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REVIEW ARTICLE

Leonard E. Swischuk

Normal cervical spine variations mimicking injuries in children

Abstract Evaluation of the cervical spine is a constant problem. This communication deals with the various normal variations and congenital anomalies that are frequently misinterpreted for traumatic lesions. Emphasis is on how to identify these anomalies and how to differentiate them from traumatic injuries of the cervical spine.

Key words Cervical spine – Children – Injuries – Normal variations

Introduction

Certain differences exist between the infant's and young child's spine when compared to the cervical spine of adolescents and adults. One of the main differences is that the cervical spine in infants and young children is much more supple and flexible, and, as a result, configurations mimicking pathology become common. While it is true that injuries in infants occur more often in the upper cervical spine [1, 2, 3], still none of these injuries are as common as they are in adolescents and adults. One of the reasons that injuries occur more commonly in the upper cervical spine of infants and young children is that the apex of the curve during flexion exists at this level [4]. In older children and adults it exists in the mid cervical spine, and as a result most injuries occur in this area.

This communication deals primarily with normal configurations of the cervical spine which often suggest an underlying, unstable injury. All of this is most important, for one can spend a lot of time investigating an apparently abnormal configuration which turns out to be merely a normal variation or a congenital anomaly.

L. E. Swischuk
Pediatric Radiology, The University of Texas Medical Branch, Galveston, Texas, USA
e-mail: lswischuk@utmb.edu, Fax: + 1-409-772380

Increased C1-C2 predental distance

An increase in the predental distance can result from traumatic dislocation of C1 on C2 but also can be normal. Traumatic C1-C2 dislocation most often occurs with flexion or rotational injuries and can occur alone or in association with fracturing of the dens. In any of these cases the predental distance is markedly increased (Fig. 1 a). However, a prominent and wide predental distance in infants and young children much more commonly is seen as a normal variation (Fig. 1 b). While in adults a distance of over 2.5 mm is generally considered abnormal, in infants and children a distance of 3 mm and even 4 mm is common. Indeed, approximately 5 % of normal individuals demonstrate a distance of 5 mm [5]. This is most important to appreciate, and in any given case it can be determined whether the problem is physiologic or pathologic with flexion-extension of the cervical spine. With flexion, if the finding is normal, maximal increase in the distance is no more than 2 mm. However, in my experience, in most of those patients who have a resting distance of 5 mm little change occurs with flexion.

A wide predental distance also commonly is seen on a congenital basis in association with hypoplasia of the dens and an associated os odontoideum [6]. The os odontoideum can be considered an overgrown os terminale, a normal structure at the tip of the dens. However, it tends to overgrow with hypoplasia of the dens and at the same time it is associated with underdevelopment of the transverse ligaments, and, as a result, the lesion becomes unstable. This is important to appreciate, for this anomaly is not uncommonly encountered in the emergency room setting. It is congenital but yet may be unstable and require surgical correction (Fig. 1 c, d).

Anterior displacement of C2 on C3

Anterior displacement of C2 on C3 occurs with the classic hangman fracture of C2, but a similar configuration can result with physiologic displacement of C2 on

Fig. 1a–d Predental distance. **a** Increased predental distance *(arrow)* secondary to dislocation of C1 on C2. In addition, note increased interspinous distance of C1 and C2 (+). **b** Normally prominent C1–dens distance *(arrow)*. Also note the prominent interspinous distance (+). **c** In this patient with a hypoplastic dens *(D)*, the C1–dens distance is markedly increased *(arrow)*. **d** Another patient with a hypoplastic dens *(D)*, but this time with an associated os odontoideum *(O)*. Note anterior displacement of C1 *(C1)* and a prominent predental distance

C3 [7]. Such physiologic displacement of C2 on C3 is very common in infants and young children, and far more common than pathologic displacement associated with a hangman fracture. With a hangman fracture, the bilateral pillar fractures render the fracture unstable. Motion is transferred from the normal apophyseal joints of C2-C3 to the fracture sites, and as a result there is anterior displacement of C1 and the entire body of C2 on C3 (Fig. 2 a). If the fracture is visible in such cases there is no problem with diagnosis, but if it is not visible one may have more difficulty. In these cases, one should apply the posterior cervical line [7]. This line was designed to differentiate physiologic from pathologic dislocation of C2 on C3 and is a line drawn from the anterior cortex of the spinus tip of C1 to the anterior cortex of the spinus tip of C3. If it misses the anterior cortex of C2 by 1.5 mm or more, an underlying hangman fracture should be suspected. Otherwise, physiologic dislocation only is present (Fig. 2 b). All of this is very important, for while hangman fractures with anterior displacement of C2 on C3 are seen in infants and children, most often such displacement is a normal finding. In these cases the posterior cervical line will be seen to touch, intersect, or not miss the anterior cortex of C2 by more than 1.5 mm [7]. Similar physiologic offsetting also can occur at the C3-C4 level and even the C4-C5 level [7, 8, 9].

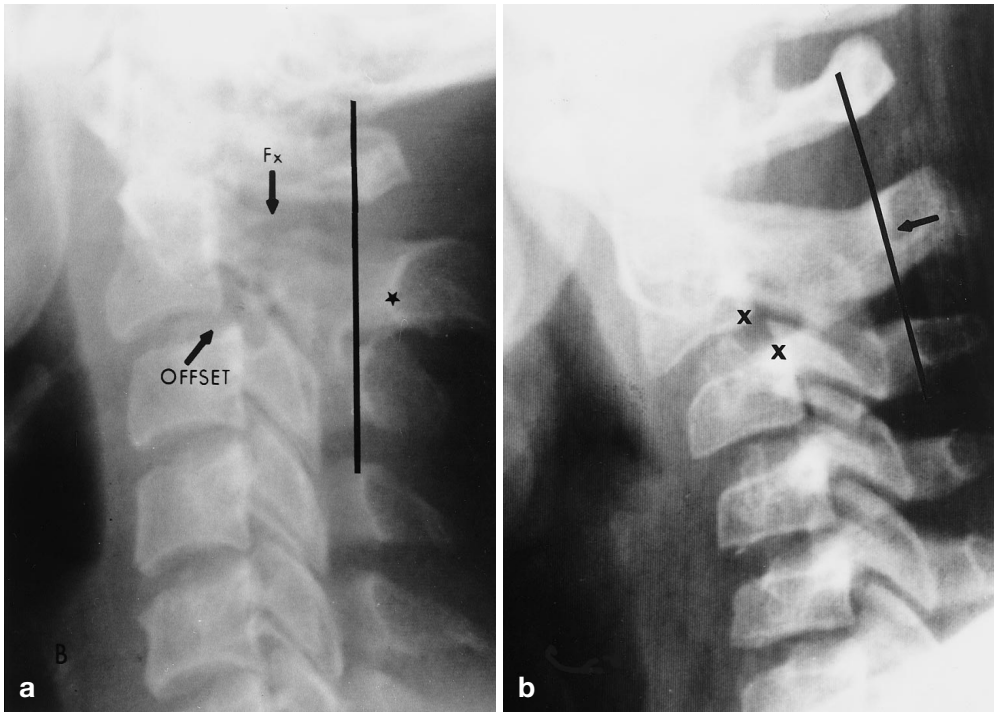

Fig. 2a, b Anterior dislocation C2 on C3. **a** Typical hangman fracture with anterior displacement of C2 on C3 (OFFSET). The posterior cervical line misses the anterior cortex of C2 by more than 2 mm (*). *Fx*, Fracture. **b** Physiologic C2 on C3 displacement. Note that C2 is anteriorly displaced on C3 *(x)*. The posterior cervical line *(line)*, however, is normal in that it touches the anterior cortex of the spinus tip of C2 *(arrow)*. (**a** From [5])

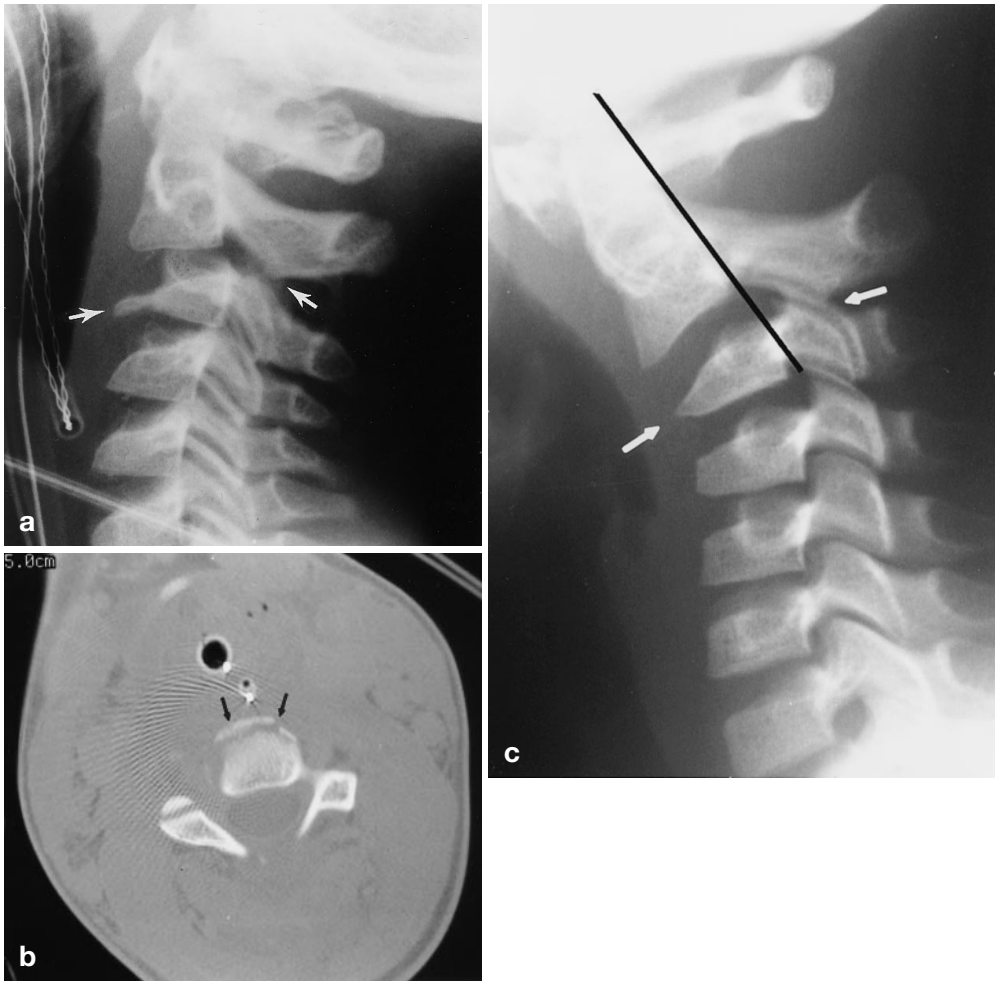

Fig. 3a–c Wedging of vertebral bodies. **a** Compression fracture of C3 *(anterior arrow)*. This vertebral body probably was normally wedged before but now demonstrates an associated teardrop fracture. Also note slight V-shaped configuration of the corresponding apophyseal joint *(posterior arrow)*. **b** CT study demonstrates the anterior teardrop fracture *(arrows)*. **c** In this patient with a chronically wedged vertebra *(anterior arrow)*, there is no associated fracture. Note that the facets of the apophyseal joints are parallel *(posterior arrow)*. This deformity is secondary to angulation of C2 on C3. The *line* drawn along the posterior aspect of C2 demonstrates that there is no anterior displacement of C2 on C3. Only angulation is present. (From [5])

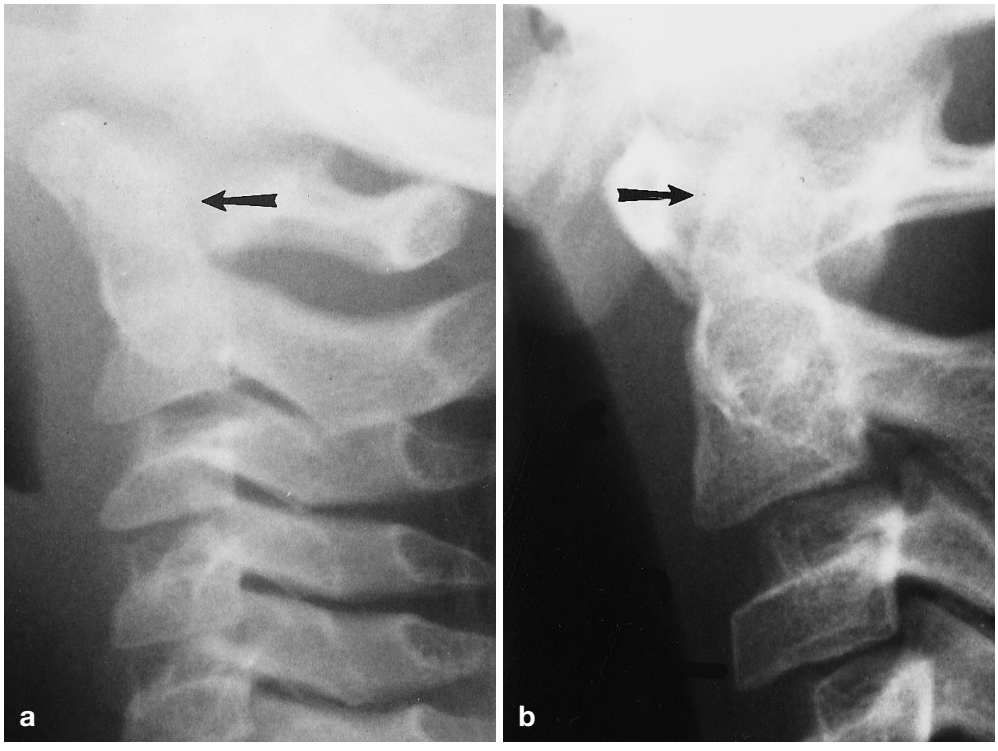

Fig. 4a, b Tilted dens. **a** Anteriorly angulated dens *(arrow)*. In this patient the deformity was secondary to an old healed anterior dens fracture through the synchondrosis. **b** Posteriorly tilted dens, normal *(arrow)*. In this patient no trauma was present

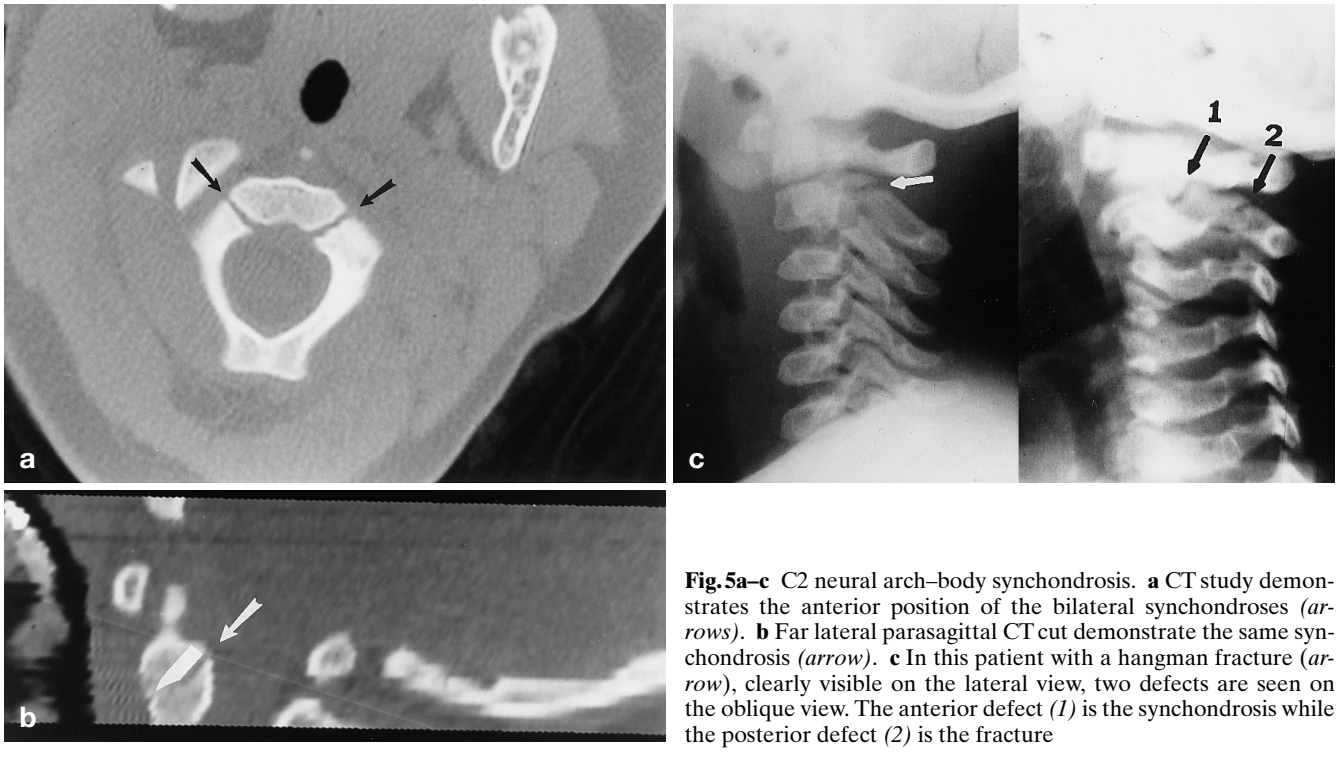

Fig. 5a–c C2 neural arch–body synchondrosis. **a** CT study demonstrates the anterior position of the bilateral synchondroses *(arrows)*. **b** Far lateral parasagittal CT cut demonstrate the same synchondrosis *(arrow)*. **c** In this patient with a hangman fracture (*arrow*), clearly visible on the lateral view, two defects are seen on the oblique view. The anterior defect *(1)* is the synchondrosis while the posterior defect *(2)* is the fracture

Anterior wedging of vertebral bodies

Anterior wedging of a vertebral body commonly is seen with hyperflexion injuries leading to anterior compression of the vertebra. This usually occurs at the C4, C5, and C6 levels in older children. Rarely, however, it can be seen on a traumatic basis at the C3 level (Fig. 3 a, b). However, most often wedging of C3, and occasionally C4, is seen as a normal variation [4]. The chronic wedging is related to physiologic anterior angulation, but

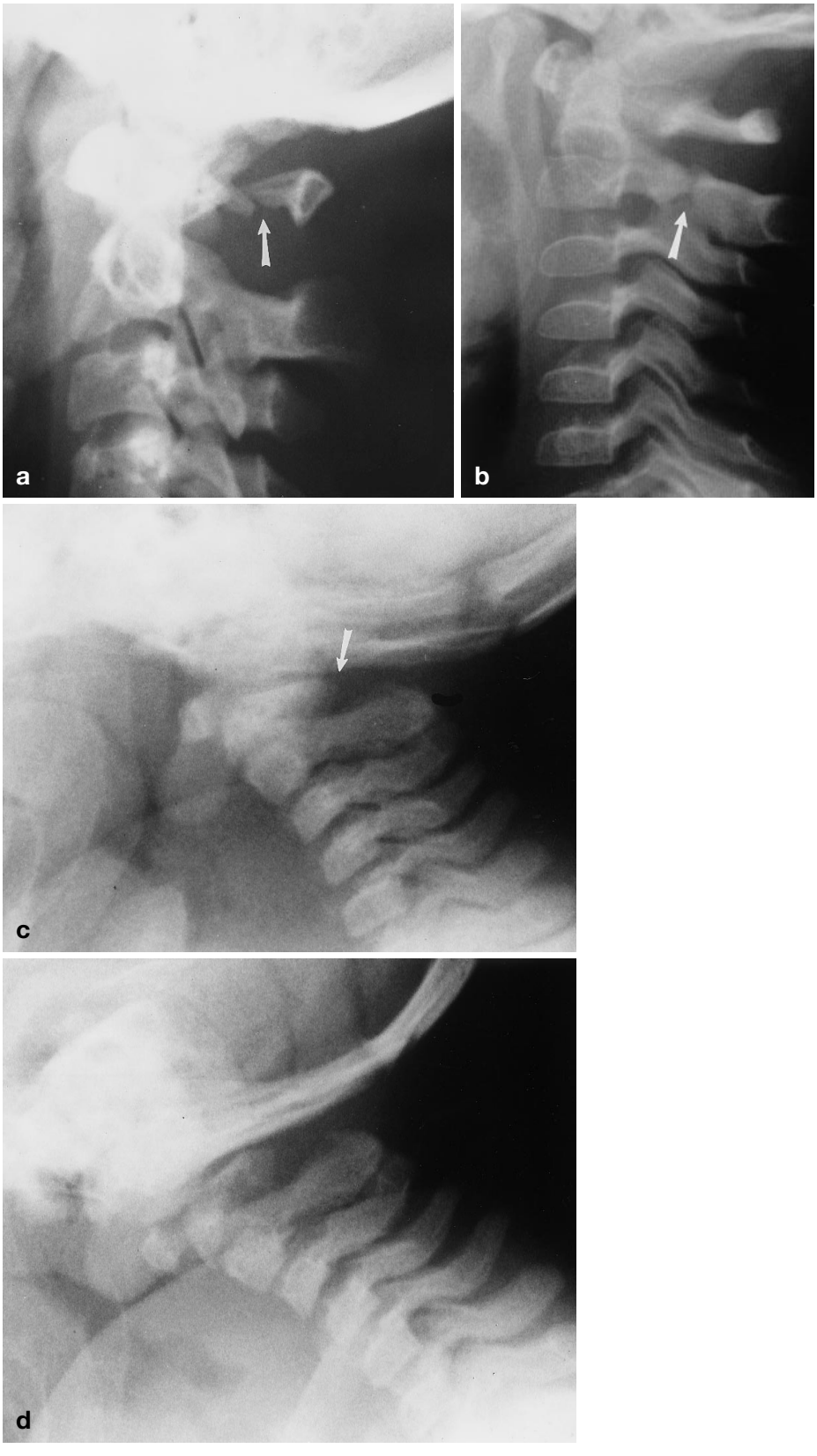

Fig. 6a–d Posterior arch defects. **a** Congenital C1 posterior arch defect *(arrow)*. Note the bizarre appearance of the remaining bony structures. **b** Congenital defect of C2 *(arrow)*. Note sclerotic margins and the somewhat elongated configuration of the neural arch. **c** Total absence of the posterior arch of C1 *(arrow)*. **d** With flexion there is minimal increase in the C1–dens distance. This is still within the normal range. However, the dens in this patient is slightly hypoplastic, and with time more hypermobility could occur. (**a, b** From [5])

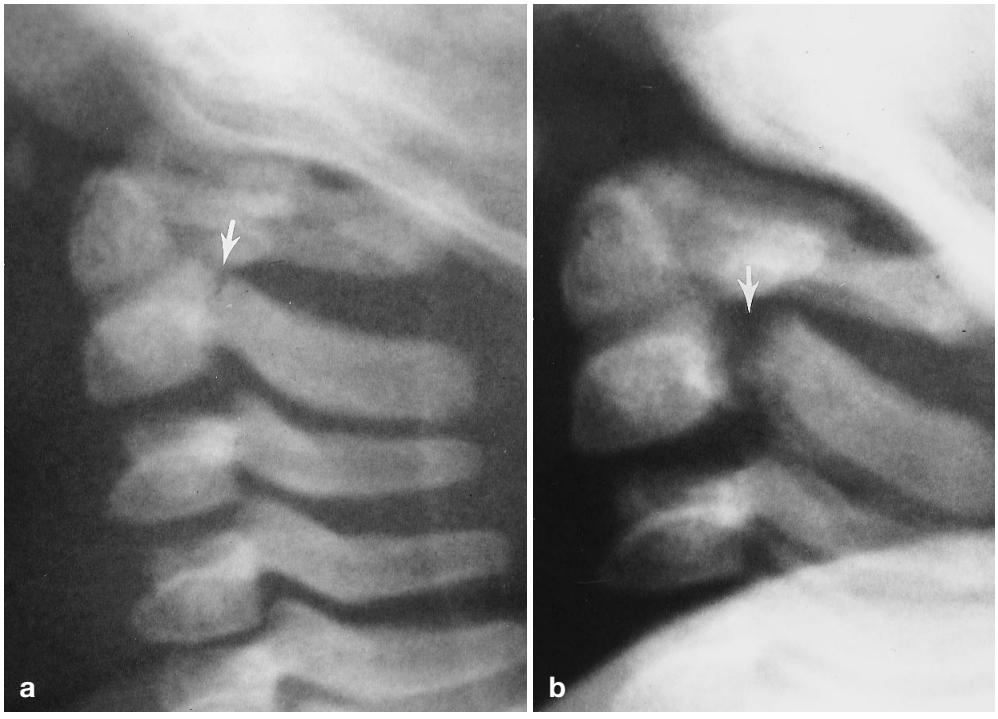

Fig. 7 a, b Hangman fracture, infant. **a** Lateral view demonstrates subtle evidence of a fracture line *(arrow)*. **b** With flexion there is marked opening of the fracture *(arrow)*, attesting to its instability

not displacement of C2 on C3. In such cases there is chronic anterior impaction of C3 leading to growth impairment of the anterior portion of the vertebral body [4] and a resulting wedge-like vertebral body deformity (Fig. 3 c). This is a very common finding in infants and young children, and if one is not certain as to whether it represents a compression fracture or a normal variation, a CT study of the cervical spine can solve the problem. The reason for this is that with wedging due to fracturing the fractures of the vertebral body will become apparent (Fig. 3 b), while if the problem is physiologic the vertebral body will appear normal on CT.

At the C3 level when anterior wedging is secondary to a C3 compression fracture, almost surely the apophyseal joints also will be sprung, and as such they assume, as they do elsewhere in the cervical spine, a V-shaped configuration (see Fig. 3 a). This is important to note because when physiologic motion only is present, the apophyseal joint facets remain parallel (Fig. 3 c).

Tilted dens

The dens can be tilted anteriorly, posteriorly, or laterally. The latter is uncommon and usually secondary to a fracture. Similarly, anterior tilting of the dens usually is secondary to an odontoid fracture, but posterior tilting of the dens is a very common normal finding and usually not due to a fracture (Fig. 4). In this regard, odontoid fractures in infants and young children tend to occur through the dens-body synchondrosis [10]. Most such fractures result from flexion injuries, and therefore if there is any displacement of the dens it will be in the anterior direction. Posteriorly displaced dens fractures in infants are much less common, but normal posterior tilting of the dens, as noted earlier, is very common as a normal finding [11].

Synchondroses of C2

The best-known synchondrosis of C2 is the horizontal one which occurs between the dens and body of C2. In addition, however, the synchondrosis between the dens and neural arch of the second vertebral body commonly is seen on oblique views of the cervical spine [12]. It also is seen on far tangential CT cuts of the spine (Fig. 5). In either case, it should not be misinterpreted as a fracture.

Arch defects

These can be seen on a congenital basis or with hyperextension injuries such as the hangman fracture of C2 and the hyperextension posterior fracture of C1. In either case the fracture defect is thin, radiolucent, and has sharp, nonsclerotic edges. These fractures can be seen at other levels but most often occur at the C1 and C2 levels. An example of a hangman fracture is seen in Fig. 2 a.

Congenital defects are very common through both the anterior and posterior arches of C1. Those through the posterior arch can appear very bizarre (Fig. 6 a), while anterior defects are seen only on axial CT studies. They usually are very straightforward, for they have sclerotic edges. Congenital defects are less common through the posterior arch of C2, and when they occur

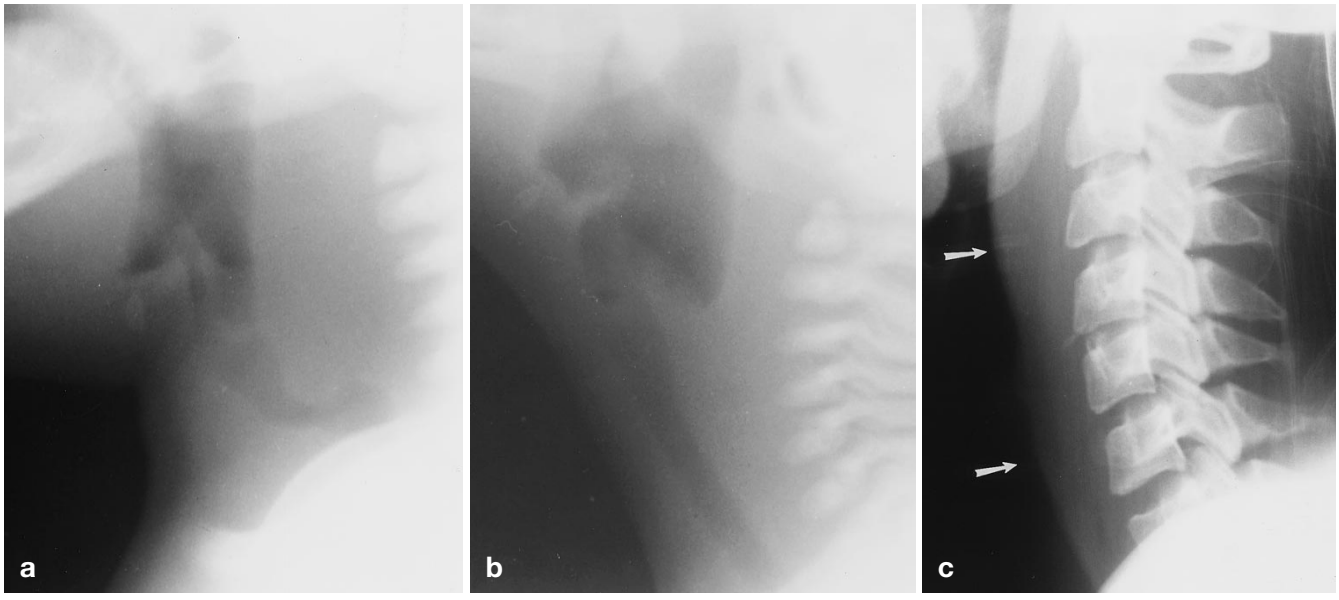

Fig. 8a–c Prevertebral soft tissues. **a** Note the bulky prevertebral soft tissues due to buckling of the airway. **b** With deeper inspiration and extension the airway is normal. There is retention of the step-off between the posterior pharyngeal wall and the posterior wall of the trachea. **c** Pathologic soft tissue thickening. Note that the entire airway is displaced anteriorly in a smooth, curving fashion *(arrows)*. There is no step-off between the posterior wall of the hypopharynx and the posterior wall of the trachea. Note the narrowed disk and associated teardrop fracture at the C4-C5 level. These findings attest to an underlying unstable injury. (From [5])

they also have sclerotic margins (Fig. 6b). They are stable abnormalities and, similarly, no matter how bizarre the C1 posterior arch defect appears, stability is the rule. The reason for this is that the defect is replaced by fibrous tissue and overall the anomaly is not unstable. If, however, there is significant associated hypoplasia of the dens and underdevelopment of the transverse ligaments, the lesion can become unstable (Fig. 6c, d).

In conclusion, defects through the posterior arch of C1 most often are congenital, while those through the posterior arch of C2 most often are secondary to a fracture, even in young infants. These latter fractures (that is, those in young infants) may remain clinically occult [13], but with flexion it will become readily apparent that an unstable fracture exists (Fig. 7).

Prominent prevertebral soft tissues

Evaluation of the prevertebral soft tissues notoriously causes constant problems in infants and young children. This is because with flexion and expiration the soft tissues can appear very thickened and distorted (Fig. 8a). The soft tissues should be evaluated only when the neck is in extension, or at least straight, and the patient is taking a deep breath (Fig. 8b), otherwise evaluation of the neck will almost always lead to erroneous interpretations. With proper views it should be noticed that normally there is a step-off between the posterior wall of the air-filled hypopharynx and the posterior wall of the air-filled trachea (Fig. 8b).

In terms of measurement of the prevertebral soft tissues, I do not know of any specific values which are of help. However, I have always used the concept that if the tissues are thickened in such a way that the posterior aspect of the air-filled hypopharynx and trachea form a continuous line, underlying pathologic thickening should be suspected (Fig. 8c). If the normal step-off between the posterior hypopharyngeal wall and the trachea is maintained, even if the tissues appear thick they probably are normal (Fig. 8b).

C1-C2 interspinous distance

The interspinous distance can be widened with flexion injuries associated with posterior ligamentous injuries. However, at the C1-C2 level, normal widening of the interspinous distance is a very common phenomenon and should not be misinterpreted as abnormal separation due to ligament injury (see Fig. 1a).

Offset C1 lateral masses

As in adults, bilateral or unilateral offsetting of a lateral mass of C1 on a well-positioned film should signify the presence of a Jefferson fracture. This fracture is easily confirmed on axial CT views of the cervical spine. In addition, it should be noted that up to the age of 2 years the lateral masses can normally appear to be laterally displaced [14].

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