# Transoral Approach to the Craniovertebral Junction: A Neuronavigated Cadaver Study

Francesco Signorelli, Alessandro Costantini, Vittorio Stumpo, Giulio Conforti, Alessandro Olivi, and Massimiliano Visocchi

## Introduction

More than 100 years after the first description by Kanavel of a transoral–transpharyngeal approach to remove a bullet impacted between the atlas and the clivus [1], the transoral approach (TOA) still represents the 'gold standard' for surgical treatment of a variety of conditions resulting in anterior craniocervical compression and myelopathy [2, 3]. Nevertheless, some concerns—such as the need for a temporary tracheostomy and a postoperative nasogastric tube, and the increased risk of infection resulting from possible bacterial contamination and nasopharyngeal incompetence [4–6]—led to the introduction of the endoscopic endonasal approach (EEA) by Kassam et al. [7] in 2005. Although this approach, which was conceived to overcome those surgical complications, soon gained wide attention, its clear predominance over the TOA in the treatment of craniovertebral junction (CVJ) pathologies is still a matter of debate [3]. In recent years, several papers have reported anatomical studies and surgical experience with the EEA, targeting different areas of the midline skull base, from the olfactory groove to the CVJ [8–19]. Starting from these preliminary experiences, further anatomical studies have defined the theoretical (radiological) and practical (surgical) craniocaudal limits of the endonasal route [20–25]. Our group has done the same for the TOA [26, 27] and compared the reliability of the radiological and surgical lines of the two different approaches. Very recently, a cadaver study, with the aid of neuronavigation, tried to define the upper and lower limits of the endoscopic TOA [28].

The purpose of the present study, whose preliminary data were published in 2015 [27], is to exploit the accuracy provided by neuronavigation in order to further compare operative craniocaudal extensions of the transnasal and transoral routes.

## Materials and Methods

### *Materials*

Two adult formalin-fixed cadavers were examined after computed tomography (CT) scanning (multidetector, 128 layers) and with the aid of neuronavigation (Medtronic StealthStation Treon Plus) and use of the following instruments: a high-speed drill (Storz, Tuttlingen Germany); vacuum aspirator (Super Vega Battery); digital camera (EOS 7D telescopic lens image stabilizer ultrasonic macro 100 mm; Canon, Tokyo, Japan); microsurgical instruments; stainless steel headholder; and jaw block.

### *Methods*

All four phases of specimen preparation (thawing, irrigation, fixation and perfusion) were performed at our centre, following a research protocol developed by our group. Before perfusion, the formalin-fixed specimens underwent high-definition CT scanning with the iodinated monomeric contrast medium Iomeprol (Iomeron®) 375 mg/mL. The imaging data (saved in DICOM [Digital Imaging and Communications in Medicine] format) were stored on compact disc (CD) and imported into the neuronavigation workstation (Medtronic Treon), and three-dimensional reconstructions were obtained. A jaw block was used to achieve maximal opening of the oral aperture.

F. Signorelli (✉) · V. Stumpo · G. Conforti · A. Olivi · M. Visocchi
Institute of Neurosurgery, Catholic University School of Medicine, Rome, Italy

A. Costantini
Institute of Radiology, Catholic University School of Medicine, Rome, Italy

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## Results

The examination of the CT scan of the two specimens did not reveal any CVJ pathology. With the aid of neuronavigation, accurate measurements were made in both cadaver heads. The results for both specimens in terms of craniocaudal and lateral exposures are summarized in Tables 1 and 2 and shown in Fig. 1.

## Discussion

The TOA, spanning ventrally from the inferior third of the clivus to the C2–C3 interspace, allows shorter, wider and more direct access to the CVJ than other approaches, including the anterior, lateral and posterior approaches [29, 30]. Because of these anatomical and surgical considerations, this approach has been considered the preferred route to treat irreducible extradural ventral lesions causing cervicomedullary compression [4, 31–33]. Extensions of the approach with palatotomy, labiomandibulotomy or osteotomy, which are sometimes required to expose lesions located more rostrally, carry high risks of various types of permanent damage, including velopharyngeal insufficiency, malocclusion, neural deficits, temporomandibular joint (TMJ) dysfunction, swallowing and speech difficulties, and need for a tracheostomy and nasogastric feeding tube [33, 34]. The need to overcome the occurrence of these comorbidities of considerable clinical significance led to the development of alternative and potentially less invasive techniques to address ventral CVJ pathology, such as the EEA. Extensive literature has demonstrated through comparative anatomical and clinical studies that an endoscope—in addition to providing increased rostral exposure, brighter illumination and closer visualization of the lesion to be treated [35, 36]—can be used during the TOA as a valid complementary tool in a combined procedure. Nevertheless, though a recent systematic review and meta-analysis [37] demonstrated a statistically significant increased risk of postoperative tracheostomy after the TOA in comparison with the EEA, it also showed a slight trend toward an increased morbidity/mortality prevalence with the EEA in comparison with the TOA (mortality 4% versus 2.9%; intraoperative cerebrospinal fluid [CSF] leakage 30% versus 0.3%; postoperative CSF leakage 5.2% versus 0.8%; meningitis 4% versus 0–4%; reoperation 5.1% versus 2.5%; velopharyngeal insufficiency 6.4% versus 3.3%; sepsis 7.7% versus 1.9%), although none of these differences were statistically significant. These data have prompted us to reconsider the presumed clear-cut superiority of the EEA over the endoscopic TOA, demonstrating the need for further comparative studies to better define and quantify real advantages and disadvantages of these techniques that are useful for the surgical decision-making process.

**Table 1** Craniocaudal exposure: comparison between transoral and transnasal approaches

| Craniocaudal exposure | Transoral | Transnasal | Percent superiority of transoral to transnasal (%) |
|---|---|---|---|
| Specimen A | 45 mm | 30.1 mm | 33.12 |
| Specimen B | 44.9 mm | 20.2 mm | 55.02 |

**Table 2** Lateral exposure: comparison between transoral and transnasal approaches

| Lateral exposure | Transoral | Transnasal | Percent superiority of transoral to transnasal (%) |
|---|---|---|---|
| Specimen A | 50 mm | 29.8 mm | 40.4 |
| Specimen B | 58.6 mm | 25.8 mm | 55.98 |

To clearly define the limits of the TOA, our research group devised a radiological ‘theoretical’ line—the palatine inferior dental arch line (PIA), a conceptual analogue of the nasopalatine line (NPL)—as a reliable predictor of the maximal superior extension of the TOA, and we then compared the reliability of the radiological and surgical lines of the two different approaches.

A recent cadaver study by LaCorte et al. was also performed with the aid of neuronavigation, with the aim of defining the upper and lower limits of the endoscopic TOA [28].

In the wake of our previous experimental volumetric studies [26, 27] and other recent contributions, we tried to exploit the accuracy provided by neuronavigation, to further compare operative sagittal and axial extensions of the transnasal and transoral corridors. Our observations were consistent with a relevant advantage of the TOA over the EEA in terms of craniocaudal and lateral extension in both specimens. It is worth noting that our measurements were performed in the setting of a minimal oral aperture as a consequence of the jaw block. Considering that this setting was suboptimal, we speculate that the actual advantage of the TOA is even greater than that reported in our study. We also conclude that even in cases in which wide opening of the mouth is not achievable, as in the case of paediatric patients, the TOA still offers a significant gain in terms of sagittal and axial exposure.

This study has limitations that are inherent to many cadaver studies: the specimens had normal cranial base anatomy, and the findings in this study may not be applicable in cases where the cranial base or oropharyngeal anatomy is abnormal as a result of disease or congenital variation. Moreover, the CVJ is a ‘moving target’, with great variability even among individuals without CVJ pathologies, as recently reported by Burke et al. [38]. In their study the CVJ was positioned below the palatine line (PL) in two thirds of

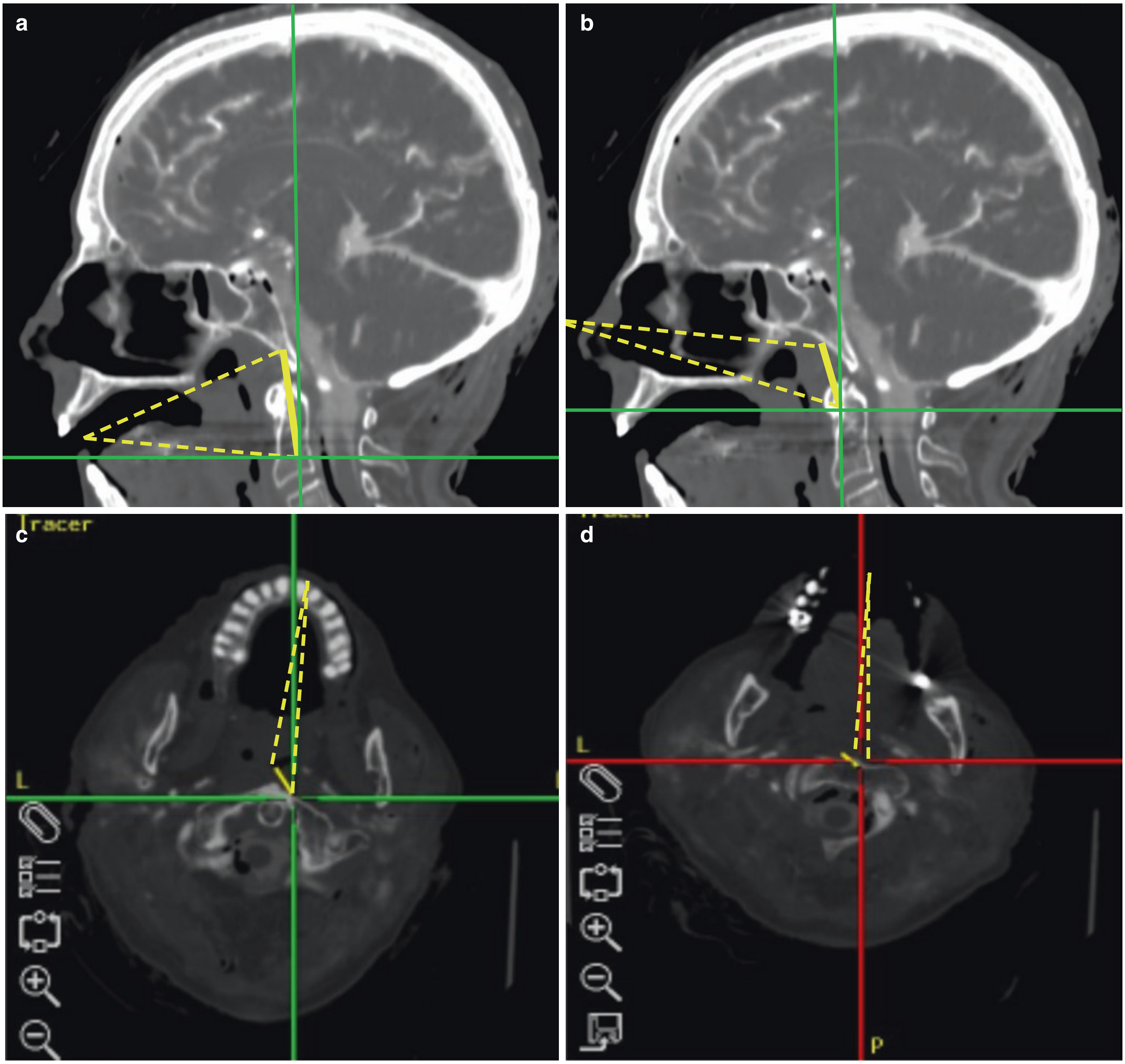


**Fig. 1** (**a**, **b**) Sagittal and (**c**, **d**) axial neuronavigated computed tomography (CT) scans with contrast medium showing (**a**) craniocaudal and (**c**) lateral exposures of the transoral approach and (**b**) craniocaudal and (**d**) lateral exposures of the transnasal approach

the control group and above it in one third of the group. Furthermore, because of the small number of specimens, our findings require validation in larger studies.

## Conclusion

Our experimental study, conducted with the aid of neuronavigation, confirms that the transoral approach (TOA) offers a wider surgical working channel than the endoscopic endonasal approach (EEA), even in conditions in which the oral aperture is suboptimal. These findings, along with recent observations that the EEA can produce complications similar to those seen with the TOA in craniovertebral junction surgery—including velopharyngeal insufficiency and severe infections—suggest that the presumed superiority of the EEA over the TOA needs to be re-examined.

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**Competing Interests** The authors declare that they have no competing interests.

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