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Anterior Subluxation of the Cervical Spine: Hyperflexion Sprain

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Anterior subluxation (hyperflexion sprain) is localized, purely ligamentous disruption of the cervical spine caused by a limited flexion force. When associated with a simple wedge fraction, also a flexion injury, anterior subluxation may be the more significant lesion. Radiographically, anterior subluxation is characteried by (1) a localized kyphotic angulation at the level of injury; (2) anterior rotation, or displacement, of the subluxed vertebra; (3) anterior narrowing and posterior widening of the disc space; (4) widening of the space between the subluxed vertebral body and the subjacent articular masses; (5) displacement of the inferior articulating facets of the subluxed vertebra with respect to their contiguous subjacent facets; and (6) widening of the interspinous space ("fanning"). The localized kyphotic angulation at the level of ligamentous disruption distinguishes pathologic anterior subluxation from diffuse "reversal of the normal cervical lordosis" produced by voluntary positioning or muscle spasm. Anterior subluxation is clinically significant because of the approximate 20% incidence of delayed instability due to impaired ligamentous healing.

Injuries of the cervical spine are common and of great variety. Often they are readily detected radiologically as outright fractures and dislocations. However, injury may be limited to ligaments, joint capsules, and intervertebral discs. The radiologic evidence in such cases may be subtle, but significant disability may result if these injuries are not recognized. An important injury of dorsal ligaments is the hyperflexion sprain resulting in anterior subluxation. This is a review of the radiologic features of the entity with which all physicians treating cervical trauma should be familiar.

Normal Anatomy and Physiology

The cervical spine includes two anatomically and physiologically distinct subdivisions: the cervicocranium and the lower cervical segments; the transition is at the C2–C3 level. The cervicocranium consists of the occiput, atlas, and the axis, while the lower cervical spine includes the third through seventh vertebrae. Because anterior subluxation (hyperflexion sprain) seldom involves the cervicocranium, this description of normal anatomy and physiology will be limited to the lower cervical spine.

Throughout the cervical spine, including the cervicocranium, the vertebrae are typically aligned in lordosis (fig. 1A). In that configuration, an imaginary line connecting the anterior cortex of the vertebral bodies and another connecting their posterior cortical margins would constitute smooth, continuous convex curves. However, in about 20% of people, the cervical spine may be straight or kyphotic in the neutral lateral position and voluntary assumption of the "military" (i.e., chin-on-chest) position causes reversal of cervical lordosis in about 70% of normal individuals [1].

Normally, the distance between the posterior cortex of the vertebral bodies

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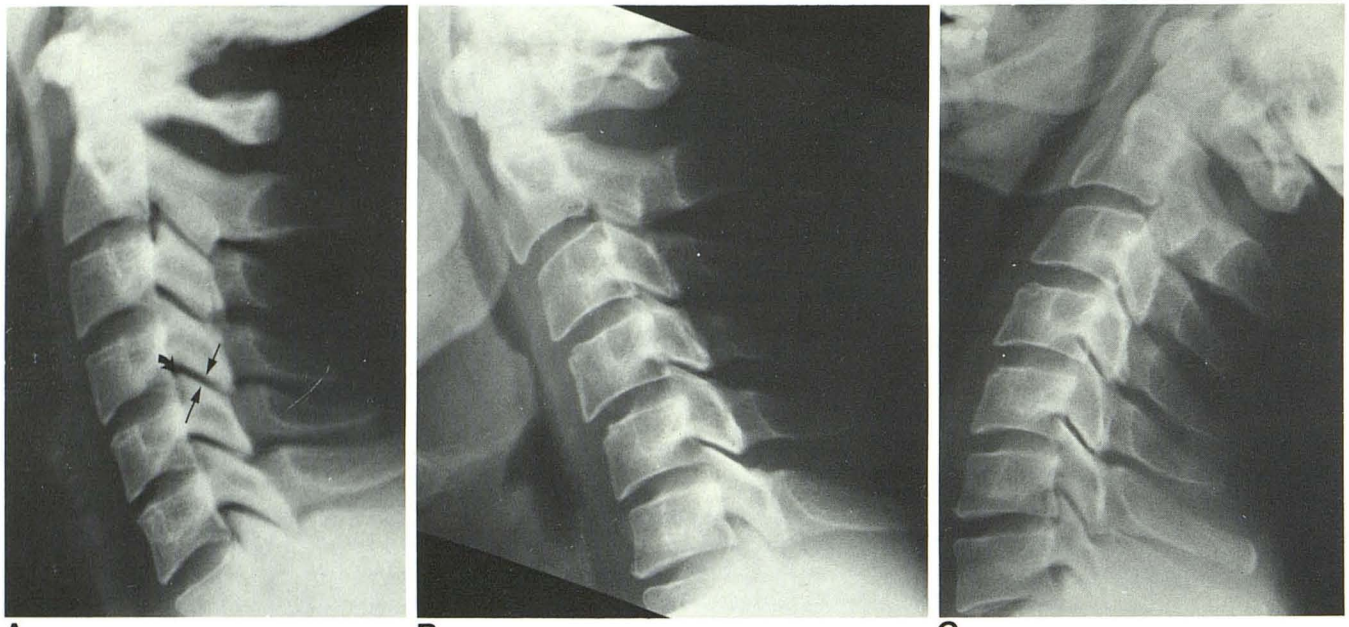

Fig. 1.—**A**, Normal adult cervical spine, neutral position. Normal cervical lordosis, articular masses precisely superimposed, facetal joint surfaces (*long arrows*) parallel, distance between posterior cortex of vertebral body and anterior cortex of subjacent articular masses (*curved arrow*) similar at each level from C3 through C7 and does not exceed 3.5 mm. Interspinous spaces are of similar height. **B**, Flexion. Cervical lordosis diffusely reversed in smooth uninterrupted fashion, each vertebral body slightly more anteriorly displaced than subjacent body, superior facets are slightly and uniformly anteriorly displaced, interfacetal joint spaces uniformly widened posteriorly, interspinous spaces all uniformly widened. **C**, Extension. Lordosis exaggerated, disc spaces slightly widened anteriorly and narrowed posteriorly, surfaces of interfacetal joints converge posteriorly, superior facets of each joint posteriorly displaced, spinous processes converge.

and the subjacent articular masses is uniform throughout the mid and lower cervical segments and does not exceed 3.5 mm [2] except in instances of dislocation or fracture-dislocation.

The inferior articulating facets of the vertebra above are symmetrically and uniformly superimposed on the contiguous superior articulating facets of the vertebra below.

The facets constituting a facetal (interfacetal, apophyseal) joint are parallel and their posterior margins are superimposed.

The posterior cortical margins of the individual articular masses are convex, posteriorly. However, an imaginary line drawn connecting these cortical surfaces would be concave posteriorly, paralleling that of the posterior cortical margins of the vertebral bodies. The interspinous spaces, with exception of that at the C2–C3 level, are of similar height.

In flexion (fig. 1B), the cervical vertebrae physiologically slide, or rotate anteriorly. The amount of forward motion is progressively greater at each successively higher level. Consequently, each successively higher vertebral body is slightly more anteriorly displaced than the body below. The inferior facets of the cephalad vertebra move forward and upward with respect to the contiguous superior facets of the subjacent vertebra, the interfacetal joint spaces widen posteriorly, and the interspinous spaces from C3 to C7 widen, usually uniformly. In a normal individual, the result is a smooth, continuous, reversal of the cervical lordosis which occurs *diffusely* throughout the cervical spine.

In extension, normally, all of the physiologic changes that occur in flexion are reversed, and the cervical lordosis becomes exaggerated. The interspinous spaces narrow and the spinous processes converge (fig 1C).

The ligaments involved in anterior subluxation include the supra- and interspinous ligaments, the ligamentum flavum, the capsules of the interfacetal joints ("posterior ligament complex") [3], the posterior longitudinal ligament, and the intervertebral disc (fig. 2A).

Pathophysiology

Selecki and Williams [5] used fresh, unembalmed cadaver specimens of the cervical spine to demonstrate that anterior subluxation is the result of a flexion force of less than 49 kg/cm^2 which causes disruption of the posterior ligament complex, the posterior longitudinal ligament, and a horizontal tear of varying length in the posterior part of the corresponding intervertebral disc. Most of the disc, and the anterior longitudinal ligament, remain intact. Consequent to the ligamentous disruption, the involved vertebra, pivoting on the anterior inferior corner of the body, rotates (fig. 2B), or may be slightly (1–3 mm) displaced, anteriorly. The concept of anterior subluxation as an acute injury of the cervical spine has been extensively described in orthopedic and neurosurgical literature [2, 3, 6–14] but less frequently in radiologic literature [4, 15–17].

Radiographic Signs

The radiographic signs of anterior subluxation (fig. 3) include (1) a localized kyphotic angulation of the cervical spine limited to the level(s) of the ligamentous disruption;

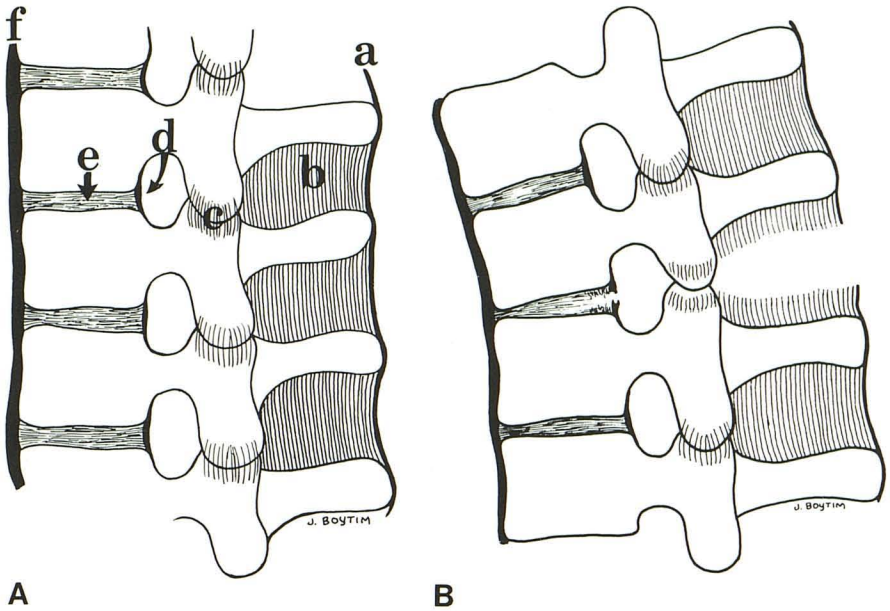

Fig. 2.—**A**, Ligamentous structures of normal cervical spine. Supraspinous ligament (a); interspinous ligament (b); capsule of interfacetal joint, (c); posterior longitudinal ligament (d); intervertebral disc (e); anterior longitudinal ligament (f). Ligamentum flavum not depicted. Together, supra- and interspinous ligaments, ligamentum flavum, and capsule of interfacetal joints constitute "posterior ligament complex." **B**, Pathology of anterior subluxation; disruption of supra- and interspinous ligaments, capsule of interfacetal joints, posterior longitudinal ligament, and short tear of posterior aspect of intervertebral disc. Ligamentum flavum, not demonstrated here, is torn as well. (Reprinted from [4].)

Fig. 3.—Anterior subluxation of C5 on C6: hyperkyphotic angulation at C5–C6 level. C5–C6 interspinous space (*white arrow*) is abnormally wide ("fanning"), inferior facets of C5 are anteriorly and superiorly displaced and their posterior margins are no longer superimposed (*arrows*) as at other, uninvolved, levels (*arrowheads*). Distance between posterior cortex of body of C5 and anterior cortex of pillars of C6 (*open arrow*) is abnormally wide and fifth disc space is widened posteriorly and narrowed anteriorly.

(2) anterior rotation and/or slight (1–3 mm) displacement of the subluxed vertebra; (3) anterior narrowing and posterior widening of the intervertebral disc space; (4) increase in the distance between the posterior cortex of the subluxed vertebral body and the anterior cortex of the articular masses of the subjacent vertebra; (5) anterior and superior displacement of the superior facets of the involved interfacetal joints with respect to their contiguous inferior facets, with resultant widening of the posterior aspect of the interfacetal joint space; and (6) abnormal widening of the involved interspinous space ("fanning"). The incidence of each of these signs on the initial neutral lateral radiograph of 25 patients with anterior subluxation is indicated in table 1. All of the signs, except widening of the space between the subluxed vertebral body and the subjacent articular mass and alternation of the configuration of the disc space, were present in all patients. Measure of the space between the posterior cortical margin of the subluxed vertebral body and the anterior cortex of the articular masses of the subjacent vertebrae requires a true lateral radiograph. In some of our patients, minor degrees of rotation precluded an accurate evaluation of this distance. In some of the patients with minimal degrees of anterior subluxation, it was not possible to be certain of posterior widening and anterior narrowing of the height of the involved intervertebral disc space on the initial neutral lateral radiograph.

These changes are exaggerated in flexion and reversed, or eliminated, in extension. Therefore, with minor degrees of anterior subluxation in which the neutral lateral radiograph may be equivocal, lateral flexion and extension radiographs, preferably under direct medical supervision, are necessary to establish the correct diagnosis (fig. 4). When there are signs of subluxation in the neutral lateral projection, and they are not exaggerated in flexion, it has been suggested that there is less extensive tearing of the posterior ligamentous structures and that delayed instability may not be as common in these patients [13].

TABLE 1: **Frequency of Signs and Anterior Subluxation in Initial Neutral Lateral Radiograph**

Sign	No. Patients (n = 25)
Localized hyperkyphosis	25
Anterior rotation or displacement of subluxed vertebra	25
Altered configuration of disc space	16
Increase in vertebral body-articular mass distance	16
Altered configuration of interfaced joints	25
"Fanning" of spinous processes	25

Kyphous Deformity at Level of Subluxation

The attitude of the cervical spine in anterior subluxation is characterized by localized kyphosis limited to the level(s) of subluxation (figs. 3–5). This feature distinguishes anterior subluxation from the smooth, diffuse, physiologic reversed lordosis associated with voluntary positioning or muscle

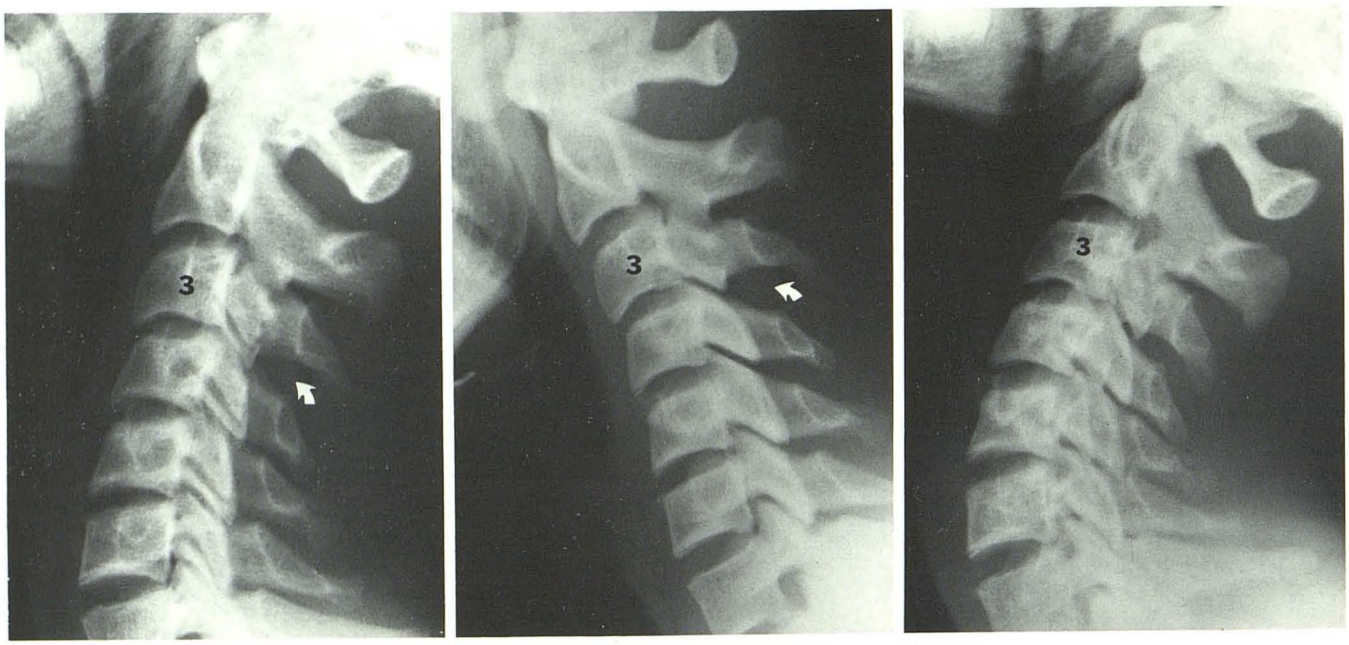

Fig. 4.—Anterior subluxation of C3 and C4. **A**, Neutral position. Minor kyphous deformity C3–C4 level with abrupt disruption of normally smooth anterior convexity of vertebral bodies. C3–C4 interspinous space widened (*white arrow*). Other vertebrae remain in normal lordotic attitude. **B**, Flexion. All signs of anterior subluxation accentuated. **C**, Extension. Spine appears normal.

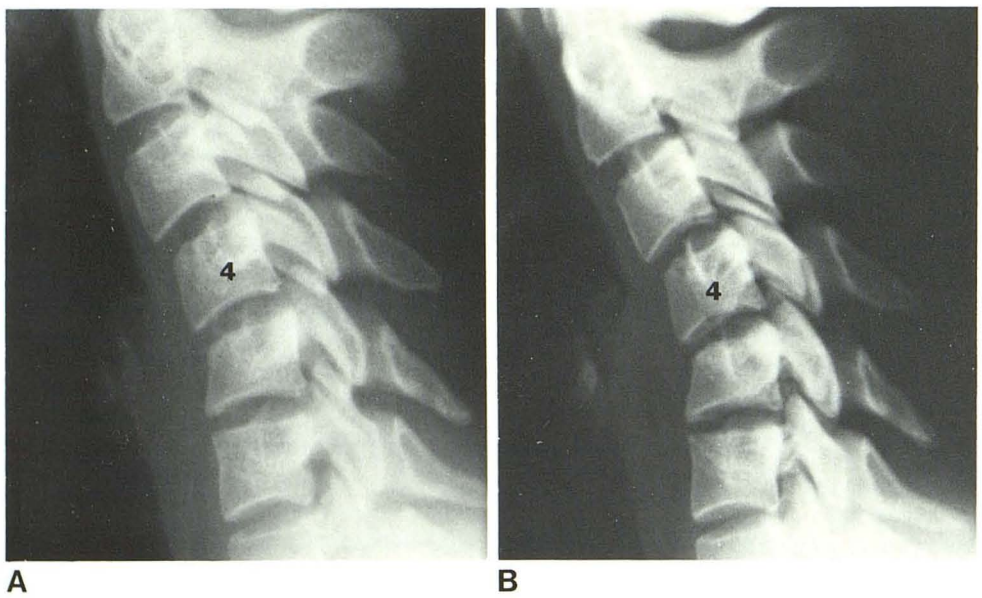

Fig. 5.—Anterior subluxation of C4 on C5 with delayed instability. **A**, Initial neutral lateral radiograph. Obvious signs of subluxation. Patient was treated for "cervical sprain" with soft collar until acute symptoms subsided. **B**, 3 months later. Radiograph obtained because of chronic complaints. Greater degree of subluxation. (Reprinted from [4].)

spasm. "Reversal of the normal cervical lordosis," the phrase most commonly used to describe the posture in anterior subluxation, is not only imprecise, but is frankly misleading because it implies that the appearance of the cervical spine in anterior subluxation is the same as that caused by voluntary flexion, or by muscle spasm. Failure to recognize, or appreciate, the difference between the diffuse reversal due to positioning or muscle spasm and the localized hyperkyphosis of anterior subluxation is probably the principal reason why anterior subluxation is frequently missed or considered to be of minor significance [17]. However, minor anterior angulation (up to 11°) may be normal in the absence of any of the other radiographic signs of anterior subluxation [18–20]. Another distinguishing feature of the cervical spine in anterior subluxation is that the vertebrae above, as well as those below, the kyphous deformity commonly maintain their normal lordotic posture (figs. 3–5), while in the voluntary positioning or muscle spasm, the cervical lordosis will be obliterated or reversed throughout the cervical spine.

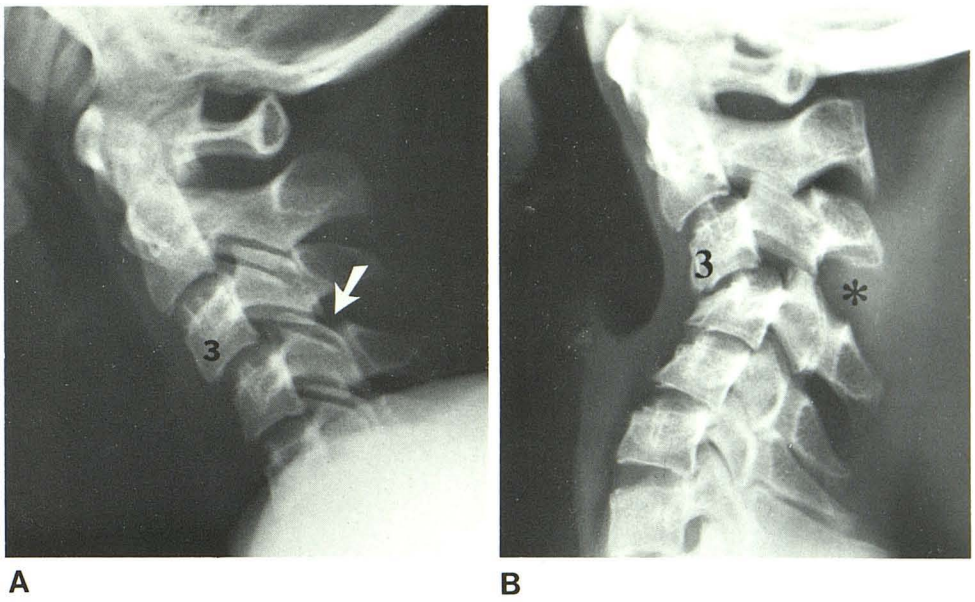

Fig. 6.—Acute anterior subluxation of C3 with delayed instability. **A**, initial examination. Superior facets of interfacetal joints anteriorly and superiorly displaced; interfacetal joint spaces widened posteriorly (*arrow*). **B**, After prolonged rigid immobilization. (Reprinted from [4].)

Anterior Rotation and/or Displacement of Subluxed Vertebra

Usually, the subluxed vertebra is simply anteriorly rotated on the anterior inferior corner of the body (fig. 3). With greater flexion force and more extensive soft-tissue injury, the vertebra may be anteriorly displaced, in addition to being rotated (figs. 4–6). Such anterior displacement does not exceed 1–3 mm in anterior subluxation. Anterior (horizontal) displacement in excess of 3.5 mm indicates frank dislocation or fracture [2] or "pseudosubluxation" or "pseudodislocation" of infancy and childhood [19, 21–23]. The minor displacement in anterior subluxation is less than that associated with frank cervical vertebral dislocation or fracture and bears no relation to the physiologic "pseudodislocation" of infancy and early childhood.

Anterior Narrowing and Posterior Widening of Disc Space

Anterior narrowing and posterior widening of the intervertebral disc space (figs. 3, 5, and 6) are manifestations of rotation of the subluxed vertebra and the tear in the posterior aspect of the intervertebral disc. These changes are frequently subtle.

Localized Increase in Distance Between Subluxed Vertebra and Subjacent Articular Masses

Localized, abnormal widening of the space between the posterior cortical margin of the subluxed vertebral body and the anterior cortical margin of the subjacent articular masses (figs. 3, 5, and 6) is a manifestation of the rotation and/or anterior displacement of the subluxed vertebra. Evaluation of this subtle, inconsistent radiographic sign requires a true lateral radiograph and comparison of the "body-mass" distance at the level of ligamentous disruption with the same interval at adjacent, normal levels.

Alteration of Configuraton of Interfacetal Joints

Anterior and superior displacement of the inferior articulating facets of the subluxed vertebra produce radiographically discernible changes in the relation of the facets and the geometry of the joint spaces (figs. 3–6). Normally the posterior cortical margins of the facets at each level should lie on about the same vertical plane. In anterior subluxation, the posterior margin of the inferior facets of the subluxed vertebra may lie as much as 3–5 mm anterior to the posterior cortical margins of the contiguous subjacent facets. Instead of being parallel, the surfaces of the involved faceted joints are divergent posteriorly, and the joint spaces at the level of ligamentous disruption, instead of being of uniform width, are widened posteriorly.

Abnormal Widening of Interspinous Space

Abnormal widening of the involved interspinous space ("fanning") reflects the torn supra- and interspinous ligaments and the anterior rotation of the subluxed vertebra. Normally, the interspinous spaces, particularly from C3 through C7, are of similar height in the neutral lateral radiograph. In anterior subluxation, the interspinous space at the level of ligamentous disruption is obviously wide, and is wider than the other interspinous spaces throughout the lower cervical spine (figs. 3–10).

Complications

Delayed instability is the principal and most clinically significant complication of anterior subluxation. Fielding and Hawkins [2] define instability as "weakness of intervertebral bonds that render them unable to withstand trauma tolerable to the normal spine and allows actual or potential abnormal excursion of one segment on another, implying a potential or actual compromise of neural elements." "Delayed" in-

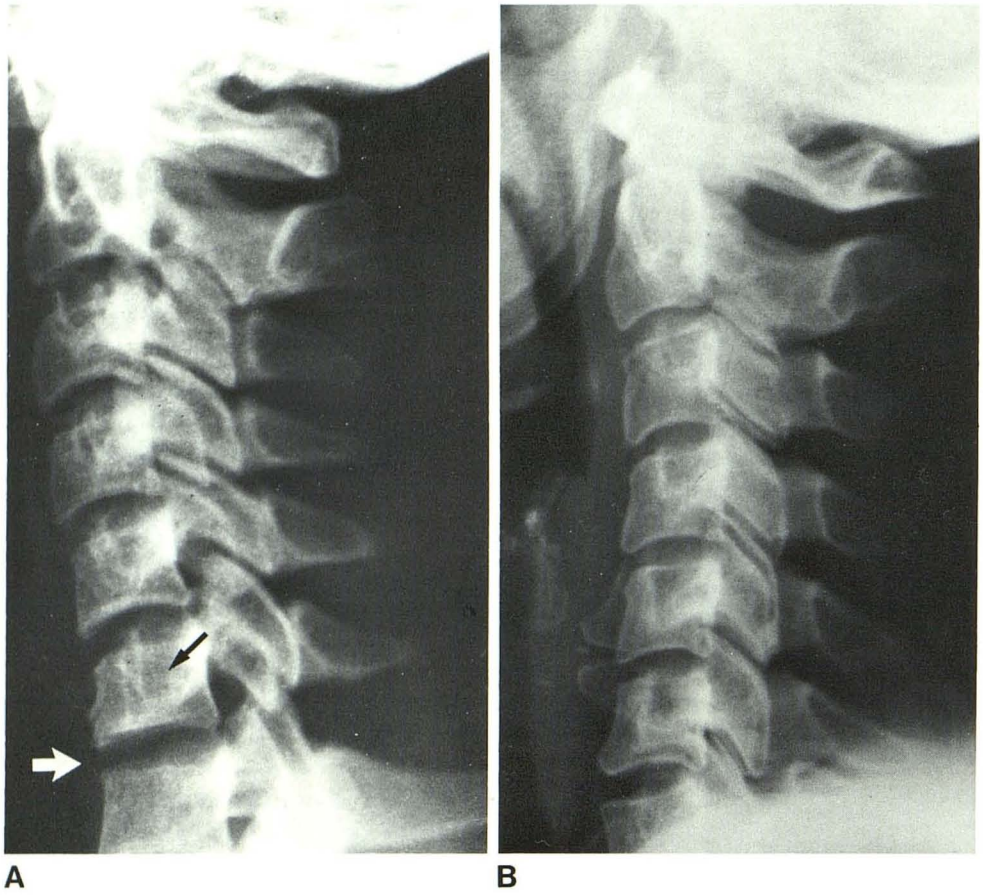

Fig. 7.—Anterior subluxation of C6 on C7 with simple wedge fracture of C6. **A**, Localized hyperkyphotic angulation (*white arrow*), and all other signs of anterior subluxation at C6–C7 level. C6 = *black arrow*. **B**, Another patient (asymptomatic): "military" position. Cervical lordosis diffusely and smoothly reversed throughout unlike localized kyphosis with anterior subluxation.

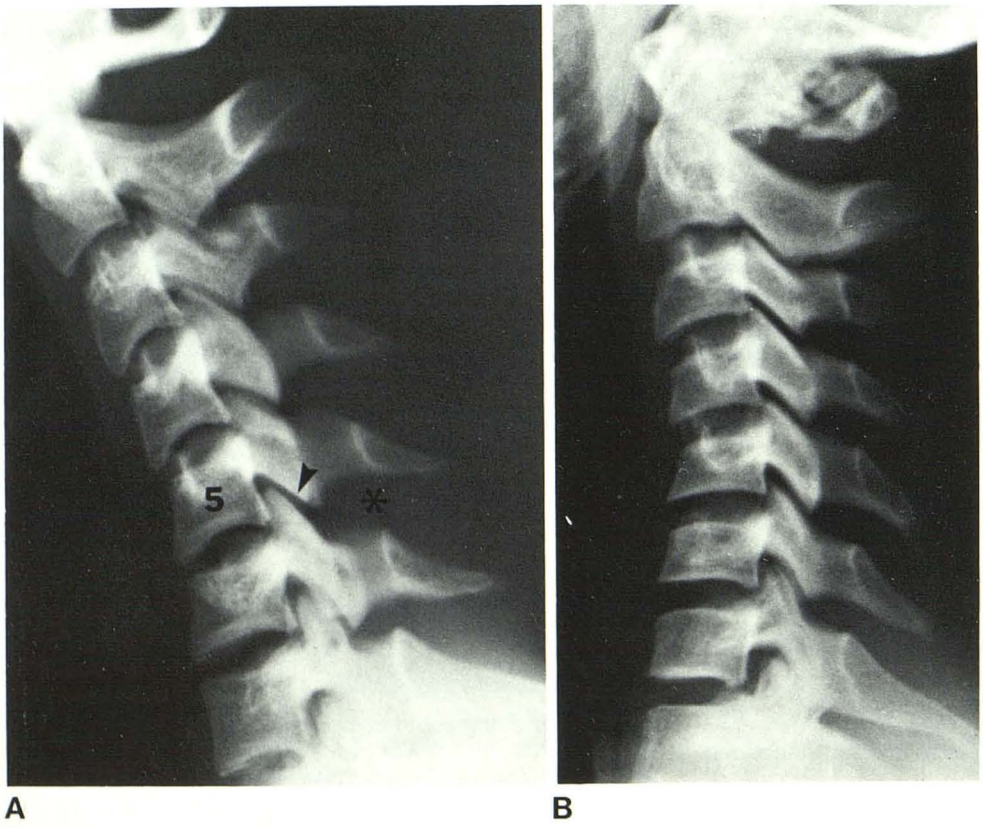

Fig. 8.—Anterior subluxation of C5. **A**, Localized hyperkyphosis at C5–C6 level; fifth interspinous space abnormally widened (*); superior facets of involved interfacetal joints (*arrowhead*) anteriorly and superiorly displaced. **B**, Another patient, with muscle spasms secondary to fracture of posterior arch of C1. Cervical lordosis smoothly and diffusely reversed throughout, unlike localized kyphosis of anterior subluxation.

Fig. 9.—Anterior subluxation, with minor anterior displacement, of C4 in patient with degenerative arthritis.

Fig. 10.—Anterior subluxation, with moderate anterior displacement, of C5 in patient with extensive degenerative arthritis of cervical spine. Abnormal prevertebral soft-tissue swelling (*) in lower cervical spine.

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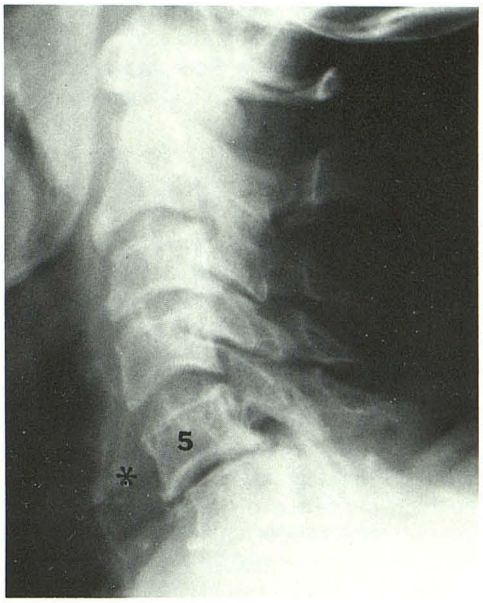

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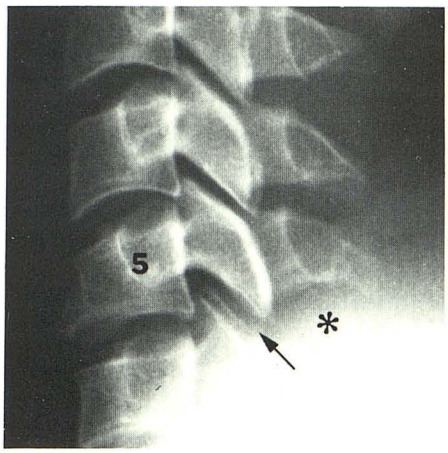

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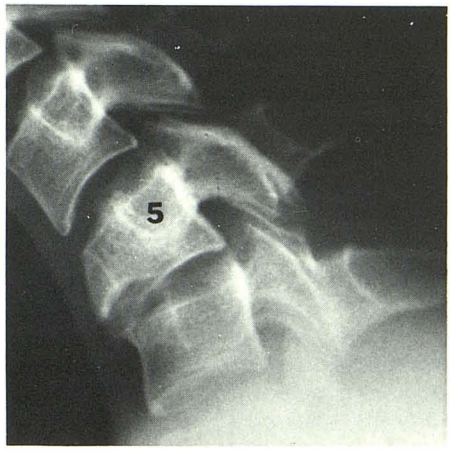

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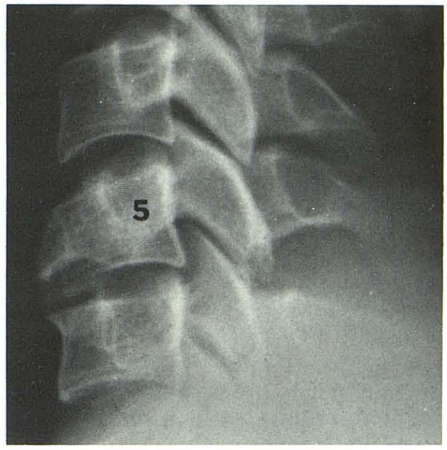

C

Fig. 11.—Anterior subluxation with acute, simple, wedge fracture of C5. **A**, C5–C6 interfacetal joint spaces abnormally widened (*arrow*) and, although not completely visualized, interspinous space is abnormally widened (*). Several months later: flexion (**B**) and extension (**C**) radiographs. Abnormal range of motion of C5 indicating instability. (Reprinted from [4].)

stability has been described as instability that persists after conservative treatment. It occurs in about 20% of patients with anterior subluxation, an incidence greater than that found in any other type of cervical injury [24].

The cause of delayed instability is failure of the posterior ligament complex and the posterior longitudinal ligament to heal. Consequently, the subluxed vertebra remains free to move through an abnormally wide range of motion, particularly in flexion, and the radiographic signs of anterior subluxation may be even more striking in the follow-up radiographs than on the original radiographic study (fig. 5).

Delayed or incomplete healing is an inherent characteristic of ligamentous injuries and may occur despite prolonged and appropriate immobilization (fig. 6). This concept is well recognized with respect to ligamentous injuries involving the knee and ankle. It is less well appreciated in regard to ligamentous injuries of the cervical spine.

Discussion

The recognition of anterior subluxation depends entirely on the appreciation of the radiographic signs of this common, purely ligamentous flexion injury. These signs although occasionally subtle, are identifiable and reflect the changes in vertebral alignment attributable to the flexion force and ligamentous disruption. Being limited to the level of ligamentous injury, they are distinctly different from the diffuse, generalized reversal of the cervical lordosis which occurs voluntarily in the "military" position or in flexion (fig. 7) or involuntarily, secondary to muscle spasm (fig. 8).

Anterior subluxation is commonly regarded as an injury

of younger people, particularly those who are athletically active. This misconception may dismiss consideration of anterior subluxation in older patients, or those with degenerative arthritis of the cervical spine, who sustain a relatively minor flexion injury of the neck. Figures 9 and 10 are examples of patients with preexisting degenerative arthritis of the cervical spine who experienced acute anterior subluxation as the result of an indirect flexion injury of the neck.

If the radiographic signs of anterior subluxation are either not recognized or are misinterpreted as representing simply the effect of positioning or muscle spasm, the correct diagnosis is not likely to be established, since the clinical signs and symptoms of anterior subluxation are nonspecific. In that event, it is highly probable that the treatment will be symptomatic only, and if so, it will almost certainly be inadequate to provide optimum conditions for ligamentous healing. Such diagnostic failures undoubtedly contribute to the high incidence of delayed instability associated with anterior subluxation. Therefore, it is particularly important that the radiologist accept anterior subluxation as a specific pathologic entity and be fully aware of its radiographic signs.

Another factor that contributes to the inordinate incidence of delayed instability associated with anterior subluxation is the innate characteristic of ligamentous injuries to heal poorly. This concept is well recognized with respect to ligamentous injuries involving the ankle and knee, but is not appreciated in cervical spine injuries. While anterior subluxation usually occurs as an isolated injury, it is occasionally associated with a simple wedge fracture. In this instance, the ligamentous disruption of anterior subluxation may be the more important lesion. It is not uncommon for the wedge fracture to heal, while failure of the ligamentous injury to do so results in prolonged morbidity associated with delayed instability (fig. 11).

In summary, anterior subluxation (hyperflexion sprain) usually occurs as an isolated soft-tissue lesion resulting from a flexion injury causing disruption of the "posterior ligament complex" and a variable segment of the intervertebral disc. Its recognition depends entirely on the radiographic signs of localized kyphotic hyperangulation at the level of ligamentous disruption, with or without minimal (1–3 mm) anterior displacement of the subluxed vertebra. Anterior subluxation is clinically significant because of about 20% incidence of posttraumatic "delayed instability" due to impaired ligamentous healing. When present in conjunction with a simple wedge fracture, anterior subluxation is usually the more significant lesion.

REFERENCES

1. Weir DC. Roentgen signs of cervical injury. *Clin Orthop* **1975**;109:9–17
2. Fielding JW, Hawkins RJ. Roentgenographic diagnosis of the injured neck. In: *Instructional course lectures, American Academy of Orthopedic Surgeons*, vol 25. St. Louis: Mosby, **1976**: 149–170
3. Holdswath F. Fractures, dislocations and fracture dislocations of the spine. *J Bone Joint Surg [Am]* **1970**;52:1534–1551
4. Harris JH Jr. *The radiology of acute cervical spine trauma*. Baltimore: Williams & Wilkins, **1978**
5. Selecki BR, Williams HBL. Injuries to the cervical spine and cord in man. In: *Australia Medical Association medical monograph*, no. 7. South Wales: Australian Medical, **1970**
6. Taylor RG, Gleave JRW. Injuries to the cervical spine. *Proc R Soc Med* **1962**;55:1053–1058
7. Hohl M. Soft-tissue injuries of the neck in automobile accidents. *J Bone Joint Surg [Am]* **1974**;56:1675–1681
8. Rogers WA. Fractures and dislocations of the cervical spine. *J Bone Joint Surg [Am]* **1957**;39:341–376
9. Stringa G. Traumatic lesions of the cervical spine—statistics, mechanism, classification. In: *Proceedings of the IXth Congress of the International Society of Orthopedic Surgeons and Traumatology*. Brussels: Imprimerie des Sciences, **1963**:69–97
10. Jackson R. Up-dating the neck. *Trauma* **1970**;1:9–89
11. Kewalramani LS, Taylor RG. Injuries to the cervical spine from diving accidents. *Trauma* **1975**;15:130–142
12. Evans DK. Anterior cervical subluxation. *J Bone Joint Surg [Br]* **1976**;58:318–321
13. Webb JK, Broughton RBK, McSweeney T, Park W. Hidden flexion injury of the cervical spine. *J Bone Joint Surg [Br]* **1976**;58:322–327
14. Babcock JL. Cervical spine injuries and surgery. *Arch Surg* **1976**;111:646–651
15. Braakman R, Penning L. The hyperflexion sprain of the cervical spine. *Radiol Clin Biol* **1968**;37:309–320
16. Whitley JE, Forsyth HF. The classification of cervical spine injuries. *AJR* **1969**;107:493–504
17. Scher AT. Anterior cervical subluxation: an unstable position. *AJR* **1979**;133:275–280
18. Juhl JH, Miller SM. Roentgenographic variations in the normal spine. *Radiology* **1962**;78:591–597
19. Catell HS, Filtzer DL. Pseudosubluxation and other normal variations of the spine in children. *J Bone Joint Surg [Am]* **1965**;47:1295–1309
20. White AA, Johnson RM, Panjabi MM, Southwick WO. Biomechanical analysis of clinical stability in the cervical spine. *Clin Orthop* **1975**;109:85–95
21. Bailey DK. The normal cervical spine in infants and children. *Radiology* **1952**;59:712–719
22. Swischuk LE. Anterior dislocation of C_2 in children: physiologic or pathologic? A helpful differentiating line. *Radiology* **1977**;122:759–763
23. Caffey J. *Pediatric x-ray diagnosis*, 6th ed. Chicago: Year Book Medical, **1972**
24. Cheshire DJE. The stability of the cervical spine following the conservative treatment of fractures and fracture-dislocations. *Paraplegia* **1969**;7:193–203