Minimally Invasive Supracondylar Transtubercular (MIST) Approach to the Lower Clivus

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Key words
- Clivus
- Endoscope-assisted surgery
- Far-lateral approach
- Jugular tubercle
- Microsurgical anatomy
- Supracondylar transtubercular approach

Abbreviations and Acronyms
CN: Cranial nerve
FLA: Far-lateral approach
JT: Jugular tubercle
MIST: Minimally invasive supracondylar transtubercular
PICA: Posteroinferior cerebellar artery
VA: Vertebral artery
VB: Vertebrobasilar
VBJ: Vertebrobasilar junction

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OBJECTIVE: **Drawbacks of the far-lateral approach to the lower clivus and pontomedullary region include the morbidity of a large incision extending into the cervical musculature and tedious exposure of the vertebral artery (VA), particularly when performing the transcondylar and transtubercular extensions. The authors describe a minimally invasive alternative to the far-lateral approach that has the potential to minimize operative morbidity and decrease the need for VA manipulation.**

METHODS: **The minimally invasive supracondylar transtubercular (MIST) and far-lateral supracondylar transtubercular (FLST) approaches were performed in 10 adult cadaveric specimens (20 sides). The microsurgical anatomy of each step and the surgical views were analyzed and compared. In addition, the endoscopic view through the MIST was examined in five fresh cadaveric specimens (10 sides).**

RESULTS: **The MIST approach provided exposure of the inferior-middle clivus, the anterolateral brainstem, and the premedullary cisterns, including the PICA-VA and vertebrobasilar junctions. The endoscope provided a clear view of cranial nerves III through XII, as well as the vertebrobasilar system. The FLST approach increased visualization of the anterolateral margin of the foramen magnum; otherwise, the surgical view is similar between the MIST and FLST approaches.**

CONCLUSIONS: **The MIST approach could be considered as a potential alternative to the FLST approach in the treatment of lesions involving the inferior and middle clivus, and anterolateral lower brainstem; it does not require a C1 laminectomy, significant disruption of the atlanto-occipital joint, nor extensive exposure of the extracranial VA. Moreover, the MIST approach is an ideal companion to endoscope-assisted neurosurgery.**

INTRODUCTION

The far-lateral approach (FLA), consisting of a lateral suboccipital craniotomy with removal of the C1 arch (**Figures 1** and **2**), has been the primary surgical approach used to access lesions involving the inferior clivus, pontomedullary junction, lateral medulla, vertebrobasilar junction (VBJ) and posteroinferior cerebellar artery (PICA; 2, 5, 10-12, 14, 15, 21, 22, 24, 27, 28, 31). Depending on the localization of the lesion and the anatomic characteristics of the surrounding structures, the surgeon may be required to perform a vascular transposition of the vertebral artery or to further drill osseous obstacles, in order to extend the exposure of the basic FLA. The transcondylar extension involves the extradural removal of the posterior third of the occipital condyle (**Figures 1** and **2**). Further exposure can be achieved by removing the jugular tubercle (JT), which significantly improves access to the anterolateral brainstem and the structures located in the premedullary cisterns (**Figures 1** and **2**). Drawbacks to the extended FLAs include the morbidity of a large incision extending into the upper cervical spine, the exposure and manipulation of the horizontal V3 segment of the vertebral artery (VA), and operative time.

METHODS

A total of 10 cadaveric specimens (20 sides) were included in this study. The arteries and veins were infused with colored silicone. Using ×3 to ×40 magnification, the microsurgical anatomy was examined bilaterally while performing the minimally invasive supracondylar transtubercular (MIST) approach and the far-lateral supracondylar transtubercular approach. In addition, the endoscopic view through the MIST was examined in five fresh cadaveric specimens (10 sides) using a rigid endoscope.

MIST Surgical Technique

Specimens were dissected in a manner to simulate patient positioning in a Park bench, three-quarter prone position, with

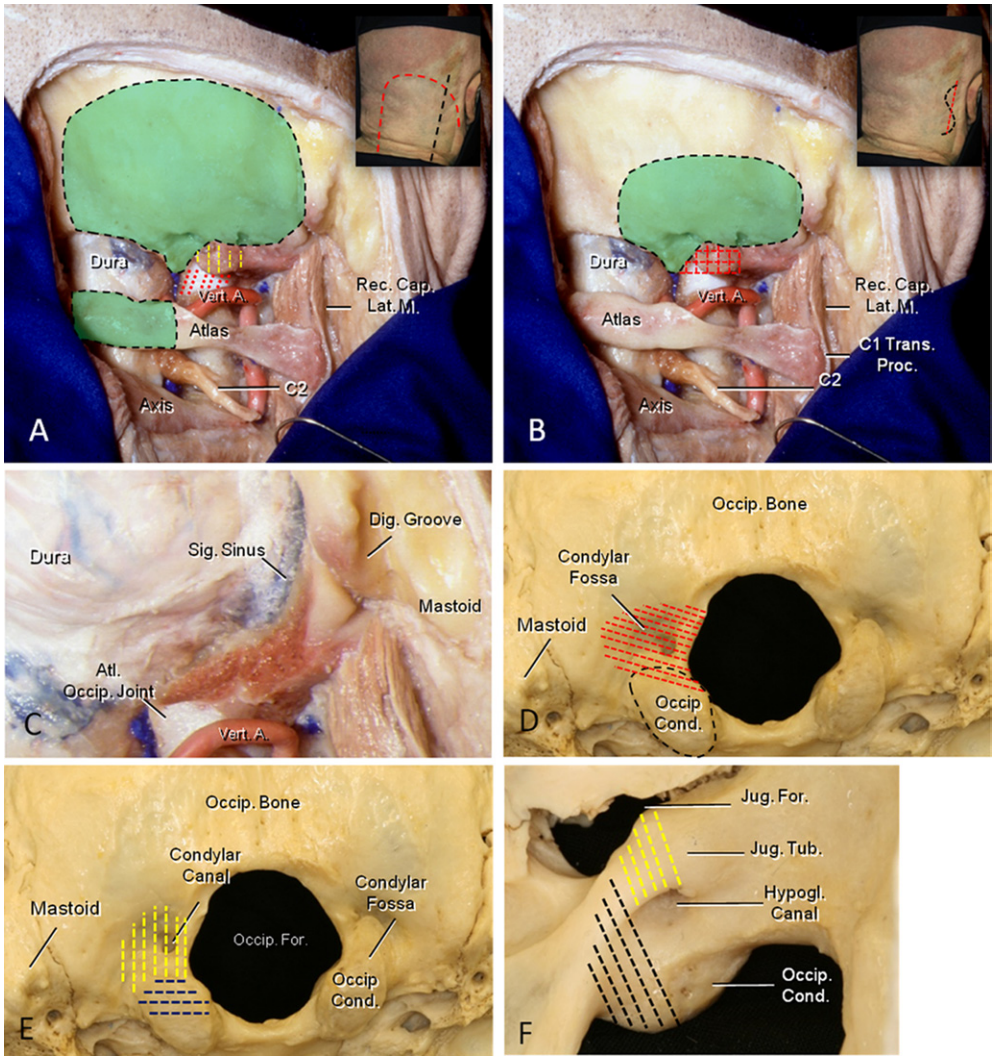

Figure 1. (**A**) Far-lateral approach and its extensions. A large hockey-stick or paramedian straight skin incision, extending into the upper cervical spine, is commonly selected for the far-lateral exposure (insert). In this cadaveric dissection, the muscles forming the margins of the suboccipital triangle have been removed to show the vertebral artery and the C2 nerve exiting between the C1 and C2 laminas. The vertical part and the distal loop of the V3 segment of the vertebral artery are exposed. The horizontal segment of V3 occupies the groove of the posterior arch of the atlas and pierces the dura just medial to the condyle. Before drilling, this segment of the vertebral artery must be identified in order to prevent iatrogenic vascular injury. Classic far-lateral craniotomy (*green-colored area*) includes the resection of the C1 hemilamina. The transcondylar approach includes drilling of the posterior third of the occipital condyle until reaching the posterior wall of the hypoglossal canal (*oblique red dotted lines*). The supracondylar transtubercular extension of the approach (*yellow dotted lines*) involves drilling through the condylar fossa and the jugular tubercle. (**B**) Minimally invasive supracondylar transtubercular (MIST) approach. A small vertical or slightly S-shaped skin incision, centered approximately 2 cm medial to the mastoid process is chosen when performing the MIST approach (insert). A small lateral suboccipital craniotomy (*green-colored area*) is required; it includes the resection of the posterolateral rim of the foramen magnum and extends laterally until the medial edge of the sigmoid sinus. A small portion of the superior–posterior–medial edge of the occipital condyle is resected with minimal joint disruption. Next, the condylar fossa is drilled from superficial to deep in order to remove the jugular tubercle (*red dotted line*). (**C**) Lateral suboccipital craniotomy includes resection of the posterolateral rim of the occipital foramen and extends laterally until the medial border of the sigmoid sinus. Any bony impedance medial to the sigmoid sinus and occipital condyle is removed with a shaving burr. (**D**) Posteroinferior view of the occipital bone and foramen magnum. In the MIST approach, bony removal includes also a partial resection of the most superior–posterior–medial edge of the occipital condyle, and drilling of the condylar fossa above the condyle (*red dotted lines*). Most of the occipital condyle is left intact. (**E** and **F**) Supracondylar and transcondylar extensions of the far-lateral approach. (**E**) Posteroinferior view of the occipital bone and foramen magnum. The supracondylar approach includes drilling through the condylar fossa (*yellow dotted lines*). The condylar fossa is a depression located on the external surface of the occipital bone, behind the occipital condyle; there is often an emissary vein and associated posterior condylar canal through which the posterior condylar vein connects the vertebral artery venous plexus to the sigmoid sinus. The condylar fossa lies superficial to the jugular tubercle and lies between the jugular bulb laterally and the posterolateral portion of the foramen magnum medially. The transcondylar approach involves drilling of the posterior third of the occipital condyle. The soft cancellous bone of the condyle is removed until reaching the cortical bone that forms the posterior wall of the hypoglossal canal. (**F**) Medial view of the occipital condyle, intracranial opening of hypoglossal canal and jugular tubercle. The posterior third of the occipital condyle is removed until reaching the posterior margin of the hypoglossal canal, during the transcondylar approach (*black dotted lines*). The *yellow dotted lines* indicate the supracondylar drilling through the condylar fossa, above the occipital condyle and hypoglossal canal and extending anteriorly through the jugular tubercle. A., artery; Atl., atlanto-; Cap., capitis; Cond., condyle; Dig., digastric; For., foramen; Hypogl., hypoglossal; Jug., jugular; Lat., lateralis; M., muscle; Occip., occipital; Proc., process; Rec., rectus; Sig., sigmoid ; Trans., transverse; Tub., tubercle; Vert., vertebral.