Surgical Experience of Infratentorial Meningiomas: Clinical Series at a Single Institution during the 20-Year Period

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Objective: Based on surgical outcomes of patients with infratentorial meningiomas surgically treated at our institution, we analyzed the predictors for surgical resection, recurrence, complication, and survival.

Methods: Of surgically treated 782 patients with intracranial meningioma, 158 (20.2%) consecutive cases of infratentorial location operated on between April 1993 and May 2013 at our institute were reviewed retrospectively. The patients had a median age of 57.1 years (range, 16–77 years), a female predominance of 79.7%, and a mean follow-up duration of 48.4 months (range, 0.8–242.2 months).

Results: Gross total resection (Simpson’s grade I & II) was achieved in 81.6% (129/158) of patients. Non-skull base location was an independent factor for complete resection. The recurrence rate was 13.3% (21/158) and the 5-, 10-, and 15-year recurrence rates were 8.2%, 12.0%, and 13.3%, respectively. Benign pathology, postoperative KPS over 90, low peritumoral edema, and complete resection were significantly associated with longer recurrence-free survival rate. The 5-, 10-, and 15-year survival rates were 96.2%, 94.9%, and 94.9%, respectively. Benign pathology, postoperative KPS over 90 and complete resection were significantly associated with a longer survival rate. The permanent complication rate was 13% (21/158). Skull base location and postoperative KPS less than 90 were independent factors for the occurrence of permanent complication.

Conclusion: Our experience shows that infratentorial meningiomas represent a continuing challenge for contemporary neurosurgeons. Various factors are related with resection degree, complications, recurrence and survival.

Key Words: Complication · Intracranial meningioma · Infratentorial · Recurrence · Surgical outcome · Survival.

INTRODUCTION

As reported in Henschen, a petrous ridge meningioma was first described by Rokitansky in 1855. In 1938, Harvey Cushing described seven cases of meningiomas. Only one did well and, accordingly, he emphasized a high surgical risk in dealing with infratentorial meningiomas. Because of its deep location, narrow visual field of operation and proximity to cranial nerves, brain stem and important blood vessels, surgical intervention for this pathology have a high lethal and crippled rate. Clinical presentation and microsurgical anatomy, particularly in regard to cranial nerve dislocation, critically depend on the tumor's dural origin. Infratentorial meningiomas include cerebellar convexity, tentorial, cerebellopontine angle, jugular foramen, petroclival, peritectoral, and foramen magnum.

The ideal primary treatment of these tumors is total surgical resection. However, infratentorial meningiomas have been a challenge for operation, because of its close proximity to critical vascular and neurologic structures and slow growth. In the early series, the surgical try to remove these lesions was associated with high rates of morbidity and mortality. As developing radiologic tools, microsurgical techniques and surgical approaches of these tumors, surgical management has been evolving and shown good outcomes along with a decrease in surgical morbidity and
mortality. Despite these improvements, surgery for infratentorial meningiomas is still associated with high morbidity and complications. In the present study, we analyzed surgical outcomes of patients with infratentorial meningiomas surgically treated at our institution to postulate the predictors for surgical resection, recurrence, complication, and survival.

MATERIALS AND METHODS

Patients

The study is in compliance with the Declaration of Helsinki (Sixth Revision, 2008). This study fulfills all the requirements for patient anonymity was approved by the institutional review board. Between April 1993 and May 2013, 782 cases of intracranial meningioma were surgically resected at our institution. Among these cases, 158 patients (20.2%) were diagnosed with infratentorial meningioma by means of radiological studies [non-enhanced and enhanced computed tomographic (CT) scanning and magnetic resonance imaging (MRI)] and their surgical records. Recurred cases were excluded from this study.

Analysis variables

To define the clinical and radiological characteristics of the patients, several variables such as age, sex, presenting symptoms, pathology, tumor features (size, location, peritumoral edema), preoperative and postoperative KPS, postoperative transient/permanent complications, recurrence and survival rate were evaluated. These clinicoradiological variables are summarized in Table 1.

The patients consisted of 32 males and 126 females (female predominance, 79.7%), with a median age of 57.1 years (range, 16–77 years). The most common presenting symptoms were headache, followed by dizziness and disturbance of gait. Some patients presented with mental change, another with cranial nerve palsy. The exact location of the patients was decided by radiological study and operation records, with regard to the origin of the mass, including tentorial meningioma in 39 patients, cerebellopontine angle (CPA) in 75 patients, petroclival in 21 patients, peritortcular in 8 patients, cerebellar convexity in 7 patients, foramen magnum in 6 patients, and jugular foramen in 2 patients.

Tumor locations were classified into 3 groups according to their origin site (Group I, cerebellopontine angle & cerebellar convexity; Group II, tentorial & peritortcular; Group III, petroclival & other skull base location). Based on T1-weighted enhanced & T2-weighted non-enhanced MRI, the maximal size of the tumor and peri-tumoral edema was evaluated. Based on T1-weighted enhanced & T2-weighted non-enhanced MRI, the maximal size of the tumor and peri-tumoral edema was evaluated. Four centimeter was cut-off value as the size parameter (<4 cm vs. ≥4 cm). According to the peri-tumoral edema, the patients were divided into two groups [none or minimal (<5 mm in edema thickness) vs. moderate or severe (≥5 mm in edema thickness)].

The extent of tumor resection was classified according to the Simpson's classification. Gross total resection was defined as Simpson's Grades I and II resection without any visible tumor remnant on surgical finding and follow-up MRI. All tumors were graded pathologically according to the World Health Organization (WHO) classification system. According to the pa-

Table 1. Clinical characteristics of 158 patients with infratentorial meningiomas

| Characteristic                | No. of patients (%) |
|------------------------------|---------------------|
| Age, median (range)          | 57.1 (16–77 years)  |
| Sex                          |                     |
| Male                         | 32 (20.5)           |
| Female                       | 126 (79.5)          |
| Type of symptom              |                     |
| Headache & dizziness         | 74 (46.8)           |
| Motor & sensory change       | 28 (17.7)           |
| Cranial nerve symptom        | 34 (21.5)           |
| Etc.                         | 22 (13.9)           |
| Preoperative KPS             |                     |
| 90–100                       | 108 (68.4)          |
| 70–80                        | 47 (29.7)           |
| <60                          | 3 (1.9)             |
| Location*                    |                     |
| Group I                      | 82 (51.9)           |
| Group II                     | 47 (29.7)           |
| Group III                    | 29 (18.4)           |
| Size (cm)                    |                     |
| <2                           | 15 (9.5)            |
| 2–4                          | 67 (42.4)           |
| 4–6                          | 60 (38.0)           |
| <6                           | 16 (10.1)           |
| Edema                        |                     |
| No or mild                   | 105 (66.5)          |
| Moderate to severe           | 53 (33.5)           |
| Simpson grade                |                     |
| Grade I, II                  | 129 (81.7)          |
| Grade III, IV                | 28 (17.7)           |
| Grade V                      | 1 (0.6)             |
| Pathology (WHO grade)        |                     |
| Grade I                      | 148 (93.0)          |
| Grade II                     | 9 (5.7)             |
| Grade III                    | 1 (0.6)             |
| Postoperative KPS            |                     |
| 90–100                       | 123 (77.8)          |
| 70–80                        | 28 (17.7)           |
| <60                          | 7 (4.4)             |
| Postoperative complication   |                     |
| Cranial nerve                | 7 (4.4)             |
| Hemorrhage                   | 5 (3.2)             |
| Others                       | 7 (4.4)             |

*Group I: cerebellopontine angle and cerebellar convexity; Group II: tentorial & peritortcular; Group III: skull base locations including petroclival, foramen magnum, and jugular foramen. WHO: World Health Organization, KPS: Karnofsky performance scale.
thology had been classified by WHO grade that grade I in 148 patients, grade II & III in 10 (9 patients in Grade II & 1 in III). On follow-up MRI, new enhancing mass in completely resected case or re-growing symptomatic mass in non-completely resected case was regarded as a recurred lesion. Surgery-related complication was defined as a new developed neurological deficit or aggravated pre-existing deficit. The postoperative complications were separated of transient and permanent. The transient complication was defined as the new or aggravated postoperative problem resolved generally within 3–6 months after the operation. If the problem persisted or needed another operation, it was regarded as the permanent complication. The pre- and post-operative clinical status was quantified retrospectively using the KPS. The time to measure of post-operative KPS was 6 months after the operation. Good performance status was defined as above KPS 80. All surviving patients were monitored; the mean duration of follow-up was 48.4 months with a range of 0.8 to 242.2 months.

Statistical analysis

Recurrence-free survival (RFS) was calculated as the time from surgery to the date of recurrence. The probability of RFS was analyzed according to the Kaplan-Meier method and compared with the log-rank test. Overall survival was also calculated as the time from surgery to the date of death or last follow-up visit. For the multivariate analysis, independent prognostic factors were determined using the Cox's proportional hazards model. The relation between resection degree/permanent complication occurrence and categorical variables was compared by using a chi-square test or Fisher-exact probability test. Furthermore, binary logistic regression test was applied for multivariate analysis. All statistical analyses were performed using SPSS version 20.0 software program for Windows (Chicago, IL, USA). The level of significance was set at $p<0.05$.

RESULTS

Resection

Commonly used approaches were lateral or midline suboccipital. For some cases, far lateral, subtemporal, or orbitozygomatic route was selected to resect the lesion located on skull base region. In our series, 129 patients (81.6%, 129/158) were classified into Simpson's grade I and II, 28 patients (17.7%) into grade III and IV and 1 patient (0.6%) into grade V. On univariate analysis, female ($p=0.019$), non-skull base location ($p<0.001$) and postoperative KPS over than 90 ($p=0.012$) were significantly related with the possibility of complete resection (Table 2). However, only non-skull base location was associated with complete resection, on multivariate analysis [hazard ratio (HR) : 0.162, 95% confidence index (CI) : 0.065–0.405, $p<0.001$].

Recurrence

In this study, recurrence rate was 13.3% (21/158) and the 5-, 10-, and 15-year recurrence rates were 8.2%, 12.0%, and 13.3%, respectively (Fig. 1). The results of analyses of the variables that could be correlated with recurrence are shown in Fig. 2 and Table 3.

On univariate analysis, age, pathology, postoperative KPS, postoperative complication, edema, size, preoperative symptom and Simpson's grade showed statistical significance. The patient's age at the operation was important factor for RFS [mean value, 36.5±5.2 months (group <40 years) vs. 155.5±12.9 months (40≤ group <60 years), 107.6±6.5 months (group ≥60 years), $p=0.004$]. The younger-aged group showed shorter RFS than the older-aged group (mean value, 36.5±5.2 months vs. 153.4±11.1 months, $p=0.001$). The more aggressive pathology group (WHO grade II and III) showed the recurrence in earlier postoperative period than the benign group (mean value, 45.6±12.5 months vs. 155.7±11.1 months, $p<0.001$). The size of tumor was also an important factor [mean value, 175.2±9.8 months (group <4 cm) vs. 107.7±12.9 months (4 cm≤ group <6 cm), 106.3±22.8 months (group ≥6 cm), $p=0.026$]. In the group with large-size tumor (≥4 cm), the RFS was shorter than small-size group (mean value, 175.2± 9.8 months vs. 113.3±11.1 months, $p=0.007$). The patient with brain stem or cranial nerve sign showed a shorter RFS time, compared to the patient with other minor symptoms (value, 157.9±12.8 months vs. 113.8±11.4 months, $p=0.038$). Not surprisingly, non-complete resection group (Simpson's grade III-V) demonstrated a shorter RFS compared to complete resection group (mean value, 154.0±12.1 months vs. 114.0±21.9 months, $p=0.002$). The absence of postoperative complication (mean value, 157.6±11.3 months vs. 70.4±12.4 months, $p=0.001$) and postoperative KPS over than 90 (mean value, 163.2±12.0 months vs. 71.5±9.7 months, $p<0.001$) were significantly related with recurrence in a longer follow-up period.

On multivariate analysis, pathologic grade, postoperative KPS, peritumoral edema and resection degree were independent predictable factors for tumor recurrence. Benign pathology (HR 0.109, 95% CI 0.026–0.453, $p=0.002$) and postoperative KPS over 90 (HR 0.078, 95% CI 0.025–0.243, $p<0.001$) showed significant statistical significance. Low peritumoral edema (HR 0.134, 95% CI 0.046–0.392, $p<0.001$) complete resection (HR 0.226, 95% CI 0.077–0.669, $p=0.007$) were significantly associated with longer RFS time.

Overall survival

The incidence of death rate was 5.0% over follow-up period (8/158). The surgery-related mortality which the death occurred within one month after resection was 3.16% in this study (5/158). The 5-, 10-, and 15-year survival rates were 96.2%, 94.9%, and 94.9%, respectively (Fig. 3). The results of analyses of the variables that could be correlated with survival time are shown in Fig. 4 and Table 4.

On univariate analysis, pathology, location, size, postopera-
The incidence of recurrence rate is 13.3% (21/158) with the mean recurrence time of 149.7 months (95% confidence index: 128.3-171.2 months), the median recurrence time has not reached.

Fig. 1. Overall recurrence-free survival.

Table 2. Univariate and multivariate analysis for resection predictors in patients with infratentorial meningiomas

| Variables                  | Resection grade | Univariate | Multivariate |
|---------------------------|-----------------|------------|--------------|
|                           | Grade I/II (%)  | Grade ≥III (%) | p value | HR | 95% CI | p value |
| Age                       | 1.000           | ND          | ND          | 0.629 |
| <40 years                 | 11 (84.6)       | 2 (15.4)    | 0.019       | ND | ND     | 0.227     |
| ≥40 years                 | 118 (81.4)      | 27 (18.6)   |             |    |        |           |
| Sex                       | 0.092           | ND          | ND          | 0.871 |
| Male                      | 21 (63.6)       | 11 (36.4)   |             |    |        |           |
| Female                    | 108 (85.7)      | 18 (14.3)   |             |    |        |           |
| Preoperative symptom*     | 0.079           | ND          | ND          | 0.91 |
| No stem sign              | 82 (86.3)       | 13 (13.7)   |             |    |        |           |
| Stem sign                 | 47 (74.6)       | 16 (25.4)   |             |    |        |           |
| Location†                 | <0.001          | 0.065-0.405 | <0.001      |    |        |           |
| Group I                   | 73 (89.0)       | 9 (11.0)    | 0.162       |    |        |           |
| Group II                  | 41 (87.2)       | 6 (12.8)    |             |    |        |           |
| Group III                 | 15 (51.7)       | 14 (48.3)   |             |    |        |           |
| Pathology (WHO grade)     | 0.442           | ND          | ND          | 0.442 |
| Grade I                   | 122 (82.4)      | 26 (17.6)   |             |    |        |           |
| Grade II, III             | 7 (70)          | 3 (30)      |             |    |        |           |
| Size (mm)                 | 0.079           | ND          | ND          | 0.91 |
| <40                       | 71 (86.5)       | 11 (13.5)   |             |    |        |           |
| ≥40                       | 58 (76.3)       | 18 (23.7)   |             |    |        |           |
| Edema                     | 0.897           | ND          | ND          | 0.450 |
| No or mild (<5 mm)        | 86 (54.4)       | 19 (12)     |             |    |        |           |
| Moderate to severe         | 43 (27.2)       | 10 (6.3)    |             |    |        |           |
| Preoperative KPS          | 0.122           | ND          | ND          | 0.256 |
| 90–100                    | 85 (85.0)       | 15 (15.0)   |             |    |        |           |
| ≤80                       | 37 (74.0)       | 13 (26.0)   |             |    |        |           |
| Postoperative KPS         | 0.012           | NA          | NA          | NA |
| 90–100                    | 99 (86.1)       | 16 (13.9)   |             |    |        |           |
| ≤80                       | 23 (65.7)       | 12 (34.3)   |             |    |        |           |
| Postoperative Cx.         | 0.122           | NA          | NA          | NA |
| No                        | 116 (83.4)      | 23 (16.6)   |             |    |        |           |
| Yes                       | 13 (68.4)       | 6 (31.6)    |             |    |        |           |

*No stem sign: headache, dizziness, seizure. Stem sign: mental changes, motor weakness, cranial nerve deficit. †Group I: cerebellopontine angle & cerebellar convexity, Group II: tentorial & peritortorial, Group III: skull base locations including petroclival, foramen magnum, and jugular foramen. ‡Reference variable: non-skullbase location groups (Group I+II). Cx: complication, KPS: Karnofsky performance scale, NA: non-available, ND: non-detected, WHO: World Health Organization.

tive complication and KPS, and Simpson’s grade showed statistical significance. The more aggressive pathology group (WHO grade II and III) showed a shorter survival time than the benign group (mean value, 40.1±16.2 months vs. 227.4±6.2 months, p<0.001). The tumor location was important factor for survival time [mean value, 167.1±6.7 months (group I) vs. 236.6±5.5 months (group II), 98.0±8.6 months (group III), p=0.009]. The group located at skull base showed shorter survival time than the non-skull base group (mean value, 98.0±8.6 months vs. 232.3±6.3 months, p=0.002). The size of tumor is also important variable in survival time [mean value, 200.5±2.6 months (group <4 cm) vs. 192.1±20.8 months (4 cm≤ group <6 cm), 152.7±11.2 months (group ≥6 cm), p=0.023]. In larger-sized group (≥4 cm), the survival time was shorter compared that of small-size group (mean value, 200.5±2.6 months vs. 200.8±15.9 months, p=0.008). Interestingly, non-complete resection group (Simpson’s
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The results of analyses of the variables that could be correlated with permanent complications are shown in Table 5. On univariate analysis, location, preoperative symptom, and preoperative KPS showed statistical significance. The tumor location was an important factor for development of permanent complication (8.1% in group I vs. 2.3% in group II, 28.0% in group III, \( p = 0.002 \)). The group located at skull base showed higher possibility of permanent complication than the non-skull base group (28.0% vs. 6.0%, \( p = 0.001 \)). The patient with brain stem or cranial nerve sign showed higher possibility for postoperative complication, compared to the patient with other minor symptoms (19.0% vs. 7.4%, \( p = 0.043 \)). The patient with low level of postoperative KPS (<90) was also significantly associated with permanent complication (37.1% vs. 3.5%, \( p < 0.001 \)).

On multivariate analysis, location and postoperative KPS were independent predictable factors for development of permanent complication. Non-skull base location (HR 0.206, 95% CI 0.058–0.727, \( p = 0.014 \)) and postoperative KPS over 90 (HR 0.048, 95% CI 0.012–0.197, \( p < 0.001 \)) were significantly related with a higher complication rate.

DISCUSSION

A rising number of patients with intracranial meningiomas...
have been operated on in recent years and a few surgical series were reported in the literature\(^2\). And, surgical results with infratentorial meningiomas have much improved during the last two decades, but radical removal continues producing a high morbidity rate and still occasional mortality\(^3\).

In intracranial meningioma resection, surgical outcome and its predictive factors were not fully identified. Some authors mentioned the presence of peritumoral edema as a predictor of poor outcome in elderly patients\(^3,8\), whereas others did not find any relationship between edema and unfavorable outcome\(^10,23\). Tumors size has been considered as a predictive factor for postoperative outcome by some authors\(^3,8\). In other reports, however, tumor size did not have any significant influence on surgical morbidity\(^10,15,24\). Some authors have pointed out that outcome is less favorable in elderly patients with meningiomas located at the base of the skull, especially the posterior fossa\(^1,2,4,5,20\). Other authors reported that KPS present a relationship of postoperative outcome\(^13,29\). In consideration of previous studies, surgery for infratentorial meningioma is still associated with significant postoperative deficits, thus confirming that these lesions represent a great challenge even for contemporary neurosurgeons\(^25\).

| Table 3. Univariate and multivariate analysis for recurrence predictors in patients with infratentorial meningiomas |
|-------------------------------------------------|----------------|----------------|----------------|----------------|----------------|
| Variables                                      | Recurrence-free survival | Univariate | Multivariate |                  |
| Mean duration±SD (mos)                         |                | HR    | 95% CI | p value |                |
| Age                                            |                | 0.001 | ND    | ND     | 0.234 |
| <40 years                                      | 36.5±5.2       | ND    | ND    | ND     | 0.239 |
| ≥40 years                                      | 153.4±11.1     | ND    | ND    | ND     | 0.239 |
| Sex                                            |                | 0.533 | ND    | ND     | 0.901 |
| Male                                           | 101.3±8.4      | ND    | ND    | ND     | 0.901 |
| Female                                         | 149.5±11.4     | ND    | ND    | ND     | 0.901 |
| Preoperative symptom*                          |                | 0.038 | ND    | ND     | 0.901 |
| No stem sign                                   | 157.9±12.8     | ND    | ND    | ND     | 0.901 |
| Stem sign                                      | 113.8±11.4     | ND    | ND    | ND     | 0.901 |
| Location†                                       |                | 0.556 | ND    | ND     | 0.694 |
| Group I                                        | 135.6±7.6      | ND    | ND    | ND     | 0.694 |
| Group II                                       | 142.4±15.2     | ND    | ND    | ND     | 0.694 |
| Group III                                      | 96.1±9.3       | ND    | ND    | ND     | 0.694 |
| Pathology (WHO grade)                          |                | <0.001| 0.026 | 0.453  | 0.002 |
| Grade I                                        | 155.7±11.1     | 0.109 | ND    | ND     | 0.702 |
| Grade II, III                                  | 45.6±12.5      | 1     | ND    | ND     | 0.702 |
| Simpson grade                                  |                | 0.002 | 0.077 | 0.669  | 0.007 |
| Grade I, II                                    | 154.0±12.1     | 0.226 | ND    | ND     | 0.074 |
| Grade III, IV, V                               | 114.0±21.9     | 1     | ND    | ND     | 0.074 |
| Size (mm)                                      |                | 0.007 | ND    | ND     | 0.074 |
| <40                                            | 175.2±9.8      | ND    | ND    | ND     | 0.074 |
| ≥40                                            | 113.3±11.1     | ND    | ND    | ND     | 0.074 |
| Preoperative KPS                               |                | 0.125 | ND    | ND     | 0.702 |
| 90–100                                         | 150.0±13.6     | ND    | ND    | ND     | 0.702 |
| ≤80                                            | 115.9±11.8     | ND    | ND    | ND     | 0.702 |
| Postoperative KPS                              |                | <0.001| 0.025 | 0.243  | <0.001 |
| 90–100                                         | 163.2±12.0     | 0.078 | ND    | ND     | <0.001 |
| ≤80                                            | 71.5±9.7       | 1     | ND    | ND     | <0.001 |
| Postoperative Cx.                              |                | 0.001 | ND    | ND     | 0.515 |
| No                                             | 157.6±11.3     | ND    | ND    | ND     | 0.515 |
| Yes                                            | 70.4±12.4      | ND    | ND    | ND     | 0.515 |
| Edema                                          |                | <0.001| 0.046 | 0.392  | <0.001 |
| No or mild (<5 mm)                             | 168.1±11.4     | 0.134 | ND    | ND     | <0.001 |
| Moderate to severe                             | 73.0±8.6       | 1     | ND    | ND     | <0.001 |

*No stem sign : headache, dizziness, seizure, Stem sign : mental changes, motor weakness, cranial nerve deficit, \(^1\)Group I : cerebellopontine angle & cerebellar convexity, Group II : tentorial & peritocrural, Group III : skull base location including petroclival, foramen magnum, and jugular foramen, \(^2\)Reference variable : non-skullbase location groups (Group I+II). Cx : complication, KPS : Karnofsky performance scale, ND : non-detected, WHO : World Health Organization
Since the first classification of infratentorial meningiomas was proposed by Cushing and Eisenhardt in 1938, Castellano and Ruggiero subdivided these tumors into five groups; cerebellar convexity, tentorium, posterior petrous, clivus and foramen magnum meningiomas. Based on this classification, total 158 patients with infratentorial meningiomas underwent surgery during 20 years in our hospital (20.2%, in total 782 patients with intracranial meningiomas).

Resection
Although a radical resection of these histologically benign tumors is the ideal objective of surgical therapy, this is not always possible. During surgical planning, it should be kept in mind that meningiomas show a marked tendency to invade dura, nerves, and surrounding bone. The dura surrounding the tumor should be resected and the bony invasion should be drilling until normal bone is seen. And vascular encasement, although representing an additional surgical problem, by itself did not generally prevent the pursuance of gross total removal. In fact, as noted by Sekhar et al., blood vessels are surrounded by an arachnoid plane that can be carefully dissected by experienced surgeons. Subtotal resection carries a lower risk of morbidity than radical excision, but residual tumor may lead some patients to the initial clinical scenario sooner or later, and reoperation is usually less successful and more risky than initial surgery, particularly when the patient is given radiotherapy after the initial operation. At the present moment the majority of authors recommend subtotal resection for old patients or when there are factors defying complete removal. The critical factors influencing the possibility of radical and safe resection of meningiomas are tumor-vascular relationships and the integrity of the arachnoid plane between the tumor and the brainstem. In our series, non-skull base location was a significant factor for complete resection.

Recurrence
The recurrence rate of infratentorial meningiomas is particularly difficult to estimate because of differences in the reported series regarding the rates of radical excision, the methods of assessment of complete removal, the follow-up periods, the average age of the patients and the percentage of patients receiving postoperative radiotherapy. Some studies have shown that meningiomas may recur after an apparently radical excision, but it is clear that completeness of resection is the main factor preventing regrowth in all locations. Others indicated that frozen section analysis for intraoperative pathological sample is appropriate since a diagnosis of meningioma will direct that bone adjacent to the tumor site of origin be removed to reduce recurrence rate. In our series, non-benign pathology, non-complete resection, moderate or severe degree of peritumoral edema, and low postoperative KPS (<90) were independent factors for short RFS in multivariate analysis. It is not difficult to anticipate that meningioma with high pathological grade or non-complete

Fig. 3. Overall survival. The incidence of death rate was 5.0% (8/158) with the mean survival time of 224.1 months 95% confidence index : 211.3–237.0 months, the median survival time was not reached.

Fig. 4. Kaplan-Meier analysis of overall survival for enrolled patients according to independent predictors on multivariate analysis (overall comparison was estimated using a log-rank test). A : Simpson’s grade. B : Pathology. C : Postoperative Karnofsky performance scale.
Survival and complication

Considering that the goal of surgery of meningiomas is gross total resection with minimal morbidity and low mortality, single-stage total removal should be attempted. But the attempt for aggressive surgical resection continues producing a high morbidity rate and still occasional mortality. The perioperative mortality rate in the surgical management of infratentorial meningiomas has varied from 0–15.7%. In our series, the total death rate during the follow-up period was 5.0% (8/158) of case. The postoperative mortality rate, as defined patients ware expired within 30 days after initial operation, was 3.16% (5/158). Non-benign pathology, non-complete resection, and

resection frequently recurred after the surgery. The postoperative KPS was higher, the recurrence rate was lower. It means, in our opinion, that the group of postoperative KPS under 80 tend to have subtotal resection because of intraoperative events, such as accidental injuries or poor dissection plane of cranial nerves, surrounding en-passing vessels, or brain stem, even though initial attempt for gross total resection. Therefore, these groups seem to have lower postoperative KPS, have higher recurrence rate. The more have edema, the more have recurrence rate. This is probably because the patients have moderate to severe edema tend to have high-grade pathology, large size, or poor dissection plane, leading to eventual recurrence of tumor.

**Table 4. Univariate and multivariate analysis for death predictors in patients with infratentorial meningiomas**

| Variables                                | Survival time | Univariate | Multivariate |
|-------------------------------------------|---------------|------------|--------------|
|                                           | Mean duration±SD (mos) | p value | HR | 95% CI | p value |
| Age                                       |               | 0.250 | ND | ND | 0.611 |
| <40 years                                 | 45.5±4.4      |        |    |     |       |
| ≥40 years                                 | 184.2±6.4     |        |    |     |       |
| Sex                                       |               | 0.131 | ND | ND | 0.926 |
| Male                                      | 104.1±8.3     |        |    |     |       |
| Female                                    | 228.4±6.5     |        |    |     |       |
| Preoperative symptom*                     |               | 0.455 | ND | ND | 0.090 |
| No stem sign                              | 230.5±5.8     |        |    |     |       |
| Stem sign                                 | 139.9±8.6     |        |    |     |       |
| Location†                                 |               | 0.009 | ND | ND | 0.810 |
| Group I                                   | 167.1±6.7     |        |    |     |       |
| Group II                                  | 236.6±5.5     |        |    |     |       |
| Group III                                 | 98.0±8.6      |        |    |     |       |
| Pathology (WHO grade)                     |               | <0.001 | 0.005-0.343 | 0.003 |
| Grade I                                   | 227.4±6.2     |        | 0.041 |       |
| Grade II, III                             | 40.1±16.2     |        | 1 |       |
| Simpson grade†                            |               | <0.001 | 0.029-0.769 | 0.023 |
| Grade I, II                               | 232.8±5.7     |        | 0.150 |       |
| Grade III, IV, V                          | 139.1±17.2    |        | 1 |       |
| Size (mm)                                 |               | 0.008 | ND | ND | 0.120 |
| <40                                       | 200.8±15.9    |        |    |     |       |
| ≥40                                       | 200.5±2.6     |        |    |     |       |
| Preoperative KPS                          |               | 0.051 | ND | ND | 0.923 |
| 90–100                                    | 234.5±4.4     |        |    |     |       |
| ≤80                                       | 132.9±10.2    |        |    |     |       |
| Postoperative KPS                         |               | <0.001 | 0.005-0.351 | 0.004 |
| 90–100                                    | 239.4±2.8     |        | 0.041 |       |
| ≤80                                       | 89.7±9.2      |        | 1 |       |
| Postoperative Cx.                         |               | 0.001 | ND | ND | 0.876 |
| No                                        | 233.1±4.5     |        |    |     |       |
| Yes                                       | 85.9±12.9     |        |    |     |       |
| Edema                                     |               | 0.140 | ND | ND | 0.192 |
| No or mild (<5 mm)                        | 230.3±5.9     |        |    |     |       |
| Moderate to severe                        | 129.0±6.6     |        |    |     |       |

*No stem sign : headache, dizziness, seizure, Stem sign : mental changes, motor weakness, cranial nerve deficit, †Group I : cerebellopontine angle & cerebellar convexity, Group II : territorial & peritocrular, Group III : skull base location including petroclival, foramen magnum, and jugular foramen, ‡Reference variable : non-skullbase location groups (Group I+II). Cx : complication, KPS : Karnofsky performance scale, ND : non-detected, WHO : World Health Organization*
low postoperative KPS (<90) were independent factors for short survival in multivariate analysis. In our study, the group of gross total resection has more survival rate. It is presumably related with recurrence rate and postoperative condition. Patients with high postoperative KPS represented lower complication rate and good postoperative condition. For this reason, the postoperative KPS was significant predictive factor of survival.

As previously reported by several authors, the most common postoperative complication was found to be cranial nerve paresis or palsy. In our study, the permanent neurological deficits occurred in 12% (19/158) of case and the most common type is cranial nerve injury (47%, 9/19). In multivariate analysis, skull base location and low postoperative KPS were independent factors for the occurrence of permanent complication. Because of more difficult anatomical factor in petroclival, foramen magnum or jugular foramen, surgical resection for these lesions have high risk of permanent complication, even though experienced neurosurgeon.

**CONCLUSION**

In this study, gross-total resection was achieved in 81.6% of the cases and related with non-skull base location. The recurrence rate was 13.3% and longer RFS was associated with benign pathology, postoperative KPS over than 90, low peritumoral edema, and complete resection. The 5-, 10-, and 15-year overall survival rates were 96.2%, 94.9%, and 94.9%, respectively. Benign pathology, postoperative KPS over than 90 and complete resection were independent factor for a longer survival. The permanent complication was developed in 13% of the patients and related with

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**Table 5. Univariate and multivariate analysis for permanent complication predictors in patients with infratentorial meningiomas**

| Variables                     | Complication (%) | Univariate | Multivariate |
|-------------------------------|------------------|------------|--------------|
|                               | No               | Yes        | p value      | HR           | 95% CI       | p value |
| Age                           |                  |            | 0.193        | ND           | ND           | 0.420   |
| <40 years                     | 10 (76.9)        | 3 (23.1)   |              |              |              |         |
| ≥40 years                     | 129 (89.0)       | 16 (11.0)  |              |              |              |         |
| Sex                           |                  |            | 0.069        | ND           | ND           | 0.210   |
| Male                          | 25 (78.1)        | 7 (21.9)   |              |              |              |         |
| Female                        | 114 (90.5)       | 12 (9.5)   |              |              |              |         |
| Preoperative symptom*         |                  |            | 0.043        | ND           | ND           | 0.895   |
| No stem sign                  | 88 (92.6)        | 7 (7.4)    |              |              |              |         |
| Stem sign                     | 51 (81.0)        | 12 (19.0)  |              |              |              |         |
| Location†                     |                  |            | 0.002        | 0.058-0.727  | 0.014       |
| Group I                       | 74 (90.2)        | 8 (9.8)    |              |              |              |         |
| Group II                      | 45 (95.7)        | 2 (4.3)    |              |              |              |         |
| Group III                     | 20 (69.0)        | 9 (31.0)   |              |              |              |         |
| Pathology (WHO grade)         |                  |            | 0.122        | ND           | ND           | 0.052   |
| Grade I                       | 132 (89.2)       | 16 (10.8)  |              |              |              |         |
| Grade II, III                 | 7 (70.0)         | 3 (30.0)   |              |              |              |         |
| Simpson grade                 |                  |            | 0.122        | ND           | ND           | 0.882   |
| Grade I, II                   | 116 (89.9)       | 13 (10.1)  |              |              |              |         |
| Grade III, IV, V              | 23 (79.3)        | 6 (20.7)   |              |              |              |         |
| Size (mm)                     |                  |            | 0.631        | ND           | ND           | 0.390   |
| <40                           | 71 (86.6)        | 11 (13.4)  |              |              |              |         |
| ≥40                           | 68 (89.5)        | 8 (10.5)   |              |              |              |         |
| Preoperative KPS              |                  |            | 0.099        | ND           | ND           | 0.241   |
| 90–100                        | 92 (92.0)        | 8 (8.0)    |              |              |              |         |
| ≤80                           | 41 (82.0)        | 9 (18.0)   |              |              |              |         |
| Postoperative KPS             |                  |            | <0.001       | 0.012-0.197  | <0.001      |
| 90–100                        | 111 (96.5)       | 4 (3.5)    |              |              |              |         |
| ≤80                           | 22 (62.9)        | 13 (37.1)  |              |              |              |         |
| Edema                         |                  |            | 0.442        | ND           | ND           | 0.124   |
| No or mild (<5 mm)            | 94 (89.5)        | 11 (10.5)  |              |              |              |         |
| Moderate to severe            | 45 (84.9)        | 8 (15.1)   |              |              |              |         |

*No stem sign : headache, dizziness, seizure, Stem sign : mental changes, motor weakness, cranial nerve deficit. †Group I : cerebellopontine angle & cerebellar convexility, Group II : tentorial & petroclival, Group III : skull base location including petroclival, foramen magnum, and jugular foramen. ‡Reference variable : non-skullbase location groups (Group I+II). Cx : complication, KPS : Karnofsky performance scale, ND : non-detected, WHO : World Health Organization
skull base location and postoperative KPS less than 90. Our results show relatively low morbidity and mortality rates, and good surgical resection and low recurrence rate, compare to the results of past, due to significant advances contemporary neurosurgical techniques, neuromonitoring and neuroanesthesia. However, infratentorial meningioma still has been a challenge for neurosurgeon because of their close to critical vascular and nerves structure. To achieve the goal that a little more lower morbidity and mortality, the surgeon need to consider of these factors and try to appropriate surgical planning of each case.

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