Original Article

Intraoperative occipital to C2 angle and external acoustic meatus-to-axis angular measurements for optimizing alignment during posterior fossa decompression and occipitocervical fusion for complex Chiari malformation

ABSTRACT

Background: Excess flexion or extension during occipitocervical fusion (OCF) can lead to postoperative complications, such as dysphagia, respiratory problems, line of sight issues, and neck pain, but posterior fossa decompression (PFD) and OCF require different positions that require intraoperative manipulation.

Objective: The objective of this study was to describe quantitative fluoroscopic morphometrics in Chiari malformation (CM) patients with symptoms of craniocervical instability (CCI) and demonstrate the intraoperative application of these measurements to achieve neutral craniocervical alignment while leveraging a single axis of motion with the Mayfield head clamp locking mechanism.

Methods: A retrospective cohort study of patients with CM 1 and 1.5 and features of CCI who underwent PFD and OCF at a single-center institution from March 2015 to October 2020 was performed. Patient demographics, preoperative presentation, radiographic morphometrics, operative details, complications, and clinical outcomes were analyzed.

Results: A total of 39 patients met the inclusion criteria, of which 37 patients (94.9%) did not require additional revision surgery after PFD and OCF. In this nonrevision cohort, preoperative to postoperative occipital to C2 angle (O-C2a) ($13.5^\circ \pm 10.4^\circ$ vs. $17.5^\circ \pm 10.1^\circ$, $P = 0.047$) and narrowest oropharyngeal airway space (nPAS) (10.9 ± 3.4 mm vs. 13.1 ± 4.8 mm, $P = 0.007$) increased significantly. These measurements were decreased in the two patients who required revision surgery due to postoperative dysphagia (mean difference -16.6° in O C2a and 12.8° in occipital and external acoustic meatus to axis angle). Based on these results, these fluoroscopic morphometrics are intraoperatively assessed, utilizing a locking Mayfield head clamp repositioning maneuver to optimize craniocervical alignment prior to rod placement from the occipital plate to cervical screws.

Conclusion: Establishing a preoperative baseline of reliable fluoroscopic morphometrics can guide surgeons intraoperatively in appropriate patient realignment during combined PFD and OCF, and may prevent postoperative complications.

Keywords: Chiari malformation, craniocervical instability, fluoroscopic morphometrics, occipitocervical fusion, postoperative dysphagia

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INTRODUCTION

Chiari malformation (CM) 1 is the displacement of the cerebellar tonsils below the foramen magnum.[1] The resulting dorsal brainstem compression and obstruction of cerebrospinal

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fluid (CSF) flow can lead to a constellation of symptoms, including exertional occipital headaches, nausea, gait ataxia, paresthesia, and dysphagia. Symptomatic CM unresponsive to conservative measures can be an indication for surgical treatment with posterior fossa decompression (PFD).[2] However, in a subset of CM patients, the pathophysiology involves craniocervical instability (CCI) exacerbated by underlying connective tissue disorders (CTDs), such as Ehlers–Danlos syndrome (EDS), and/or structural anomalies including a retroflexed odontoid.[3-5] In these complex patients, increased susceptibility to ventral brainstem compression may lead to failure of PFD to adequately address their symptomatology, requiring additional surgeries or revisions.[6] Occipitocervical fusion (OCF), in addition to PFD, should be considered in CM patients with CCI.[7] During fusion, achieving neutral craniocervical alignment is crucial to both address the ventral medullary compression and prevent postoperative complications related to hyperflexion or extension. This alignment traditionally relies on limited qualitative intraoperative assessments. These assessments can be especially challenging in patients with CM and CCI undergoing simultaneous PFD and OCF.[7] In previous studies, it has been demonstrated that short-term positive postoperative computed tomography (CT)/magnetic resonance imaging (MRI) skull base morphometric changes after OCF with or without ventral decompression were associated with improved clinical outcomes in both adults and children, suggesting the importance of increased attention to intraoperative morphometrics.[8,9]

Atlantoaxial instability may be a contributing factor to CM development and symptom experience. Defined by alteration of atlantodental interval on flexion-extension of the craniovertebral junction, atlantoaxial instability may underlie CM development.[10] Prior studies have suggested the limited therapeutic effect of traditional surgical decompression, favoring a more targeted approach of initial atlantoaxial stabilization and posterior cervical, specifically atlantoaxial segmental arthrodesis.[11] While early evidence shows promise of additional posterior arthrodesis with decompression for CM with CCI,[12] there still remains debate due to the lack of sufficient evidence and the complexity of these cases.[13,14] Nevertheless, the symptomatic improvement in select CM patients who undergo C1–2 fixation,[15] or OCF, has raised questions as to how to optimize surgical techniques for posterior arthrodesis in this population.

For this study, we describe methodology for quantitative intraoperative assessment of surgical correction and alignment and retrospectively analyzed associations between intraoperative and immediate postoperative X-ray skull base morphometrics with postoperative complications and clinical outcomes. The morphometrics we examined include the occipital to C2 angle (O C2a), occipital and external acoustic meatus to axis angle (O-EAa), C2 tilting angle (C2Ta), and narrowest oropharyngeal airway space (nPAS), which have been shown to be predictors for postoperative complications.[1,8,16] A case illustrating prospective applications of intraoperative fluoroscopic morphometrics and technique for manipulating the Mayfield head clamp locking mechanism is also presented.

METHODS

Patient selection

This study was approved by our Institutional Review Board (19-07020505), and all patients and/or legal guardians gave informed consent for surgical intervention after extensive discussions of risks, benefits, and alternatives. We retrospectively reviewed all CM 1 and 1.5 patients who underwent PFD and OCF at our institution between March 2015 and October 2020. Those with retroflexed odontoids who also received planned, staged ventral decompression in the form of endoscopic endonasal or transoral odontoidectomy were excluded from this study because the indication for OCF in these cases was to correct induced instability from odontoidectomy itself, which would also preclude accurate postoperative morphometric measurements. Patients were followed postoperatively for 15.4 months on average. We collected data on demographics, baseline clinical characteristics, perioperative X-ray morphometrics, operative details, postoperative complications, and clinical outcomes.

There do not exist clear, established guidelines for indications or selection of optimal patients in which PFD should be supplemented with OCF. Our preoperative assessment for both adult and pediatric patients relied on various clinical and radiographic factors: evaluation of CM symptomatology, especially symptoms attributable to ventral brainstem compression, a history of prior Chiari surgery, underlying hypermobility or CTDs affecting ligamentous laxity with genetic testing when clinically warranted, assessment of dynamic CCI on flexion-extension films, and findings on preoperative CT and/or MRI. Importantly, we evaluated for symptomatic improvement with trials of external cervical orthosis over the span of 2–3 months – we used the degree of clinical improvement as a proxy for the extent of symptomatic contribution from underlying CCI.

Surgical procedure

Before each OCF, upright X-rays of the craniocervical junction were taken with the patient's head positioned in the optimal and most comfortable alignment, with or without external orthosis, while assessing for symptoms of hyperextension or flexion, in order to derive target measurements for the intraoperative angles.

The exact surgical details depended on the nature of each patient's dorsal compression and CCI, especially if they had a prior history of PFD. In general, PFD consisted of suboccipital craniectomy and C1 laminectomy (in certain cases of severe caudal tonsillar herniation, C2 laminectomy was also performed) with or without duraplasty. The decision to open the dura depended on the severity of dorsal compression, assessed by both preoperative MRI and intraoperative ultrasound, as well as the presence and severity of syringomyelia, and it was not an exclusion criterion in this analysis. In all cases who required opening the dura, autologous duraplasty was performed using a pericranial graft harvested from the midline region of the scalp apex.

Following suboccipital decompression with or without duraplasty, the instrumented fusion portion of the case is performed. Using either X-ray fluoroscopic guidance, or intraoperative CT with three-dimensional computer navigation, the lateral mass screws are placed at appropriate levels in the subaxial cervical spine. Pars or pedicle screws can be placed at C2, and C1 is either skipped or gets lateral mass screws with a smooth shank placed to minimize irritation of the C2 nerve root. An occipital plate is placed over the suboccipital region superior to the craniotomy defect. Occipital plate screws are sized based on the thickness of the midline keel, targeting bicortical purchase. Following X-ray or intraoperative CT scan confirmation of appropriate screw placement, the patient's alignment is optimized. Over sterile drapes, the Mayfield head clamp is firmly held as the Mayfield knob is unlocked for the surgeon to carefully extend the patient's head under fluoroscopy, with concurrent assessments of the intraoperative O-C2a and O-EAa. Once the optimal position is locked in place, bilateral hinged rods are placed spanning the occipital plate down to the most caudal lateral mass screw tulip. Bending of the rod is performed to contour to the patient's alignment as needed. Autograft or allograft is placed and wired to rods with contact to the lateral edge of the suboccipital bone and the upper cervical spine joints to augment occipital-atlas-axis arthrodesis. The facet joints are decorticated and additional autograft and/or allograft is placed in the lateral gutters. Completion of instrumentation is followed by a multilayer muscle flap advancement by plastic surgery. The patient is placed in a hard cervical collar and then returned supine for extubation.

X-ray morphometric measurements

We focused on four validated morphometrics: O-C2a, O-EAa, C2Ta, and nPAS, which are demonstrated and further explained in Figure 1.[17] These morphometrics were measured preoperatively from available CT scout or standing X-rays. The same parameters were measured on intraoperative fluoroscopic scans to assess deviation from the patient's baseline metrics. If the intraoperative films suggested any risk of overflexion or overextension, necessary adjustments of the head were carefully made with the Mayfield knob until intraoperative metrics matched the patient's preoperative baseline measurements [Figure 2]. Postoperative measurements were taken on upright X-rays.

Statistical analysis

Statistical analyses were performed using R (version 4.0.0; The R Project for Statistical Computing, Vienna, Austria) with RStudio (version 1.2.5042). For hypothesis testing, Wilcoxon signed rank test was used for paired continuous variables. Statistical significance was defined with an alpha of 0.05.

RESULTS

Sample characteristics

We identified a total of 39 patients, whose preoperative characteristics are summarized in Table 1. Overall, 56.4% were older than 21 years, and 76.9% were females. CTDs were notably prevalent in this cohort – 61.5% carried a

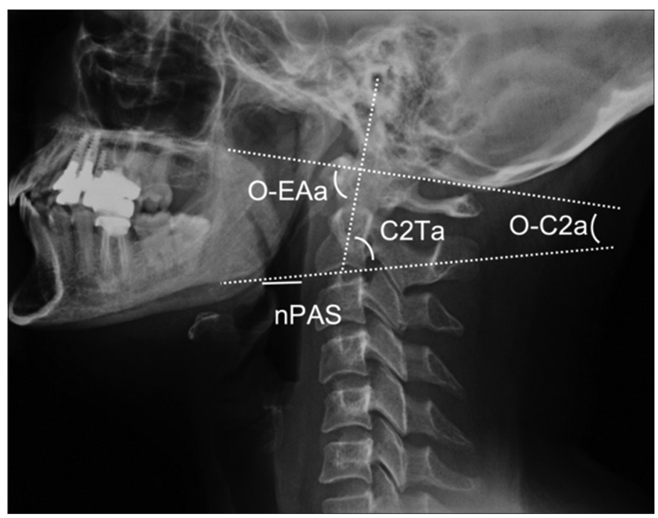

Figure 1: X-ray morphometric measurements. The occipital to C2 angle (O-C2a) is the angle measured between the McGregor line (drawn between the hard palate and the most caudal point of the occipital curve) and the caudal endplate of C2. C2 tilting angle (C2Ta) is formed by the caudal endplate of C2 and a line from the external acoustic meatus to the inferior endplate of C2. The sum of O C2a and C2Ta, occipital and external acoustic meatus to axis angle (O EAa) is formed by McGregor line and the line from external acoustic meatus to the inferior endplate of C2. Measured in millimeters, narrowest pharyngeal airway space is the smallest anteroposterior distance from the back of the tongue to the posterior pharyngeal wall. O-C2a - Occipital-to-C2 angle; O-EAa - External acoustic meatus-to-axis angle; C2Ta - C2 tilting angle; nPAS - narrowest oropharyngeal airway space

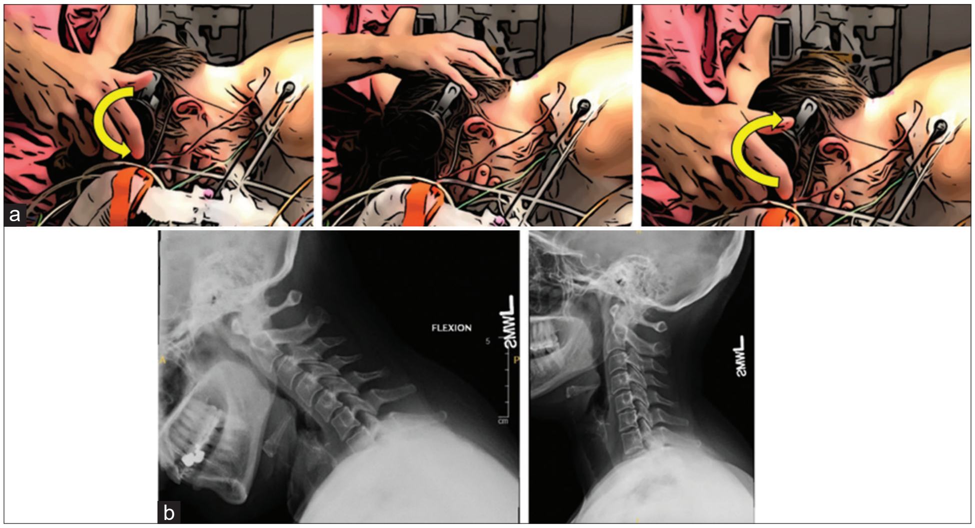

Figure 2: Proposed Mayfield head clamp locking mechanism for repositioning of the head from flexion to extension. (a) Patient in flexion for initial posterior fossa decompression (PFD). Surgeon manipulates Mayfield knob (yellow arrow) to carefully position head to neutral (left). Surgeon manipulates the head in preparation for occipitocervical fusion (OCF) after achieving intraoperative fluoroscopic measurements similar to the patient's preoperative baseline (middle). Head is held in place by clamping with Mayfield knob (right) in clockwise direction (yellow arrow). (b) Corresponding X ray when the patient is in flexion during initial PFD (left) and moved into neutral position for subsequent OCF (right)

formal diagnosis of EDS, and another 12.8% had other forms of CTD. In addition, 61.5% had a history of prior PFD with or without duraplasty for their CM. The three most common preoperative symptoms were headaches (100%), neck pain (87.2%), and paresthesia (76.5%). Bulbar symptoms were also common, and they included dysphagia (61.5%), tinnitus (53.8%), and respiratory issues (46.2%). The mean postoperative follow-up period was 15.4 months.

Retrospective review of X-ray morphometrics of nonrevision and revision cases

Out of 39 cases, 37 cases did not experience any complications that required revision surgery. When preoperative and immediately postoperative morphometric values in these nonrevision cases were compared [Table 2], O-C2a (13.5° ±10.4° vs. 17.5° ±10.1°, P = 0.047) and nPAS (10.9 ± 3.4 mm vs. 13.1 ± 4.8 mm, P = 0.007) increased significantly. O-EAa trended toward a higher value after surgery without reaching statistical significance, and C2Ta remained relatively unchanged.

Two cases, however, did require revision surgery due to postoperative complications, and their X-ray measurements are shown in Table 3. Revision case 1 was a 38-year-old woman with CM 1.5, EDS, and neurocardiogenic syncope, who presented preoperatively with years of exertional occipital headaches, paresthesia, dysphagia, visual disturbances, and gait instability. She underwent a PFD with split-thickness duraplasty and occiput-to-C3 posterior fusion. In the immediately postoperative course, the patient developed dysphagia – she failed bedside swallow evaluation and was deemed to be of high aspiration risk. Relative to her preoperative scan, her postoperative X-ray showed a sharp decrease in O-C2a (21.3° vs. 2.2°), O-EAa (95.6° vs. 79.6°), and nPAS (8.7 mm vs. 5.6 mm) [Figure 3]. Therefore, 7 days after the initial surgery, the patient received a revision, which consisted of removing the rods in order to reposition the head. After the revision surgery, O-C2a, O-EAa, and nPAS were reversed, similar to the preoperative values. Clinically, her preoperative symptoms and acute dysphagia in the initial postoperative course resolved after the revision.

Revision case 2 was a 30-year-old woman with a history of prior PFD at an outside hospital and EDS who presented with recurrence and progression of exertional occipital headaches, neck pain, and paresthesia, despite radiographic evidence of adequate dorsal decompression. She responded positively to a hard collar trial during which all of her symptoms resolved. She received a revision extradural PFD and occiput-to-C3 posterior fusion, after which she developed persistent dysphagia and coughs. Her postoperative X-ray showed a substantial decrease in O-C2a (20.5° vs. 6.4°) and O-EAa (89.3° vs. 79.7°). Concerned for a mechanical obstruction secondary to the hardware, she underwent a revision surgery a month later. After the revision, O-C2a was 12° and O-EAa was 84.1°, and the patient's clinical symptoms all resolved.

Case illustration: Intraoperative application of X-ray metrics to prevent hardware-related complications

Based on our retrospective analysis of X-ray metrics for nonrevision and revision cases, we reasoned that the metrics could be of intraoperative utility to avoid hardware-related

Table 1: Preoperative characteristics of 39 patients

Demographics	Continuous variable: mean (± SD) categorical variable: *n* (%)
Age at surgery	24.6 (13.8)
Adults (>21 years)	22 (56.4)
Female sex	30 (76.9)
Radiographic CM type	
1	36 (92.3)
1.5	3 (7.7)
Associated conditions	
Syrinx	7 (17.9)
EDS	24 (61.5)
Other CTDs	29 (74.4)
POTS	9 (23.1)
Prior PFD/D	24 (61.5)
Preoperative symptoms	
Headache	39 (100)
Neck pain	34 (87.2)
Back pain	19 (48.7)
Extremity pain	14 (35.9)
Dysphagia	24 (61.5)
Respiratory issues	18 (46.2)
Balance instability	14 (35.9)
Dizziness	23 (59.0)
Weakness	15 (38.5)
Decreased hearing	8 (20.5)
Tinnitus	21 (53.8)
Paresthesia	30 (76.9)
Visual disturbances	20 (51.3)
Urinary symptoms	15 (38.5)
Loss of consciousness	5 (12.8)
Cognitive impairment	13 (33.3)
Dysautonomia	17 (43.6)
Subjective functionality loss	29 (74.4)

Continuous variable expressed as mean±SD. Categorical variables expressed as *n* (%). CM - Chiari malformation; EDS - Ehlers–Danlos syndrome; CTDs - Connective tissue disorders; POTS - Postural orthostatic tachycardia syndrome; PFD/D - Posterior fossa decompression with or without decompression

Table 2: Morphometric measurements on preoperative and immediately postoperative X-rays in Chiari malformation patients who underwent occipitocervical fusion without ventral decompression (*n*=37) and did not require any subsequent revision surgery

X-ray morphometrics (mm or °), mean±SD	Preoperative	Postoperative	Mean difference	*P*
O-C2a	13.5 (10.4)	17.5 (10.1)	+4.1	0.047
O-EAa	88.4 (7.4)	92.3 (8.8)	+3.6	0.051
C2Ta	76.3 (8.6)	74.9 (9.1)	−0.8	0.48
nPAS	10.9 (3.4)	13.1 (4.8)	+2.2	0.007

O-C2a - Occipital-to-C2 angle; O-EAa - External acoustic meatus-to-axis angle; C2Ta - C2 tilting angle; nPAS - narrowest oropharyngeal airway space; SD - Standard deviation

postoperative complications that would require a revision. Here, we present a case illustration of a 39-year-old woman with CM 1, CCI, and retroflexed odontoid, who presented

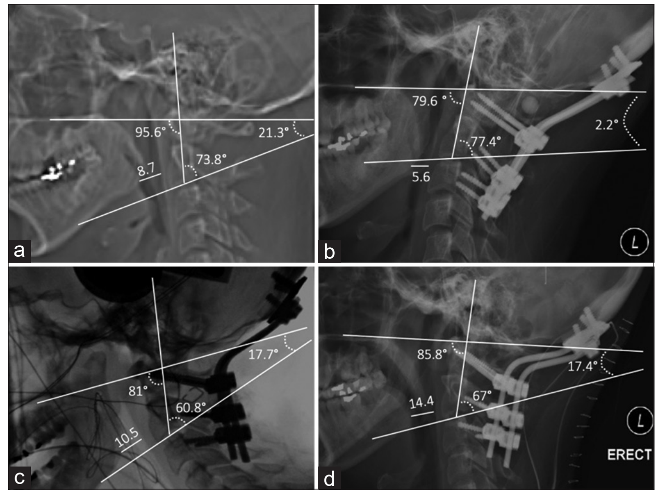

Figure 3: Radiographic presentation of patient 1 who underwent revision surgery. (a) Patient baseline metrics as defined by preoperative angular values (a) decreased to initial postoperative values in (b). Occipital to C2 angle (O-C2a) (21.3° vs. 2.2°), external acoustic meatus-to-axis angle (O-EAa) (95.6° vs. 79.6°), C2 tilting angle (C2Ta) (73.8° vs. 77.4°), and narrowest oropharyngeal airway space (nPAS) (8.7 mm vs. 5.6 mm). Note Mayfield clamp locking mechanism and morphometrics not used intraoperatively. Initial postoperative course complicated by dysphagia, requiring revision surgery. (c) Intraoperative fluoroscopic morphometrics measured during revision surgery. Mayfield head locking mechanism applied to adjust head position and hardware placement to generate preoperative baseline metrics. (d) Postrevision surgery morphometrics showed O-C2a, O-EAa, C2Ta, and nPAS to be 17.4°, 85.8°, 67°, and 14.4 mm, respectively. Postoperative dysphagia resolved completely

with frontal and occipital headaches, dysphagia, visual disturbances, paresthesia, and gait instability. Given the clinical and radiographic features of CCI, she was evaluated with a hard collar trial, during which she achieved complete symptom resolution. She, therefore, underwent a combined PFD and occiput-to-C3 fusion. Preoperative O-C2a and O-EAa were measured at 8.4° and 85.4°, respectively. Intraoperatively, the initial O-C2a and O-EAa were 25.3° and 92.1°, respectively, which was concerning for a potential overextension. We utilized intraoperative X-ray metrics to correct this by carefully readjusting the head with the Mayfield head clamp until final intraoperative O-C2a and O-EAa of 9° and 87° were achieved. Postoperative O-C2a and O-EAa were measured to be 7.3° and 88.3°, remaining consistent with preoperative values [Figure 4]. The patient did not experience any postoperative complications, and 7 months after the surgery, she reported subjective improvement in all of her clinical symptoms.

DISCUSSION

We previously showed the association of short-term CT/MRI skull base morphometric changes after OCF with positive clinical outcomes in both adults and children.[9,18] This particular study extended those findings by examining the utility of X-ray

Table 3: Changes in morphometrics of two cases who required revision surgery

X-ray morphometrics (mm or °)	Preoperative	Postinitial surgery	Difference	Postrevision surgery	Difference
Revision case 1					
O-C2a	21.3	2.2	−19.1	17.4	+15.2
O-EAa	95.6	79.6	−16	85.8	+6.2
C2Ta	73.8	77.4	+3.6	67	−10.4
nPAS	8.7	5.6	−3.1	14.4	+8.8
Revision case 2					
O-C2a	20.5	6.4	−14.1	12	+5.6
O-EAa	89.3	79.7	−9.6	84.1	+4.4
C2Ta	68.3	72.9	+4.6	71.4	−1.5
nPAS	5.2	6.3	+1.1	8.2	+1.9

O-C2a - Occipital-to-C2 angle; O-EAa - External acoustic meatus-to-axis angle; C2Ta - C2 tilting angle; nPAS - narrowest oropharyngeal airway space

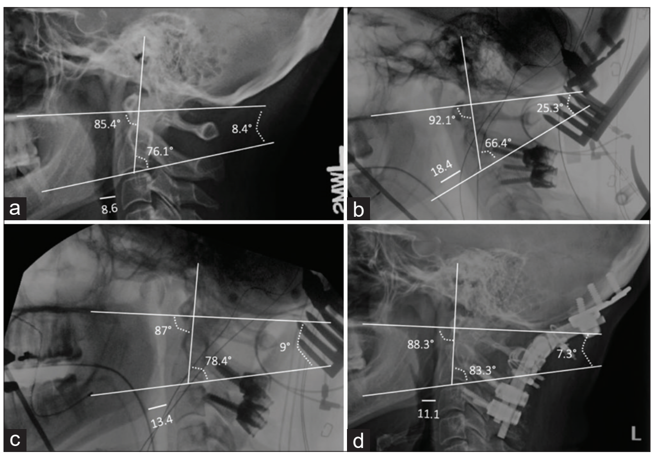

Figure 4: Application of Mayfield head clamp locking mechanism and intraoperative morphometrics during concomitant posterior fossa decompression and occipitocervical fusion. (a) Preoperatively metrics include occipital to C2 angle (O-C2a) (8.4°), external acoustic meatus-to-axis angle (O-EAa) (85.4°), C2 tilting angle (C2Ta) (76.1°), and narrowest oropharyngeal airway space (nPAS) (8.6 mm). (b) First fluoroscopic measurement prior to any head adjustment. Note O-C2a in this unadjusted position increased acutely to 25.3°. (c) Latest fluoroscopic measurement after adjustment. Values for O-C2a, O-EAa, and C2Ta resembled baseline metrics at 9°, 87°, 78.4°, and 13.4 mm, respectively. (d) Postoperative morphometrics remained consistent with the latest fluoroscopic image. The patient tolerated operation well and reported improvement in preoperative symptoms out to 7 months postoperatively

morphometrics on preventing postoperative complications in complex CM patients undergoing PFD and OCF. Based on these observations, we described via case examples a novel method to use such predictive markers pre- and intraoperatively.

Significance of X-ray morphometrics

Dysphagia is one of the most common postoperative complications of OCF. Its relation to the radiographic O-C2a has been described in multiple studies with a reduction of 5 degrees or greater postoperatively leading to oropharyngeal stenosis.[19] The sum of O-C2a and C2 tilting angle (C2Ta), the occipital and external acoustic meatus to axis angle (O-EAa), was later described to encompass both the craniocervical junction alignment and the cranial transverse motion.[20] Acute decreases in O-EAa postoperatively significantly correlate with reduced narrowest oropharyngeal airway space (nPAS) and onset of postoperative dysphagia, while O-C2Ta has less impact.[21]

Both patients requiring a revision in positioning experienced acute decreases in these metrics (mean difference: 16.6° in O-C2a and 12.8° in O-EAa) after their initial surgery. Their postoperative dysphagia resolved after the revision surgery, which also restored these metrics back to their preoperative baseline. In the nonrevision cohort, near consistency or slight increases were seen from pre- to postoperative O-C2a and O-EAa, further suggesting the predictive role of such radiographic parameters in determining the postoperative course for OCF patients.

Selection criteria for occipitocervical fusion in complex Chiari malformation

Selecting appropriate candidates for concomitant PFD and OCF for complex CM remains a controversial topic. At our institution, we rely on several clinical and radiographic variables in our decision-making algorithm. First, we rigorously assess preoperative clinical symptoms. Because complex CM patients often involve some degree of ventral brainstem compression, in addition to dorsal compression, patients most often present with bulbar symptoms, such as dysphagia, tinnitus, respiratory symptoms, and dysautonomia. Given this complex pathophysiology, we reason that PFD alone may not adequately address all symptoms.

Second, we consider their prior surgical history. While most patients with typical CM 1 do not require surgical intervention beyond primary PFD, previous studies have found that complex CM patients with atypical symptomology required a larger variety of surgical procedures.[22] In the patients studied here, 61.5% experienced a failed PFD, which enhanced their candidacy for OCF surgery. Again, this can be attributed to their complex underlying pathophysiology that PFD alone could not address completely.

Third, we work with genetics to evaluate for any signs and symptoms of underlying hypermobility or CTDs. In our cohort, 61.5% had EDS, and 74.4% had other CTDs. Genetic testing and clinical examination confirmed the formal diagnosis of specific CTDs. These conditions are particularly relevant because they have been shown to cause ligamentous laxity in the craniocervical junction, causing kinking of the brainstem and subsequent complex symptomatology.[23] Because these patients with CTDs also have increased susceptibility to postoperative wound-related complications, we often work with plastic surgery for myofascial flap closure.[24]

Fourth, potential candidates for PFD and OCF undergo a hard collar trial for 2–3 months. In our experience, patients who report complete or near-complete symptom resolution with the collar tend to respond positively to OCF. We consider this a particularly important tool in our selection criteria for OCF because it allows us to reversibly simulate the effects of the more permanent OCF and it ensures that patients can tolerate prolonged collar use, as postoperative healing requires a hard collar to facilitate fusion in this challenging population containing high rates of patients with CTDs.

Finally, we evaluate preoperative imaging. We routinely obtain flexion-extension X-rays of the cervical spine to assess for any dynamic instability. Furthermore, CT and MRI are used to evaluate skull base morphometrics, such as the clivo-axial angle (CXA), that we have previously described.[9,18] Ventral compression due to restricted CSF space between the clivus and the upper cervical spine often results in an acute CXA and bulbar symptomology.[3,17] Our prior work, along with previous studies, demonstrated significant corrections to CXA in successful OCF cases.[3,17,25,26]

Logistics and utilization of intraoperative morphometric measurements during occipitocervical fusion

Given that intraoperative fluoroscopy is very frequently used to evaluate hardware placement in posterior cervical decompression and fusion,[27] we felt it important to extend its application to assess proper alignment in complex CM patients undergoing concomitant PFD and OCF. During this same-day, two-stage surgery, the neck is slightly flexed during PFD and then subsequently extended to its neutral position for OCF. Because of this intraoperative manipulation, ascertaining neutral craniocervical alignment is particularly important. Often, a tool to measure one or more of the predictive radiographic parameters mentioned here is embedded in the fluoroscopic imaging software. However, even without such a function, a variety of applications can be downloaded to allow for quick angular measurements on such an image. Obtaining such a metric can then guide surgeons to adjust the head position in a single flexion-extension axis using the Mayfield clamp in the direction that would result in similar preoperative baseline values. This process may be repeated until the fluoroscopic image generates metrics in the range that will reduce the risk of revision surgery.

Limitations and future directions

There were several limitations to this study. First, our analyses were limited by its retrospective data collection at a single center and a relatively small sample size. Second, because intraoperative fluoroscopy is performed with the patient in the prone position, it is unclear to what degree its measurements differ from those obtained from standing preoperative and postoperative X-rays. Third, our intraoperative application of these metrics to achieve proper craniocervical alignments and avoid postoperative complications ultimately needs more prospective data to more definitively show its utility. With more data, we would also be able to investigate whether these X-ray metrics have any associations with long-term clinical outcomes, beyond just the immediately postoperative period.

CONCLUSION

Our study demonstrates the predictive ability of radiographic morphometrics for postoperative OCF dysphagia. Harnessing these morphometrics in guiding hardware placement real time during OCF, especially for patients with CM complicated by CTDs, may prove advantageous in achieving neutral craniocervical alignment and preventing the need for revision surgery.

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Conflicts of interest

There are no conflicts of interest.

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