Muscular-stage Dissection during Far Lateral Approach and Its Transcondylar Extension

Akihito Sato^{1,2} Sakyo Hirai^{1,3} Yoshiki Obata⁴ Taketoshi Maehara² Masaru Aoyagi^{1,3}

¹Department of Neurosurgery, Shioda Memorial Hospital, Chiba, Japan

²Department of Neurosurgery, Tokyo Medical and Dental University, Tokyo, Japan

³Department of Neurosurgery, Kameda Medical Center, Chiba, Japan

⁴Department of Neurosurgery, Tokyo-Kita Medical Center, Tokyo, Japan

Address for correspondence Akihito Sato, MD, Department of Neurosurgery, Shioda Memorial Hospital, 550-1 Kouri, Nagara, Chosei-gun, Chiba, 297-0203, Japan
(e-mail: sotrecnocnipohc@gmail.com).

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Abstract

Background The far lateral approach includes exposure of the C1 transverse process, vertebral artery, posterior arch of the atlas, and occipital condyle. We designed a method for systematic muscular-stage dissection and present our experience with this approach.

Operative Methods We used a horseshoe scalp flap that was reflected downward and medially. The lateral muscle layers were separated layer to layer to expose the suboccipital triangle. The medial muscle layers were separated in the midline and reflected in a single layer. At this stage, the midline of the C1 process and the foramen magnum were identified. The rectus capitis posterior major muscle was reflected to expose the posterior arch of the atlas. The C1 transverse process and vertebral artery were identified by reflection of the superior oblique muscle. The occipital condyle was separated accordingly.

Results We used this method of muscular dissection in 10 patients (foramen magnum meningioma, $n = 5$; hypoglossal schwannoma, $n = 2$; others, $n = 3$). Systematic muscular-stage dissection facilitates identification of the anatomical landmarks with no vertebral artery injury. Gross total removal was obtained in all 9 patients with complex tumors. The patient with vertebral artery dissection successfully underwent proximal clipping.

Conclusion Our muscular-stage dissection could contribute to safe and effective surgery for the far lateral approach.

Keywords

- ▶ far lateral
- ▶ skull base
- ▶ surgical approach
- ▶ muscular dissection

Introduction

The far lateral approach has been applied for the surgery of tumors or vascular lesions around the ventral portions of the foramen magnum or craniocervical junction.^{1–6} The main advantage of this approach is the direct view offered of the anterior rim of the foramen magnum without requiring brain-stem retraction.³ Neurosurgeons should master the far lateral approach to ensure safe and smooth dissection, because identification of muscle layers and anatomical landmarks is some-

times confusing and thus time-consuming for neurosurgeons unfamiliar with this approach.⁴ Important anatomical landmarks include the C1 transverse process, the V3 portion of the vertebral artery, the posterior arch of the atlas, and the occipital condyle.⁵ A systematic approach to identify important anatomical landmarks is essential for safe and successful surgery.

Although the lazy S-shaped skin incision⁷ and the C-shaped skin incision⁸ have been proposed to minimize excessive muscle dissection and skin elevation that may lead to the development of cerebrospinal fluid (CSF) leaks, the standard skin

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incision for the far lateral approach remains the classic horseshoe scalp flap incision.^{4,5,8} We have so far adopted the standard horseshoe scalp flap incision to obtain wide exposure. In a cadaveric study description of the horseshoe scalp flap incision,^{4,5} the muscles were reflected separately, but in actual operations, the scalp and muscles superficial to the suboccipital triangle are reflected from the suboccipital area in a single layer. However, even with wide exposure by the horseshoe scalp flap, making a systematic approach to identify important anatomical landmarks is essential for safe and successful surgical operations. This study details our experience with this approach, particularly the muscular-stage dissection, facilitating safe and quick identification of the important anatomical structures.

Patients and Methods

Fifteen patients with tumors and vascular lesions around the craniocervical junction underwent surgical treatment via the far lateral approach from 2001 to 2016. In the 7-year period from 2009 to 2016, we used our systematic surgical technique in 10 cases. These surgical series included 5 cases of foramen magnum meningioma, 1 case of jugular foramen meningioma, 2 cases of hypoglossal schwannoma, 1 case of subependymoma, and 1 case of vertebral artery dissection. Mean age at the time of surgery was 51.6 years (range, 20–72 years). Six patients were female and 4 were male. Informed consent was obtained from each individual to report radiological images and pictures taken

Fig. 1 Schematic drawing of muscular-stage dissection during the far lateral approach. (A) Lateral muscle layers are separated from the suboccipital triangle and reflected downward. (B) Muscles from the medial group are separated in the midline and elevated from the bone surface in a single layer. The posterior ridge of the foramen magnum and the C1–C2 spinous process is identified. (C) The posterior arch of the atlas is separated both from the medial and lateral directions along with the inferior oblique muscle. (D) Important anatomical landmarks. Abbreviations: Semispin. Cap. M., semispinalis capitis muscle; Long. Cap. M., longissimus capitis muscle; Sup. Obl. M., superior oblique muscle; Inf. Nuchal L., inferior nuchal line; Splen. Cap. M., splenius capitis muscle; Sternocleidomas. M., sternocleidomastoid muscle; Rec. Cap. Post. Min. M., rectus capitis posterior minor muscle; Rec. Cap. Post. Maj. M., rectus capitis posterior major muscle; V. A., vertebral artery; Occip. Cond., occipital condyle; C1 Trans. Proc., C1 transverse process; Cond. Emissary Vein, condylar emissary vein; Inf. obl. m., inferior oblique muscle; Post. Arch of C1, posterior arch of C1.

during surgery in the academic journals using a form provided by the ethics committees at our institutions.

Surgical Technique and Results

Surgical Technique

A lumbar spinal drain is inserted for CSF drainage after general anesthesia has been administered. To prevent CSF leak, lumbar drainage was maintained from 3 to 4 days after surgery. The patient is placed in the lateral position, keeping the upper body elevated 20° to minimize venous bleeding, and the neck is flexed toward the floor to open the angle between the shoulder and skull base, but preventing compression of the contralateral jugular venous drainage.

We use a horseshoe scalp flap incision. The skin incision begins in the midline at the posterior tubercle of C2 and is directed upward to just above the external occipital protuber-

ance, turning laterally just above the superior nuchal line, reaching the mastoid and turning downward 2-cm below the mastoid tip.⁴ The skin flap is reflected downward and medially.

The concept of our muscular-stage dissection is that the lateral muscle layers are separated layer to layer to expose suboccipital triangle, then the medial muscle layers are separated in the midline and reflected in a single layer. First, the sternocleidomastoid muscles are dissected and separated laterally. The splenius capitis and longissimus capitis muscles are separated from the suboccipital triangle and reflected downward (►Figs. 1A, 1B). The medial group of muscles, including semispinalis capitis and rectus capitis minor muscles, are separated in the midline, cut along the superior nuchal line, and elevated from the bone surface in a single layer (►Figs. 1B, 2A, 2B). We identify the posterior ridge of the foramen magnum and the C1–C2 spinous process at this stage of midline muscular dissection, as done in the suboccipital

Fig. 2 Surgical pictures taken during muscular-stage dissection with the far lateral approach. This case is Case 10 from ►Table 1. (A) Muscles from the lateral group are separated layer to layer to expose suboccipital triangle. (B) Muscles from the medial group are separated in the midline and elevated from the bone surface. (C) The posterior ridge of the foramen magnum and the C1 spinous process are identified. (D) The posterior arch of the C1 and the vertebral artery are identified. Abbreviations: O. A., occipital artery; C1 Spinous Proc., C1 spinous process; For. Magnum, foramen magnum; Post. Arch of the atlas, posterior arch of the atlas.

midline approach (►Figs. 1B, 2B). We avoid separation between the cutaneous and muscle layers as much as possible to protect the cutaneous vascular supply. Next, we elevate the superior oblique muscle from the bone surface at the inferior nuchal line. The rectus capitis posterior major and minor muscles are elevated and reflected downward together with the semispinalis capitis muscle (►Figs. 1C, 2C). The posterior arch of the atlas is separated from both medial and lateral directions along with the inferior oblique muscle attached to the C1 transverse process and the posterior tubercle of C2 (►Figs. 1C, 2C). The superior oblique muscle is further separated from the fat tissues and the paravertebral venous plexus toward the C1 transverse process to identify the V3 segment of the vertebral artery running above and along the lateral C1 vertebral groove (►Figs. 1D, 2D). Laminectomy of the posterior arch of the C1 is then performed. The occipital condyle is identified after coagulation and cutting of the condylar emissary vein. Suboccipital craniotomy with exposure of the lower part of the sigmoid sinus is performed. If necessary, drilling the occipital condyle or lateral part of the jugular tubercle proceeds as required accordingly.

We made a small dural incision at the C1 level to relieve tension on the brain by CSF drainage. After further opening the dura of the posterior fossa along the sigmoid sinus, we could approach the ventral portions of the foramen magnum or craniocervical junction (►Fig. 3).

Surgical Results

We adopted our method for the far lateral approach using systematic muscle stage dissection in 10 patients between 2009 and 2016 (►Table 1). Systematic muscular-stage dissection facilitates identification of the anatomical landmarks with no vertebral artery injury. Gross total removal was obtained in all 9 patients with tumors. The patient with vertebral artery dissection successfully underwent proximal clipping. Gait ataxia in 5 patients with large foramen magnum meningioma dramatically improved postoperatively. CSF leak was identified as a complication in 2 patients (Cases 1 and 10 in ►Table 1), even with the use of lumbar drainage. Both underwent reoperation, 47 and 21 days after the first surgery, respectively, where the dural leakage was closed by suturing dura using muscle fascia and coating with fibrin glue. Points of CSF leakage were found at the sutured dura over the major cistern. Preoperatively, 3 patients complained of dysphagia and dysphonia that deteriorated postoperatively, but improved and became capable of oral intake 5 weeks after surgery in every patient. A temporary nasogastric tube was required in 1 patient (Case 3) for 2 weeks postoperatively. Tracheostomy was not needed in any case. Skin adaptation was quite good in all 10 patients.

Discussion

The far lateral approach is suitable for the surgery of tumors or vascular lesions located around the ventral portions of the foramen magnum or craniocervical junction.^{1–6} Identification of the important anatomical landmarks is essential for safe and successful surgery, but is sometimes complex during the actual surgery.⁴ Important anatomical landmarks include

Fig. 3 T1-weighted MR images with gadolinium enhancement (A and B) and surgical pictures (C and D) before (A and C) and after (B and D) total removal of a left-side large meningioma attached to the anterior rim of the foramen magnum. Representative images are of Case 9 from ►Table 1.

the C1 transverse process, the V3 portion of the vertebral artery, the posterior arch of the atlas, and the occipital condyle.^{4,5} The V3 segment of the vertebral artery is well known to lie within the suboccipital triangle, which is formed by the superior oblique muscle, inferior oblique muscle, and rectus capitis posterior major muscle.^{4,5} However, identification of this triangle and dissection of the V3 segment is not always straightforward in the actual surgery.⁷

In a cadaveric study, Wanibuchi et al⁷ reported a systematic method to identify the V3 segment using 4 bony landmarks. They used a small lazy S-shaped skin incision and did not use the guidance of muscular-stage dissection. The key point they indicate is to follow the midline of the posterior ridge of the foramen magnum and then find the posterior tubercle of C1, which is followed anteriorly from the tubercle to find the “J-groove,” which cradles the vertebral artery. However, when using the postauricular small lazy S-shaped skin incision, the posterior midline of the foramen magnum and C1 spinous process seem difficult to find in the actual

Table 1 Surgical results of patients who underwent the far lateral approach

No.	Age (years)	Sex	Diagnosis	Size (cm)	Preope symptom	Surgery	Postope complication	Curative	Follow-up (months)
1	44	F	FM meningioma	4.0	Ataxia	GTR	CSF leak	Reope (POD 47)	70
2	71	M	FM meningioma	4.0	Ataxia	GTR	None		68
3	37	F	Hypoglossal schwannoma	4.0	Dysphagia, dysphonia	GTR	Dysphagia, dysphonia	NGT(+) (2 wk)	57
4	52	F	Jugular foramen meningioma	4.0	Dysphagia, dysphonia	GTR	Dysphagia, dysphonia	NGT(–)	52
5	72	F	FM meningioma	3.0	Ataxia, Headache	GTR	None		50
6	45	M	Hypoglossal schwannoma	5.0	Dysphagia, dysphonia	GTR	Dysphagia, dysphonia	NGT (–)	50
7	65	F	FM meningioma	3.5	Ataxia	GTR	None		27
8	58	F	FM meningioma	3.5	Ataxia	GTR	None		15
9	20	M	Subependymoma	4.0	Headache	GTR	None		14
10	52	F	VA dissection	–	Headache	Proximal clipping	CSF leak	Reope (POD 21)	11

Abbreviations: CSF, cerebrospinal fluid; FM, foramen magnum; GTR, gross total resection; NGT, nasogastric tube; POD, postoperative day; Postope, postoperative; Preope, preoperative; Reope, reoperation; VA, vertebral artery.

surgery. Because patients are usually set in the lateral head position during the far lateral approach, accurate location in the midline is difficult. We adopted a wide horseshoe skin incision allowing safe and quick identification of the posterior midline by dividing between the right and left semispinalis capitis muscles that lie just beneath the skin incision, as usually done in the suboccipital midline approach. We could identify the posterior ridge of the foramen magnum and C1–C2 spinous process at this stage of midline muscular dissection. The concept of our muscular-stage dissection is that the medial muscle layers are separated in the midline and reflected in a single layer, and the lateral muscle layers are separated layer to layer to expose the suboccipital triangle. The rectus capitis posterior major and minor muscles are elevated and reflected downward together with the semispinalis capitis muscle. The posterior arch of the atlas is separated from both medial and lateral directions along with the inferior oblique muscle, which is attached to the C1 transverse process and posterior tubercle of C2. Our approach using a wide horseshoe skin incision facilitates use of a systematic muscular-stage dissection that can help to identify the important anatomical landmarks, C1 transverse process, posterior arch of the atlas, V3 portion of the vertebral artery, and occipital condyle.

Although the wide horseshoe skin incision may be invasive, when compared with the lazy S-shaped⁷ or C-shaped⁸ skin incisions, we avoid separation between the cutaneous and muscle layers as much as possible to protect the vascular supply of the skin. No problems in skin adaptation were encountered in any patients. CSF leakage was complicated in 2 of the 10 patients. This complication could be overcome by carefully suturing the dura over the

major cistern and using lumbar CSF drainage maintained from 3 to 4 days after surgery. We believe our systematic muscular-stage dissection can help to identify important anatomical landmarks during the far lateral approach and thus contributes to safe and successful surgery for complex pathologies.

Conclusion

We reported our systematic muscular-stage dissection with a horseshoe skin incision during the far lateral approach. The concept of our approach is that the lateral muscle layers are separated layer to layer to expose the suboccipital triangle, and the medial muscle layers are separated in the midline and reflected in a single layer. Systematic muscular-stage dissection facilitates identification of the important anatomical landmarks, the C1 transverse process, the posterior arch of the atlas, V3 portion of the vertebral artery, and the occipital condyle. These anatomical landmarks are identified safely and quickly. Our muscular-stage dissection could contribute to safe and effective surgery during the far lateral approach.

Conflict of Interest
None.

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