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The Importance of Platybasia and the Palatine Line in Patient Selection for Endonasal Surgery of the Craniocervical Junction: A Radiographic Study of 12 Patients

Ivan H. El-Sayed, MD^{1,2}, Jau-Ching Wu, MD^{2,3,4}, Nripendra Dhillon, MBBS, MS⁵, Christopher P. Ames, MD², and Praveen Mummaneni, MD²

¹ Department of Otolaryngology-Head and Neck Surgery, University California San Francisco

² Department Neurological Surgery, University California San Francisco

³ Department of Neurosurgery, Taipei Veterans General Hospital, Taiwan

⁴ School of Medicine, National Yang-Ming University, Taiwan

⁵ Department of Anatomy, University of San Francisco California

Abstract

Objectives—Ventral decompressive surgery of the craniocervical junction is performed to manage a variety of conditions, including basilar invagination which can be associated with platybasia. We have noted that the anatomic changes of platybasia could affect the height of the odontoid over a line drawn along the nasal cavity floor, the palatine line (PL). This anatomic change may influence the use of nasal endoscopic surgery for patients with platybasia who also have basilar invagination. We investigated if the height of the craniocervical junction is elevated over the PL in patients with and without platybasia.

Methods—We conducted a retrospective review of consecutive craniovertebral junction surgical cases over a 14 month period. During that time we treated twelve patients, including 4 with platybasia and 8 without. The average age was 50 (range 18–64) years old. Pre- and post-operation radiographic images were evaluated and charts reviewed.

Results—The mean height of the odontoid over the PL without platybasia was 3.5mm (range 0–19.0). In those with platybasia, it was 15.5mm (range 7–26.0) (p=.021). There was a statistically significant rise in the height of the clival tip and C1 ring in patient with platybasia as well.

Conclusion—Platybasia is associated with a rise in the odontoid and craniocervical junction over the PL. This rise in height has implications for endoscopic approach selection in patients with platybasia. Platybasia patients with basilar invagination may be better suited to a transnasal approach.

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Author for correspondence: Jau-Ching Wu, M.D., Department of Neurosurgery, Taipei Veterans General Hospital, Taiwan, School of Medicine, National Yang-Ming University, Taiwan, Department Neurological Surgery, University of California, San Francisco, 505, Parnassus Ave, M-780, San Francisco, CA 94143-0112, jauching@gmail.com, Phone: 415-353-3998, Fax: 415-353-3907.

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Keywords

Platybasia; Palatine Line; Endoscopic; Basilar Invagination; Craniocervical Junction; Endonasal; McGregor's Line; Chamberlain's Line

INTRODUCTION

Platybasia, congenital flattening of the skull base, is occasionally seen in association with basilar invagination. (1–3) Compromise of the foramen magnum, reduction of the posterior fossa volume, and protrusion of the odontoid process into the ventral brain stem may cause neurological symptoms in some of these patients. Anterior surgical decompression of the craniocervical junction may be thus considered to treat this problem. (4–6)

Surgical approaches to the craniocervical junction have traditionally been achieved transorally (6–9) (with or without splitting of the soft palate). More recently, several endoscopic approaches have been introduced including a transnasal approach, (10–15) transcervical endoscopic approach, (16,17) and a combined endonasal endo-oral approach. (18) Little data exists in the literature describing the anatomic relationships of the craniocervical junction from an endoscopic perspective. In particular, there is currently no staging system or identification of factors to aid in the endoscopic approach selection to the craniocervical junction. Previously accepted anatomic references for the odontoid are McGregor's line and Chamberlain's line. (1,19) These lines are described as being drawn from the posterior edge of the hard palate to the occiput. However these two lines do not adequately describe the view of the odontoid from an endoscopic approach because the occiput, like the posterior edge of the palate, can vary in its relationship to the craniocervical junction. Thus, the line drawn from the posterior palate will change its relationship to the odontoid as the occiput is moved up or down and the height of the craniocervical junction over these lines does not directly relate to the view achieved from an endonasal approach. We sought another marker to help establish the minimal plane of approach needed to access the tip of the odontoid with the use of an endoscopic approach. We have found that a line drawn along the floor of the nasal cavity extending from the premaxilla parallel to the hard palate at the craniocervical junction, the palatine line (PL), provides a better planning tool for an endoscopic approach to the craniocervical junction (Figure 1).

This study aimed to determine if the condition of platybasia is associated with an increased height of the craniocervical junction and odontoid over the plane of the palate. Hypothetically, preoperative assessment of the height of the surgical target over the palate can identify cases appropriate for an endonasal versus an endo-oral approach.

METHODS

We performed a retrospective review of a series of 12 consecutive patients who, over a 14 month period, had an anterior approach for decompression to the craniocervical junction at our institution. Patients were included if they had an anterior approach, either endoscopic or microscopic transoral, to either the clivus, or C1, or C2. Patients undergoing surgery for central skull base lesions limited to the sphenoid, or pituitary were excluded. One patient required exposure from C1 down to C7 and was included for purposes of radiographic analysis (to capture all patients having surgery at the level of the craniocervical junction). Choosing the best surgical approach evolved as our surgical experience with the endoscope increased. The choice of open approach was based on the surgeon preference at the time of surgery, and most open cases were performed early in the series prior to our building

experience in endoscopic transnasal decompression. The endoscopic surgical approaches were chosen to allow the least morbid procedure for each patient.

Medical records and radiographic imaging (magnetic resonance imaging and computed tomography scans) were reviewed for demographics and disease specific information (including age, sex, diagnosis, level of spine disease, surgical approach, prior surgery to the anterior cervical spine, indications for surgery, and length of hospitalization after surgery). Data was stored in a Microsoft Excel spreadsheet and transferred to SAS (SAS Institute Inc., Cary, NC) for data analysis. Data was analyzed through the UCSF department of biostatistics using Fisher's exact test and the Mann-Whitney test where appropriate. Approval was obtained from the UCSF Committee on Human Research.

Odontoid Height and Platybasia in Surgical Cases

Radiographic imaging of computed tomography (CT) and/or magnetic resonance (MRI) were used to analyze craniocervical anatomy with respect to angles of the skull base to determine presence of basilar kyphosis or platybasia using the technique of Koenigsberg(3). In order to establish the minimal plane of access of an endoscope, the PL is drawn along the floor of the nasal cavity extending from the premaxilla parallel to the hard palate through the craniocervical junction (Figure 1). The height of the odontoid, the anterior ring of C1, and the inferior edge of the clivus above or below the PL was measured.

RESULTS

Surgical Approaches

Twelve patients had surgery on the craniocervical junction (from the lower clivus to the C2 body). Four of the patients had platybasia, and 8 of them did not. The average age was 50 (range 18–64) years old and there were 6 males and 6 females undergoing surgery for basilar invagination (4), rheumatoid pannus (3), infection (3), and malignant tumor (2). Four of the 12 patients had surgery using an open approach to the spine including a transoral palate split(2), an endoscopic assisted transoral palate split(1) and a palate split with mandibulotomy(1). Eight patients had purely endoscopic surgery via an endo-nasal approach (2), an endo-oral approach (2), or a combined endonasal/endo-oral approach (4). (Figure 2)

The height of the craniovertebral structures with relation to the PL is shown in tables 1 and 2. All the 4 patients with platybasia had the tip of their odontoid lying above the palatine line, whereas 7 of the 8 patients without platybasia had the tip of their odontoid lying below the palatine line.

Height of Odontoid Process

The median height of the odontoid over the PL in those without platybasia was 3.5 mm (range 0–19.0) and in those with platybasia was 15.5 mm (range 7–26.0) ($p=.021$). There was a statistically significant rise in the height of the clival tip and C1 ring in patient with platybasia as well (22.0 vs 7.5 mm, $p=.041$). The median distance from the PL to the anterior superior edge of the C1 ring was 12.0 mm in patients with platybasia, whereas it was –1.0 mm without platybasia ($p=.023$). (Figure 1, Table 1) Platybasia patients had significantly higher odontoid process position above the PL than in those without platybasia.

Relationship between Palatine Line and the Atlas Ring

We found that all of our four patients with platybasia (100%) had the atlas ring located above the level of PL whereas only 1 of our 8 patients without platybasia had the atlas ring located above the PL. This difference was statistically significant ($p=.010$) (Table 2).

Preoperative imaging findings of the relative positions of odontoid process, atlas, and the PL posed important influences upon options for surgical approach in the series. Platybasia appears to be associated with increased odontoid height. Figure 3 demonstrates the great variability of the height of the odontoid. Figure 3B illustrates why platybasia may be related to a higher craniocervical junction. The clival tip is extremely elevated with respect to the palatine line due to the flattened angle of the skull base in such patients. Since the clival tip maintains close proximity to the C1 ring and odontoid tip, these structures are also elevated in relation to the palatine line in patients with platybasia. A transoral palate split approach would require significant hard palate resection in these patients. Furthermore, if the patient in Figure 3B had a concurrent limited oral opening (due to poor jaw excursion), then a mandibulotomy would be required to reach the surgical target. We found the endoscopic transnasal approach to be the most direct approach in such cases.

DISCUSSION

Approaches to the craniocervical junction are undertaken for a variety of reasons. Congenital conditions such as platybasia may alter the anatomy, and should be taken into consideration when considering the approach. Recently several endoscopic approaches have been proposed including a pure transnasal approach and an endoscopic transcervical approach. In a prior study, we suggested lesions with significant inferior extension could be accessed through the a combined endo nasal/endo oral approach.(20) (Figure 5) Other authors have suggested that a transcervical approach is advantageous to avoid pharyngeal contamination.(16) This study highlights the variability in patients' anatomy and demonstrates that a "one approach for all" is not appropriate. Our case series illustrates that patients with platybasia who have craniocervical junction pathology would be difficult to access either through a transcervical approach or through a transoral corridor.

Basilar invagination may be congenital or developmental.(21) Congenital malformations involving the occipital bone, atlas, and axis can be associated with basilar invagination (i.e. condylar hypoplasia, assimilation of atlas, and axial segmentation failure). On the other hand, Paget's disease, rheumatoid arthritis, or excessive weight loading during childhood may cause a developmental upward protrusion of odontoid process and resultant ventral compression of brain stem. Not uncommonly, a mixture of the two processes is encountered in clinical practice. Furthermore, the two reciprocally overlapping entities might be treated from different surgical strategies. Despite the presence of ventral brain stem compression, decompression from an anterior approach is not always necessary. Reduction of deformity from a posterior approach in combination with occipito-cervical fixation (without anterior decompression) has been reported to be successful.(22–25)

Our data indicates that the condition of platybasia is commonly associated with a rise of the odontoid tip over the plane of the hard palate. In a prior report in the literature examining the relationship of the odontoid tip to the nasal floor, the authors reported the height of the odontoid to range from -9mm to +18.7mm over the palate.(26) We have found that the palatine line appropriately guides this new surgical perspective endonasally. The height of craniocervical junction in reference to this line is an important predictor of accessibility through an endonasal approach. The choice of endonasal versus endoral approach has to do with a combination of the position of the palate and the height of the odontoid. When the surgical target lies at 2 cm above the palate, it appears the endonasal approach is the better approach.

De Almeida et al(26) examined the limit of endoscopic approaches to the craniocervical junction by defining a line drawn from the nasal bones to the posterior hard palate as the nasalpalatine line. They reported that this line intersects the spinal column at a mean of 8.9

mm (range -9.0–8.7 mm) above the base of the C2 body. However, the purely transnasal approach as described, requires resection of a significant portion of the nasal cavity and sinuses including the middle turbinate, the unilateral ethmoids and posterior nasal septum. The resultant large cavity causes significant nasal morbidity in the form of mucus crusting and possibly atrophic rhinitis and requires the patient to perform lifelong daily nasal irrigations. Although De Almeida has demonstrated that most lesions of the craniocervical junction can be reached from the nasal corridor, it is questionable whether all lesions *should* be approach from this corridor due to the consideration of patient morbidity. By using a second corridor through the oral cavity, little morbidity is added, and it may be possible to avoid extensive dissection in the oral cavity. Thus, instead of asking if the surgery can be done through the nasal cavity, the surgeon should question if the surgery needs to be done purely through the nose. In our series, we found only two patients with extreme superior position of the odontoid requiring a purely nasal approach. Other patients could be managed with a combined approach or endo oral approach, thereby avoiding extensive nasal dissection.

This case series reveals that the relation of the craniocervical junction to the nasal cavity is significantly altered when platybasia is present. Examining our data, the palatine line appears useful, in addition to the nasopalatine line, to guide the choice of approach in patients with platybasia. Since platybasia is associated with a high lying odontoid process, a transoral approach may not allow adequate access without a palate split, and increased morbidity. Therefore, in conditions requiring treatment for basilar invagination with platybasia, we believe adding the concept of palatine line allows improved endoscopic approach selection.

This study may suffer bias from patient selection due to the fact our series only includes patients presenting for surgery. Since symptoms of basilar invagination are due to elevation of the height of the odontoid, the height of the odontoid and C1 ring would be expected to be increased. However we also looked at the height of the clival tip, which should predict the relative location of the odontoid before it started to slip. Further studies of larger populations of patients are necessary to determine if this finding holds true only in the diseased state, or if it is a true anatomic relation. Such a study is being initiated at our institution.

Predicting the best corridor for approach to the craniocervical junction can help reduce patient morbidity and improve surgical efficiency. Attempting to do all procedures using a single approach is not ideal, and anatomic variability has to be identified and acknowledged. The palatine line can be used to identify the appropriate corridor of approach. In our practice we have found that lesions can be located above, at, or below the palatine line with significant variability. This line along the palate floor appears to be an important line because it represents the access that can be achieved through an endoscopic transnasal approach as instruments are brought in through the nose and limited inferiorly by the hard palate. Although an expanded endonasal approach can provide additional lower resection with the use of an angled endoscope, the technical challenge of the approach increases in such cases.(26,27)

De Almeida et al(26) described measurements indicating that lesions of the odontoid may be accessed from below the palate by angling up into the soft tissue of the nose. Baird et al also compared the extent of resection between endonasal, transoral, and transcervical approaches. (27) However, the palatine line that we have described in association with the position of odontoid process should be deemed as a categorization tool. It might assist endoscopic surgeons to identify an easy working channel preoperatively. In this study, analysis of cases using the palatine line (extension along the hard palate) reveals the elevated position of odontoid in patients with platybasia is evident from a surgical perspective Preoperative

assessment in relation to the palatine line allows categorization of surgical targets in patients with and without platybasia. In our series we have found that we can reach lesions extending below this line much more easily by opening the oral cavity and working through two corridors (combined endo-nasal and endo-oral approaches). (Figure 5) We prefer a combined approach in such cases because a pure transnasal corridor may require destruction of the nasal anatomy (i.e. resection of the middle turbinate, sphenoid walls and posterior septum) to have adequate working room. If the oral corridor is used, then an endoscope can be brought in through the nose, while instruments come in through the oral cavity with preservation of the nasal anatomy thus avoiding the need for an expanded endonasal approach. (Figure 2)

CONCLUSION

A paradigm instituting a single surgical approach (transcervical, transnasal, or transoral) is not ideal for all patients with ventral craniocervical junction pathology. This series reveals patients with platybasia typically have elevation of the odontoid tip over the palatine line. Analyzing lesions in relation the palatine line helps predict the least morbid surgical approach. Patients with platybasia may have surgical targets high above the palatine line that require an endonasal approach, while other lesions may reside below the palate line and accessible to the addition of the endo oral approach. be treated with an endo-nasal approach to remove lesions at the ventral craniocervical junction. The approach selection for patients should be tailored to their individual anatomy to produce the least morbidity by avoiding extensive dissection of the nasal cavity or a palate split. The use of the palatine line provides an excellent guide to assess whether an endonasal approach is ideal for such patients.

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Abbreviations

PL	palatine line
CT	computed tomography
MRI	magnetic resonance image
CL	clival tip
C1R	ring of C1 spine
Od	odontoid tip

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Figure 1. Relations of the Palatine Line

PL: Palatine line, CL: clival tip, C1R: ring of C1 spine, Od: odontoid tip. The PL is a line drawn parallel along the superior edge of the palatine process starting posterior to the anterior nasal spine. Platybasia is defined as abnormal flattening of the skull base, and occasionally is combined with basilar invagination. Basilar invagination, the upward displacement of the basilar and condylar portions of the occipital bone, causes impression of the foramen magnum, reduction of the posterior fossa, and consequent protrusion of the upper cervical spine into the anterior brain stem. Measurements are made of the distance above or below the PL to CL, C1R, and Od.

Figure 2. Distributions of Approaches in the Series

Total 12 patients were categorized by endoscopic versus open, transnasal versus transoral, and presence of platybasia. Basilar invaginations with the coexistence of platybasia were never approached via the transoral-only approach.

Figure 3. Varying Height of Odontoid to PL

A) Preoperative sagittal computed tomography imaging demonstrates elevation of the odontoid over the PL as part of the disease process of pure basilar invagination (white arrow). The tip of the clivus serves as a second reference point for the true craniocervical junction (black arrow) in relation to the PL.

B) Demonstrates an extreme increase in the height of the odontoid tip to the PL in patient with platybasia.

Figure 4. Decompression via Combined Endoscopic Transnasal and Transoral Approaches
Pre- and post-operative sagittal reformatted CT images demonstrating the result of decompression from a combined endoscopic transnasal and transoral approachin for basilar invagination with platybasia.

Figure 5. Intraoperative photographs of Combined Endo nasal/Endo oral Approach

- A) Start of incision, scope in the oral corridor
- B) Continued dissection, scope in the nasal corridor
- C) Begin of drilling in the midline, scope in the oral corridor
- D) Extension of drilling for decompression, scope in the oral corridor
- E) Reach of the upper extent, scope in the nasal corridor
- F) Stitch closure of the mucosa, scope in the oral corridor

Table 1

Relation of Platybasia to Craniocervical Junction.

Measurement*	Platybasia		p-value
	No	Yes	
PL-OD Distance of palatine line to odontoid tip	3.5 (0.0–19.0)	15.5 (7.0–26.0)	0.021 [†]
PL-CL Distance of palatine line to inferior clival tip	7.5 (1.0–11.0)	22.0 (8.0–26.0)	0.041 [†]
PL-CIR Distance of palatine line to anterior superior edge of the C1 ring	–1.0 (–11.0 to 2.0)	12.0 (1.0–21.0)	0.023 [†]

PL= palatine line

OD= odontoid tip

CL= inferior clival tip

CIR= anterior superior edge of the C1 ring

* millimeters, mean (range)

[†] Significance by Mann-Whitney test.

Table 2

Relationship of C1 ring to palatine line in platybasia.

<i>Position of C1 Ring</i>	<i>Platybasia</i>			<i>P value</i>
	<i>No</i>	<i>Yes</i>	<i>Total</i>	
Above PL	1 (12.5%)	4 (100.0%)	5 (41.7%)	0.010*
Below PL	7 (87.5%)	0 (0.0%)	7 (58.3%)	
Total	8	4	12	

C1R= C1 ring

PL=palatine line,

Yes = patient has platybasia

No= patient do not have platybasia

* Significance by Fisher' s exact test.