Endonasal Access to the Upper Cervical Spine: Part 2—Cadaveric Analysis

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Abstract

Objectives The study aims to determine factors that augment endonasal exposure of the cervical spine.

Setting We used fluoroscopy and endoscopy to study endonasal visualization of the upper cervical spine.

Participants Ten cadavers with normal anatomy were studied.

Main Outcome Measures Endoscopic visualization was simulated with projected lines from an endoscope to the cervical spine in multiple positions.

Results Neck position alone did not affect the extent of endonasal exposure of the upper cervical spine, although there was a trend correlating the extended neck position with more caudal exposure. The greatest impact was with concurrent use of a 30-degree endoscope and neck extension, and more caudal access was achieved by tilting the endoscope against the piriform aperture, using the posterior tip of the hard palate as the fulcrum.

Conclusions Concurrent use of a 30-degree endoscope and neck extension increased the degree of exposure down the cervical spine. Maximum endonasal exposure of the upper cervical spine was obtained by maneuvering instruments at the fulcrum of the posterior hard palate and the nares, rather than changing the position of the neck alone. These results complement radiographic morphometric data in Part 1 of this study for preoperative assessment and surgical planning.

Keywords

- cervical spine
- endoscopic
- minimally invasive
- morphometric
- odontoidectomy
- endonasal

Introduction

The transnasal endoscopic corridor to the ventral cervical spine has recently generated interest as a feasible approach for conditions affecting the odontoid and upper cervical spine.^{1–5} As an alternative to transoral–transpalatopharyngeal

approaches, it has the potential advantage of avoiding retraction of the tongue and extensive dissection of oropharyngeal and nasopharyngeal structures which often result in infection, dysphonia, and prolonged intubation.^{1–5}

Some authors have relied upon the nasopalatine angle to delineate the lower limits of endonasal exposure for surgical

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Fig. 1 Lateral fluoroscopic evaluation of theoretical endonasal cervical exposure. Projection lines (red dashes) from the endoscope at 0 and 30 degrees simulated the maximum possible endoscopic view if unobstructed by soft palate. These intersect the odontoid line (blue) at specific anatomic zones; from superior to inferior the odontoid was divided into three equal zones: Oa, Ob, and Oc, followed by the C2–3 disc space (D1) and the C3 vertebral body divided into two equal zones: C3a and C3b. Points of intersection were recorded with the head in neutral with (A) the endoscope flush with the hard palate (head neutral, scope flat), (B) tilted against the piriform aperture (head neutral, scope up), (C) in head extension with endoscope flat (head extension, scope flat), or (D) in head extension with endoscope tilted (head extension, scope up). Images were also analyzed with the head in flexion with the endoscope flush or tilted (data not shown).

planning.^{6,7} However, in the context of anatomic variation, improved instruments, and use of angled endoscopes, these limits remain poorly defined. In part 1⁸ of this article, we found that the radiographic relationships between hard palate length, distance to the odontoid, and the angle formed between the two influenced the extent of the exposure, but this was based on bony landmarks with the head in neutral position. The purpose of this cadaveric study was to determine the additional contributions of head position and instrument position to the limits of this endonasal approach corridor.

Methods

This study was approved by the Institutional Review Board (IRB) of Thomas Jefferson University Hospital (IRB no. 08D.567). We performed lateral fluoroscopy on 10 cadavers to evaluate the positions and anatomic relationships of the hard palate and cervical spine. We also performed endoscopic endonasal dissection on the cadavers to determine to what extent exposure was technically feasible given soft tissue anatomic constraints.

Fluoroscopic Evaluation

In an attempt to estimate maximum possible endoscopic endonasal access to the upper cervical spine based on bony landmarks, lateral fluoroscopy was performed with the endoscope placed along the floor of the nasal cavity and its tip just beyond the posterior edge of the hard palate. On the radiographs, straight lines were projected posteriorly from the endoscope at 0 and 30 degrees, simulating the maximum possible endoscopic view. A second straight line was drawn connecting the tip of the odontoid process to the midpoint of the base of the C2 vertebral body and extended both superiorly and inferiorly (the odontoid line).

The regions of the upper cervical spine were divided into anatomic zones (►Fig. 1). From superior to inferior, the odontoid was divided into three equal zones: Oa, Ob, and Oc. The disc space between C2 and C3 was labeled as D1. The C3 vertebral body was divided into two equal zones: C3a and C3b. The C3–4 disc space was labeled D2. The C4 vertebral body was also divided into two equal zones of C4a and C4b.

These zones served as descriptive markers for the point at which the lines projecting from the endoscope intersected the odontoid line. These points were recorded with the neck in neutral position, flexion, or extension with the endoscope either flush with the floor of the nasal cavity (scope flat) or tilted up against the superior aspect of the piriform aperture (scope up), using the posterior edge of the hard palate as the fulcrum (►Fig. 1).

Endoscopic Evaluation

To determine whether a neck position or endoscope position could affect the estimated endonasal visualization of the cervical spine, commercially available endoscopes with optic angles of 0, 30, and 45 degrees were used along with fluoroscopy. Each endoscope was positioned with the tip at the posterior edge of the hard palate and either kept flush along the floor of the nasal cavity (scope flat), or raised against the superior aspect of the piriform aperture of the nose, using the posterior edge of the hard palate as the fulcrum (scope up).

Results

Fluoroscopic Evaluation

In accordance with the exclusion criteria in our previous report of radiographic morphometric analysis,⁸ no cadavers had evidence of cervical spine fractures, cervical spine instrumentation, severe degenerative joint disease or osteopenia, vertebral body collapse, or autofusion across two or

more vertebral bodies. Demographic and body measurement data for cadavers were not available. In some cases, stiff cadaveric musculature prevented the adequate positioning of the head in full flexion or extension and these specimens were excluded.

Flexion of the head had no effect on the level of the cervical spine transected by lines projected from the endoscope (data not shown). For neutral and extended head positions, the frequency (N) with which each level of the cervical spine was transected by projected lines is graphically portrayed (►Fig. 2).

With the endoscope flush against the floor of the nasal cavity, projected lines at 0 degrees transected the odontoid line above the odontoid process or near its tip (zone Oa), both in neutral position (►Fig. 2A) and in extension (►Fig. 2B). For both head positions, the 30-degree projection transected more caudally, in some cases at the base of the odontoid (zone Oc). The frequency of transecting zone Oc with the 30-degree projection was slightly higher in extension ($N = 2$) than in neutral ($N = 1$), indicating that there might be a trend toward more caudal visualization with head extension. This trend, however, was not statistically significant.

By tilting the endoscope upward against the superior aspect of the piriform aperture, the lowest zone that the 0-degree projection lines transected was the midpoint of the odontoid (Ob). The 30-degree projection lines transected as low as the third cervical vertebra (zone C3a or C3b). The frequency of transecting the third cervical vertebra (zone C3a

Theoretical C-Spine Exposure in Neutral Head Position

Theoretical C-Spine Exposure in Head Extension

Fig. 2 Frequency of anatomic zones transected by projected lines. Lines extended from the endoscope projected either above the odontoid (above) or through a defined anatomic zone of the upper cervical spine (Oa, Ob, Oc, C3a, or C3b). Points of intersection between the 0-degree or 30-degree projected lines and the odontoid line were recorded with the endoscope flush against the hard palate (flat-0, flat-30) or tilted against the piriform aperture (up-0, up-30).

Average Change in Zone Transected by Projected Endoscope Line
Based on Initial Zone in Neutral Position

Fig. 3 Average change in zone transected by projected endoscope line. The change in the zone (more caudal) transected by the projected endoscope line was based on the initial zone transected with the head in neutral position, endoscope flat against the palate, using the 0-degree angle. The changes for all 10 cadavers were averaged and rounded to the nearest whole number.

and C3b) with the 30-degree projection was higher in extension ($N = 4$) than in neutral ($N = 1$), once again indicating that there might be a trend toward more caudal visualization with head extension.

Based on the initial zone transected with the head in neutral position, the average change in the most caudal zone transected by either tilting the endoscope upward, extending the head, using the 30-degree angled scope, or a combination of these manipulations is graphically portrayed (►Fig. 3). With the head in neutral position, an average of one additional zone in the caudal direction was transected by either tilting the endoscope upward or using the 30-degree angle. With a combination of these, an average of two additional zones was transected. With the head in extended position, there is a similar benefit of tilting the endoscope upward or using the 30-degree angle, as with the head in neutral position. However, with the head extended, the endoscope tilted, and the use of the 30-degree angle, the projection lines transected three additional zones more caudally.

Endoscopic Visualization

The ability to visualize the posterior pharynx was assessed using 0, 30, and 45-degree angled endoscopes. Soft tissue obscured the view with the 45-degree endoscope, regardless of position. In contrast, unobstructed views of the posterior pharynx were obtained using 0 or 30-degree endoscopes (►Fig. 4). The maximum tilt of the endoscope was limited by the superior extent of the piriform aperture (►Fig. 5).

Discussion

For some lesions of the craniocervical junction, for example, C1–2 tumors, os odontoideum, basilar invagination, and so on, the endonasal approach may have advantages over the traditional microscopic transoral–transpalatopharyngeal approach by providing improved lateral visualization and preservation of velopharyngeal function.^{1–5}

Fig. 4 Endoscopic endonasal view of the posterior pharynx during a cadaver dissection.

Fig. 5 The piriform aperture: the anterior end of the bony nasal opening, connecting the external nose with the skull.

In Part 1 of this study, we found that a larger angle between the hard palate and odontoid line could theoretically contribute to a more caudal exposure of the cervical spine based on radiographic features.⁸ As Part 1 was based on computed tomography with the head in neutral position, one could infer that a way to potentially increase caudal exposure would be through neck extension by tilting the hard palate in relation to the odontoid line. However, in the current study (Part 2) we found that flexion or extension of the neck by itself had no statistically significant effect on the caudal extent of cervical spine exposure.

We did see a trend in favor of more caudal cervical spine exposure using head extension (not flexion); however, as previously mentioned, it was not statistically significant. It is our hypothesis that the reason it did not reach statistical significance was because our scale of measurement using cervical zones was too broad. If we had used a more finite scale to detect the difference with extension (e.g., divided the odontoid line into 1 mm increments, instead of the larger

zones), we would have captured it more convincingly. This small difference with extension, however, is amplified when extension is used in conjunction with a 30-degree endoscope, and/or by tilting the endoscope against the superior aspect of the piriform aperture, as graphically portrayed in ►Fig. 3. There was no additional benefit by using a 45-degree angled endoscope, as visualization was obscured by the tissue of the soft palate and the posterior pharyngeal wall.

In our actual practice, we have kept the endoscope as low as possible in the nasal cavity so as to introduce operating instruments above the endoscope for ease of maneuvering. For this reason, some maneuvering advantage may be lost by tilting the endoscope upward, but with modification of technique, lower lesions could potentially be reached without utilizing traditional microscopic transoral approaches.

Although certain levels of the cervical spine were visualized and endoscopically dissected in this cadaveric study, it does not necessarily mean that one will always be able to maneuver instruments adequately at these levels when addressing patients with pathology in the operating room. The results of this cadaveric study may be helpful for preoperative planning and complement the morphometric analysis done in Part 1, however, it must be corroborated with prospective clinical studies, which are forthcoming. The development of new instruments and the possibility of the application of robotic technology may further facilitate endoscopic endonasal cervical spine surgery in the future.

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