The Use of a Three-Dimensional Novel Computer-Based Model for Analysis of the Endonasal Endoscopic Approach to the Midline Skull Base

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Key words
- Endoscopic endonasal approach
- Neuroanatomy
- Pituitary surgery
- Skull base surgery
- Suprasellar area
- Surgical anatomy
- Three-dimensional anatomy
- Transsphenoidal surgery

Abbreviations and Acronyms
CT: Computed tomography
DICOM: Digital imaging and communications in medicine
PACS: Picture archiving and communication system
VOI: Volume of interest

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■ OBJECTIVES: **To apply a three-dimensional geometric model to various endoscopic endonasal approaches to analyze the bony anatomy of this area, quantify preoperatively bone removal, and optimize surgical planning.**

■ METHODS: **Investigators dissected 18 human cadaveric heads at the Laboratory of Surgical NeuroAnatomy (LSNA) of the University of Barcelona (Spain). Before and after each dissection, a computed tomography (CT) scan was performed to create a three-dimensional geometric model of the approach performed in the dissection room. The model protocol was designed as follows: *(i)* a preliminary exploration of each specimen using the preoperative CT scan, *(ii)* creation of a computer-generated three-dimensional virtual model of the approach, *(iii)* cadaveric anatomic dissection, and *(iv)* development of a CT-based model of the approach as a result of the superimposition of predissection and postdissection digital imaging and communications in medicine (DICOM) images of specimens.**

■ RESULTS: **This method employing preliminary virtual exploration of each specimen, the creation of a three-dimensional virtual model of the approach, and the overlapping of the predissection and postdissection three-dimensional models was useful to define the exact boundaries of the endoscopic endonasal craniectomy.**

■ CONCLUSIONS: **Aside from laboratory anatomic dissection itself, this model is very effective in providing a depiction of bony landmarks and visual feedback of the amount of bone removed, improving the design of the craniectomy in the endoscopic endonasal midline skull base approach.**

INTRODUCTION

Technologic progress and continuous surgical advances in recent decades have led to a progressive reduction of the invasiveness of transcranial procedures to the skull base and have shed light on the possibility to access this area through a different surgical corridor—the transsphenoidal. In 1987, Weiss (40) originally termed and described the extended transsphenoidal approach, in which additional bone removal along the tuberculum sellae and the posterior planum sphenoidale between the optic canals is performed so that, after the opening of dura mater above the diaphragma sellae, midline access and direct visualization of the suprasellar space can be achieved without brain manipulation. More recently, as a result of otorhinolaryngologists' improved experience in endoscopic sinus surgery (29, 32, 37), the endoscope was introduced first during traditional transsphenoidal surgery (18, 21) and thereafter as the sole visualizing tool during the whole procedure in the "pure" endoscopic endonasal approach (4, 9, 13, 22). The advent of the endoscope further promoted efforts in the field of surgical anatomy research: Endoscopic endonasal approaches have being continuously refined and evaluated in terms of efficacy, morbidity, and mortality. The wider panoramic view offered by the endoscope boosted the development of various modifications of the transsphenoidal approach targeted mainly to the entire skull base from the most anterior areas to the craniovertebral junction and adjacent regions (5, 7, 11, 12, 14, 17, 24-28).

Although this approach has been gaining acceptance, perfect knowledge is needed of areas dealt with from a different, opposite, point of view. Anatomic laboratory dissection, even in this field of neurosurgery, remains the "gold standard" in training surgeons, offering a unique experience of a wide range of sensorial inputs that cannot be replaced by any machine. Such rehearsal gives surgeons technical skills to become confident with the surgical technique and provides the opportunity to understand the

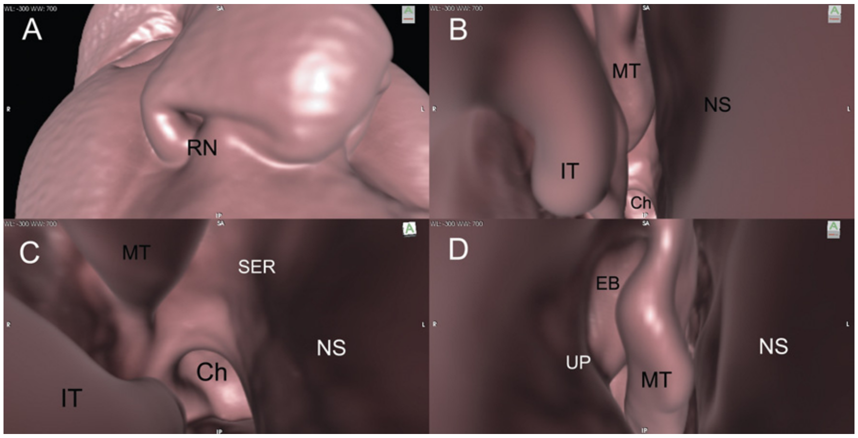

Figure 1. Virtual preoperative exploration of each specimen using three-dimensional endoscopy module supported by the OsiriX software. Ch, choana; EB, ethmoid bulla; IT, inferior turbinate; MT, middle turbinate; NS, nasal septum; RN, right nostril; SER, sphenoethmoidal recess; UP, uncinate process.

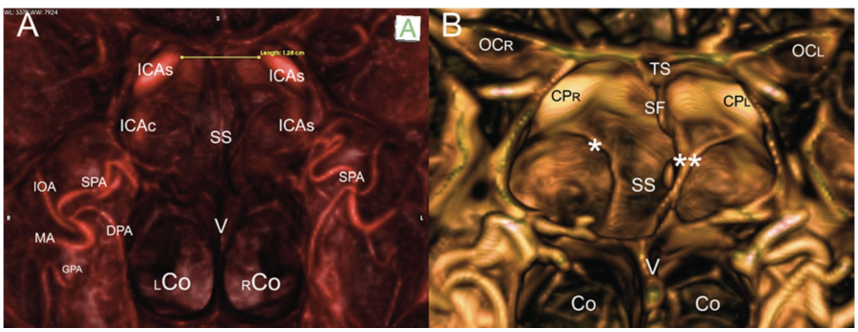

Figure 2. Volume-rendering reconstruction using OsiriX software of main vascular **(A)** and bony **(B)** anatomic structures involved in the approach as seen from the endonasal perspective. CPL, left carotid prominence; CPR, right carotid prominence; DPA, descending palatine artery; GPA, greater petrosal artery; ICAc, paraclival tract of the internal carotid artery; ICAs, parasellar tract of the internal carotid artery; IOA, infraorbital artery; lCo, left choana; OCL, left optic canal; OCR, right optic canal; rCo, right choana; SF, sellar floor; SPA, sphenopalatine artery; SS, sphenoid sinus; TS, tuberculum sellae; V, vomer; *right paramedian septation; **left bifid median and paramedian septation.

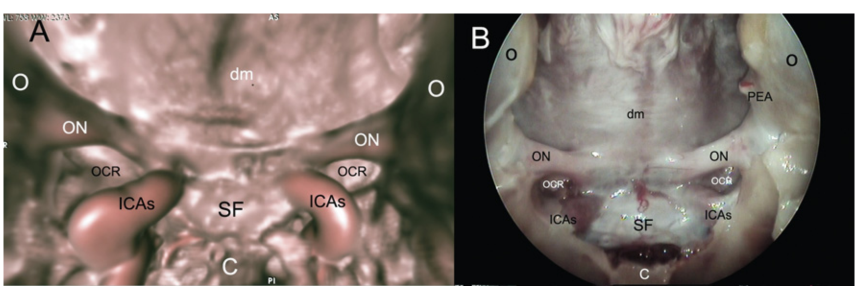

Figure 3. Postoperative endonasal virtual exploration **(A)** using the volume-rendering module supported by OsiriX software of the same specimen **(B)**. This is an endonasal view after opening of the sphenoid sinus, drilling of the anterior skull base, and removal of the medial wall of the orbit bilaterally. The optic canals have been opened to the lateral part of the optocarotid recesses, exposing the dura covering both optic nerves. C, clivus; dm, dura mater covering the anterior skull base; ICAs, parasellar tract of the internal carotid artery; O, orbit; OCR, optocarotid recess; ON, optic nerve; SF, sellar floor.

anatomic spatial relationship (8). The study of surgical anatomy slightly changed recently, however, being upgraded by modern imaging systems: Anatomic knowledge has to be integrated by complete, detailed preoperative imaging planning to achieve an overall better understanding for a successful surgical procedure.

Advances in computer technology and medical image processing techniques have enabled stereoscopic vision of anatomic structures from computed imaging data (33, 34, 39) to create a surgical simulation on screen, which has become an indispensable part of neurosurgical training (2, 23, 30, 31, 36, 41, 42). In the present study, we apply our novel computer-based three-dimensional anatomic model to the endoscopic endonasal approach to the midline skull base. Our method enabled us to obtain a detailed computed tomography (CT)–based virtual exploration and reconstruction of the approach by processing predissection and postdissection data in a single three-dimensional model. The use of this model for other skull base approaches has been previously reported by our group (15, 16, 19, 20).

METHODS

To achieve as much real surgical information as possible, 18 formalin-fixed cadaveric heads were dissected, simulating the surgical position performed in the operating room. Only the arterial system was injected with red latex. Dissections were performed at the Laboratory of Surgical NeuroAnatomy (LSNA) of the University of Barcelona. An endoscopic endonasal transsphenoidal approach to the midline skull base procedure was performed using a rigid 0-degree endoscope, 18 cm in length and 4 mm in diameter (Karl Storz Endoscopy, Tuttlingen, Germany), as the sole visualizing instrument. After having completed the basic steps required to gain an adequate surgical corridor, craniectomy was performed by removing the bone from the crista galli to the craniocervical junction as previously described (10). Two specimens were dissected with the assistance of an image guidance system, neuronavigation, which provided an adjunctive set of measurements to be compared.

The development of our computer based three-dimensional model required several tools being interfaced, including a CT scan-