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# The Cervicocranium: Its Radiographic Assessment<sup>1</sup>

Acute injuries of the cervicocranium (from the occiput to the second cervical intervertebral disk) may be radiographically obscure due to minimal displacement of fracture fragments, minor alterations of normal anatomic relationships (occipitotantal subluxation), or superimposition of normal skeletal structures. With the nasopharynx adequately distended with air, the normal cervicocranial prevertebral soft-tissue contour is congruent with the anterior cortical margin of the cervicocranium; namely, concave above, convex anterior to, and concave below the anterior tubercle of C1. Alterations of the normal cervicocranial prevertebral soft-tissue contour due to hemorrhage into the retropharyngeal fascial space from subtle fractures or ligamentous injuries should prompt further assessment of the cervicocranium by means of computed tomography (CT). Cervicocranial CT prompted by an abnormal cervicocranial prevertebral soft-tissue contour has yielded a 16% positive injury rate, approximately three times the rate of acute cervical spine injuries reported in the literature.

The cervicocranium is defined as extending from the skull base through the second cervical intervertebral disk. Of the entire cervical spine, the cervicocranium is the most difficult to evaluate radiographically because of its complex anatomy, the physiologic motions and normal variants that may simulate acute injury, and the inherent difficulty in obtaining a diagnostic study of the cervicocranium in both frontal and lateral projections. These factors have particularly adverse implications in patients clinically suspected of having blunt cervicocranial trauma, when it is impossible to obtain a useful open-mouth view and given the fact that any injuries to the cervicocranium are radiographically subtle. Further, three cervicocranial injuries are simply not visible on the lateral cervical spine radiograph and may not be visible on the open-mouth radiograph.

The purpose of this article is to describe and illustrate the normal cervicocranial prevertebral soft-tissue contour and changes in that contour that may serve as an indirect sign of cervicocranial injury requiring further assessment with computed tomography (CT) and/or magnetic resonance (MR) imaging. The concept of cervicocranial prevertebral soft-tissue contour changes being useful in this regard is based on the following hypotheses:

1. On the normal lateral cervical spine radiograph, the cervicocranial prevertebral soft-tissue contour reflects the prevertebral soft-tissue anatomy of the cervicocranium, which, in turn, closely follows the contour of the anterior cortex of the cervicocranial skeleton.
2. Hemorrhage from acute cervicocranial injuries accumulates in the cervicocranial ligaments and/or retropharyngeal fascial space.
3. Blood in the retropharyngeal fascial space alters the normal cervicocranial prevertebral soft-tissue contour.
4. Therefore, patients suspected of having blunt cervical spine trauma and an abnormal cervicocranial prevertebral soft-tissue contour on the lateral cervical spine radiograph should undergo cervicocranial CT to identify radiographically occult cervicocranial injury.

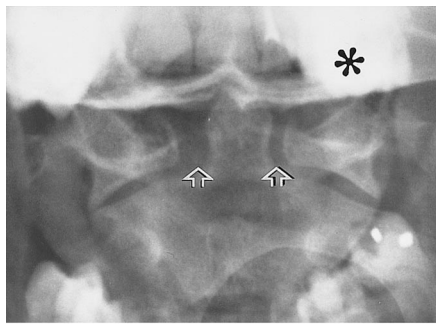
## BACKGROUND

Traditionally, radiographic assessment of the cervicocranium is based on the anteroposterior "open-mouth" radiograph of the cervicocranium and the lateral radiograph of the

cervical spine. The open-mouth view is generally regarded as satisfactory if the tip of the dens is visible. Frequent limitations to this definition include common obscuration or complete obliteration of the occipital condyles by the maxillary premolar and molar teeth (Fig 1), obscuration of the lateral masses of C1 by the occipital bone, superimposition of maxillary incisor teeth on the dens, Mach lines of the inferior cortical margin of the posterior arch of C1 superimposed on the dens or the axis body, and the presence of a previously introduced endotracheal and/or nasogastric tube. In addition, it is impossible to obtain an open-mouth view in patients who are unconscious, who are uncommunicative for whatever reason, or who have sustained major midfacial or mandibular fractures.

Fractures of the occipital condyles and of the lateral masses of C1 are simply not visible on the lateral radiograph of the cervicocranium because of the inherent anatomic relationship of the occipitoatlantal articulations, the bilateral superimposition of the lateral masses of C1 and the occipital condyles, and the superimposition of the mastoid processes on the occipitoatlantal articulations. Similarly, the posterior obliquity of the anterior arch of C1 between the anterior tubercle and lateral masses renders fractures of the anterior arch of C1 invisible on the lateral radiograph of the cervical spine. Given these limitations of both the open-mouth and the lateral cervical spine radiograph, it is reasonable to wonder how the cervicocranium can be radiographically "cleared" (ie, declared normal) after blunt cervical spine trauma.

Hay in 1939 (as cited by Keats [1]) and Penning (2) in 1981 presumably attempted to address this question by their efforts to define the normal shadow of the cervical—including the cervicocranial—prevertebral soft-tissue thickness on the lateral cervical spine radiograph. The clear implication was that a cervical prevertebral soft-tissue shadow thickness exceeding these normal limits (Fig 2) was indicative of an injury to the cervical spine, given a history of acute trauma. Invalidating factors common to both the Hay and the Penning methods include the target-to-film distance of 72 inches (1.83 m) and failure to take into account the effect of such variables as the degree of pharyngeal aeration, the normally variable location of the cervical esophagus relative to the cervical vertebrae, and the effect of flexion and extension on the cervicocranial prevertebral soft-tissue contour. Limitations peculiar to the Hay

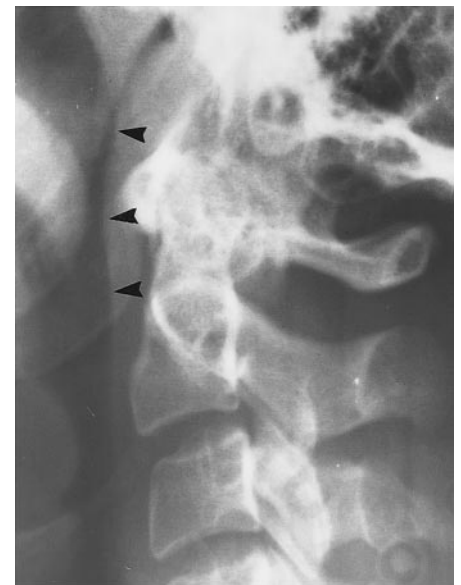


a.

#### Prevalence of Cervical Spine Injury

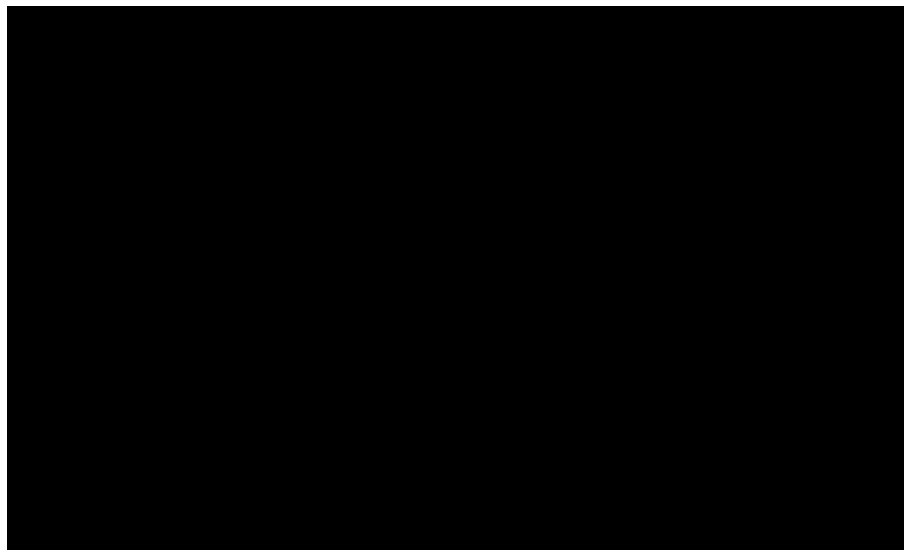
Patient Group	Prevalence (%)*
All patients	1.7–3.8 (21–26)
Patients with multiple trauma	5.9 (27)
Patients with cervicocranial fracture	5 (28)
Patients with abnormal cervicocranial prevertebral soft-tissue contour	16

\* Numbers in parentheses are reference numbers.



b.

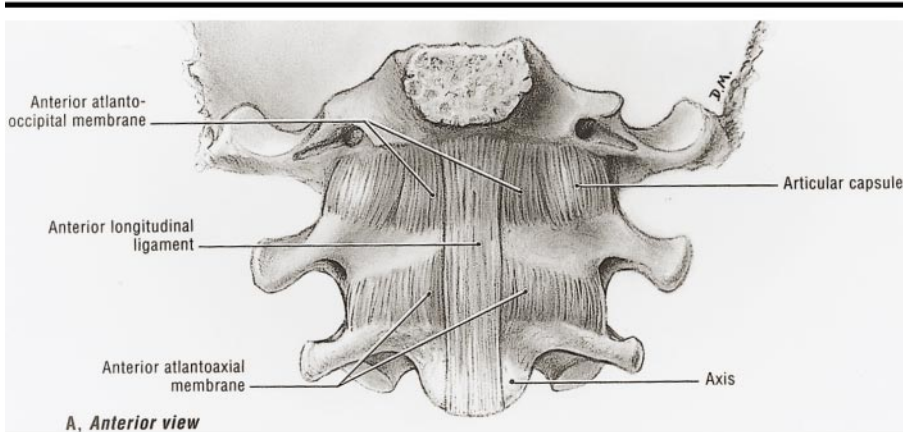
**Figure 1.** (a) Typical adequate open-mouth radiographic projection. The principal shortcoming of this particular open-mouth view is complete obscuration of the occipital condyles by the maxillary premolar and molar teeth (\*). Obscuration of the tip of the dens is of secondary importance because of the rarity of a type I dens fracture. The lateral atlantodental asymmetry (arrows) is positional. The limitations of this open-mouth view are negated by (b) the normal cervicocranial prevertebral soft-tissue contour (arrowheads) as seen in this lateral projection, and the cervicocranium can be declared radiographically normal.



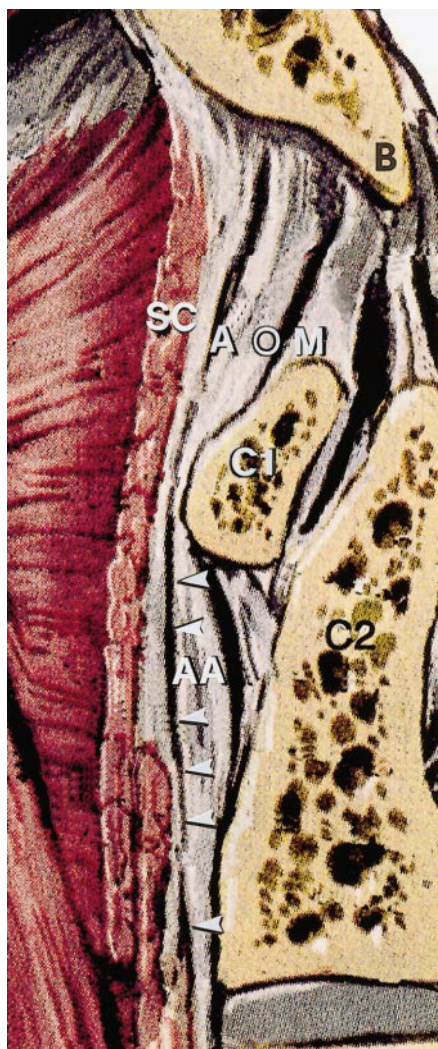
**Figure 2.** Permission to reprint this image was denied by the publisher. See Print version.

method include the use of the variably radiographically visible thyroid and cricoid cartilages as landmarks for measure-

ment, determination of the normal soft-tissue thickness by using fractional multiples of the anteroposterior width of



a.



b.

**Figure 3.** (a) Schematic representation shows an anterior view of the anterior ligaments of the cervicocranium. (Reprinted, with permission, from reference 3.) (b) Midsagittal schematic representation of the anterior soft-tissue anatomy of the cervicocranium. Arrowheads = retropharyngeal fascial space, AA = atlantoaxial ligament, AOM = anterior atlanto-occipital membrane, B = basion, C1 = anterior tubercle of the atlas, C2 = axis including its odontoid process, SC = superior constrictor muscle. (Adapted and reprinted, with permission, from reference 4.)



**Figure 4.** Midsagittal cadaveric section shows the normal cervicocranial prevertebral soft-tissue contour (arrowheads), which is concave above and below the anterior tubercle (T) and convex anterior to the tubercle. (Reprinted, with permission, from reference 5.)

the body of C5, age specificity (on an annual basis from birth to 7 years), and a single formula applicable to all adults. In addition to these limitations, the Hay system is difficult to use on a routine basis.

Although the Penning standards of normal prevertebral soft-tissue width were obtained from lateral neutral, flexion, and extension radiographs, the range of normal at most vertebral levels is so wide as to create many false-normal readings.

## Cervicocranial Anatomy

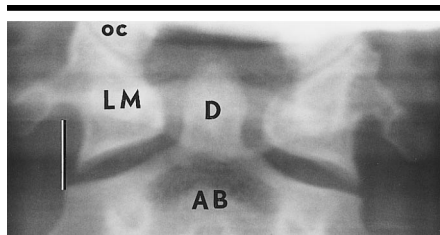
The cervicocranium extends from the skull base through the second cervical intervertebral disk and includes the clivus; foramen magnum and contiguous occipital bone; the biconvex occipital condyles, which articulate with the biconcave superior articulating surfaces of C1; the atlas and its articulations with the dens and the superior facets of the articular masses of C2; and the axis.

Although many important ligaments support the cervicocranium, only those germane to this discussion will be described and illustrated. From below upward, the anterior longitudinal ligament inserts onto the anteroinferior corner of the axis body. The dense fibrous tissue extending upward from the axis body to the anterior arch of C1 is the anterior atlantoaxial membrane. A thin upward extension of the anterior longitudinal ligament distinct from but adherent to the anterior atlantoaxial membrane also extends rostrally to insert onto the inferior cortex of the anterior tubercle of C1 (Fig 3a). The more rostral extension of these ligaments from the superior cortex of the anterior arch of C1 to the clivus is the anterior atlanto-occipital membrane. At direct visual inspection, the atlantoaxial membrane appears to be simply a rostral extension of the anterior longitudinal ligament. In the fresh nonembalmed cadaver, these ligaments are firmly adherent to the anterior cortex of the axis body and the base of the dens.

In the midsagittal plane, the anterior atlantoaxial membrane curves anterosuperiorly from the anterior cortex of the axis and base of the dens to the anterior tubercle of C1. The anterior atlanto-occipital membrane extends in a posteriorly concave configuration from the anterior tubercle of C1 to the more posteriorly situated clivus and basion. The potential retropharyngeal fascial space lies directly anterior (superficial) to the cervicocranial ligaments described earlier. The superior constrictor muscles are anterior to the retropharyngeal fascial space and are covered by the retropharyngeal mucosa (Fig 3b). In the cadaver, the soft tissues just described essentially follow, or are congruous with, the anterior cortical surfaces of the skeletal components of the cervicocranium from the basion to the second cervical intervertebral disk (Fig 4).

## Cervicocranial Radiographic Anatomy

The normal cervicocranial skeletal anatomy is clearly shown on an optimally po-

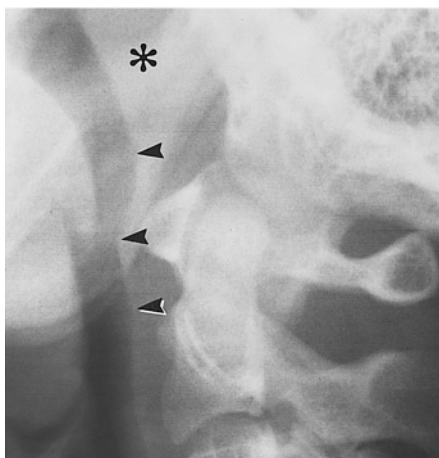


**Figure 5.** Optimal open-mouth radiographic projection shows the intact occipital condyles (*oc*) and lateral masses (*LM*) of C1, the entire dens (*D*), and the axis body (*AB*). The right articular lateral mass of C1 is congenitally smaller than the left, which explains why the lateral atlantodental intervals are symmetric, while the lateral corner of the right lateral mass of C1 is not on the same vertical plane (line) as its C2 counterpart.

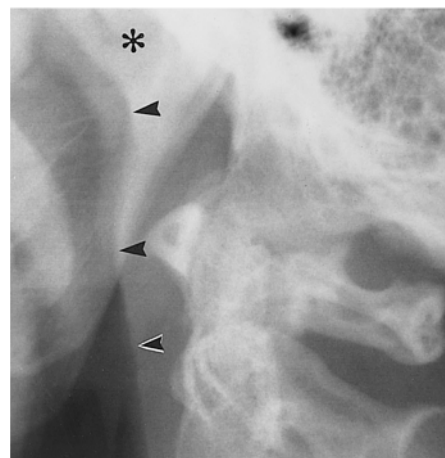
sitioned open-mouth radiograph (Fig 5). The open-mouth projection shows skeletal anatomy; anatomic relations, which may be altered physiologically or pathologically; and only direct signs of some cervicocranial injuries. Specifically, the prevertebral soft tissues are not visible on the open-mouth view.

From the preceding description of the anatomy of the cervicocranial prevertebral soft tissue, it should be apparent that the soft-tissue contour can be seen only on the lateral cervical radiograph. The normal cervicocranial prevertebral soft-tissue contour of two 150-lb (68.2-kg) adults is shown in Figure 6. The cervicocranial prevertebral soft-tissue contour is normally concave above and below the anterior tubercle of the atlas and convex anterior to the tubercle. The interface between air and soft tissue is optimally demonstrated when the pharynx is well distended by air. The cervicocranial prevertebral soft-tissue contour may be partially obscured by superimposition of the ascending rami of the mandible (Fig 7) and/or the styloid processes. Usually, however, careful analysis of the linear opacity representing the posterior cortical margins of the ascending mandibular rami and/or the obliquely oriented styloid processes will allow the distinction. In large adults, the thickness of the cervicocranial prevertebral soft-tissue shadow is wider than that in the average-sized adult, but the contour is not normally altered by the extra width (Fig 8). The purpose of this statement and the images shown in Figures 6 and 8 is to emphasize that the important observation relative to the cervicocranial prevertebral soft-tissue shadow is contour and not thickness.

In infants and young children, the cer-

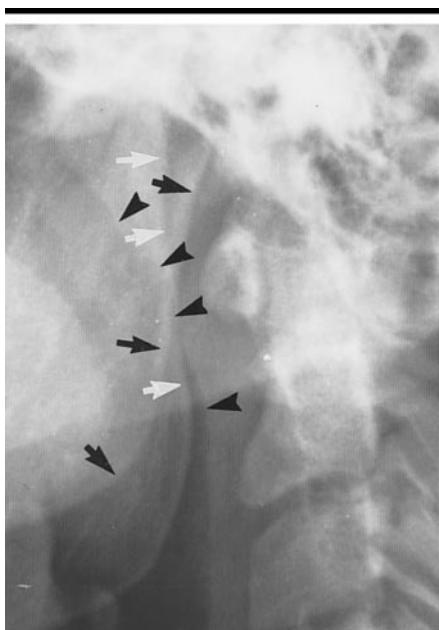


**a.**

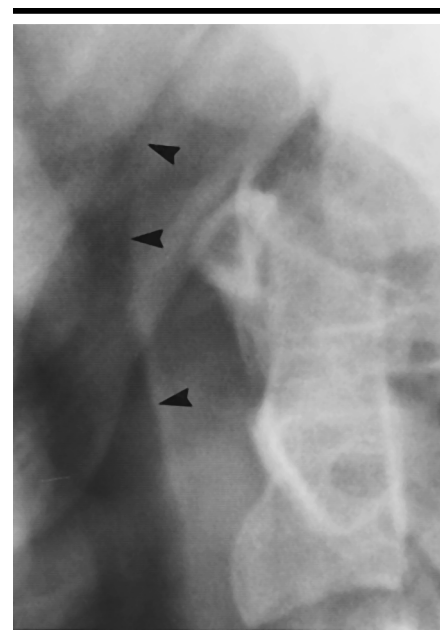


**b.**

**Figure 6.** (a, b) Contact lateral radiographs show normal cervicocranial prevertebral soft-tissue contour (arrowheads) in two adults. Residual adenoidal tissue (\*) can be seen in both.



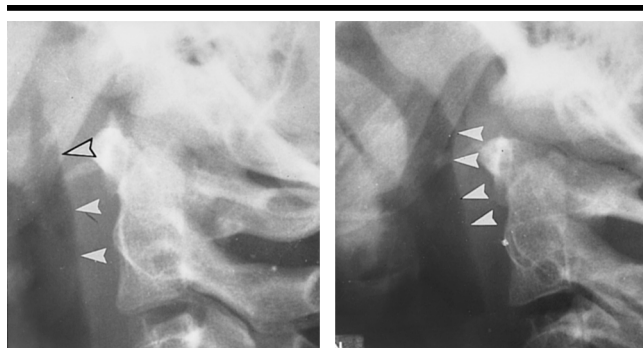
**Figure 7.** Contact lateral radiograph in a 150-lb (68.2-kg) adult shows a normal cervicocranial prevertebral soft-tissue contour (arrowheads) partially obscured by the ascending mandibular rami (arrows).



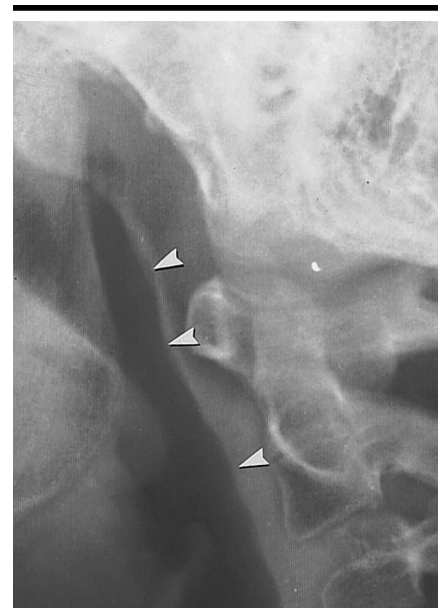
**Figure 8.** Contact lateral radiograph shows a normal cervicocranial prevertebral soft-tissue contour (arrowheads) in a large adult. Although it is obvious that the thickness of the cervicocranial prevertebral soft-tissue shadow is greater than that in 150-lb (68.2-kg) adults (as in Fig 7), the contour remains the same and is normal.

vicocranial prevertebral soft-tissue contour is usually not as distinct as it is in adults. This is due largely to the physiologic laxity of the cervical prevertebral soft tissues in infants and young children and the fact that the lateral cervical spine radiograph frequently is inadvertently obtained during expiration. If the cervicocranial prevertebral soft-tissue contour appears abnormal on the initial lateral radiograph, the technologist should be instructed to time the subsequent expo-

sure to occur during patient inspiration—for example, when the child is inhaling preparatory to crying. The second radiograph, when so timed, should show a distinct change in the width of the cervicocranial prevertebral soft-tissue shadow (Fig 9) and occasionally a cervicocranial prevertebral soft-tissue contour similar to that in adults (Fig 10). With normal growth and development to about the age of 8–10



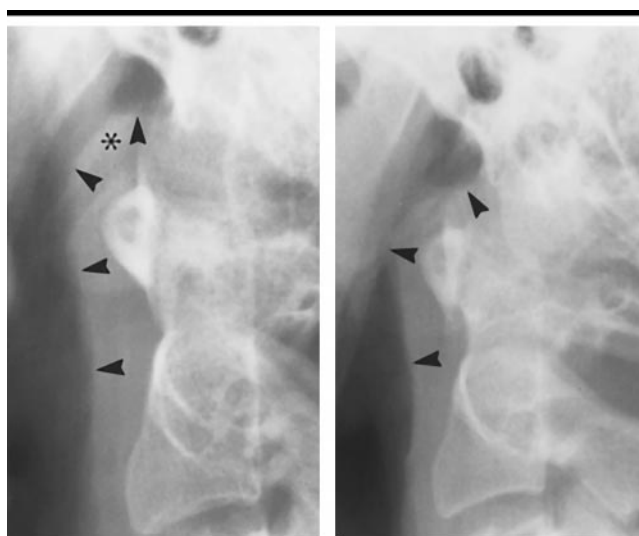
**Figure 9.** The effect of pharyngeal distention on the cervicocranial prevertebral soft-tissue contour in infants and young children. (a) On the initial contact lateral radiograph in an infant, the contour of the cervicocranial prevertebral soft tissue is diffusely abnormally convex (arrowheads). (b) On the repeat contact lateral radiograph obtained minutes later during inspiration, the cervicocranial prevertebral soft-tissue contour inferior to the C1 tubercle is concave (arrowheads) and, therefore, normal. The cervical spine was also declared clinically normal.



**Figure 11.** Contact lateral radiograph of the cervical spine shows a normal cervicocranial prevertebral soft-tissue contour (arrowheads) in a 9-year-old child.



**Figure 10.** Lateral cervical spine radiograph shows a normal cervicocranial prevertebral soft-tissue contour in a 3-year-old child. While not as precisely defined as in adults, the cervicocranial prevertebral soft-tissue contour (arrowheads) is concave above and below the atlas tubercle and convex anterior to the tubercle.



**Figure 12.** Comparison of (a) routine and (b) contact lateral radiographs obtained minutes apart in the same patient. (a) On a routine lateral radiograph, the cervicocranial prevertebral soft-tissue contour (arrowheads) is ill-defined and appears abnormal above (\*) the C1 tubercle. Caudal to the tubercle, the contour is ambiguous. (b) Contact lateral radiograph shows the cervicocranial prevertebral soft-tissue contour (arrowheads) to be normal.

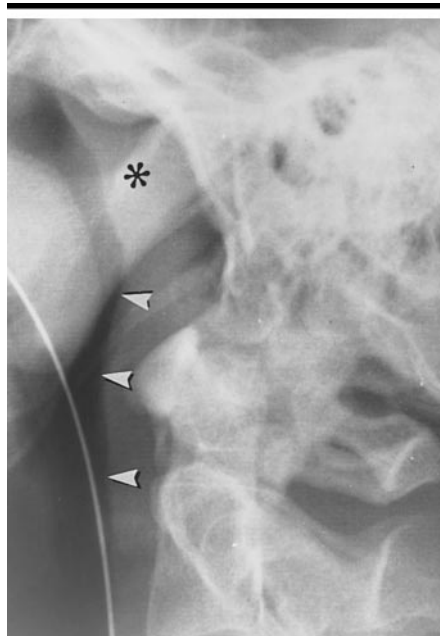
years, the cervicocranial prevertebral soft-tissue contour should approach that of the adult, particularly when a contact lateral radiograph is obtained during pharyngeal distention (inspiration) (Fig 11).

The effect of nasopharyngeal adenoid tissue on the cervicocranial prevertebral soft-tissue contour will be discussed and illustrated subsequently.

### Radiographic Examination

The radiographic examination of the cervicocranium must include at least the open-mouth radiograph, when clinically possible, and the routine lateral cervical spine projection obtained with the cassette lateral to the shoulder, whether the

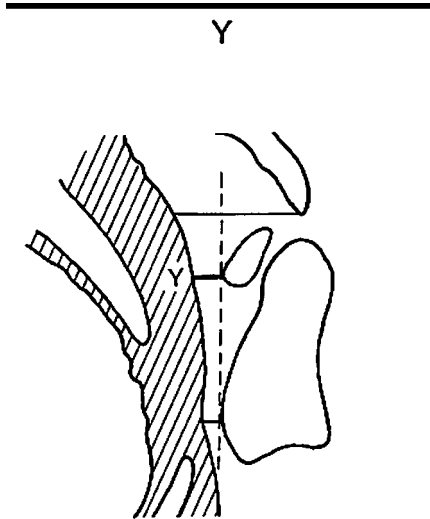
patient is erect or supine. Because of the magnification inherent in this standard lateral projection, we routinely also include a contact lateral radiograph, principally to assess the cervicocranium. This projection is obtained with the cassette placed above the shoulder and in direct



**Figure 13.** Contact lateral radiograph of the cervicocranium shows a normal cervicocranial prevertebral soft-tissue contour (arrowheads) in the presence of a nasogastric tube. \* = adenoidal tissue.

contract (hence, “contact lateral”) with the patient’s cheek. Magnification is reduced on the contact lateral radiograph, which, in turn, enhances delineation of the cervicocranial pharyngeal air–soft-tissue interface and, consequently, delineation of the cervicocranial prevertebral soft tissue contour (Fig 12). The contact lateral radiograph is an integral part of our radiographic examination of the cervical spine and is obtained in all patients except infants. The target-to-film distance for both the routine and the contact lateral radiographs is 40 inches (1 m).

Routine lateral and contact lateral radiographs are obtained in all patients suspected of having blunt cervical spine trauma, regardless of the magnitude of injury or prior intubation. (In patients with multiple trauma, the routine lateral and contact lateral cervical spine radiographs—along with images from conventional radiographic examinations of other anatomic areas included in our major trauma protocol—are obtained during the primary patient assessment and, therefore, do not extend patient length of stay at the trauma center.) The purpose of the contact lateral radiograph is to assess the cervicocranial skeleton and prevertebral soft-tissue contour with equal importance. Prior endotracheal intubation severely limits visualization of the cervicocranial prevertebral soft tissue;



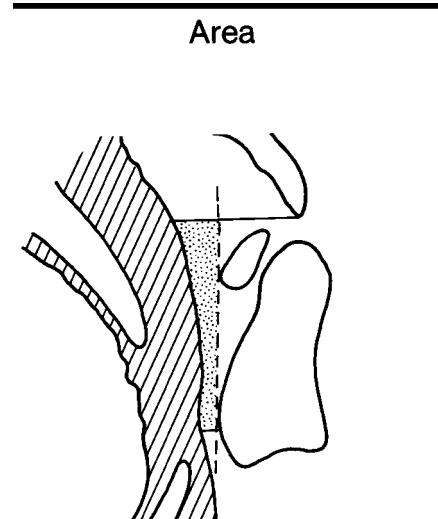
Group	N	Distance (mm)
Normal	37	4.38 ± 0.22
JBF	9	8.89 ± 0.75*
HD	11	9.73 ± 1.08*
LD	12	7.00 ± 0.48*
All	32	8.47 ± 0.50*

(\*p < 0.001 vs. Normal)

**Figure 14.** Schematic shows the comparison of the average width of the cervicocranial prevertebral soft-tissue shadow anterior to the anterior tubercle of C1 (Y) between healthy individuals and patients with subtle fracture. The reader is urged to ignore the measurements per fracture type and instead compare the “Normal” width with the “All” width. The latter represents the average thickness in all patients in the fracture group. HD = high dens fracture (type II), JBF = Jefferson bursting fracture, LD = low dens fracture (type III).

naso- or orogastric intubation may not (Fig 13).

Optimum delineation of the cervicocranial prevertebral soft-tissue contour is contingent on maximum distention of the pharynx. Consequently, when alert and communicative, the patient is instructed to inspire deeply through the open mouth, with the radiographic exposure timed to occur during inspiration. Another maneuver designed to maximize pharyngeal distention on the contact lateral image is to have the patient forcibly exhale against closed lips to the extent that the patient’s cheeks bulge outward much like that of some trumpet players, Louis Armstrong in particular. This technique is called the “trumpet”



Group	N	Area (mm <sup>2</sup> )
Normal	37	222 ± 14
JBF	9	397 ± 45*
HD	11	442 ± 46*
LD	11	402 ± 16*
All	31	415 ± 21*

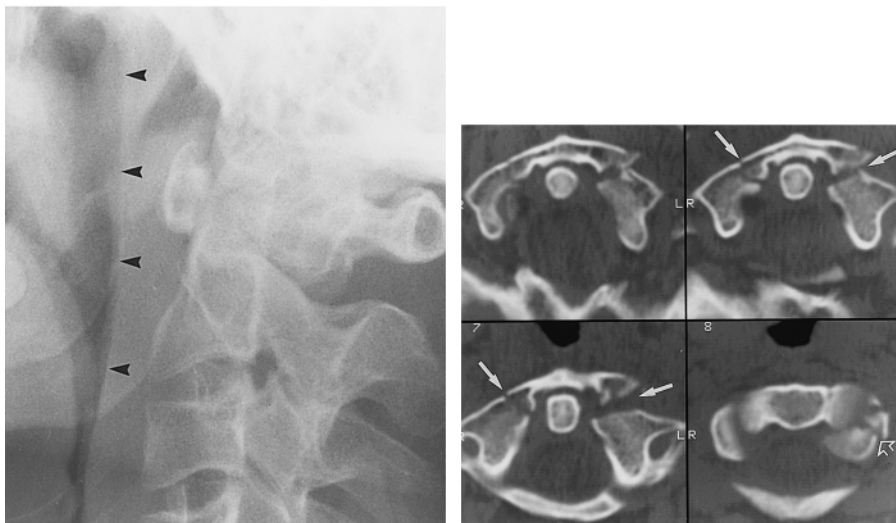
(\*p < 0.001 vs. Normal)

**Figure 15.** Schematic shows the comparison of the average area (stippled) between healthy individuals (Normal) and patients with subtle cervicocranial fracture (All). The reader is urged to compare only the averages to recognize the statistically significant difference between the healthy subjects and the fracture group. HD = high dens fracture (type II), JBF = Jefferson bursting fracture, LD = low dens fracture (type III).

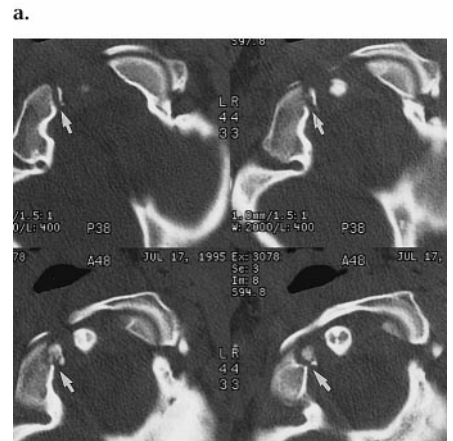
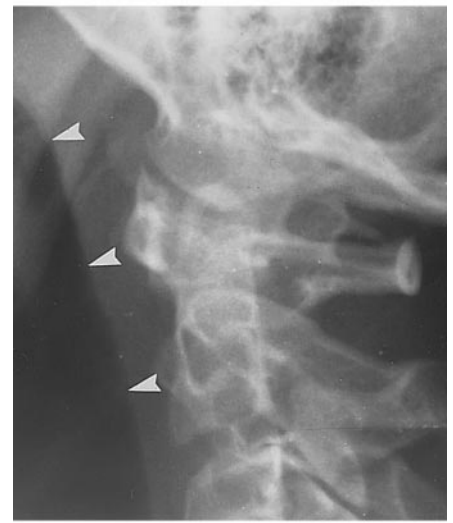
view. Comparison of transverse MR images obtained during quiet inspiration and during the trumpet maneuver clearly demonstrate active distention of the pharynx by means of the trumpet technique (Sardina et al, unpublished data, 1999).

#### Effect of Cervicocranial Trauma on Cervicocranial Prevertebral Soft-Tissue Contour

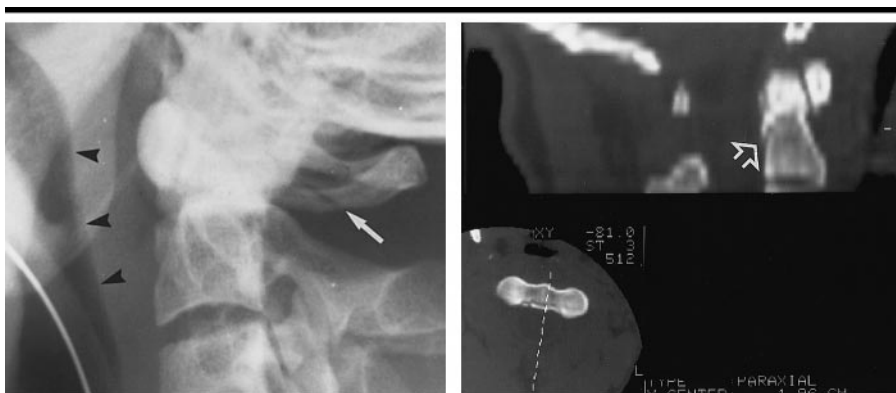
Having determined an anatomic basis for the normal contour of the cervicocranial prevertebral soft-tissue shadow, it was necessary to establish whether a hematoma associated with subtle cervicocranial injury altered the normal cervi-



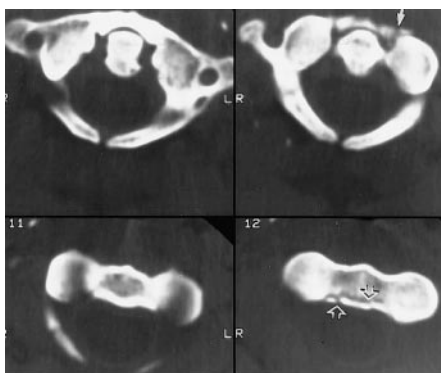
**Figure 16.** (a) Contact lateral radiograph shows diffusely abnormal cervicocranial prevertebral soft-tissue contour (arrowheads) in a patient with bilateral C1 anterior arch fractures. (b) Transverse CT images show the bilateral C1 anterior arch fractures (solid arrows). On the left, the fracture extends into the left lateral mass of C1 (open arrow).



**Figure 18.** (a) Contact lateral radiograph shows an anterosuperiorly oblique abnormal cervicocranial prevertebral soft-tissue contour (arrowheads). (b) Transverse CT images show that this patient has a type III right occipital condylar fracture (arrows).



**Figure 17.** Focally abnormal cervicocranial prevertebral soft-tissue contour. (a) On the contact lateral radiograph, the cervicocranial prevertebral soft-tissue shadow is convex (arrowheads) inferior to the anterior tubercle of C1 in a patient with a minimally displaced Jefferson bursting fracture (arrow). (b) Transverse and (c) sagittal CT images show the Jefferson bursting fracture (solid arrow in b) and a minimally displaced low (type III) dens fracture (open arrows in b and c).

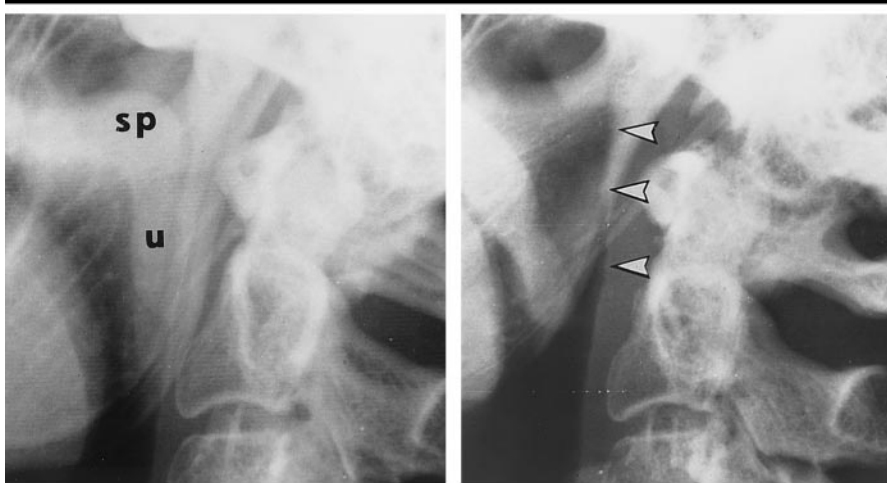


**Figure 17b.** Transverse CT images show the Jefferson bursting fracture (solid arrow) and a minimally displaced low (type III) dens fracture (open arrow).

measured on lateral cervical spine radiographs in 37 healthy adult subjects and 31 adult patients with a minimally displaced Jefferson bursting or high (type II) or low (type III) dens fracture (Fig 14). On the same radiographs, the area of an irregular parallelogram was determined, bounded by the air-soft-tissue interface anteriorly, a vertical line connecting the anterior tubercle of C1 and the most

prominent cortex of the axis body posteriorly, the lines perpendicular to the vertical at the level of the anterior tubercle of C1 superiorly, and the most prominent anterior cortex of the axis body inferiorly (Fig 15). In each instance, the average measurement for the injured group of patients was significantly greater than that of the healthy group ( $P < .001$ ), which established that a posttraumatic hematoma in the cervicocranial prevertebral soft tissues produces a radiographically visible soft-tissue abnormality.

The normal adult cervicocranial prevertebral soft-tissue contour is illustrated in Figures 6–8 and 11. The abnormal contour may appear in one of two configurations, namely convexity of the cervicocranial prevertebral soft-tissue shadow, which may be diffuse (Fig 16) or focal (Fig



**Figure 19.** The importance of pharyngeal distention relative to assessment of the cervicocranial prevertebral soft-tissue contour. (a) On the initial lateral cervical spine radiograph obtained with the patient recumbent, the soft palate (*sp*) and the uvula (*u*) are in contact with the posterior pharyngeal wall, thereby making assessment of the cervicocranial prevertebral soft-tissue shadow impossible. (b) On a contact lateral radiograph obtained during inspiration, a few minutes after **a**, the pharynx is well distended with air, revealing a normal cervicocranial prevertebral soft-tissue contour (arrowheads); therefore, the cervicocranium is negative.



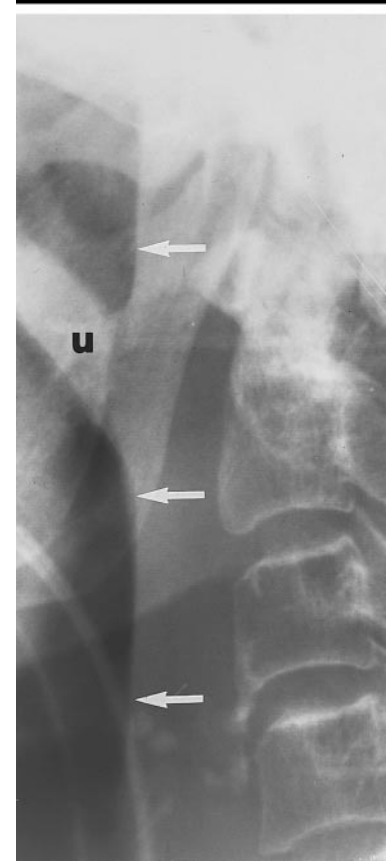
**Figure 20.** Change in the cervicocranial prevertebral soft-tissue contour secondary to flexion. (a) On the neutral contact lateral radiograph, the cervicocranial prevertebral soft-tissue is concave (arrowhead) caudal to the atlantal tubercle. (b) On the flexed contact lateral radiograph, however, it becomes convex (arrowhead).

17), or an anterosuperior obliquity of the air-soft-tissue interface extending from the axis body to the clivus (Fig 18).

#### Conditions Affecting Cervicocranial Prevertebral Soft-Tissue Contour Changes Not Related to Cervicocranial Trauma

Both physiologic conditions and non-cervicocranial injuries may cause the cer-

vicocranial prevertebral soft-tissue contour to appear abnormal or be unrecognizable. The observer must be aware of these conditions because they invalidate the diagnostic value of the cervicocranial prevertebral soft-tissue contour, much like a poor inspiratory chest radiograph or the presence of a large pleural effusion reduces the diagnostic value of the chest radiograph.

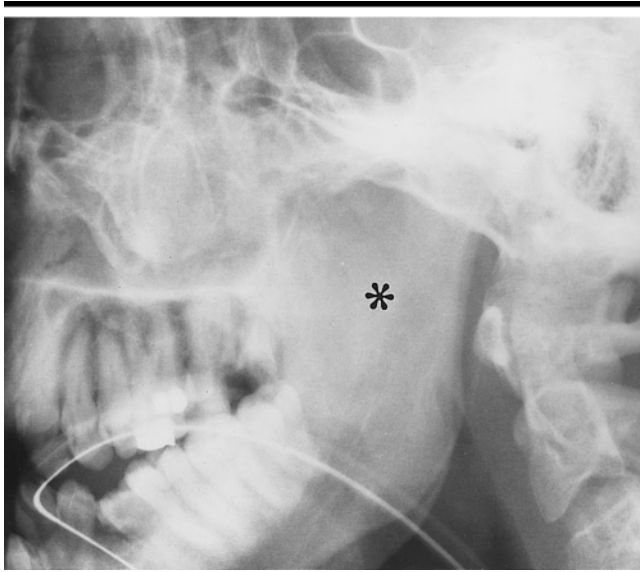


**Figure 21.** Obliteration of the cervicocranial prevertebral soft-tissue contour by fluid. Contact lateral radiograph of the cervicocranium with the patient supine shows the long air-fluid level (arrows) in the pharynx and nasopharynx interrupted by the uvula (*u*); this represents saliva or blood in the posterior recess of the pharynx.

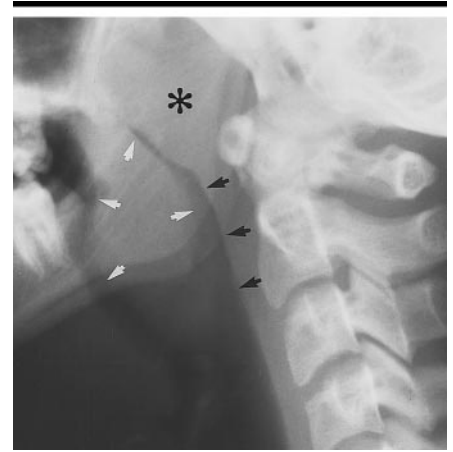
Physiologic conditions that tend to alter or obscure the normal cervicocranial prevertebral soft-tissue contour include inadequate pharyngeal distention (Fig 19), cervical spine flexion (Fig 20), swallowing during the radiographic exposure, saliva pooling in the posterior pharynx in recumbency (Fig 21), and nasopharyngeal adenoidal tissue (Figs 6, 9).

In pathologic conditions, the cervicocranial prevertebral soft-tissue interface is usually not visible in the presence of an endotracheal tube. The contour is obliterated by the large nasopharyngeal hematoma frequently associated with a severe midfacial (Fig 22) or displaced posterior mandibular fracture, the diffuse retropharyngeal hematoma of hyperextension dislocation (Fig 23), blood pooling in the nasopharynx in recumbency (Fig 21), retropharyngeal cellulitis without (Fig 24) or with (Fig 25) pharyngeal lymphoid hyperplasia, or abscess.

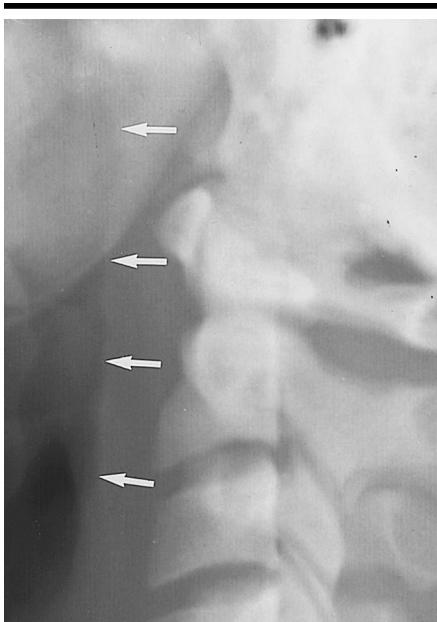




**Figure 22.** Lateral cervical spine radiograph shows a large nasopharyngeal hematoma (\*) associated with a LeFort type III midfacial fracture that has completely obliterated the nasooropharyngeal airway and, consequently, impaired the ability to assess the cervicocranial prevertebral soft-tissue contour rostral and anterior to the anterior tubercle of the atlas. Therefore, this patient requires CT for evaluation of the cervicocranium.



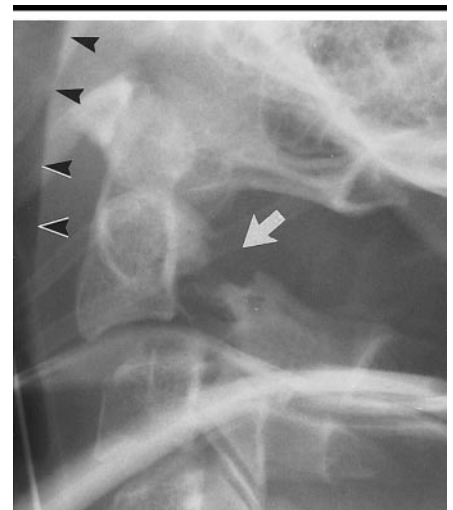
**Figure 25.** Lateral radiograph shows abnormal cervicocranial prevertebral soft-tissue contour (black arrows) secondary to retropharyngeal cellulitis associated with massive adenoidal (\*) and pharyngeal tonsillar hypertrophy (white arrows).



**Figure 23.** Lateral radiograph shows obliteration of the cervicocranial prevertebral soft-tissue contour by means of prevertebral soft-tissue swelling (arrows) associated with hyperextension dislocation of the lower cervical spine.



**Figure 24.** Lateral radiograph shows abnormal cervicocranial prevertebral soft-tissue contour (arrows) secondary to retropharyngeal cellulitis in which the air-soft-tissue interface is irregular and ill defined, which is characteristic of retropharyngeal inflammation.



**Figure 26.** Contact lateral radiograph shows a radiographically obvious type II traumatic spondylolisthesis (arrow). Although not necessary for diagnostic purposes, the cervicocranial prevertebral soft-tissue contour is abnormally convex (arrowheads) throughout its extent.

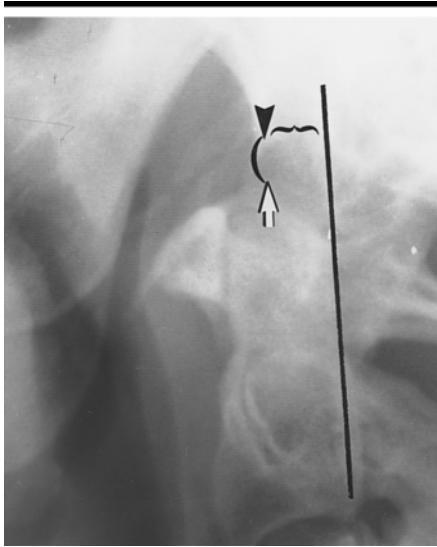
### Application of the Cervicocranial Prevertebral Soft-Tissue Contour in Assessing the Cervicocranium

Because most cervicocranial fractures are radiographically readily apparent (Fig

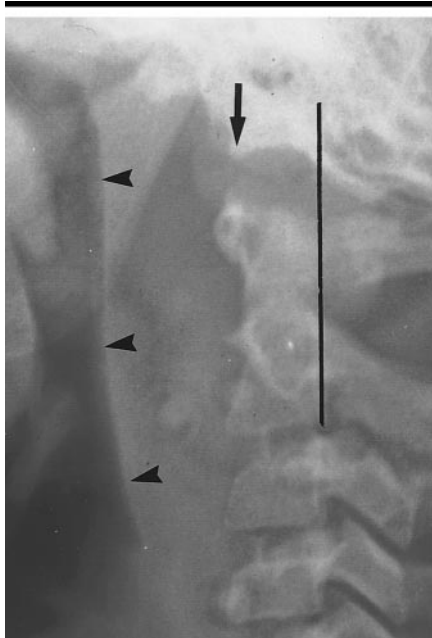
26), appropriate management is promptly instituted. Radiographically subtle or frankly invisible cervicocranial injuries pose a greater threat to the patient, owing to prolonged initial morbidity, the poten-

tial for brainstem and spinal cord injury, or remote cervicocranial morbidity if the injury is neither recognized nor treated. Obviously, therefore, identification of subtle cervicocranial injuries is of more than academic interest.

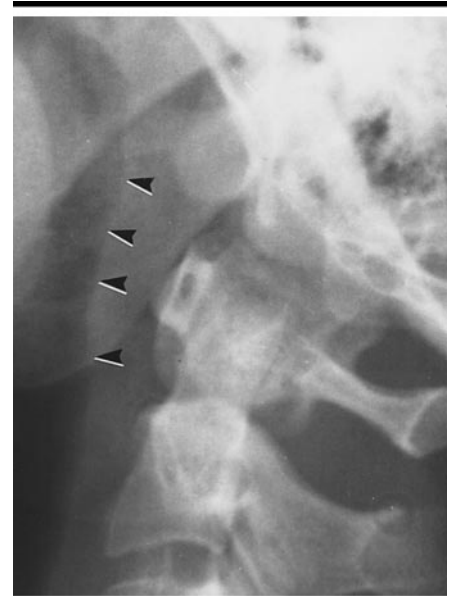
An approach to the search for cervicocranial injuries is to consider them on the basis of anatomic "proximities," from rostral to caudal, beginning with occipitoatlantal dissociation (both dislocation and subluxation), occipital condylar fracture, lateral mass of C1 fracture, Jefferson bursting fracture, traumatic rupture of



**Figure 27.** Normal basion-axial interval (curly brace) and basion-dental interval (curved line). On the contact lateral radiograph of the cervicocranium, the basion-axial interval is the distance between the basion (arrowhead) and the posterior axial line (straight line). The basion-dental interval is the distance between the basion and the superior cortical margin of the dens (arrow). Normally, neither the basion-axial interval nor the basion-dental interval should exceed 12 mm.



**Figure 28.** Lateral radiograph shows a grossly abnormal convex cervicocranial prevertebral soft-tissue shadow (arrowheads) associated with anterior-distracted occipitoatlantal subluxation in which the basion (arrow) is more than 12 mm anterior to the posterior axial line (line).



a.



b.

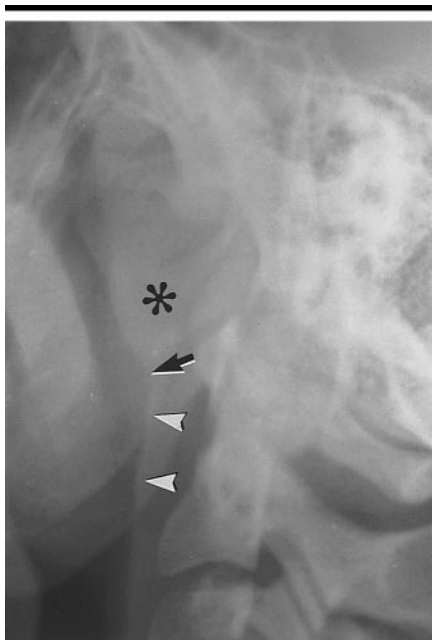
**Figure 30.** Occipital condylar fracture with ipsilateral fracture of the mass of C1. (a) On the contact lateral radiograph, the cervicocranial prevertebral soft-tissue contour is abnormally convex (arrowheads) rostral to the anterior tubercle of C1. (b) Transverse CT image at the occipitoatlantal level shows the occipital condylar fracture (arrowhead) and fracture of the ipsilateral articular mass and transverse process of C1 (arrow).

the transverse atlantal ligament, dens fractures (type I, II, or III), and traumatic spondylolisthesis (type I). Each of these cervicocranial injuries will be discussed in the sequence just described, and the importance of an abnormal cervicocranial prevertebral soft-tissue contour will be illustrated.

### Occipitoatlantal Dissociation

Occipitoatlantal dislocation is neither a clinical nor a radiographic enigma. In relatively recent studies of occipitoatlantal dissociation (7,8), 27 of 28 patients with occipitoatlantal dislocation were dead on arrival or died at the emergency center.

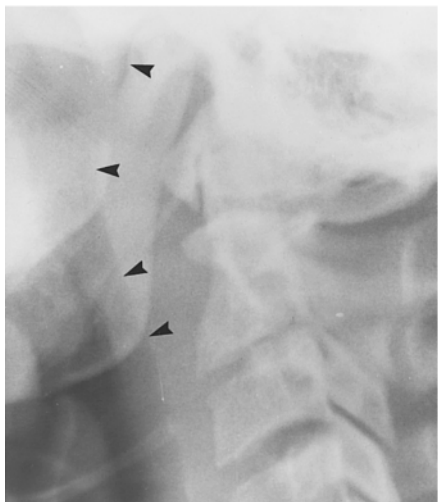
Conversely, occipitoatlantal subluxation is radiographically subtle, and patients usually survive. The diagnosis of occipitoatlantal subluxation is dependent on recognition of an abnormal basion-axial interval and/or basion-dental interval, both of which may be subtle. Normally, neither the basion-axial nor the basion-dental interval should exceed 12 mm (Fig 27) (7). The radiographic possibility of occipitoatlantal subluxation is strongly suggested by an abnormal cervicocranial prevertebral soft-tissue contour, particularly rostral to the anterior



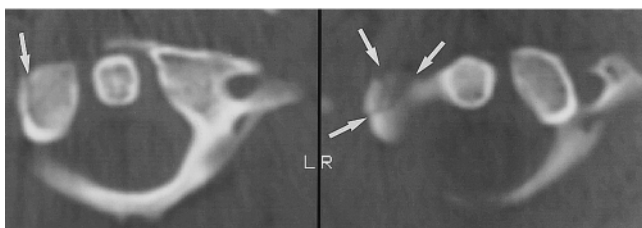
**Figure 29.** Contact lateral radiograph shows the normal short angle (arrow) at the junction of the adenoidal tissue (\*) and the cervicocranial prevertebral soft-tissue shadow (arrowheads).

tubercle of the atlas (Fig 28). It is important to distinguish the physiologic appearance of the cervicocranial prevertebral soft-tissue contour due to adenoidal

tissue from that associated with a high cervicocranial prevertebral soft-tissue hematoma. Nasopharyngeal adenoidal tissue occupies the space immediately beneath the clivus and is radiographically characterized by a soft-tissue mass with a smooth or irregularly lobulated inferior surface. The junction of the adenoidal mass with the cervicocranial prevertebral soft-tissue contour rostral to the anterior tubercle of the atlas may normally appear as a smooth posterior concavity (Figs 6, 10; top arrowhead in Fig 13) or as a short, rather acute posterior angulation (Fig 29). The high cervicocranial hematoma



a.



b.

**Figure 31.** Fracture of the lateral mass of C1. (a) The only abnormality seen on the contact lateral radiograph is the abnormal convex cervicocranial prevertebral soft-tissue contour (arrowheads). (b) Transverse CT images show a minimally displaced fracture of the right lateral mass of C1 (arrows). Fractures of the lateral mass of C1 are rarely, if ever, visible on the lateral cervical spine radiograph.

associated with occipitoatlantal subluxation either obliterates this normal angle, making it anteriorly convex (Fig 28), or renders the cervicocranial prevertebral soft-tissue shadow abnormal in an anterosuperiorly upward oblique contour (Fig 18a).

### Occipital Condylar Fractures

Occipital condylar fractures may occur in one of three types (9). A type I fracture is characterized by one or both occipital condyles being split or comminuted by an axial loading force similar to that which produces the Jefferson bursting fracture, a type II fracture is a fracture of the occipital bone that extends into the condyle, and a type III fracture is an avulsion fracture of the medial surface of the condyle at the site of attachment of the alar “check” ligament. Occipital condylar fractures may be associated with other cervicocranial fractures, particularly those involving the contiguous lateral mass of C1. Occipital condylar fractures, either alone or in conjunction with a fracture of

the lateral mass of C1, produce an abnormally convex cervicocranial prevertebral soft-tissue contour, typically superior to the anterior tubercle of C1 (Fig 30). Occipital condylar fractures are not visible on the lateral cervical radiograph because of superimposition of other related skeletal components.

### Fractures of Atlas Vertebra

Fractures of C1 that may be radiographically subtle, or frankly not visible, if a lateral radiograph of the cervicocranium alone is obtained include fracture of the lateral mass (Fig 31) and of the anterior arch (Fig 32). The anterior arch component of the Jefferson bursting fracture is rarely visible on the lateral cervical spine radiograph (Fig 33). The differential diagnosis of fracture of the posterior arch of C1 includes only a Jefferson bursting fracture and an isolated fracture of the posterior arch of C1 caused by

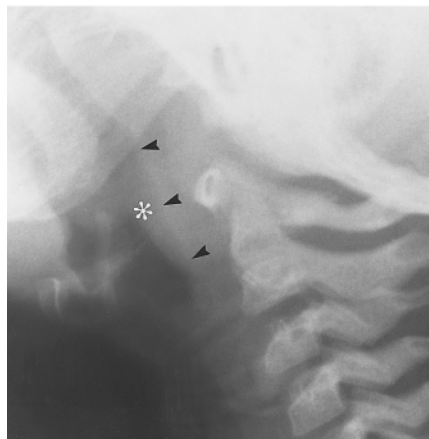
hyperextension. CT is necessary to make the distinction. Both the Jefferson bursting fracture and the fracture of the anterior arch of C1 produce an abnormal cervicocranial prevertebral soft-tissue contour.

### Acute Traumatic Rupture of the Transverse Atlantal Ligament

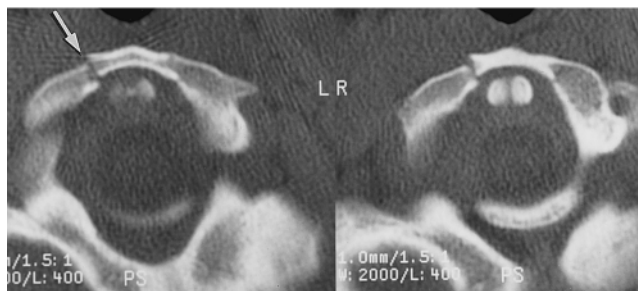
The mechanism of injury of acute traumatic rupture of the transverse atlantal ligament is protean. The traditional radiographic sign of this injury is increased width of the anterior atlantodental interval. Because of the typically associated anterior translation of C1 and the skull, bleeding due to injury to the anterior atlanto-occipital membrane results in an abnormal cervicocranial prevertebral soft-tissue contour (Fig 34).

### Dens Fracture

Type II (high) and type III (low) dens fractures can both be difficult to identify



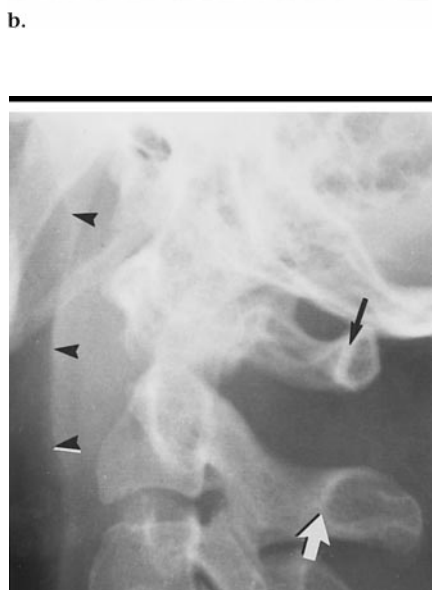
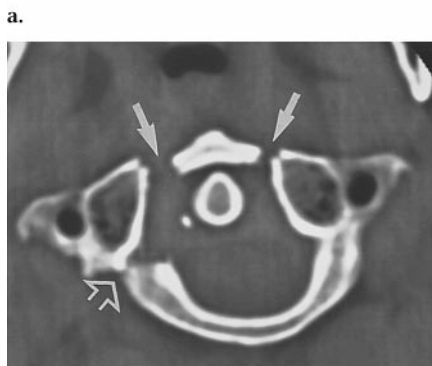
a.



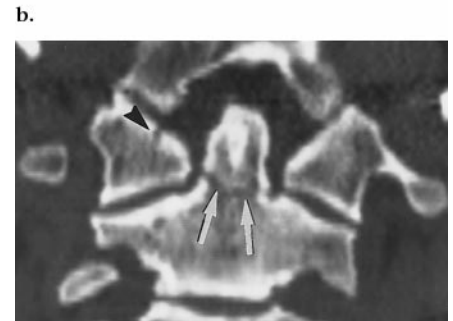
b.

**Figure 32.** Fracture of the anterior arch of C1 in a 2-year-old child. (a) The cervicocranial skeleton is negative on the contact lateral radiograph, but the cervicocranial prevertebral soft-tissue contour (arrowheads) is abnormally convex. The small soft-tissue mass (\*) extending anterior to the cervicocranial prevertebral soft-tissue-air interface represents posterior pharyngeal lymphoid tissue. (b) Transverse CT images show that the abnormal convex contour in a is secondary to acute fracture of the right side of the anterior arch of C1 (arrow).

**Figure 33.** Jefferson bursting fracture of C1. (a) The only abnormality on the contact lateral radiograph in this patient, who was in a major motor vehicle collision, is a grossly abnormal cervicocranial prevertebral soft-tissue contour (arrowheads). Specifically, all of the visualized cervicocranial skeleton is intact and in normal alignment. The abnormal cervicocranial prevertebral soft-tissue contour was the indication for (b) transverse cervicocranial CT, which demonstrated bilateral anterior arch of C1 fractures (solid arrows) and a subtle fracture at the junction of the lateral mass and the posterior arch of C1 on the right (open arrow).



**Figure 34.** Abnormal cervicocranial prevertebral soft-tissue shadow associated with acute traumatic rupture of the transverse atlantal ligament. With this relatively underexposed contact lateral radiograph of the cervicocranium, it is difficult to assess the width of the anterior atlantodental interval. However, anterior displacement of the spinolaminar line of C1 (black arrow) with respect to that of C2 (white arrow) and the abnormal cervicocranial prevertebral soft-tissue contour (arrowheads) should create a high level of suspicion for this injury, which must then be confirmed with CT or MR imaging.



**Figure 35.** Subtle type II dens fracture with abnormal cervicocranial prevertebral soft-tissue contour. (a) Contact lateral radiograph shows an abnormally convex cervicocranial prevertebral soft-tissue contour (arrowheads) extending inferior to the anterior tubercle of C1. The axis ring is intact, and the base of the dens is obscured. (b) Sagittal and (c) coronal CT images confirm the minimally displaced type II dens fracture (arrows). The vertical hypopattenuating line of the superior facet of the right lateral mass of C1 (arrowhead in c) represents the superior margin of the tubercle for attachment of the transverse atlantal ligament and should not be mistaken for a fracture.

## DISCUSSION

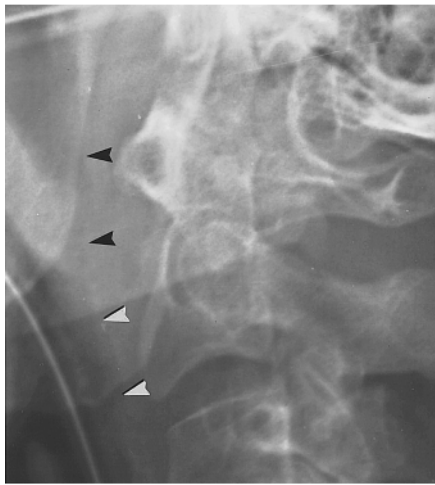
Now that I have described and illustrated the basic elements of the indirect signs of cervicocranial injury, it is appropriate to describe “how I do it” regarding the radiologic assessment of the cervicocranial

radiographically. On the lateral cervical spine radiograph, a minimally displaced type II dens fracture may be obscured due to superimposition of the lateral masses of C1 and, on the open-mouth projection, superimposition of incisor teeth, the posterior arch of C1, or the occipital bone. Overlooked type II dens fractures result in a greater incidence of nonunion (os odontoideum) than do those identified and properly treated.

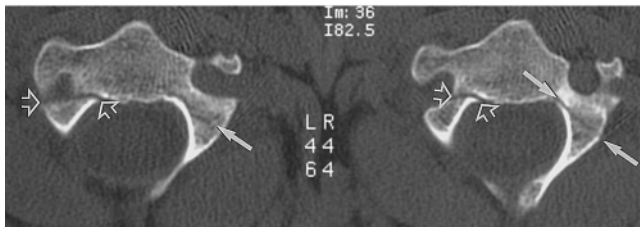
The low dens fracture can be obscured on the open-mouth radiograph for the same reasons as discussed with regard to the high (type II) dens fracture. On the lateral cervical spine radiograph, disruption of the axis ring (10) and the “fat axis body” sign (11) may both be subtle and easily overlooked. Both type II (Fig 35) and type III dens fractures, however, produce an abnormal cervicocranial prevertebral soft-tissue contour, which must prompt further evaluation with CT.

## Traumatic Spondylolisthesis

By definition, type I traumatic spondylolisthesis or its variant, atypical traumatic spondylolisthesis (10,12), is characterized by a normal relationship between C2 and C3 without evidence of disruption of the second intervertebral disk (13). Innately, then, pars interarticularis fractures of type I traumatic spondylolisthesis or of atypical traumatic spondylolisthesis will be minimally displaced and subtle. Both type I traumatic spondylolisthesis and atypical traumatic spondylolisthesis are rarely recognizable on the open-mouth projection. In light of this, the most obvious sign of possible traumatic spondylolisthesis or atypical traumatic spondylolisthesis is an abnormal cervicocranial prevertebral soft-tissue contour (Fig 36), primarily caudal to the anterior tubercle of the atlas.

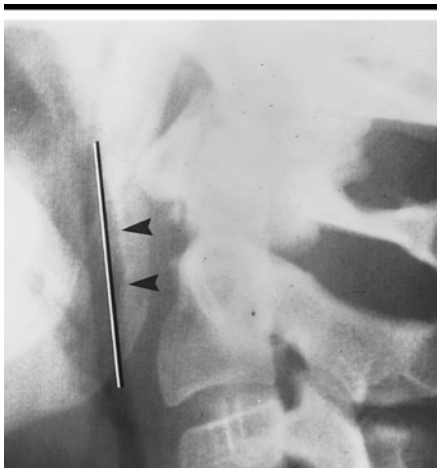


a.



b.

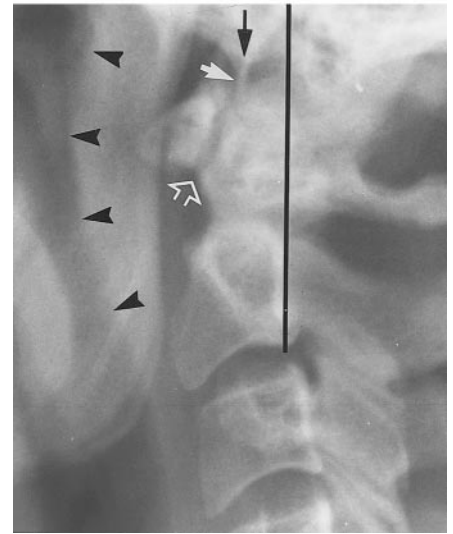
**Figure 36.** Type I atypical traumatic spondylolisthesis heralded by an abnormal cervicocranial prevertebral soft-tissue contour. (a) Contact lateral radiograph of the cervicocranium shows the abnormally convex cervicocranial prevertebral soft-tissue contour (arrowheads), even in the presence of a nasogastric tube. A pars interarticularis fracture line is not visible. (b) Transverse CT images show the atypical fracture line on the right (open arrows) and the pars interarticularis fracture on the left (solid arrows).



**Figure 37.** Contact lateral radiograph demonstrates objective confirmation of an equivocal concavity of the cervicocranial prevertebral soft tissue (arrowheads) below the anterior atlantal tubercle. The thin column of air posterior to the line from the soft tissue anterior to the atlantal tubercle to the soft tissues anterior to the anterior-most cortex of the axis body demarcates the cervicocranial prevertebral soft-tissue concavity.

nium. The process includes both conventional radiographs—open mouth and contact lateral—and CT. This concept is applicable to all patients, with modifications only for the patient's age, ability to communicate, and level of consciousness.

In infants and young children who cannot cooperate sufficiently to help obtain an open-mouth view, the cervicocranium is assessed on the lateral projection alone. In this age group, if the cervicocranial prevertebral soft-tissue contour appears abnormal, as is common because of the physiologic laxity of the cervicocranial soft tissues and because the image is most commonly, but inadvertently, obtained during patient expiration, lateral radiography must be repeated with the technologist instructed to time the radiographic exposure to coincide with patient inspiration. A change in the cervicocranial prevertebral soft-tissue contour on the repeat lateral radiograph indicates the absence of a cervicocranial hematoma which, when combined with a nor-



**Figure 38.** False-positive cervicocranial prevertebral soft-tissue contour. On this contact lateral radiograph in a patient clinically suspected of having an acute cervical spine injury, the cervicocranial prevertebral soft-tissue contour is abnormally convex (arrowheads). A CT image of the cervicocranium (not shown), obtained because of the abnormal contour, was negative. Occipitoatlantal subluxation is excluded owing to the normal (<12-mm) distance between the posterior axial line and the basion (black arrow; basion-axial interval). The calcified dentate ligament (solid white arrow) indicates a normal basion-dental interval, which also is less than 12 mm. Rupture of the transverse atlantal ligament is excluded because of the normal anterior atlantodental interval (open white arrow).

mally aligned and intact cervicocranial skeleton, allows the cervicocranium to be declared normal radiographically (Fig 9). Should the cervicocranial prevertebral soft-tissue contour remain abnormal on the repeat lateral radiograph, CT is indicated.

In older children who are alert, communicative, and of normal mentation, the radiographic examination should include the open-mouth and contact lateral views. The open-mouth view, although it does not typically include the occipital condyles and is of little value with respect to the diagnosis of occipitoatlantal subluxation, acute rupture of the transverse atlantal ligament, or traumatic spondylolisthesis, provides valuable information relative to other injuries of the cervicocranium. Therefore, continued use of the open-mouth view is justified. When the contact lateral radiograph shows that both the cervicocranial skeleton and the cervicocranial prevertebral soft-tissue contour are normal, it, coupled with the normal open-mouth view,

is sufficient to allow the cervicocranium to be declared radiographically normal. Conversely, should the cervicocranial prevertebral soft-tissue contour be abnormal even in the presence of a normal cervicocranial skeleton, cervicocranial CT is indicated to search for occipital condylar, lateral mass of C1, or other cervicocranial fractures that, for whatever reason, are not visible on the radiographs (Figs 30–32).

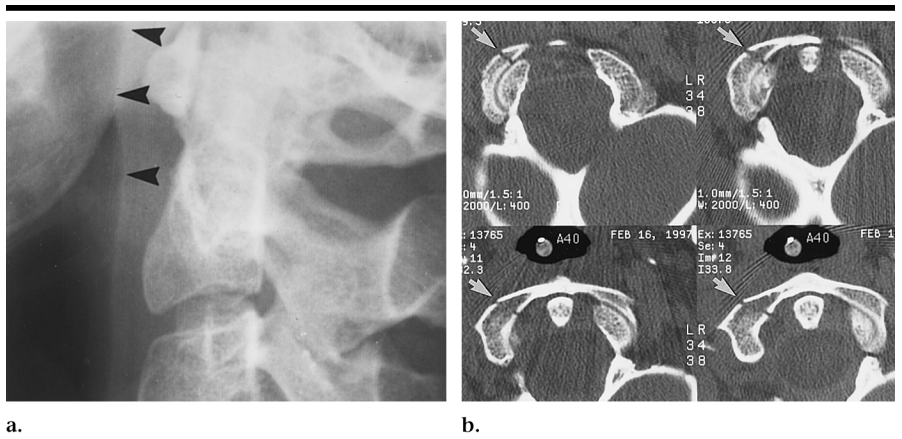
Prior naso- or orogastric intubation is not a contraindication to the acquisition of a contact lateral radiograph of the cervicocranium, because the majority of cervicocranial injuries will be visible and the tube does not necessarily preclude visualization of the cervicocranial prevertebral soft-tissue contour (Fig 13).

The presence of an endotracheal tube precludes delineation of the cervicocranial prevertebral soft tissues because there will be little or no air in the pharynx. The indication for contact lateral radiography in the presence of an endotracheal tube is to record those cervicocranial injuries visible on conventional radiographs. CT of the cervicocranium is necessary in this circumstance as the definitive study of the cervicocranium after endotracheal intubation. An open-mouth view is not attempted with an endotracheal tube in place.

The cervicocranial prevertebral soft-tissue concavity caudal to the anterior tubercle of C1 may be very shallow, difficult to perceive, and even more difficult to be persuasive for attending physicians. In this instance, simply connecting the soft-tissue shadow anterior to the atlantal tubercle to the soft-tissue shadow covering the anterior-most cortex of the axis body, either by using the edge of an adjacent image or by drawing a line (Fig 37), will help establish the presence of the concavity.

Respected radiologic investigators of acute cervical spine trauma have not discussed (14–17), questioned (18), or related (19,20) the cervicocranial prevertebral soft-tissue shadow to cervicocranial acute injury. However, a comparison of the prevalence of subtle cervicocranial injuries discovered at CT as the result of an abnormal cervicocranial prevertebral soft-tissue contour with the reported prevalence of all cervicocranial spine injuries (Table) seems to justify the approach described in this article.

The approximately 16% true-positive rate is obviously associated with an 84% false-positive (Fig 38) rate in the context of an abnormal cervicocranial prevertebral soft-tissue contour. How-



**Figure 39.** False-negative cervicocranial prevertebral soft-tissue contour. **(a)** Lateral radiograph shows a normal cervicocranial prevertebral soft-tissue contour (arrowheads). **(b)** However, transverse CT images obtained because of severe cervicocranial pain and painful limitation of motion demonstrate a minimally displaced fracture of the right anterior arch of C1 (arrows).

ever, the 16% true-positive rate is four times greater than the rate of acute cervical spine injuries reported for all trauma patients admitted to emergency centers and is approximately three times greater than that reported in patients with multiple trauma (28). The false-negative rate in our experience is less than 1% (Fig 39).

## SUMMARY

The cervicocranium can be declared radiographically normal when the cervicocranial prevertebral soft-tissue contour is normal and the cervicocranial skeleton is normally aligned and intact. An abnormal cervicocranial prevertebral soft-tissue contour in a patient suspected of having a cervical spine injury is an indication that CT of the cervicocranium is required, even if the cervicocranial skeleton appears radiographically normal.

Assessment of the cervicocranial prevertebral soft-tissue shadow requires adequate distention of the pharynx, which can be attained by timing the radiographic exposure to coincide with inspiration or by using the trumpet view. Prior transnasal or transoral endotracheal intubation necessitates cervicocranial CT for proper evaluation of the cervicocranium.

Radiographic evaluation of the cervicocranium requires close collaboration between the radiologic technologist, to obtain the appropriate study; the radiologist, who must be familiar with the normal and abnormal appearance of the cervicocranial prevertebral soft-tissue contour; and the attending physician, who must be comfortable with a false-positive

rate of approximately 80% and who understands that clinical-radiologic discordance necessitates additional imaging.

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