the patients in this study aged between 31 to 60 years which also correlates with the analysis done by **Scott and Rhoton (1991)** [2].

## 3) DURATION OF SYMPTOMS BEFORE PRESENTATION

**Table no. 3: Duration of symptoms before presentation**

| | Mean duration (months) | Range (months) |
|---|---|---|
| **Present study** | 20.8 | 2 – 60 |
| **Yasuoka et al (1978)** [24] | 24 | --- |
| **Guidetti and Spallone (1980)**[21] | 42 | 3 – 156 |
| **Meyer et al (1984)**[25] | 27 | 5 – 66 |
| **George B (1997)**[22] | 9 | 1 – 18 |

The duration of symptoms before presentation in the present study ranged from 2 months to 5 years with a mean duration of 20.8 months. **Yasuoka et al (1978)** [24] reported a mean duration of 24 months between the onset of symptoms and surgery. **Meyer et al (1984)** [25] in their series on 102 cases of benign tumors of the foramen magnum, observed that the time from appearance of initial symptom to diagnosis and treatment ranged from 5 months to 6½ years, the average being 27 months. Similarly, **Guidetti and Spallone (1980)** [21] reported a delay in diagnosis and treatment for benign extramedullary tumors in the region of foramen magnum ranging from 3 months to 13 years (mean 3½ years). All these observations attest the statement made by **Dodge et al (1956)** [16] who felt that the "CSF cisterns of the foramen magnum region allow room for steady continued growth and displacement of adjacent neurologic structures to a sometimes marked degree before the limit of this tolerance is reached or before the continued presence of the growing tumor causes impingement of the adjacent neural tissue against some hard unyielding surface."

In the present study, the maximum duration observed was 5 years in a lady who was previously misdiagnosed as having cluster headache, while in another female, it was 4 years and she was previously misdiagnosed as cervical spondylosis. The literature on foramen magnum meningioma is replete with reports of erroneous diagnoses such as multiple sclerosis, cervical spondylosis, syringomyelia, intramedullary tumor, carpal tunnel syndrome and even normal pressure hydrocephalus. [24, 25,32,33,35]

**George B (1997)** [22] reported a mean duration of 9 months (range 1 – 18 months) between onset of symptoms and diagnosis. He attributed the shorter interval to the prompt use of CT and MRI to investigate all cases.

## 4) FIRST SYMPTOM

**Table no. 4: First symptom (Present study)**

| First Symptom | No. of Patients (n) | Percentage (%) |
|---|---|---|
| Neck pain / suboccipital headache | 12 | 60 |
| Weakness | 03 | 15 |
| Numbness / paraesthesia | 03 | 15 |
| Dysphagia | 01 | 5 |
| Dyspnoea | 01 | 5 |
| Total | 20 | 100 |

**Cohen L (1975)** [1] reported that pain in the suboccipital and posterior cervical region on the side of the tumor is either the first symptom or is an early and prominent complaint. **Yasuoka et al (1978)** [24] reported suboccipital or neck pain as an initial symptom in 49.1%, weakness in 5.3%, dysesthesias of extremities in 38.6% and dysphagia in 1.8 %. Similarly, **Guidetti and Spallone (1980)** [21] also reported suboccipital or neck pain in 72.2 % and cold dysesthesia in 16.6% as the first symptom. They also reported weakness of extremities in 44.4% and paresthesias in 27.7% as the early symptoms. The observations in the present study correlate well with those of the above mentioned series. **Gupta et al (2004)** [96] in their series on 27 patients with benign lesions of the foramen magnum, reported 3 patients who were in respiratory distress needing ventilatory support at the time of admission. In the present study, one patient having lower cranial nerve involvement presented with mild respiratory dysfunction necessitating early surgery.

## 5) SYMPTOMATOLOGY

**Table no. 5 : Symptomatology**

| Symptoms | Present study (n=20) (%) | Dodge et al (1956) [16] (n=30) (%) | Yasuoka et al (1978) [24] (n=57) (%) | Guidetti & Spallone (1980) [21] (n = 18) (%) | Meyer et al (1984)[25] (n=102) (%) | Arnautovic et al (2000) [4] (n = 18) (%) |
|---|---|---|---|---|---|---|
| Neck pain | 85 | 66.66 | 75.4 | 100 | 65.7 | 72 |
| Weakness | 85 | 86.66 | 91.2 | 88.8 | 67.6 | 28 |
| Gait unsteadiness | 60 | 40 | 47.4 | _ | 49 | 33 |
| Numbness | 50 | _ | 94.7 | 27.77 | 58.8 | 50 |
| Paresthesias | 55 | 86.66 | _ | 38.88 | _ | _ |
| Dysesthesia | 15 | _ | 19.2 | 55.55 | 7.0 | _ |
| Dysphagia | 25 | 30 | _ | 11.1 | 12.8 | 33 |
| Dysarthria | 10 | _ | _ | 16.6 | 2.9 | 06 |
| Dyspnoea | 35 | 20 | _ | 27.7 | 5.9 | _ |
| Urinary disturbance | 40 | _ | 33.3 | 38.8 | 21.6 | _ |
| Clumsiness | 10 | _ | 42.1 | _ | 26.5 | 06 |
| Cough headache | 05 | _ | _ | _ | 10.8 | _ |
| Flexor spasms | 05 | _ | 15.8 | _ | _ | _ |
| Raised ICP headache | 05 | _ | _ | 27.7 | _ | 06 |

In most of the series including the present one, suboccipital / posterior cervical pain is the earliest and the most frequent symptom, ranging from 65% – 100%[4,16,21,24,25]. A feeling of weakness of one or more extremities was also one of the most frequent presenting symptoms in the present study. This correlates well with the reports of **Dodge et al (1956)** [16], **Yasuoka et al (1978)** [24], **Guidetti & Spallone (1980)** [21] **and Meyer et al (1984)** [25]. Twelve (60%) patients complained of "unsteady" gait or difficulty in walking on rough terrain. Gait unsteadiness was usually the combination of ataxic gait and spastic gait. The incidence of gait unsteadiness reported in various series ranges from 33% – 49%.[4, 16, 24, 25]

Numbness or a tingling sensation in the hands and fingers were recorded in 10 cases (50%). These symptoms were of gradual onset and generally were of a constant nature. The frequency of numbness described in various reports is highly variable ranging from 27% - 94%[4, 21, 24, 25]. Cold dysesthesia commonly described as one of the classical symptoms of extramedullary tumors in the region of foramen magnum [2, 30, 32], was observed in only one patient while two patients complained of burning dysesthesia.

Symptoms suggestive of lower cranial nerve deficits such as dysphagia and dysarthria were observed in 25% and 10% patients respectively in this study [4, 21, 25]. This correlates with the frequency reported in most of the series. Respiratory distress was observed in 35% patients. Respiratory failure may result from compression of the medullary respiratory centers, diaphragmatic paralysis from tumor involvement of the C2, C3 and C4 nerve roots, or impairment of the gag reflex and vocal cord paralysis from injury to vagus and glossopharyngeal nerves. [25]

Similarly the incidence of bladder disturbance (40%) also correlated with that reported in the above mentioned series.[21, 24]

Hand clumsiness or astereognosis was described in 10% of the patients, often noticed first by decreased writing ability or difficulty in buttoning clothes. These symptoms occurred before weakness or hypoesthesia was manifest, and results of neurological examination at this point usually were essentially negative except for indicating minimal weakness or sensory loss in the hands.

## 6) NEUROLOGICAL FINDINGS

**Table no. 6: Neurological findings**

| **Neurological deficits** | Present study (n = 20) (%) | Stein et al (1963) [17] (n = 25) (%) | Yasuoka et al (1978) [24] (n = 57) (%) | Guidetti & Spallone (1980) [21] (n = 18) (%) | Meyer et al (1984) [25] (n =102) (%) | Gupta et al (2004) [96] (n=13) (%) |
|---|---|---|---|---|---|---|
| **Cranial nerve** | **55** | **72** | – | **55.5** | **56.86** | **30.77** |
| V | 10 | 16 | -- | 16.66 | 5.9 | -- |
| IX, X | 35 | 44 | 6.4 | 16.66 | 13.6 | 23.08 |
| XI | 35 | 44 | 31.9 | 33.33 | 27.8 | -- |
| XII | 10 | 4 | 4.3 | 5.55 | 7.8 | 7.69 |
| **Motor deficits** | **85** | **96** | **68.1** | **94.4** | **67.6** | **92.31** |
| Tetraparesis/ plegia | 75 | 80 | 25.5 | 27.7 | 14.7 | 76.92 |
| Hemiparesis | 10 | 16 | 14.9 | 44.4 | 13.7 | -- |
| **Muscle wasting** | **80** | -- | -- | -- | -- | -- |
| Hand | 55 | 52 | 17 | 38.8 | 12.8 | 30.77 |
| Generalized | 20 | -- | -- | -- | -- | -- |
| Suboccipital | 5 | 12 | -- | -- | -- | -- |
| Sensory deficits | 70 | 60 | 80.35 | 94.4 | -- | 61.54 |
| Cerebellar signs | 15 | 20 | 0.00 | 16.6 | 37.3 | 23.08 |
| Gait disturbance | 50 | -- | 40.4 | -- | 46.6 | -- |
| Nystagmus | 35 | 28 | 12.8 | 50 | 24.5 | -- |
| C2 hypoesthesia | 30 | -- | 34 | 33.3 | 17.6 | -- |
| Babinsky's sign | 75 | -- | 57.4 | -- | 57.8 | -- |
| Papilledema | 5 | 4 | 0.00 | 11.1 | 6.8 | 7.69 |

## 6) NEUROLOGICAL FINDINGS

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| Hand | 55 | 52 | 17 | 38.8 | 12.8 | 30.77 |
| Generalized | 20 | -- | -- | -- | -- | -- |
| Suboccipital | 5 | 12 | -- | -- | -- | -- |
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| Cerebellar signs | 15 | 20 | 0.00 | 16.6 | 37.3 | 23.08 |
| Gait disturbance | 50 | -- | 40.4 | -- | 46.6 | -- |
| Nystagmus | 35 | 28 | 12.8 | 50 | 24.5 | -- |
| C2 hypoesthesia | 30 | -- | 34 | 33.3 | 17.6 | -- |
| Babinsky's sign | 75 | -- | 57.4 | -- | 57.8 | -- |
| Papilledema | 5 | 4 | 0.00 | 11.1 | 6.8 | 7.69 |

In the present study, cranial nerve involvement included V$^{th}$ cranial nerve deficits secondary to compression of the descending sensory tract in the brainstem in 10% of cases. Eleventh cranial nerve compromise was seen in impressive 35% patients. Also, 35% patients presented with IX$^{th}$-X$^{th}$ cranial nerve deficits, while 10% patients had XII$^{th}$ cranial nerve deficit. **Meyer et al(1984)** [25] suggested that XI$^{th}$ cranial nerve involvement is highly indicative of a foramen magnum tumor, especially if X$^{th}$ cranial nerve function is normal, thereby eliminating the possibility of jugular foramen lesions. The incidence of cranial nerve deficits in the present study correlates with that in most of the above-mentioned series.[17, 21,24,25,96]

Motor deficits including hemiparesis and tetraparesis / plegia were observed in 85% of patients in this study. Three (15%) patients had no motor deficits at the time of presentation. Seven (35%) patients were bed bound before surgery. **Yasuoka et al (1978)** [24] suggested a clinical pattern of weakness in which the deficit begins first with paresis of an upper extremity. However in our review, the patients presented with either hemiparesis or tetraparesis. Atrophy of intrinsic hand muscles occurred in 55% patients, the exact mechanism of which remains controversial.

Cerebellar signs were noted in only 15% patients. **Stein et al (1963)**[17] noted that there is a distinct paucity of cerebellar findings unless the tumor has a large posterior fossa component.

The incidence of sensory deficits in most series ranges from 60% to 94%.[17,21,24,96] In this study, 70% patients had sensory deficits at presentation, while C2 hypoesthesia was found in 30% cases, which correlates with the findings of other series. [21,24]

Nystagmus was seen in 35% of cases. All the patients had horizontal nystagmus. No patient had upbeat or downbeat nystagmus. **Stein (1985)** [59] attributes this finding to "pressure on the sulco marginal fibres which are an extension of the medial longitudinal fasciculus.

One patient with a large posterior foramen magnum meningioma presented with raised ICP headache and had papilledema on examination.

## 7) LOCATION OF THE TUMOR

**Table no. 7: Location of tumor**

| | n | Anterior | Lateral / Anterolateral | Posterior / Posterolateral |
|---|---|---|---|---|
| Present study | 20 | 06 (30%) | 13 (65%) | 01 (5%) |
| **Castellano and Ruggiero (1953)** [20] | 24 | 13 (54.2%) | 7 (29.2%) | 4 (16.7%) |
| **Stein et al (1963)** [17] | 25 | 1 (4%) | 21 (84%) | 3 (12%) |
| **Meyer et al (1984)** [25] | *102 | 61 (60%) | 20 (19.5%) | 21 (20.5%) |
| **Guidetti and Spallone (1988)** [32] | 17 | 4 (23.5%) | 10 (58.8%) | 3 (17.6%) |
| **French Cooperative study (1995)** [112] | 106 | 33 (31.13%) | 59 (55.66%) | 14 (13.21%) |
| **George B (1997)** [22] | 51 | 24 (47.06%) | 26 (50.98%) | 1 (1.96%) |

*Includes 23 neurofibromas , 1 teratoma.

In the present study the most common location of foramen magnum meningioma was lateral which correlates with the reports of **Stein et al (1963)** [17], **Guidetti and Spallone (1988)** [32], **French Cooperative study (1995)** [112], **and George B (1997)** [22]. Ventral meningioma comprised the second most common location in this series, although **Meyer et al (1984)** [25] and **Castellano and Ruggiero (1953)**[20] found it to be the most common location. In all the series including the present one, posterior location is the least common site for foramen magnum meningiomas.

## 8) RELATIONSHIP OF THE TUMOR TO VERTEBRAL ARTERY

**Table no. 8: Relationship of the tumor to vertebral artery (Present study)**

| Location of tumor | Vertebral artery encased | Vertebral artery not encased | Total |
|---|---|---|---|
| Anterior | 04 | 02 | 06 |
| Lateral | 01 | 12 | 13 |
| Total | 05 | 14 | 19* |

* One patient with posterior foramen magnum meningioma not included

Encasement of the vertebral artery was observed in 40 to 48% of the cases in different reports [22,97,100] and was an independent predictor for incomplete tumor removal in some series [100,112]. The vertebral artery was encased by the meningioma in 25% of our patients. However all these tumors could be removed safely along an arachnoid dissection plane. Most anterior or ventral meningiomas were particularly adherent at the dural entrance zone of the vertebral artery because this area was notoriously devoid of an arachnoid cleavage plane. The tumor was coagulated in this area using low-current bipolar coagulation.

## 9) RELATIONSHIP TO DURA

**Table no. 9 : Relationship to dura (Present study)**

| Location of tumor | Intradural (%) | Intradural / Extradural (%) | Total (%) |
|---|---|---|---|
| Anterior | 06 (30) | 00 | 06(30) |
| Lateral | 11(55) | 02(10) | 13(65) |
| Posterior | 01(05) | 00 | 01(05) |
| Total | 18(90) | 02(10) | 20(100) |

Most meningiomas grow in the intradural compartment, while few cases are extradural or intraextradural. **George B et al (1997)** [22] in their series on 40 cases of foramen magnum meningiomas reported 6 (15%) cases of with extradural extension. Two (5%) of these were completely extradural, while the four (10%) others were intra-extradural meningiomas, all of which featured invasion of bone and cervical soft tissues. In the present study, 18 (90%) patients had completely intradural tumor. Two patients (10%) had intradural tumor with extradural extension. None of the patients had purely extradural tumor in the present study.

## 10)PULMONARY FUNCTION TEST (PFT)

**Table no. 10 : Pulmonary function test (Present study)**

| PFT | No. of patients (%) |
|---|---|
| No restriction | 08 (40) |
| Restriction | 12 (60) |
| Mild | 01(05) |
| Moderate | 02 (10) |
| Severe | 07 (35) |
| Very severe | 02 (10) |
| Total | 20 (100) |

Respiratory disturbances typically arise late in the clinical course of foramen magnum meningioma [2] .The majority of patients in early reports succumbed to pulmonary complications [16]. In the present study, out of the total 20 patients, 12 (60%) patients had restricted pulmonary function as seen on PFT. Amongst these 12 patients, one had mild, two had moderate, 7 patients had severe and two patients had very severe restriction of pulmonary function.

Respiratory failure may result from compression of the medullary respiratory centers, diaphragmatic paralysis from tumor involvement of the C2, C3 and C4 nerve roots, or impairment of the gag reflex and vocal cord paralysis from injury to vagus and glossopharyngeal nerves. [25]

**Gupta et al (2004)** [96] in their series on 27 patients with benign lesions at the foramen magnum, reported 3 patients who were in respiratory distress needing ventilatory support at the time of admission. In the present study, one patient having lower cranial nerve involvement presented with mild respiratory dysfunction necessitating early surgery.

## 11)VERTICAL EXTENT OF TUMOR

**Table no. 11 : Vertical extent of tumor**

| Vertical extent of tumor | Present study (n=20) (%) | **Bassiouni et al (2006)[113] (n=25) (%)** |
|---|---|---|
| Lower 1/3rd clivus to foramen magnum rim | 10 | 0.0 |
| Lower 1/3rd clivus to lower border of C1/ upper border of C2 | 30 | 16 |
| Lower 1/3rd clivus to lower border of C2 | 30 | 32 |
| Foramen magnum rim to lower border of C1/ upper border of C2 | 10 | 04 |
| Foramen magnum rim to lower border of C2 | 20 | 48 |
| Total | 100 | 100 |

In the present study, most of the patients had medium sized tumor with vertical extension from lower 1/3rd clivus to lower border of C1 / upper border of C2 in 6 (30%) patients and from foramen magnum rim to lower border of C2 in 4 (20%) patients. Six patients (30 %) had large tumor extending from lower 1/3rd clivus to lower border of C2 , while 4 (20%) patients had small tumor, extending from lower 1/3rd clivus to foramen magnum rim in 2 patients and from foramen magnum rim to lower border of C1/ upper border of C2 in another 2 patients. A search in literature on foramen magnum meningiomas revealed only one study classifying the size of the tumor on the basis of vertical extent [113]. However, the impact of vertical extent of the tumor on completeness of surgical excision is not mentioned even in this series. Most of the studies on surgical outcome of foramen magnum meningioma have considered the size of the tumor in antero-posterior dimension and / or extradural extension. [22]

Although both the patients in the present study who underwent subtotal resection had medium or large sized tumor as determined by the vertical extent, it seems likely that the vertical extent does not influence the completeness of surgical excision, which can be achieved by simply increasing the extent of cervical laminectomy.

## 12)SURGICAL APPROACH AS PER LOCATION OF TUMOR

**Table no. 12: Surgical approach as per location of tumor (Present study)**

| Location of tumor | Midline posterior approach (%) | Posterolateral approach (%) | Total (%) |
|---|---|---|---|
| Anterior | 01 (05) | 05 (25) | 06 (30) |
| Lateral | 06 (30) | 07 (35) | 13 (65) |
| Posterior | 01 (05) | 00 (00) | 01 (05) |
| Total | 08 (40) | 12 (60) | 20 (100) |

**Boulton and Cusimano (2003)** [68] suggested that 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. They found that most tumors, once advanced enough to produce symptoms, have at least an adequate corridor. Because the majority of foramen magnum meningiomas are anterolaterally situated, their growth tends to displace the brainstem in a posterior and contralateral direction. They suggested that this in situ retraction creates an adequate surgical corridor for resection of most of these lesions. They reported that in their series, no drilling of the occipital condyle was necessary to achieve resection, and in the cases in which residual tumor remained, resection of the condyle would not have affected the degree of resection.

Although most investigators would agree that posterior and posterolateral foramen magnum meningiomas can safely be resected via a midline suboccipital approach, considerable controversy exists regarding optimal treatment of tumors located on the ventral aspect of the foramen magnum. **Heros (1986)** [87] described the posterolateral retrocondylar approach to target vascular lesions located in front of the brainstem. This approach has been used successfully in the removal of anterior foramen magnum meningiomas. [2,97,98,99,100] To enhance vision of the ventral medulla, **Seeger** [88] resected the jugular tubercle and medial part of the occipital condyle in 1978. Several variations of this approach, usually without resection of the jugular tubercle, have been used to treat ventral foramen magnum meningiomas. These include up to one-third condylectomy [22,94,101,102,103,104], up to one-half condylectomy [4,90,105,106] and up to two-third condylectomy. [107] Most surgeons have dissected and transposed the third part of the vertebral artery to facilitate condylar drilling and to enlarge access to the tumor. [4,90,103,105,106,107] Other investigators have found mobilization of the vertebral artery not to be necessary [22,91]. Some surgeons have added a partial mastoidectomy. [90,105,106] It has been argued that the retrocondylar approach requires undue retraction of the brainstem, particularly in anteriorly located meningiomas, and some series have reported subtotal tumor resection after performing a suboccipital craniotomy because of inadequate exposure. [22,90,104] These surgical impressions were echoed by several cadaveric studies showing that condylar resection provides a wider angle of exposure when targeting lesions located on the anterior foramen magnum region. [108,109] **Bassiouni et al (2006)**[113] noted that measurement results obtained from cadaveric studies did not consider the presence of an extraaxial space–occupying lesion, which creates additional working space.

**Nanda et al (2002)**[98] concluded from their anatomic study that resection of the occipital condyle was not required for safe and complete removal of intradural foramen magnum tumors. Similarly, **Sharma BS et al (1999)** [114] in their series on 20 patients with intradural foramen magnum lesions reported that the far lateral inferior suboccipital approach without resection of the occipital condyle, is adequate for removal of most anterior or anterolaterally located foramen magnum lesions. **Goel A et al (2001)** [97] in their series on 17 cases of anterior foramen magnum meningiomas reported total excision in 14 patients using a conventional posterior suboccipital approach with craniectomy extending up to the occipital condyle. They required resection of the posterior one-third to one-fourth of the occipital condyle in only 2 patients. **Samii and Klekamp (2001)** [115] suggested that in most instances, drilling of the condyle and mobilization of the vertebral artery are not required to obtain sufficient access, even in patients with anterior foramen magnum meningiomas. They further suggested that only in *small* tumors in this location is drilling of the posterior third of the occipital condyle indicated. Otherwise, the tumor itself provides all the space required to visualize all the structures adequately.

In the present study, almost all the anteriorly located tumors (5 out of 6) were operated by a posterolateral approach. Drilling of the posterior one third of the occipital condyle was required in only one of these anteriorly located tumors. In this case, the tumor was of a small size causing minimum in situ retraction of the brainstem. Mobilization of the third part of the vertebral artery was not required in any of the patients in the present study.

In one bed-bound patient with tetraplegia who had severe restriction of pulmonary function, a midline posterior approach was used to remove the anteriorly located tumor to shorten the operative time. The tumor was approached from both sides of medulla and a gross total excision was achieved.

Most of laterally located tumors could also be removed by midline posterior approach. Posterolateral approach was required in 7 out of 13 patients. Two of these patients had intradural tumor with extradural extension, while in the remaining 5 patients, a posterolateral approach was required due to small size of the tumor where the space provided by tumor enlargement was relatively less. One patient with intradural posteriorly located tumor was operated by midline posterior approach.

## 13)EXTENT OF RESECTION

**Table no. 13 : Extent of resection (Present study)**

| Location of tumor | Gross Total Resection (Simpson's grade II) n (%) | | Subtotal Resection (Simpson's grade III) n (%) | | Total n (%) |
|---|---|---|---|---|---|
| | Midline posterior | Postero Lateral | Midline posterior | Postero Lateral | |
| Anterior | 01 (05) | 05(25) | 00 | 00 | 06(30) |
| Lateral | 06 (30) | 05(25) | 00 | 02(10) | 13(65) |
| Posterior | 01(05) | -- | -- | -- | 01(05) |
| Total | 08(40) | 10(50) | 00 | 02(10) | 20(100) |

In the present study, gross total resection (Simpson's grade II) could be achieved in 18 (90%) patients. Gross total resection was achieved in all the 6 (100%) anteriorly located tumors, while 11 (84.61%) out of the 13 laterally located tumors could be removed gross totally. Gross total resection could also be achieved in one patient with posteriorly located tumor by a midline posterior approach.

The two patients (10%) who underwent subtotal resection (Simpson's grade III) had laterally located intradural tumor with extradural extension which rendered complete resection difficult. As mentioned by **Levy et al (1982)** [83] for spinal meningiomas, intradural tumors with extradural extension are often invasive and consequently raise difficulties in achieving a complete removal. This was also obvious in the **French Cooperative Study (1995)** [112] in which the rates of complete removal for the 91 intradural meningiomas, 4 extradural meningiomas and 11 intraextradural meningiomas were 83%, 50%, and 45%, respectively. **George B et al (1997)** [22] in their series on 40 cases of foramen magnum meningiomas reported 4 cases of intraextradural meningiomas, all of which featured invasion of bone and cervical soft tissues. Three of these patients required a combined procedure (anterolateral and midline posterior approaches) and had a subtotal removal.

In the present study, 18 (90%) patients had completely intradural tumor, all of which underwent gross total excision (Simpson's grade II). Two patients (10%) had intradural tumor with extradural extension. Gross total excision was not possible in these two cases and only subtotal excision (Simpson's grade III) could be achieved.

**14) INTRA-OP COMPLICATIONS**

In the present study, intra-op complications were noted in only 4 (20%) patients. In one patient, vertebral artery got injured in the sulcus arteriosus while removing the posterior C1 arch, which was controlled with weck clips. In one patient, the $11^{th}$ nerve was coursing through the tumor and had to be sacrificed. Two other patients had bleeding from large marginal venous sinuses which led to transient intra-op hypotension in one.

In this series, only one patient underwent drilling of posterior one-third of the occipital condyle to facilitate excision of a small ventrally located foramen magnum meningioma. Extensive drilling of the occipital condyle, lateral mass of the atlas, or anterior spinal elements was not involved, so the possibility of injury to the hypoglossal nerve and vertebral artery and spinal instability was avoided. Exposure of the extradural vertebral artery and its manipulation and mobilization amid large venous plexuses, as necessary in some lateral approaches, involve considerable effort and possible risks.[97] Mobilization of the third part of the vertebral artery was not required in any of the patients in the present study.

## 15) NEW POST OP DEFICITS

In the present study, new post op deficits were observed in 9 (45%) patients, which included motor deficits in 4 patients and fresh cranial nerve deficits in 5 patients. The most common cranial nerve paresis seen post-operatively included IX$^{th}$ -X$^{th}$ in four patients, XII$^{th}$ nerve in three patients, and XI$^{th}$ nerve in two patients.

In the present study, the most common surgery related complication was the deficit of lower cranial nerves, the IX$^{th}$ and X$^{th}$ in particular. As other authors have also pointed out,[22,90,100,106] these deficits are the most dangerous, and they contribute significantly to prolonged length of hospital stay.

**Arnautovic et al (2000)**[4] suggested that it may be useful to try to predict the appearance of cranial nerve deficit and establish a pre operative baseline evaluation including a formal or at least bed side swallowing study. This may prevent occurrence of aspiration pneumonia and possible lethal outcomes. Post operative management of these deficits should be cautiously undertaken and tailored to the patient's circumstances. He advised early placement of nasogastric tubes and tracheostomies for such patients.

## 16) POST- OP VENTILATION AND TRACHEOSTOMY

In this study, post –op ventilation was required in 10 patients, out of which 8 patients were electively ventilated. Duration of ventilation ranged from 1 day to 8 weeks with a median duration of 3 days.

Tracheostomy was required in 5 patients. Out of these, three patients underwent tracheostomy for prolonged ventilation (10 days, 36 days and 60 days). In other two patients, tracheostomy was required because of thick oropharyngeal secretions and lower cranial nerve paresis.

## 17) OTHER POST OP COMPLICATIONS

A total of 8 (40%) patients had the following post op complications.

**Table no. 14: Post op complications (Present study)**

| Complications | No. of patients* |
|---|---|
| Respiratory tract infection | 06 |
| Urinary tract infection | 04 |
| Septicemia | 02 |
| Pseudomeningocele | 04 |
| Wound infection | 00 |
| CSF leak from wound site | 01 |
| CSF otorrhoea | 02 |
| Meningitis | 02 |

*More than one complication was observed in most patients

Respiratory tract infection was the most frequent complication encountered in 6 patients. This complication was seen in those patients who had either preop or post op lower cranial nerve deficits. However, all these patients were aggressively managed with timely placement of nasogastric tube and tracheostomy.

Four patients had pseudomeningocele which was managed with drainage L. P. in three patients and lumboperitoneal shunt in one patient. Two patients developed CSF otorrhoea, which was managed by lumbar drain. CSF leak from wound site was encountered in one patient who was managed by taking additional suture. One patient who underwent surgery for recurrent tumor expired due to septicemia and fulminant meningitis.

We did not encounter wound infection in any of the cases. This is attributed to the use of perioperative antibiotics prophylaxis and vascularized tissue to cover the surgical defect which helps preventing infection. Other precautions taken to prevent wound infection included use of sharp dissection of the muscle planes without employing electrocautery, keeping the muscles moist and avoiding over retraction.

**18) DURATION OF HOSPITAL STAY**

In the present study, duration of hospital stay after surgery ranged from 8 days to 70 days with a mean duration of 17 days. The long mean duration of hospital stay was attributed mainly to the prolonged post op ventilation required in 3 patients.

## 19) HISTOPATHOLOGICAL TYPE

**Table no. 15: Histopathological type(Present study)**

| Histopathological type | No. of patients (n) | Percentage (%) |
|---|---|---|
| Transitional | 09 | 45 |
| Psammomatous | 07 | 35 |
| Meningothelial | 03 | 15 |
| Meningiomas with papillary differentiation | 01 | 05 |
| Total | 20 | 100 |

In the present study, the most common histological subtype was transitional meningioma seen in 9 (45%) patients, followed by psammomatous variety, seen in 7 (35%) patients. Meningothelial subtype was seen in three (15%) patients and one (5%) patient had meningioma with papillary differentiation.

Detailed reports on the histology of foramen magnum meningioma are lacking. **Stein et al (1963)** [17] noted that the "majority" in their series were psammomatous, while **Arnautovic et al (2000)** [4] reported psammomatous type in only 22% of their patients. Most of the series has reported meningothelial type as the most common histological type. [4, 22, 24] No malignant foramen magnum meningiomas have been reported in literature.[2] However, we had one patient with papillary differentiation who developed multiple recurrences.

## 20) FOLLOW UP

Follow up was obtained in 17 (85%) patients. One patient was not available for follow-up.

At follow-up twelve patients (70.59 %) did not have any deficit, two (11.76%) patients were moderately disabled, (one had persisting lower cranial nerve paresis and the other had quadriparesis same as pre op status).Three (17.65%) were severely disabled and bed bound (all improving from preoperative dense quadriparesis).

## 20a) OUTCOME OF PATIENTS WITH PRE OPERATIVE CRANIAL NERVE DEFICITS

**Table no. 16: Outcome of patients with pre operative cranial nerve deficits**

| Preop Deficit | No. of cases | Complete Recovery | Partial Recovery | No Recovery |
|---|---|---|---|---|
| $V^{th}$ CN | 01 | 01 | 00 | 00 |
| $IX^{th}$-$X^{th}$ CN | 05 | 02 | 01 | 02 |
| $XI^{th}$ CN | 06 | 04 | 02 | 00 |
| $XII^{th}$ CN | 01 | 00 | 00 | 01 |
| Total | 13 | 07 | 03 | 03 |

Data from 17 patients available for follow up

In the present study, of the 13 instances of the pre-operative cranial nerve dysfunction, complete or partial recovery occurred in 10, while no recovery was seen in 3 instances. **Babu et al (1994)** [105] reported that of the 19 instances of preoperative cranial nerve dysfunction, complete or partial recovery occurred in 13 instances. However, **Samii et al (1996)** [100] in their study on 38 patients with foramen magnum meningiomas reported that majority of the pre operative cranial nerve deficits remained unchanged post operatively. This they attributed to the compromise of small perforating arteries arising from the vertebral artery by the meningioma causing ischemic lesions of the cranial nerve nuclei. **Arnautovic et al (2000)** [4] suggested that as long as the cranial nerves are anatomically preserved and manipulated cautiously during surgery, almost all patients recover completely.

## 20b) OUTCOME OF PATIENTS WITH PRE OPERATIVE NEUROLOGICAL (EXCLUDING CRANIAL NERVE) DEFICITS

**Table no. 17: Outcome of patients with pre operative neurological (excluding cranial nerve) deficits**

| Preop Deficit | No. of cases | Improved | Same as pre-op | Worsened |
|---|---|---|---|---|
| Hemiparesis | 02 | 02 | 00 | 00 |
| Tetraparesis | 10 | 07 | 03 | 00 |
| Tetraplegia | 03 | 02 | 01 | 00 |
| Sensory deficit | 12 | 12 | 00 | 00 |
| Cerebellar deficits | 03 | 02 | 01 | 00 |

Data from 17 patients available for follow up

In the present study, 15 patients presented with preoperative motor deficit. Two of these presenting with hemiparesis recovered completely. Of the ten patients presenting with tetraparesis, 70% patients recovered completely, while 30% patients had their motor power same as pre-op at the last follow up examination. Out of the 3 patients presenting with tetraplegia, two (66%) recovered completely. All the 12 (100%) patients who presented with pre-op sensory deficits had complete resolution. Cerebellar signs improved in 2 patients, while remained same as preop in one patient.

**Arnautovic et al (2000)** [4] reported that a low pre operative KPS score, a progressive clinical course, and quadriparesis are factors that portend a poor prognosis. The complete recovery in two patients with tetraplegia in the present study can be explained by relatively shorter duration of symptoms before presentation (2 and 3 months).

## 20c) OUTCOME OF PATIENTS WITH NEW POST OPERATIVE NEUROLOGICAL DEFICITS

**Table no. 18: Outcome of patients with new post operative neurological deficits**

| Post - op Deficit | No. of cases | Complete Recovery | Partial Recovery | No Recovery |
|---|---|---|---|---|
| VI$^{th}$ CN | 01 | 01 | 00 | 00 |
| VII$^{th}$ CN | 01 | 01 | 00 | 00 |
| IX$^{th}$-X$^{th}$ CN | 03 | 02 | 01 | 00 |
| XI$^{th}$ CN | 01 | 00 | 00 | 01 |
| XII$^{th}$ CN | 03 | 02 | 01 | 00 |
| Motor deficits | 03 | 03 | 00 | 00 |

Data from 17 patients available for follow up

In the present study, out of the 5 patients who sustained post operative fresh cranial nerve deficits, three patients made complete recovery; one patient had only partial recovery of 9$^{th}$, 10$^{th}$ and 12$^{th}$ cranial nerves while one patient in whom the XI$^{th}$ nerve was sacrificed during tumor removal showed no recovery. Fresh neurological deficits occur post operatively usually due to brainstem and cranial nerve handling during surgery. **Arnautovic et al (2000)** [4] suggested that as long as the cranial nerves are anatomically preserved and manipulated cautiously during surgery, almost all patients recover completely.

All the three patients who sustained post operative hemiparesis had complete resolution of their deficits at the last follow up examination.

## 21) MORTALITY

It has been claimed that patients operated on via conventional suboccipital approaches have a worse clinical outcome than patients operated on via the transcondylar route. [4,90,102,103,104] Indeed, early series in which the posterior suboccipital approach was routinely used had a high surgical mortality rate, ranging between 3.5 and 33% .[15,16,17,21,24,25] However, data from series published in the microsurgical era do not support superiority of the transcondylar approach regarding clinical outcome.[113] Permanent surgical morbidity in our series was 17.65 % and mortality was 5%. Three other series used the retrocondylar approach and had a permanent morbidity and mortality rate ranging from 0 to 5.9% and from 0 to 6.1%, respectively.[97,98,100] Series that have applied the transcondylar approach had a permanent surgical morbidity and mortality rate that ranged from 0 to 60% and from 0 to 29%, respectively.[4,22,90,91,103,104,105,106,107]

In our series, out of the 17 patients available for follow up, fourteen (82.35%) experienced amelioration of preoperative neurological symptoms and signs, and 12 (70.59%) patients regained full daily activity.

The higher morbidity in the present study (17.65%) may be explained by the poorer preoperative neurological status of the patients. It is noteworthy that 7(35%) patients in our study were bed-bound preoperatively. The operative mortality rate of 5% in this series is comparable with that of other studies.[97, 98,100]

**22) RECURRENCE**

Recurrence rate in foramen magnum meningiomas after a Simpson's grade I and grade II resection is low and has ranged between 0 and 5% in recent microsurgical series.[2, 22, 97,100,104,112] However, the follow-up period was short in most reports[4, 97,104] or was restricted to clinical examination without radiological imaging.[100] We have observed 3 cases of recurrent tumor after a mean follow-up period of 45 months. As suggested by **Arnautovic et al (2000),**[4] we advocate complete removal of the tumor during the first surgery. Recurrent meningioma at this site has an unfavorable prognosis. In the series reported by **Stein et al (1963)**[17], 20% of patients died because of problems related to tumor recurrences. In the Mayo clinic experience reported by **Meyer et al (1984)**[25], 5% of the patients died because of a tumor recurrence within 3 years after surgery.

In the present study, out of the 3 patients with recurrent tumor, 2 had asymptomatic recurrence and were kept on regular follow up. One patient with histologically proven malignant meningioma had symptomatic recurrences despite gross total excision during first surgery. He underwent re-exploration three times for symptomatic recurrence, 2 ½, 3 and 10 years after first surgery, and expired after fourth surgery due to septicemia and meningitis.

Furthermore, in most series, including the present one, recurrent tumors could only be subtotally removed and were related to major postoperative neurological compromise.[4, 22, 86, 90,100, 105, 106] **Bassiouni et al (2006)**[113] suggested that this does not contradict the concept of leaving a trace of tumor adherent to important neural and vascular structures to preserve function. There is no evidence that resection of the dura after tumor removal decreases the recurrence rate.[90,100,101]

# *Summary & Conclusions*

# SUMMARY AND CONCLUSIONS

From the present retrospective analysis, the following conclusions can be drawn:

1. Like meningiomas at other locations, foramen magnum meningiomas are more common in females, with a female to male ratio of 4:1. The average age of occurrence for these tumors is 42 years (range, 18-68 years).
2. There is a significant delay in diagnosis of foramen magnum meningiomas as noted by the prolonged duration of symptoms before presentation. This delay is probably attributable to the CSF cisterns of the foramen magnum region that allow room for steady continued growth of a tumor. However, with the widespread use of MRI, more cases are likely to get diagnosed at an earlier stage.
3. A high index of suspicion is required for the diagnosis because of the insidious, often bizarre, and occasionally remitting clinical course.
4. Suboccipital and / or posterior cervical pain is the most common and often the first presenting symptom, followed by weakness and gait unsteadiness.
5. The most frequent cranial nerves to get involved include the IX$^{th}$, X$^{th}$ and XI$^{th}$ cranial nerves. The most frequent motor deficits include a spastic tetraparesis and atrophy of small hand muscles.
6. The most common location of the tumor in the axial plane is lateral (65%), followed by anterior (30%). Posterior location is least common (5%).
7. Anteriorly located tumors are more likely to encase the vertebral artery than the laterally located tumors.
8. Most of the tumors are located intradurally (90%), while only a few patients (10%) have intradural tumor with extradural extension.

9. Respiratory dysfunction is very common in patients with foramen magnum meningiomas and most of the patients have severe restriction of pulmonary function.
10. The vertical extent of the tumor does not influence the completeness of surgical excision, which can be achieved by simply increasing the extent of cervical laminectomy.
11. Posteriorly located tumors and most of the laterally located tumors can be safely and completely excised by a midline posterior suboccipital approach. Posterolateral retrocondylar approach is required for small laterally located tumors (which do not create an adequate surgical corridor by displacing the neuraxis) or for tumors with extradural extension.
12. Most of the anteriorly located tumors can be safely and completely excised by a posterolateral retrocondylar approach without drilling the occipital condyle or the lateral mass of atlas or transposition of the vertebral artery. Condylar drilling may be required for accessing small anteriorly located tumors causing minimal displacement of the neuraxis. Drilling of posteromedial one-third of the occipital condyle is usually sufficient for accessing even small anteriorly located meningiomas, and does not appear to increase the risk of instability.
13. Tumors with extradural extension are often invasive and consequently raise difficulties in achieving a complete removal.
14. The most common surgery related complication involved deficit of the lower cranial nerves, particularly the $IX^{th}$ and $X^{th}$. However, as long as the cranial nerves are anatomically preserved and manipulated cautiously during surgery, almost all patients recover completely.
15. Presence of preoperative lower cranial nerve deficit increases the chances of postoperative respiratory complications, prolonged postop ventilation and length of hospital stay.

16. Although most patients have a transient deterioration in their neurological status after surgery, most of them (70%) recover completely at long term follow up. Permanent surgical morbidity was seen in 17.65% and correlates with poor preoperative neurological status.

17. Persistent post op neurological deficits correlate with the prolonged preoperative duration of symptoms. Patients with a shorter duration have more chances of postoperative complete recovery.

18. The operative mortality of 5% in this series is comparable with that of other studies.

19. Recurrent tumors, if symptomatic are best operated. However surgery for recurrent tumor carries a high risk of morbidity and mortality.

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