

## Vertebral Bodies and Neural Arches

In the newborn and young infant the vertebral bodies, although basically rectangular, often appear more oval because they have rounded corners, especially anteriorly (Fig. 2.1a). Thereafter the vertebral bodies become more cuboid-rectangular (Fig. 2.1b), but in some individuals can appear exceptionally flat (Fig. 2.1c). The latter configuration is not to be misinterpreted as being representative of platyspondyly, as seen with bony dysplasias, for it merely reflects the wide spectrum of the normal appearance of the vertebral bodies.

In the normal individual the neural arch of C2 usually is the largest such structure in the upper cervical spine. This is helpful when one is assessing radiographs for the presence of occipitalization. With occipitalization, C1 is fused to the base of the skull and yields to C2 as being the uppermost visualized posterior arch. Ordinarily it would be the second arch to be visualized. The posterior arch of C1 is smaller than the posterior arch of C2 and thus, when this arrangement is altered, and the uppermost visualized neural arch is the largest one present, one should suspect occipitalization.

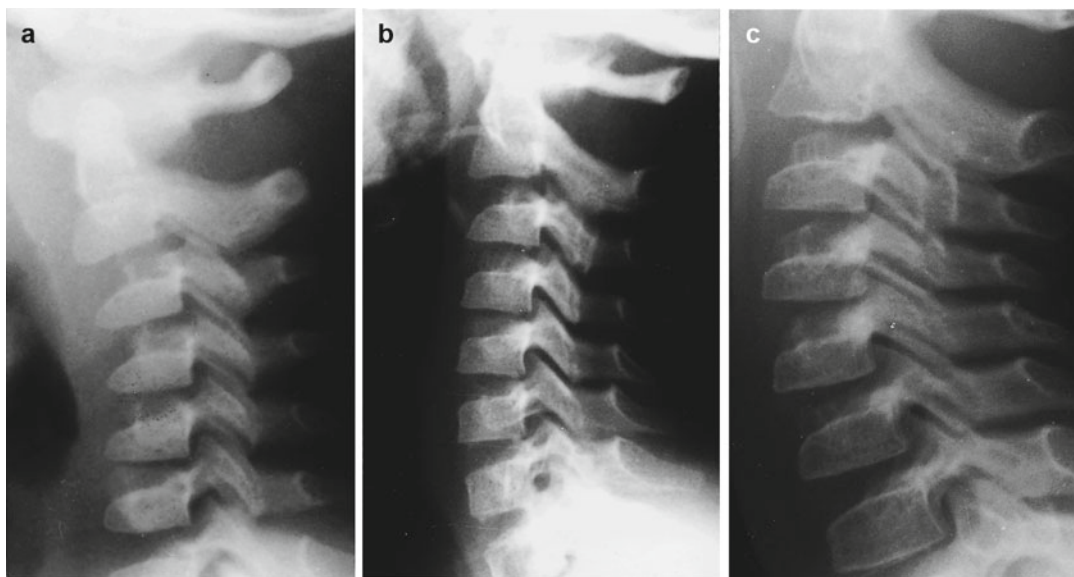
In addition to the preceding considerations, the neural arches and spinous processes of the cervical vertebrae can show even more variation in configuration. In this regard, some may be hypoplastic, and in addition, while normal spinous processes tend to point downward, occasionally

they point upward. Because of this they may erroneously suggest that a pathologic increase in the interspinous distance is present (Fig. 2.2).

Finally, because of the complicated embryonic development of the cervico-occipital junction, aberrant bony ossicles frequently are encountered in the upper cervical spine and at the base of the skull. Most of these occur anteriorly, but they also can be seen posteriorly, and at either site usually are round or oval. Such ossicles have smooth edges and should not be misinterpreted for avulsion fractures (Fig. 2.3).

## Normal Cervical Spine Motion Causing Pseudoabnormalities

In most individuals, flexion or extension of the cervical spine results in little excess motion. However, in other instances, and especially in infants and young children, since the ligaments are lax, normal physiologic hypermobility is more common and leads to spinal configurations that frequently are confused with pathologic states [1]. In addition, it is important to appreciate that the apex of the flexed cervical spine curve in infants and young children is located at a different level from that in older children and adults [2]. In infants and young children it is located in the upper cervical spine at approximately the level of C2–C3 (Fig. 2.4a), while in older children and adults it is located in the midcervical spine, that is, somewhere between C4 and C6 (Fig. 2.4b). This explains why cervical spine



**Fig. 2.1** Variable appearance of normal vertebral bodies. (a) In infancy the vertebral bodies appear more oval. (b) Typical appearance of rectangular-cuboid vertebral bodies in older children and adolescents. Note that there is

some residual rounding of the upper anterior corner of C3. (c) In some patients, still normal, the vertebral bodies appear exceptionally flat

injuries, primarily flexion induced, are more common in the upper cervical spine in infants and young children, and more common at the C4–C6 level in older children, adolescents, and adults. This also is probably why degenerative changes in adults occur primarily at the C4–C6 level. In addition, when considered with the overall increased mobility of the infant's and young child's spine, it is more readily understood why so many normal hypermobility phenomena occur in the upper cervical spine in this age group.

### High Anterior Arch of C1

This finding is common in young infants during hyperextension of the cervical spine [1]. The resultant configuration is that of a very high,

indeed dislocated appearing, anterior arch of C1 (Fig. 2.5). The finding, to the uninitiated can be quite alarming but, is entirely normal.

### Exaggerated C1–C2 Interspinous Distance

Similar to hypermobility of the anterior arch of C1, hypermobility of C1 with flexion can result in an exaggerated intraspinous distance between C1 and C2 [1]. However, as opposed to the high anterior arch of C1 phenomenon, this configuration also can be seen in older children. Indeed, distances of up to 10 or even 12 mm can be encountered and still be normal (Fig. 2.6). In these cases, however, the C1–dens distance (predental distance) is normal.



**Fig. 2.2** Anomalous spinous tip configurations. Note the upward, pointing spinous tip of C4 (*upper cross symbol*). The spinous tip of C5 (X) points downward, as is more usual. However, one could misinterpret the combined findings as being representative of a flexion injury of the cervical spine, causing an increased intraspinous distance between C4 and C5

### C1-to-Dens (Predental Distance)

It is well known that the predental distance in infants and young children can be wider than in adults. Indeed, up to 5 % of normal individuals can demonstrate a predental distance of 5 mm, but most often the distance is somewhere between 2 and 3 mm on initial, neutral cervical spine studies [3, 4]. In any of these cases, if there is no increase in the predental distance on flexion, the

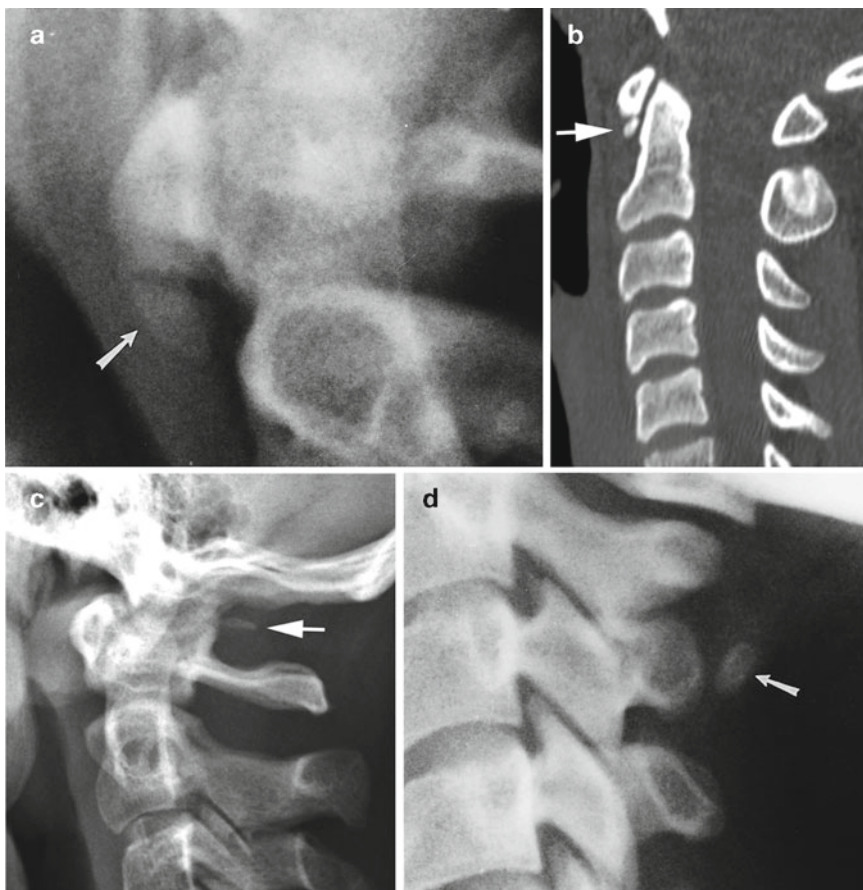
finding can be considered normal (Fig. 2.7). However, it also should be recalled that with flexion there can be a normal increase in the distance of up to 2 mm (Fig. 2.8). If there is more widening than this, one should suspect underlying instability of the ligaments, either on a traumatic or congenital basis. The latter problem is associated with anomalies of the dens, primarily dens hypoplasia and an associated os odontoides.

### Posterior Dislocation of Vertebral Bodies

Physiologic posterior dislocation of the vertebral bodies occurs less frequently than anterior dislocation. It tends to occur over the midcervical spine, and maximum normal sliding should be no more than 2 mm [5]. The displacement can occur at one or multiple levels (Fig. 2.9).

### Anterior Angulation of C2 on C3

With spasm, or rigid positioning on an “EMS transporting backboard,” a patient’s head can be cocked forward so that angulation of C2 on C3 results [1]. In such cases there is no actual anterior displacement of C2 on C3, but the severe degree of angulation encountered can erroneously suggest that the ligaments between C2 and C3 have been disrupted and that dislocation is present (Fig. 2.10a). In these cases I have found it helpful to draw a line along the posterior aspect of C2 and the dens and note whether it intersects or just touches the upper posterior corner of C3. If it does, no dislocation is present (Fig. 2.10b). *In such cases the posterior cervical line [6] should not be applied, for it will lead to erroneous conclusions.* The line was designed to be used only if anterior displacement of the body of C2 on C3 was present (see next section).



**Fig. 2.3** Extra ossicles. (a) Note the extra ossicle (*arrow*) located below the anterior arch of C1. (b) In this patient, a small extra ossicle is seen along the inferior aspect of the anterior arch of C1 (*arrow*). (c) This patient demonstrates an extra ossicle in the posterior upper cervical region

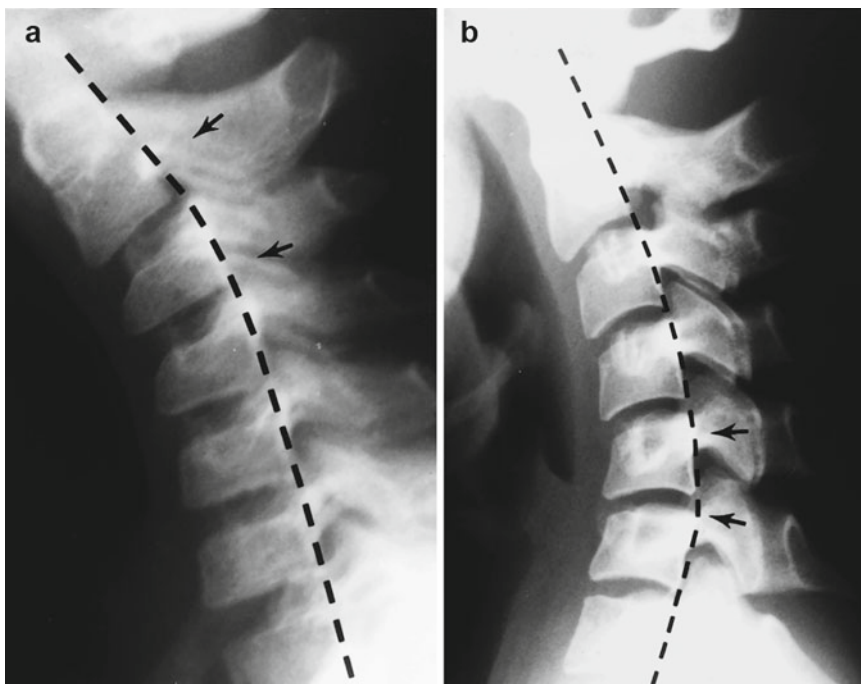
(*arrow*). (d) Note the extra posterior ossicle (*arrow*) at the C3 level. Also note that the neural arch of C3 is slightly deformed and hypoplastic (i.e., smaller than the other neural arches)

### Anterior Dislocation of C2 on C3

Anterior dislocation of C2 on C3 can occur with a hangman's fracture, but in infants and children it is far more common on a normal, physiologic basis [6, 7]. The degree of displacement is usually no more than 2 mm, but to the uninitiated a traumatic dislocation often is at first suggested (Fig. 2.11). In these cases I have found it helpful to apply a line, the posterior cervical line [6], to the anterior cortices of the spinous tips of C1 and C3, and then note

whether it intersects, touches, or comes close to the anterior cortex of the spinous tip of C2 (Fig. 2.12). If the line misses the anterior cortex of C2 by more than 1.5 mm, a hangman's fracture should be suspected. Otherwise, the finding should be considered physiologic (Fig. 2.13).

*It is important to use the anterior cervical line only when there is anterior dislocation of C2 on C3, be it traumatic or physiologic. It has no value otherwise and will be misleading. In addition, it appears erroneously normal when there is*



**Fig. 2.4** Normal apex of flexion curve. (a) In infancy and young childhood, the apex of the flexion curve is at the C2–C3 level (*arrows*) (From Swischuk et al. [2]). (b) In

older children and adolescents, the flexion curve migrates downward to a level somewhere between C4 and C6 (*arrows*)

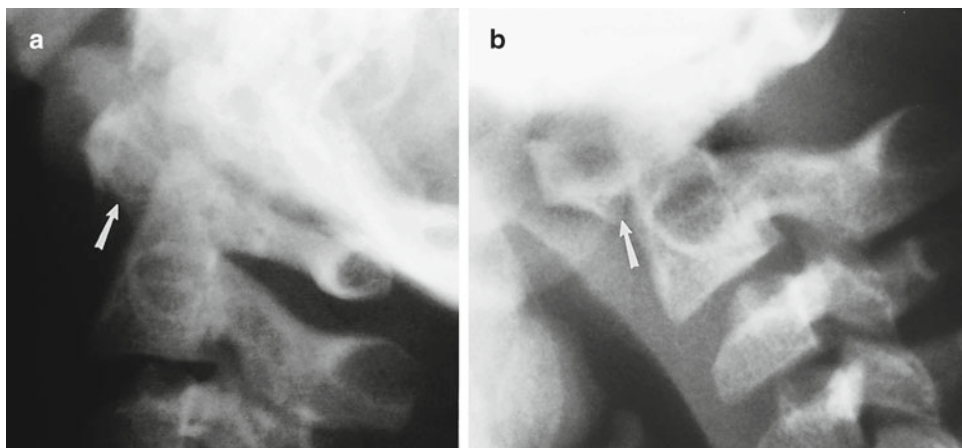


**Fig. 2.5** High anterior arch of C1. With hyperextension, the normal anterior arch of C1 (*arrow*) can assume a very high location. Indeed, it may appear that the cervico-occipital junction has been disrupted



**Fig. 2.6** Increased C1–C2 interspinous distance. Note the exaggerated, but normal distance (*arrowhead to arrowhead*) between the spinous tips of C1 and C2. Note that the predental distance is normal





**Fig. 2.7** Normal wide C1-to-dens distance. (a) Note the prominent C1-to-dens distance (arrow). The measurement was 5 mm. (b) On flexion, however, there is no increase in the distance (arrow). This patient was

normal (Reproduced with permission from LE Swischuk, *Emergency Imaging of the Acutely Ill or Injured Child*, 4th ed. Lippincott Williams & Wilkins, Baltimore, 2000)

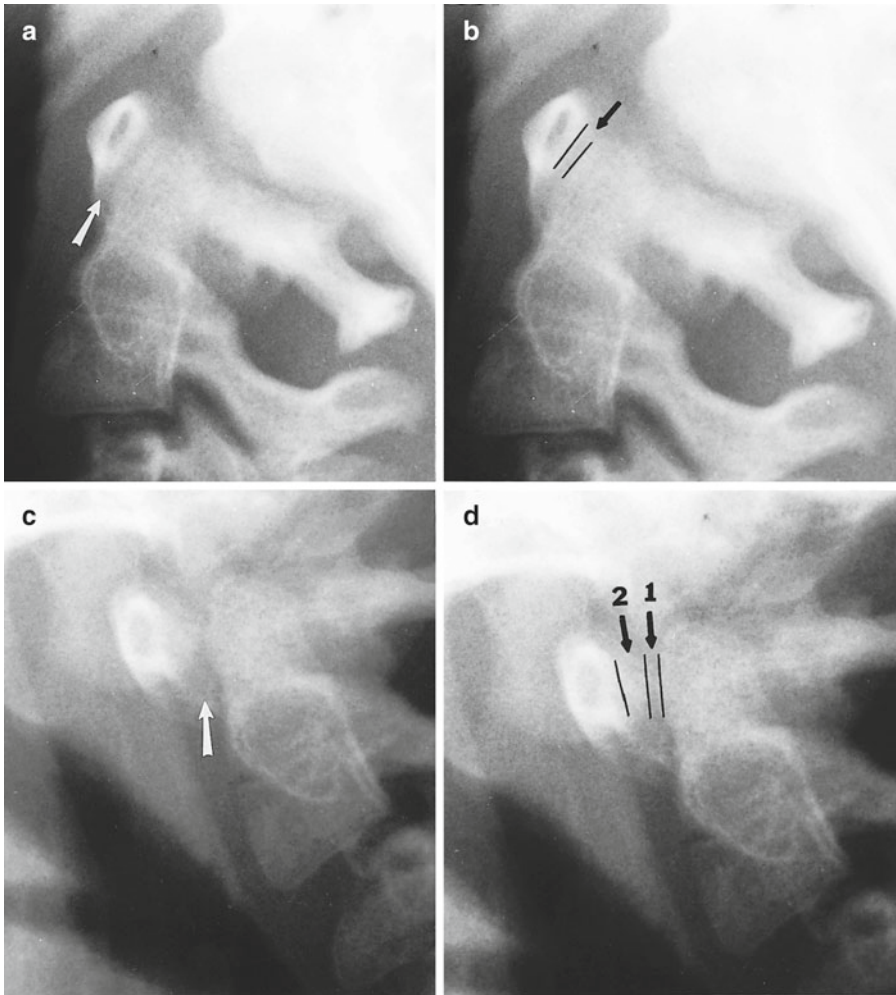
*disruption of the C2–C3 apophyseal joint and ligaments without any associated fracture* (i.e., no hangman's fracture). In such cases, however, the apophyseal joint appears V-shaped and abnormal while with physiologic dislocation, the apophyseal joint retains its normal, parallel facet orientation (Fig. 2.11). In addition at least 50 % of the inferior facet is covered by the superior facet.

Normal, anterior pseudodislocation also can occur at the C3–C4 level and every so often at the C4–C5 level (Fig. 2.14). When such subluxation is present at all these levels, there is no problem in identifying the configuration as normal or physiologic. It is problematic only when it occurs in isolated form, at the C2–C3 level. Once a patient reaches adolescence and young adulthood, physiologic anterior displacement of C2 on C3 tends to disappear. However, it has been documented in some young adults [8].

### Wedging of C3 and C4

Anterior wedging of vertebral bodies is the hallmark of a compression fracture secondary to a hyperflexion injury. However, in the upper

cervical spine of infants and young children, it is seen much more often as a normal finding [2]. In these cases physiologic hypermobility and resultant angulation of C2 on C3 lead to growth impairment of anterior upper plate of C3, producing a chronically wedged vertebra (Fig. 2.15). The same phenomenon occurs, but less frequently, at the C4, or even C5 level (Fig. 2.16). In all these cases, wedging tends to involve the superior, more than the inferior, vertebral plate, and most often it is seen as an incidental finding (Fig. 2.17). However, when such wedging is seen in a patient with trauma, it becomes necessary to determine whether it represents an acute fracture or a chronic, physiologic deformity (Fig. 2.18). This can be rapidly resolved with CT scanning: if a fracture is present, it will be apparent on the axial views. If physiologic wedging only is the problem, no fracture is seen (Fig. 2.18). In addition, on plain films the wedged vertebra has a smooth cortex and there is no suggestion of compression fracturing. The fact that such wedging is secondary to chronic compression is attested to in cases where chronic hyperflexion, due to hypotonia, can lead to the deformity (Fig. 2.19).



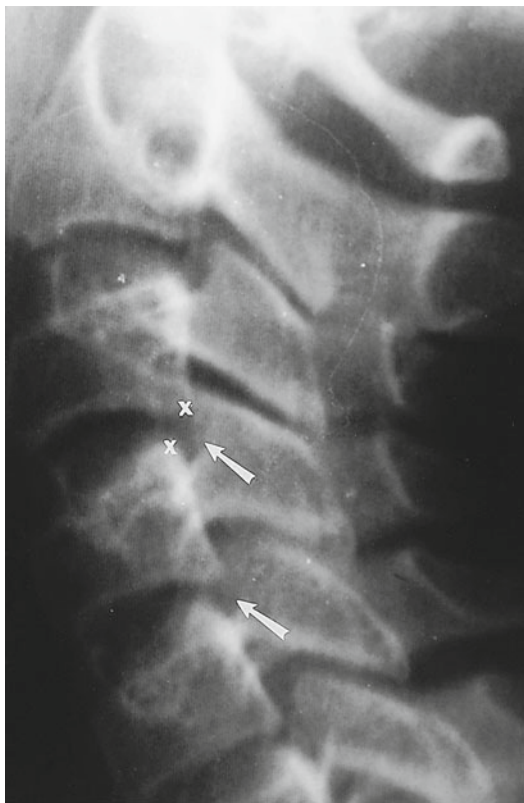
**Fig. 2.8** C1-to-dens distance, maximum normal increase. (a) On extension, the C1-to-dens distance is normal. (b) The distance measures approximately 1–1.5 mm (*lines*). (c) On flexion, however, the predental distance increases (*arrow*). (d) Lines delineate the previous predental

distance (1) and the new predental distance with flexion (2). Overall, the increase in distance with flexion is no more than 2 mm. Also note that the predental distance normally is slightly wider superiorly

Physiologic wedging gradually disappears as the individual gets older and the apex of the flexed cervical spine shifts downward to the midcervical level. As this happens, the chronic compressive forces on C3, and C4, are removed and the vertebrae are allowed to grow back to their original configuration. This probably is why the deformity is not seen in older children, adolescents, or adults.

### Normal Apophyseal Joints: Older Child

Because the flexion curve in older children and adolescents is in the lower cervical spine, some patients demonstrate slight hypermobility through the apophyseal joints in this area (Fig. 2.20). As a result joints may appear slightly V-shaped, but on flexion there will be



**Fig. 2.9** Normal posterior displacement of vertebral bodies (cross symbols). Note posterior displacement of C3 on C4 (upper arrow) and less, but still present, posterior displacement of C4 on C5 (lower arrow). This patient was normal

no excessive motion. This configuration is acceptable as a normal variation in older children and adolescents (Fig. 2.20).

### Prevertebral Soft Tissues

The prevertebral soft tissues are notoriously difficult to evaluate in infants and young children. Mostly this is because of buckling of the airway on expiration and poor (neck is flexed) positioning (Fig. 2.21). To properly evaluate the prevertebral soft tissues, the study should be

obtained on inspiration and with the neck extended or at least straight (Fig. 2.22). *The importance of this particular aspect of evaluation of the prevertebral soft tissues cannot be overstated, for if the study is improperly obtained, the initial impression will be that of pathologic prevertebral soft tissue thickening.*

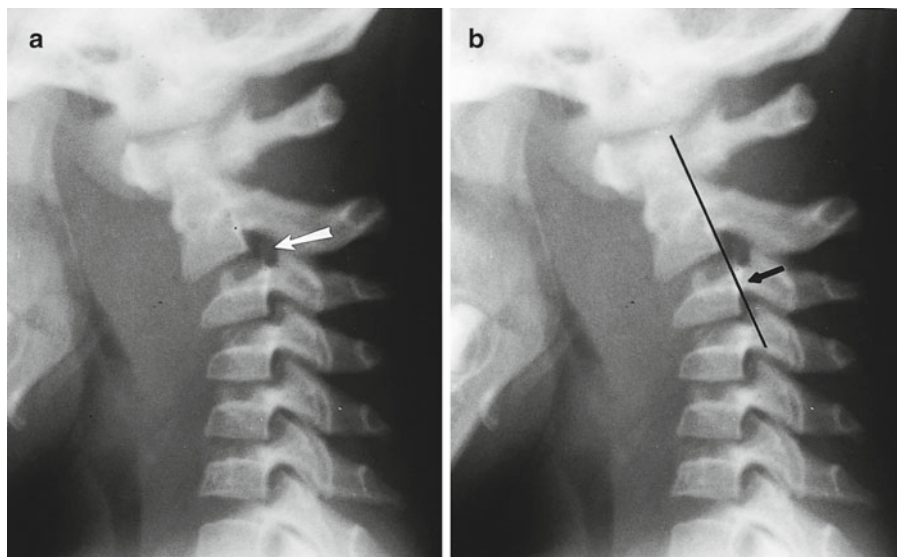
Normal measurements are available, but I have found it more useful to determine whether the posterior pharyngeal wall is located posterior to the posterior tracheal wall. This results in a stepoff of the air column at this level (Figs. 2.22b, c). If this stepoff is present, the prevertebral soft tissues likely are normal [1]. If, on the other hand, the posterior pharyngeal wall, as outlined by air, is in a continuous straight, or curving lineup with the posterior tracheal wall, pathologic prevertebral soft tissue thickening should be suspected (Fig. 2.23). Such thickening can be secondary to trauma (hematoma), abscess, lymph node enlargement, a variety of tumors, myxedematous thickening in cretinism [9], and edema secondary to the superior vena cava syndrome [10]. In addition it might be noted that the normally prominent prevertebral tissues just anterior to C1 and C2 now can be clearly demonstrated with magnetic resonance (MR) techniques and even can be seen in older children (Fig. 2.24).

Finally over the years I have come to the conclusion that one should not spend too much time on the prevertebral soft tissues. If they tell you something immediately then use them, if they do not, go on to something else.

### Ring Epiphysis

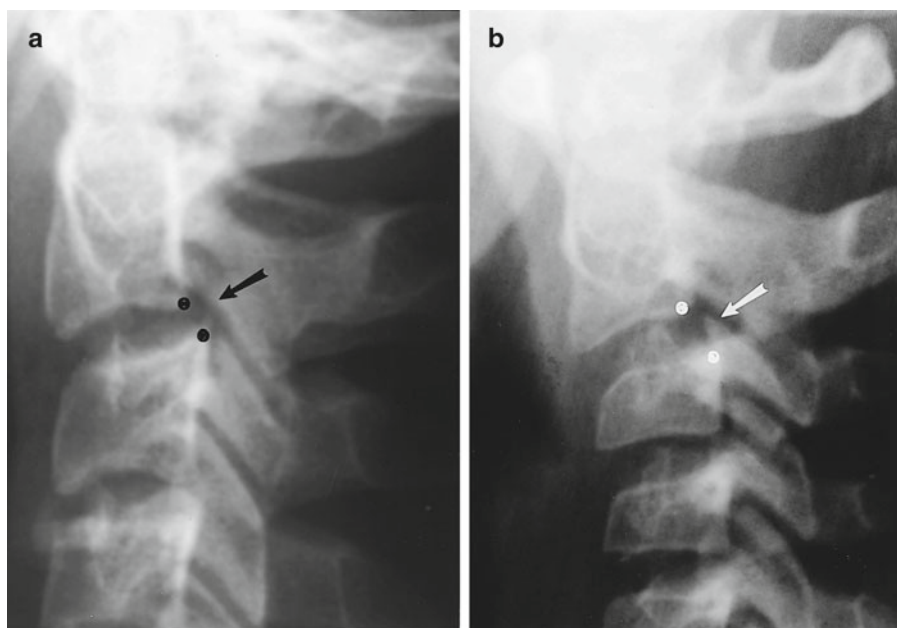
All vertebral bodies have ring epiphyses over their superior and inferior plates. On lateral view these epiphyses appear as triangular or sliver-like bony fragments (Fig. 2.25a). They should not be confused with corner avulsion fractures. However, it should be noted that the ring epiphysis can be avulsed in children and present as a form of the teardrop fracture [11].



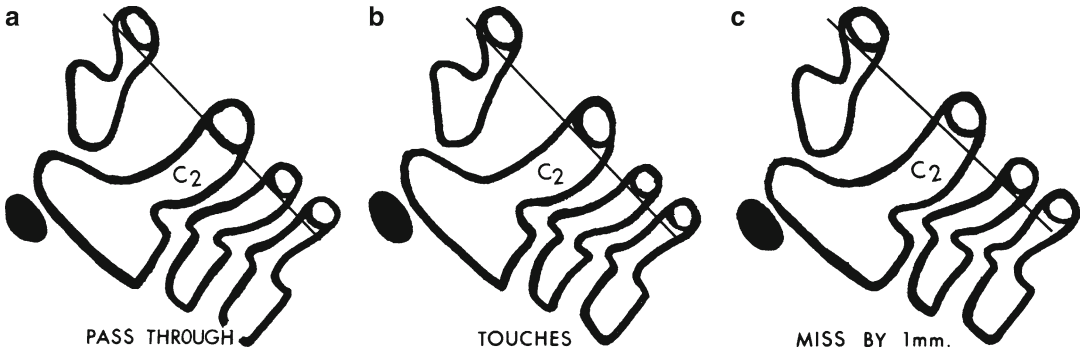


**Fig. 2.10** Anterior angulation of C2 on C3. (a) Note that C2 is angled forward on C3 (*arrow*). (b) However, the line drawn along the posterior aspect of C2 does not intersect C3, but just touches the upper posterior corner of C3 (*arrow*). Therefore, there is no anterior dislocation.

However, the prominent, but normal, C1-to-dens distance, generous C1–C2 interspinous distance, along with thickening of the soft tissues, due to improper technique, could lead one to erroneously diagnose a severe hyperflexion injury of the upper cervical spine

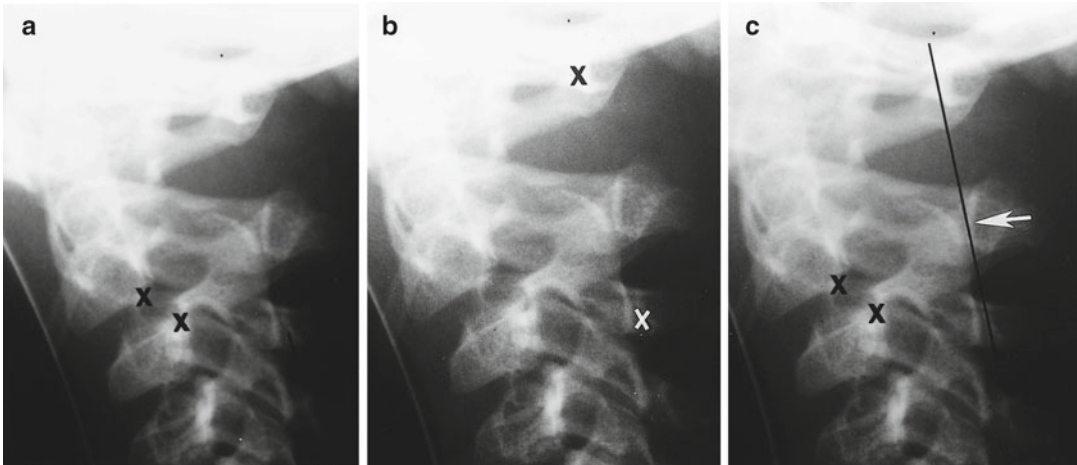


**Fig. 2.11** Physiologic anterior subluxation of C2 on C3. (a) Note that C2 is anteriorly displaced on C3 (*dots* and *arrow*). (b) Another patient with similar findings (*dots* and *arrow*). Note that the apophyseal joint facets are parallel



**Fig. 2.12** Posterior cervical line: normal limits. (a) The posterior cervical line touches the anterior cortex of C2. (b) The line passes through the anterior cortex of the

spinous tip of C2. (c) The posterior cervical line misses the anterior cortex of C2 by only 1 mm (From Cattell and Filtzer [7])



**Fig. 2.13** Physiologic subluxation C2–C3 posterior cervical line. (a) There is marked anterior displacement of C2 on C3 (cross symbols). (b) Cross symbols delineate the locations of the cortices of C1 and C3 for drawing of the

posterior cervical line. (c) The arrow points to the posterior cervical line drawn from the anterior cortex of C1 to the anterior cortex of C3 which passes through the anterior cortex of C2. It is normal

### Transverse Process Projection Over Disk Spaces

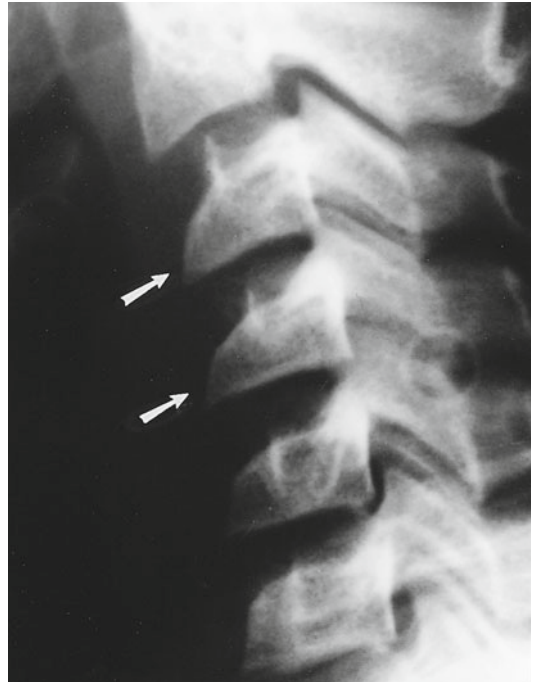
The transverse processes of the vertebrae can be projected, with slight obliquity, so that they are viewed over the disk spaces (Fig. 2.25b). This finding should not be misinterpreted for an avulsion or compression fracture of a vertebral body.

### Pseudowidening of the Spinal Canal

In infants, it is very common for the spinal canal, on anteroposterior (AP) view, to appear to be pathologically widened (Fig. 2.25c). This phenomenon can be exaggerated with slight obliquity of the spine (Fig. 2.25d), but it is entirely normal and is not a problem on lateral views of the cervical spine.



**Fig. 2.14** Multiple physiologic anterior subluxations. Note that C3 is anteriorly displaced on C4 (*upper arrow*) and that C4 is anteriorly displaced on C5 (*lower arrow*)



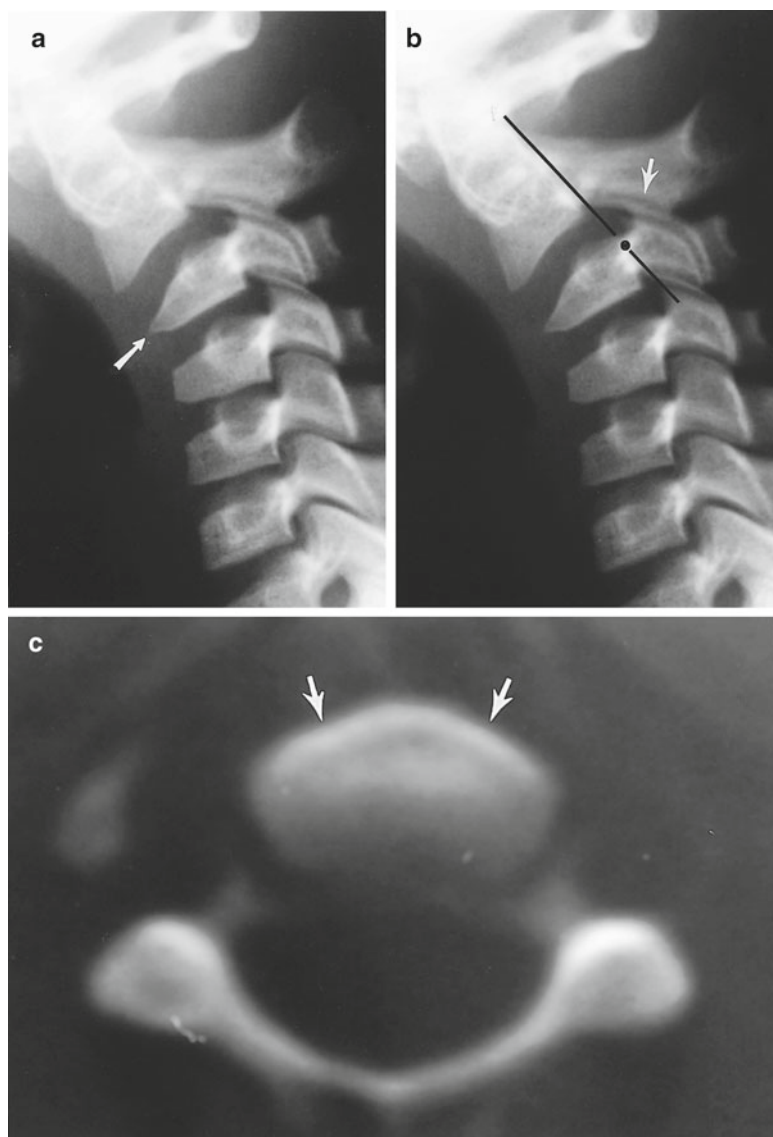
**Fig. 2.16** Normal wedged vertebra: multiple levels. Note anterior wedging of both C3 and C4 (*arrows*)



**Fig. 2.15** Normal anterior wedging of C3. Note the wedged appearance (*arrow*) of C3. Also note that the deformity involves the superior plate more than the inferior plate. The prevertebral soft tissues are somewhat prominent in this patient, but the patient was normal



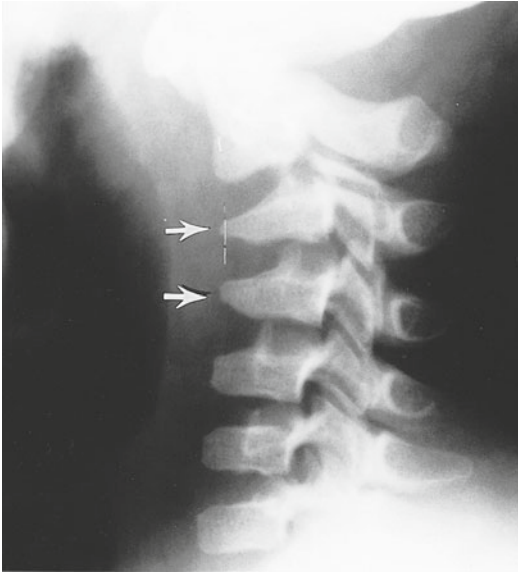
**Fig. 2.17** Wedging of C3: incidental finding. Note the wedged appearance of C3 (*arrow*). Again note that the superior plate is almost exclusively involved in producing the wedging configuration. This patient had no cervical spine trauma



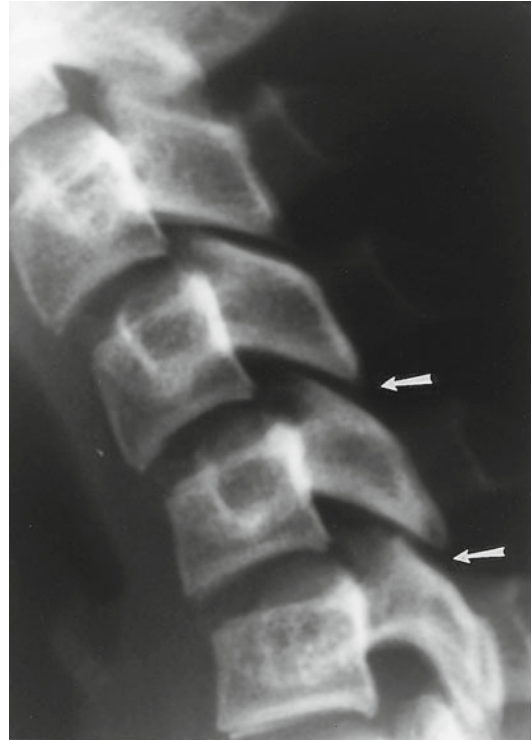
**Fig. 2.18** Anterior wedging of C3 with pseudodislocation appearance of spine. (a) Note the pronounced wedging of C3 (arrow). Dislocation at the C2–C3 level might be suggested. (b) However, a line drawn down the posterior aspect of C2 merely intersects the upper posterior corner (dot) of C3. There is no dislocation, only severe, but normal, anterior angulation of C2 on C3. Note that the

apophyseal joint (arrow) is normal in that the facets are parallel. The appearance of 50 % coverage of the facet is normal. (c) CT study demonstrates no fracture of the body of C3 (arrows) ((a, c) Reproduced with permission from LE Swischuk, *Emergency Radiology of the Acutely Ill or Injured Child*, 4th ed. Lippincott Williams & Wilkins, Baltimore, 2000)





**Fig. 2.19** Chronic wedging, no trauma. Note severe wedging of multiple vertebrae in this patient with chronic hypotonia (*arrows*)



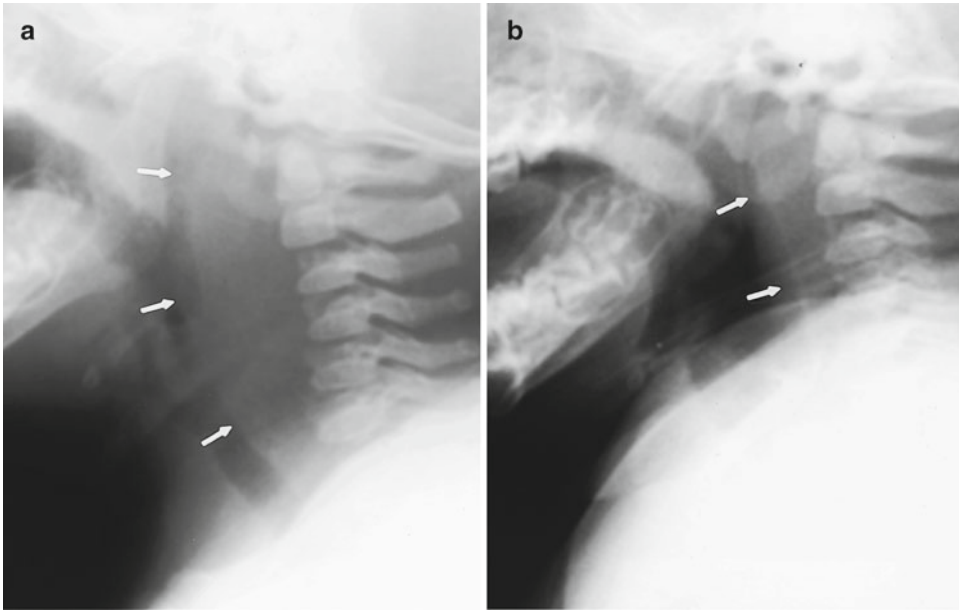
**Fig. 2.20** Lower cervical apophyseal joints. Note the slight V-shaped configuration of at least two of the lower cervical apophyseal joints (*arrows*). There was no excessive motion at these sites, and this degree of V-shaped configuration can be considered physiologic and normal in older children and adolescents

### Positioning Pseudofractures of the Upper Cervical Spine

With obliquity and slight rotation, the posterior arches of C1–C3 can appear to be fractured or offset and overall, alarmingly abnormal (Fig. 2.26a–c). In addition, with slight lateral tilting of the head and neck, the cortices of the posterior arch of C2 can become offset, erroneously suggesting an avulsion fracture (Fig. 2.26d).

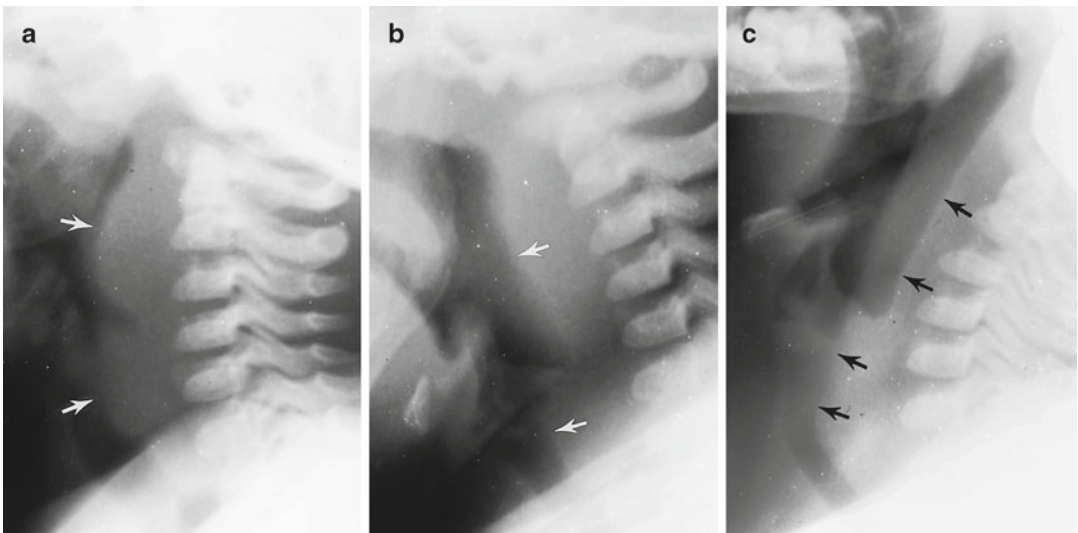
### Bilateral Offset Lateral Masses of C1 (Increase in Dens–Lateral Mass Distance)

Laterally offset masses of C1 on C2 are characteristic of Jefferson compression fractures of C1. However, under the age of 2 years, because of a differential growth factor, the lateral masses of C1 can normally appear to be offset [12]. This is important to appreciate, for the finding can be misinterpreted for traumatic lateral displacement of the lateral masses (Fig. 2.27).



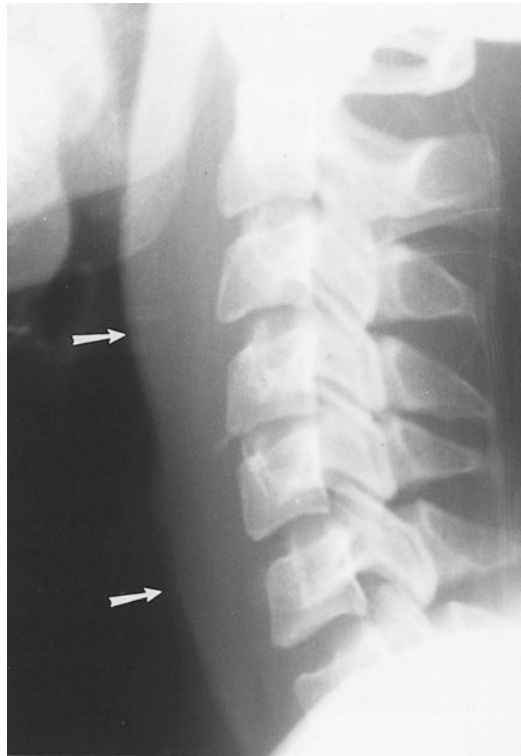
**Fig. 2.21** Pseudoprominent prevertebral soft tissues. (a) In this patient the prevertebral soft tissues appear alarmingly wide. Indeed, the posterior wall of the pharynx and trachea almost forms a continuous arc (*arrows*). (b) With

deep inspiration, however, the hypopharynx distends with air and the posterior pharyngeal wall now is in its normal posterior location. The slight remaining degree of prevertebral soft tissue prominence is normal in infancy



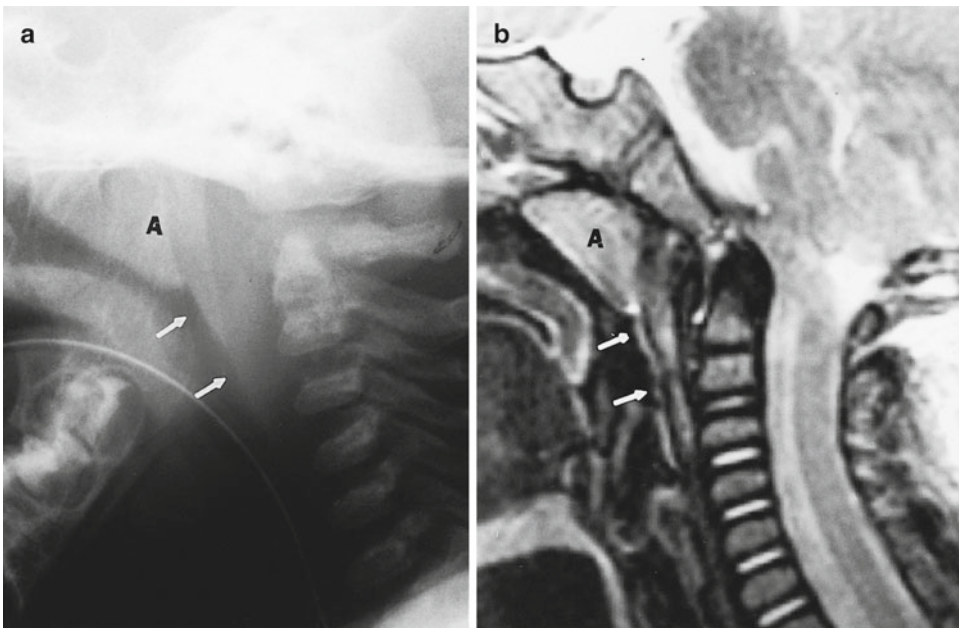
**Fig. 2.22** Pseudoprevertebral soft tissue thickening: various phases. (a) Note the bilobed appearance of the apparently thickened prevertebral soft tissues (*arrows*). (b) With slightly deeper inspiration, the posterior wall of the hypopharynx (*upper arrow*) is more clearly

delineated. It is located posterior to the air column of the trachea (*lower arrow*). (c) With full inspiration, the normal stepoff (*arrows*) between the posterior hypopharyngeal wall and posterior tracheal wall is clearly apparent



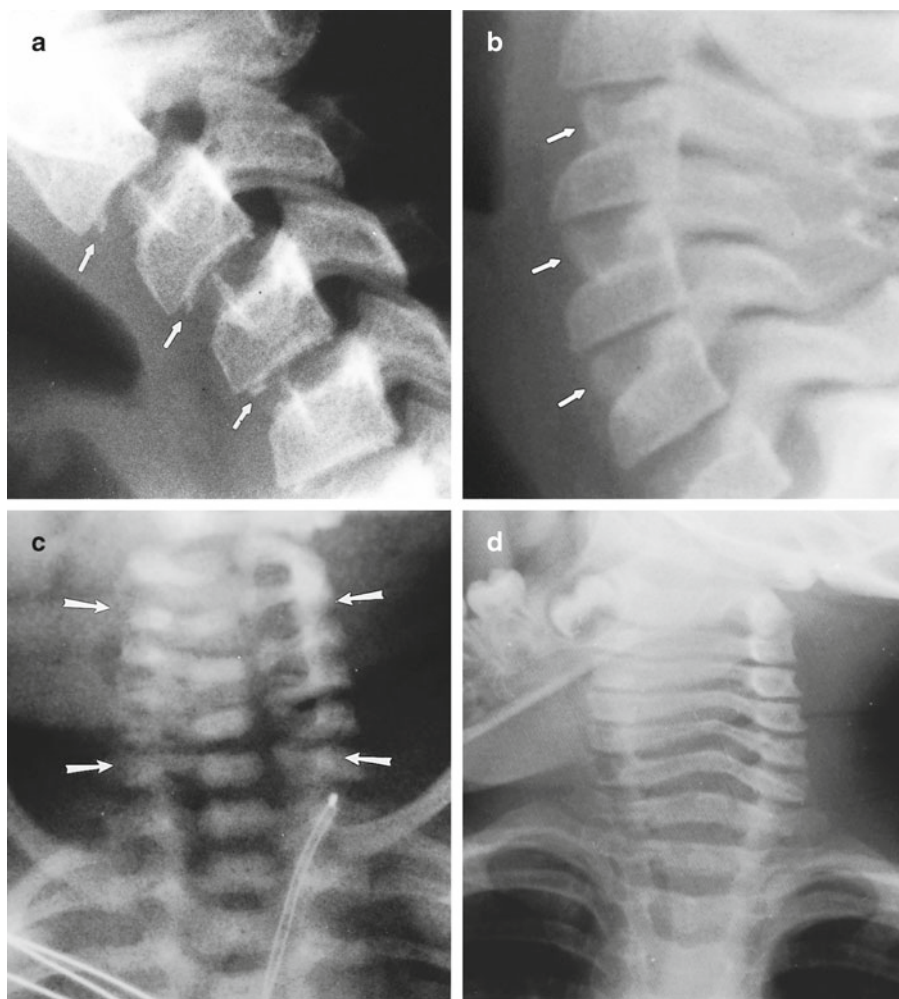
**Fig. 2.23** Pathologic prevertebral soft tissue thickening. Note the continuous arc formed by the posterior wall of the hypopharynx (*upper arrow*) and the posterior wall of the upper trachea (*lower arrow*). There is a small teardrop

fracture involving C5. The disk space between C4 and C5 also is narrowed. All these findings indicate the presence of an underlying flexion injury at this level



**Fig. 2.24** Prominent adenoids and prevertebral soft tissues. (a) The adenoids (A) are prominent and the upper prevertebral soft tissues appear alarmingly wide (*arrow*).

(b) Magnetic resonance imaging demonstrated the prominent adenoids (A) and prevertebral soft tissues (*arrows*). This patient had no trauma



**Fig. 2.25** (a) Normal “ring” epiphysis. Note the bony fragment-like appearance (*arrows*) of the normal ring epiphysis. (b) Normal transverse processes. With slight rotation, the transverse processes (*arrows*), can be projected

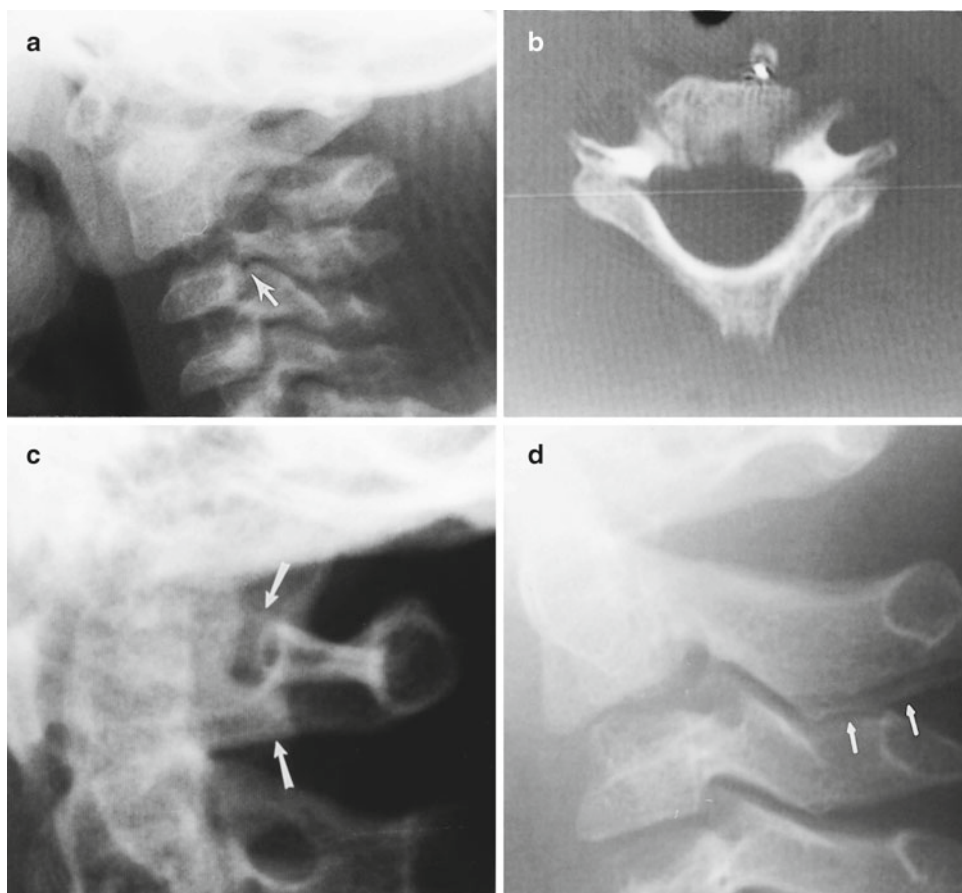
through the disk spaces. (c) Pseudowidening of the cervical spinal canal (*arrows*). Note the wide appearance of the spinal canal. (d) Rotation leads to exaggerated pseudowidening of the cervical spinal canal

### Unilateral Offset Lateral Mass of C1 (Increased Unilateral Dens–Lateral Mass Distance)

Most often unilateral offsetting of the lateral mass of C1 is secondary to rotation. *In these cases the lateral mass–dens distance is increased on one side, but on the contralateral side the distance is*

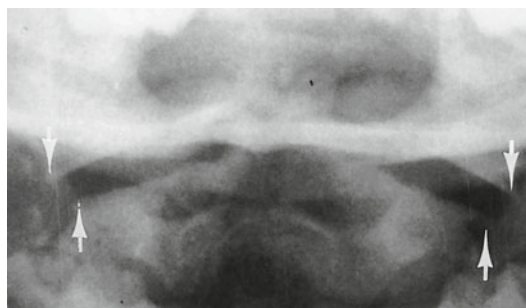
*narrower than normal* (Fig. 2.28). Such normal rotation-induced discrepancies in the distance from dens to lateral mass now are commonly seen on CT studies [13]. Finally, it should be noted that in children, hypermobility of the upper cervical spine can lead to significant lateral displacement of the lateral masses of C1 and yet no underlying abnormality is present (Fig. 2.29).





**Fig. 2.26** Pseudofractures. (a) With rotation, the posterior arch of C3 appears to be separated and dislocated from the body of C3 (arrow). (b) CT study demonstrates that no fractures are present. (c) In this patient, with rotation,

unilateral posterior C1 arch fracture–dislocation is erroneously suggested (arrow). (d) Slight rotation produces offsetting of the posterior limbs of the neural arch of C2, leading to an avulsion fracture-like appearance (arrows)



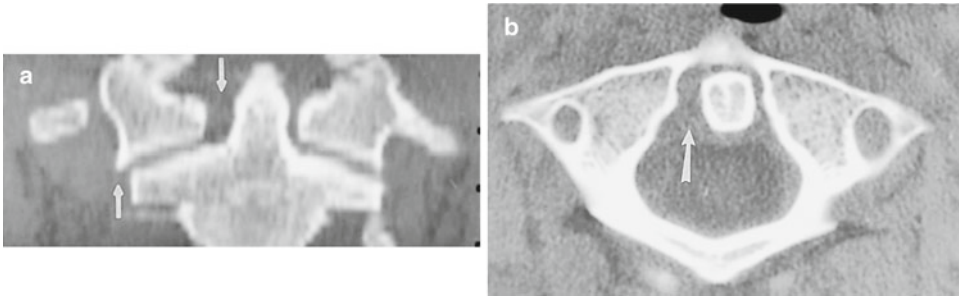
**Fig. 2.27** Pseudo-offsetting; lateral masses of C1 in infancy. Note apparent bilateral offsetting of the lateral masses of C1 on C2 (arrows). In infancy, this pseudo-Jefferson fracture appearance is normal (Reproduced with permission from LE Swischuk, *Emergency Radiology of the Acutely Ill or Injured Child*, 4th ed. Lippincott Williams & Wilkins, Baltimore, 2000)

## Central Veins

The central veins of the vertebral bodies often can be misinterpreted for fractures. This is important to appreciate, especially in the absence of other evidence of trauma to the vertebral body (Fig. 2.30).

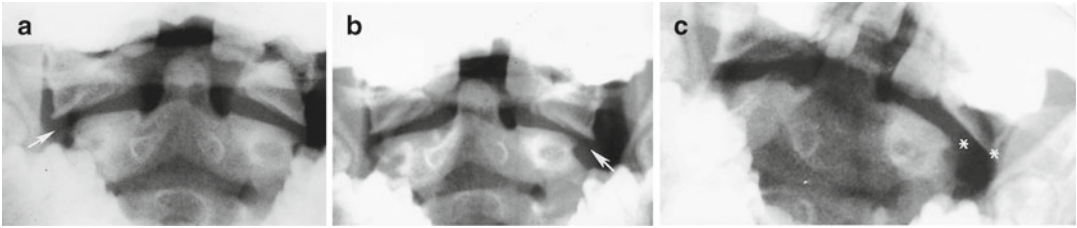
## Posticus Ponticus

The posticus ponticus represents a partial or complete bony encirclement of the vertebral artery as it exits the spinal canal and enters the calvarium. Usually there is no problem in identifying this structure (Fig. 2.31).



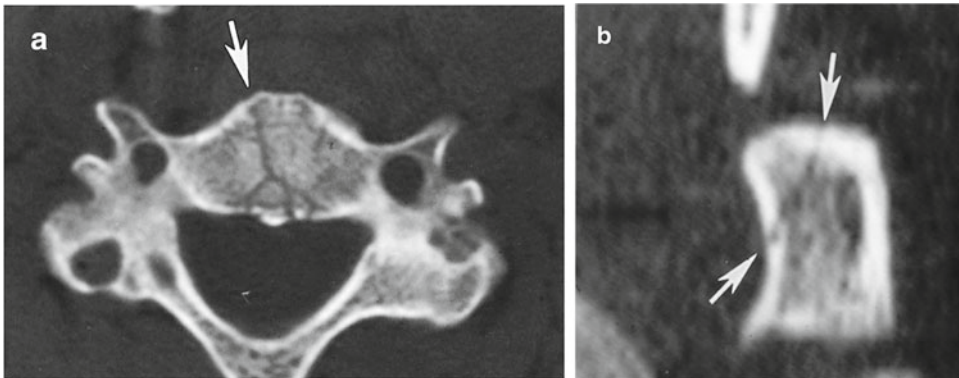
**Fig. 2.28** Pseudo-offsetting lateral mass of C1. (a) Rotation causes widening of the lateral mass–dens distance on the right (*upper arrow*). Offsetting of the lateral mass also is present (*lower arrow*). However, note that on the contralateral other side the lateral mass–dens distance

is narrower than normal. (b) Axial CT of the same patient demonstrates slight rotation and increase in the right lateral mass–dens distance (*arrow*). The same distance on the contralateral side is narrower than normal



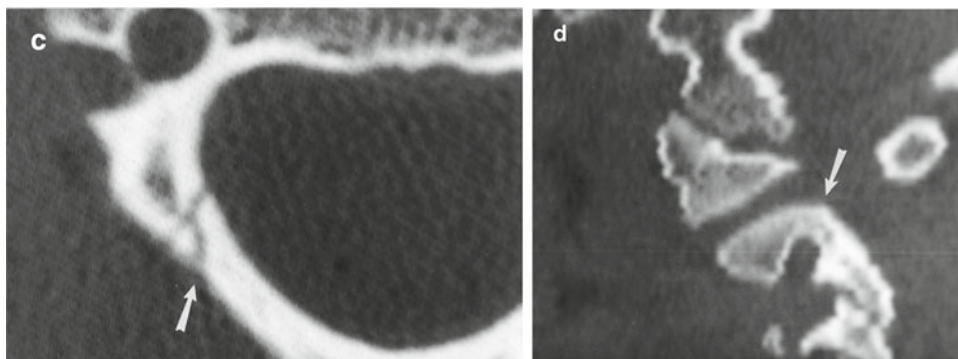
**Fig. 2.29** Hypermobility of C1 on C2, pseudopathologic offsetting. (a) In this patient, who sustained mild cervical spine trauma, there is marked offsetting of the lateral mass of C1 on the body of C2 on the right (*arrow*). The C1–dens distance also is increased. (b) Just a few moments later, it

is the left lateral mass that appears to be offset (*arrow*) on the body of C2. (c) Under fluoroscopic control, the patient's neck was flexed to the right, producing marked offsetting of the lateral mass of C1 on the left (*asterisks*). This patient had no pain and no limitation of motion. He was normal

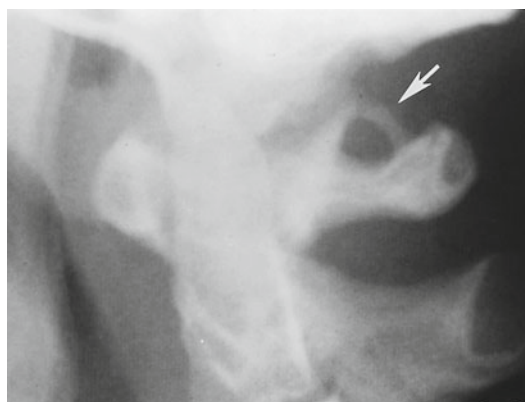


**Fig. 2.30** Central vein and course trabeculae pseudofractures. (a) Note the stellate appearance of the central veins (*arrows*). (b) Sagittal reconstructed view demonstrates a similar pseudofracture appearance (*arrows*).

(c) In this patient a fracture is suggested through the neural arch (*arrow*) because of the confluence of a venous groove and trabecular markings. (d) Sagittal reconstructed view demonstrates no fracture (*arrow*) at the site



**Fig.2.30** (continued)



**Fig. 2.31** Posticus ponticus. Note the typical appearance of the posticus ponticus (arrow)

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