Frontolateral Approach Combined with Endoscopic Endonasal Extradural Posterior Clinoidectomy to the Upper Clival Region: Anatomic and Feasibility Study

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■ BACKGROUND: **Surgical management of lesions located in the upper clival region is challenging. Complex open transcranial approaches have been used to reach surgical targets in these areas. The frontotemporozygomatic approach combined with an intradural posterior clinoidectomy has been proposed as the most reliable route to manage such lesions. We investigated combining a minimally invasive endoscopic endonasal extradural posterior clinoidectomy (EPC) with a standard frontolateral approach to expand the working area within the upper clival region.**

■ METHODS: **Investigators dissected 10 human cadaveric heads at the Laboratory of Surgical NeuroAnatomy of the University of Barcelona. The heads were positioned to simulate a supine position, enabling the simultaneous use of both endonasal and frontolateral routes. The dissections were divided into 3 steps—standard frontolateral approach, EPC, and re-evaluation of the frontolateral route—aiming to compare the surgical exposure before and after EPC.**

■ RESULTS: **After EPC, through the frontolateral pathway it was possible to improve visualization and working angles to the interpeduncular fossa and retrosellar and upper clival regions. Increase in extension of the carotid-oculomotor window was 7 mm and 10 mm before and after the posterior clinoidectomy, respectively.**

■ CONCLUSIONS: **EPC provided extra working space for the frontolateral approach to the upper clival area with 42.8% expansion of the carotid-oculomotor triangle. Surgical series are needed to demonstrate clinical advantages and disadvantages of this novel combined approach.**

INTRODUCTION

Various conventional approaches have been described to address the skull base, in particular, its posterior part. However, these exposures may be associated with significant approach-related morbidity, including damage to diencephalon or mesencephalon resulting from injury to the perforators of the posterior cerebral and basilar arteries.[1-8] Among the challenging complex regions, the retrosellar and upper clival regions have long been considered as the most difficult skull base areas to access because of their critical neurovascular relationships and their deep-seated and narrow location. Lesions such as intraparenchymal tumors as well as cerebrovascular disease located in the interpeduncular cistern, such as basilar artery (BA) aneurysms, may be difficult to approach surgically even with the extensive skull base approaches.[9-14]

During the last decade, advances in microsurgical techniques and newer generation endoscopes have allowed the field of neurosurgery to move forward with strategies to improve safe access to these areas.[1,2,7,10,12,13,15-21] As one of the problems related to the surgical management of lesions involving these regions is the difficult "wide-enough" exposition, many authors have advocated the possibility of additional removal of skull base portions to increase the space of the surgical corridor.[22-24] Among them, posterior clinoidectomy represents a well-known surgical technique providing direct access and increased exposure of the

Key words
- Anatomy
- Clivus
- Endonasal
- Endoscopic
- Frontolateral approach
- Posterior clinoid

Abbreviations and Acronyms
BA: Basilar artery
EPC: Endoscopic endonasal extradural posterior clinoidectomy
ICA: Internal carotid artery
PCP: Posterior clinoid process

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infrasellar and retrosellar regions via transcranial routes. It is mainly a technical nuance to increase the exposure in the surgical management of upper BA aneurysms and certain skull base tumors.[21,25,26] The posterior clinoid process (PCP) represents a consistent anatomic barrier preventing lateral access to the interpeduncular cistern. The advantages that can be obtained after posterior clinoidectomy include enhanced visualization of the interpeduncular cistern and its content, increased surgical corridor within the carotid-oculomotor window, and early vascular control of the posterior circulation.[20]

However, intradural transcranial posterior clinoidectomy is a technically challenging procedure because of the deep location of PCP and the presence of surrounding vital structures, such as the internal carotid artery (ICA), oculomotor nerve, and optic chiasm. The principles underlying modern cranial base surgical strategies include maximization of extradural bone removal instead of brain retraction to reach deep-seated lesions. Posterior clinoidectomy represents one of the few mandatory risky intradural maneuvers. Accordingly, owing to the risks of approach-related morbidity, some centers tend to stage the procedures, while minimizing the use of extensive bony resection. For this reason, some authors recently have demonstrated the possibility of an endoscopic endonasal extradural posterior clinoidectomy (ECP) to gain access to the interpeduncular cistern via a ventral route,[11,27,28] with or without pituitary gland transposition.[11] Therefore, the aim of the present anatomic study was to investigate the feasibility of performing ECP as an adjunct to the standard transcranial frontolateral approach to combine both routes, thus achieving a wider access to the upper clival region. This combined/staged procedure may be an effective strategy to access and manage complex lesions arising or extending in such areas.

MATERIALS AND METHODS

Computer-Based Analysis

After the surgical approaches were chosen, a virtual dissection was performed using an interface designed through specific imaging software for the manipulation of biomedical data (Amira Visage Imaging Inc., San Diego, California, USA). Our system allows the neurosurgeon to perform a step-by-step virtual dissection and to precisely tailor the extent of the posterior clinoidectomy in a virtual three-dimensional environment (**Figure 1A** and **B**). After that, a preliminary analysis of the predissection computed tomography scan was performed using an open-source software for navigating in multidimensional Digital Imaging and Communications in Medicine images (OsiriX; Pixmeo SARL, Bernex, Switzerland) to meaningfully evaluate the anatomic individual variability (**Figure 1C**). Bony structures were segmented from Digital Imaging and Communications in Medicine images using a semiautomatic thresholds-based procedure, and then a smoothing function was applied to further refine the rendering of the bony surfaces.

Anatomic Dissections

Anatomic dissections were performed at the Laboratory of Surgical Neuroanatomy in the Human Anatomy and Embryology Unit, University of Barcelona Faculty of Medicine, Barcelona, Spain, on 10 fixed cadaveric heads (20 sides). Before dissections, all specimens were scanned with a multislice helical computed tomography scanner (Siemens SOMATOM Sensation 64; Siemens Healthcare GmbH, Erlangen, Germany) with 0.4-mm-thick axial spiral sections and a 0° gantry angle. The common carotid arteries were injected with red latex. The specimens were positioned simulating a supine position with a slight extension and rotation of the head, thus enabling the use of both transcranial and endonasal routes. The dissections were divided into 3 steps: 1) standard frontolateral craniotomy, 2) ECP and dorsectomy, and 3) re-evaluation of the frontolateral route to compare the surgical exposure before and after posterior clinoidectomy. An operative microscope (Carl Zeiss AG, Oberkochen, Germany) was used for all transcranial approaches, whereas the endoscopic procedures were performed using a high-definition camera attached to rigid endoscopes (KARL STORZ GmbH & Co. KG, Tuttlingen, Germany) 4 mm in diameter and 18 cm in length with 0° lens. Multiple anatomic linear measurements were obtained during dissections and then analyzed in the post-dissection step. The linear extension of the carotid-oculomotor window was measured from the medial aspect of the brainstem origin of the oculomotor nerve to the midpoint of the posterior clinoid or the dura mater covering it in case of EPC.

RESULTS

In all the specimens analyzed, it was possible to access and resect the PCP via the nose in a purely extradural fashion without

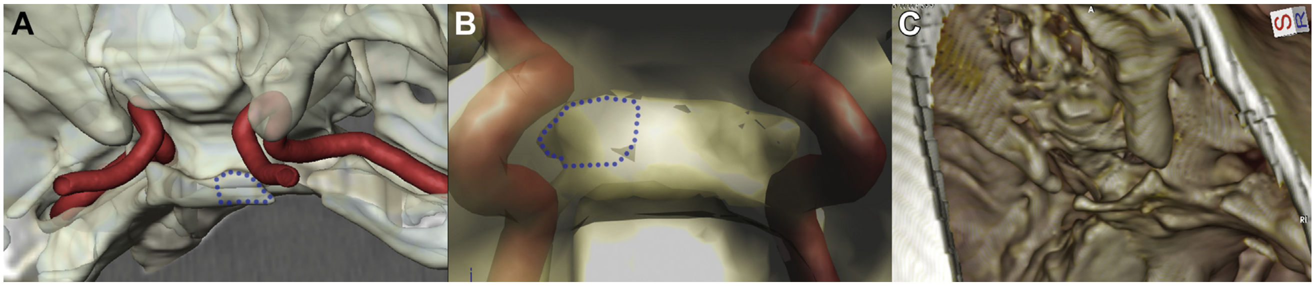

Figure 1. (**A** and **B**) Bone anatomy of the anterior skull base using an interface designed through specific imaging software for the manipulation of biomedical data. This system allows the neurosurgeon to perform a step-by-step virtual dissection and to precisely tailor the extent of the posterior clinoidectomy in a virtual three-dimensional environment. (**C**) A preliminary analysis of the predissection computed tomography scan was performed using open-source software for navigating in multidimensional Digital Imaging and Communications in Medicine images to meaningfully evaluate the three-dimensional perspective of the individual anatomic variability.