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Pseudospread of the Atlas: False Sign of Jefferson Fracture in Young Children

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Jefferson fractures are rare prior to teen-age. Three young children examined after trauma exhibited the characteristic spread appearance of the atlas, but fractures were excluded radiographically and clinically. A retrospective study demonstrated a similar appearance, termed "pseudospread," in most children aged 3 months to 4 years, including over 90% during the second year. Pseudospread results from a discrepancy between the "neural" growth pattern of the atlas and the "somatic" pattern of the axis. An "atlas spread index" is defined and a normal range presented. When an atlas fracture is suggested by apparent lateral spread of the lateral atlas masses, computed tomography is useful to demonstrate an intact atlas ring.

The Jefferson fracture is characterized by abnormal separation of the lateral masses of the atlas (C1) with fractures of its anterior and posterior arches. The wedge-shaped lateral masses are driven apart by a vertical compressive force applied to the top of the head [1]. As seen in the anteroposterior (AP) open-mouth view the lateral masses extend beyond the lateral margins of the articular surface of the axis vertebra (C2).

A similar finding was observed in three children after head trauma, leading to hospitalization for further workup of suspected Jefferson fractures. Radiographic and clinical assessment demonstrated no skeletal injury. A retrospective study of pediatric films was therefore undertaken in order to determine the prevalence, characteristics, and cause of false spread or "pseudospread" of the atlas.

Case Reports

Case 1

A 5-year-old boy fell down stairs, catching his head in the banister. He complained of headache and neck pain. Skull and cervical spine films were initially interpreted as normal, but upon review a Jefferson fracture was suggested (fig. 1A) and the child was recalled for admission. Computed tomography (CT) showed an intact atlas ring (fig. 1B).

Case 2

A 2½-year-old boy climbed out of his crib and landed "squarely on top of his head." Decreased motion of his neck was observed, and cervical spine films showed "displacement of the lateral masses of C1 laterally" (fig. 2A). A CT scan showed no fracture (fig. 2B).

Case 3

A 3-year-old boy fell out of bed and complained of neck pain and stiffness. Films showed "displaced lateral masses of C1 suggesting a Jefferson fracture" (fig. 3A), but CT was normal (fig. 3B).

In each case, plain films showed a normal atlas-odontoid distance and no prevertebral

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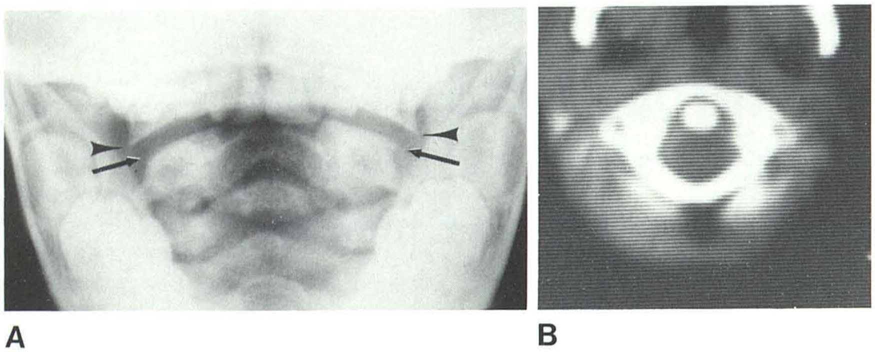


Fig. 1.—5-year-old boy. **A**, AP open-mouth view. Lower lateral margins of C1 (*arrowheads*) overhang articular surface of C2 (*arrows*). **B**, CT shows no fracture of C1.

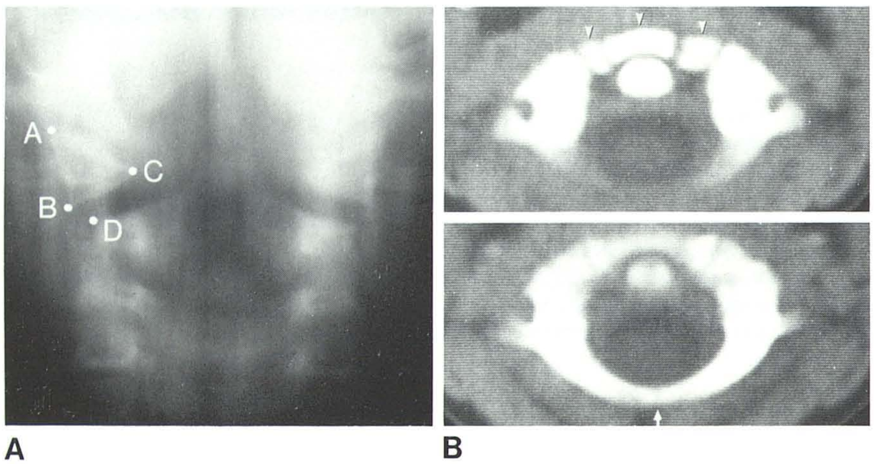


Fig. 2.—2½-year-old boy. **A**, AP tomogram shows pseudospread and points A, B, C, and D (see text). **B**, Contiguous CT slices show intact C1 ring. Posterior synchondrosis (*arrow*) is slitlike. Unusual tripartite ossification center in anterior arch (*arrowheads*) shows normal unequal spacing [3–5].

soft-tissue swelling. Each child was asymptomatic by the time of admission, showed no neurologic deficit, and was discharged after a normal CT scan was obtained.

Methods

Films of children under 7 years of age were obtained from the archives of the Montefiore Hospital and Medical Center and were analyzed retrospectively. Most were frontal skull films because this projection often shows C1 and C2 satisfactorily, especially if the child is crying (fig. 4). The three index cases were excluded. Also excluded were films showing rotation of C1 or C2 and cases with any cervical fracture or dislocation.

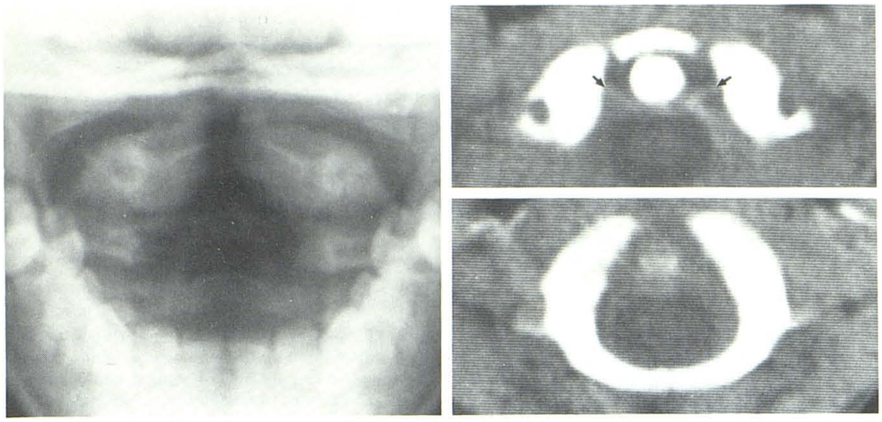
For the study of the prevalence of pseudospread, 104 cases were found in which the lateral margins of the atlantoaxial articulation (points B and D, fig. 2A) were definable bilaterally. Pseudospread was judged to be present if the lateral offsets on the two sides totaled at least 2 mm.

A ratio was sought that might characterize an abnormally spread atlas intrinsically without reference to C2. As indicated in figure 2A, the vertices of the roughly triangular lateral masses were designated A, B, and C. AA and BB represent, respectively, the distances between the upper outer corners and between the lower outer corners of the opposite lateral masses. CC is the distance between the most medial ossified points of the medial tubercles of the lateral masses. The ratios CC/AA (index I) and CC/BB (index II) were investigated as indices of the degree of spread. Each ratio, being less than unity, increases if a constant value (millimeters of pathologic spread) is added to both the numerator and the denominator. This portion of the study comprised 96 children up to age 4 in whom the AA, BB, and CC distances could be measured.

Results

Pseudospread of the atlas was found in most children 3 months to 4 years of age, with a prevalance of 91%–100% during the second year (table 1). The youngest example was 3 months old and the oldest was 5 years, 9 months. Eighty-four percent showed more than the minimum criterion of 1 mm/side (table 2). The children 3 months to 4 years of age were also evaluated according to their history of trauma, revealing no correlation with the prevalence or degree of pseudospread (table 3).

Although some temporal variation occurred, a morphologic sequence was discernible in the development of C1 and C2. During the first several months the lateral borders of C1 were slanted 30°–40° and were aligned along this diagonal with the margins of C2. By the end of the first year a definite bilateral lateral offset (pseudospread) usually interrupted this diagonal alignment. An inferolateral prominence developed on the atlas mass (fig. 4), making the orientation of its lateral border more vertical. Since no similar development appeared on the axis body, the pseudospread was increased. Aside from its short transverse process, C2 showed little bony material lateral to its pedicle, and the pedicle sat under the medial angle of the C1 lateral mass during the second and third years (figs. 2A, 3A, and 4). As the roof of the vertebral artery canal ossified, the articular plateau of C2 grew laterally but continued to terminate medial to the margin of C1 (fig. 5A). The amount of pseudospread tended to increase proportionally with the child's growth (table 2), with offsets of 1 mm on a side



A B

Fig. 3.—3-year-old boy. **A**, AP open-mouth view. Marked pseudospread, measuring 4–5 mm on each side. **B**, Contiguous CT slices show intact C1 ring. Line arcing behind odontoid represents transverse ligament of atlas (*arrows*).

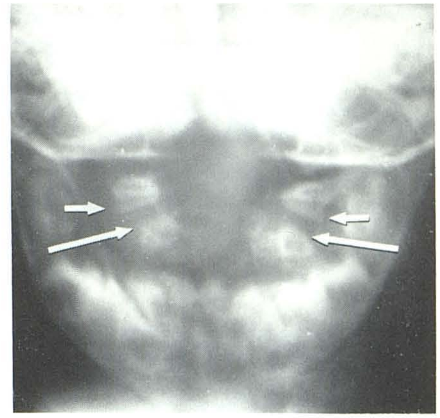


Fig. 4.—Crying child, 1 year old, provides optimal visualization of C1–C2 relationship. Marked pseudospread of atlas partly due to inferolateral prominence (*short arrows*) on each lateral mass. Lateral extent of articular surface of C2 (*long arrows*).

TABLE 1: **Age and Pseudospread**

Age (mos.)	No. Children	No. with Pseudospread (%)
0.5–3	10	1 (10)
3^+–6	14	8 (57)
6^+–9	18	14 (78)
9^+–12	10	7 (70)
12^+–18	11	10 (91)
18^+–24	9	9 (100)
24^+–36	12	8 (67)
36^+–48	9	5 (56)
4^+–7 yrs	11	2 (18)
Totals	104	64

TABLE 2: **Widths of Pseudospread in 64 Children**

Age	Total Lateral Offset of C1, Right + Left Sides (mm)					
	2	3–3.5	4–4.5	5	6	8
3–6 mos	6	1	2	0	0	0
6^+ mos–2 yrs	4	10	17	6	3	0
2^+–7 yrs	0	2	4	2	5	2

typical during the first year, 2 mm on a side during the second, and 3 mm during the third. Thereafter the pseudospread phenomenon waned and vanished, although two children, aged 3½ and 5¾, showed total spreads of 8 mm.

Of the two possible atlas spread indices, index I had slightly better relative precision and furthermore, being closer to 0.5, is theoretically more sensitive to a given degree of pathologic spread. It was also somewhat more frequently definable than index II. Table 4 gives the means and "normal ranges" of both indices. These ranges varied by small but significant amounts with age within the study group because concentric ossification of each lateral mass progressively reduces the indices until teen-age, when index I stabilizes at 0.32 ± 0.04 (2 SD) (24 normal teenagers and adults). The indices for cases 2 and 3 were normal, while points A and C were not visualized in case 1. No gender difference was observed in the prevalence of pseudospread or in the atlas spread indices.

Discussion

Pediatric Jefferson fractures are very rare. It is ironic that in Jefferson's classic review of atlas fractures [1] the earliest case, dating from 1822, was an example of this bursting type found at autopsy in a 3-year-old boy [2]. Not another documented Jefferson fracture in a child prior to teen-age has been reported in 160 years. The reasons for this scarcity are probably fourfold: children weigh less, their skulls are more plastic and absorbent of force, their necks are more flexible, and the synchondroses of C1 may serve as an elastic buffer. In other words, while the mechanism of the fracture as postulated by Jefferson [1] depends on axial loading of the craniocervical unit, children are probably less subject to and more tolerant of this type of force.

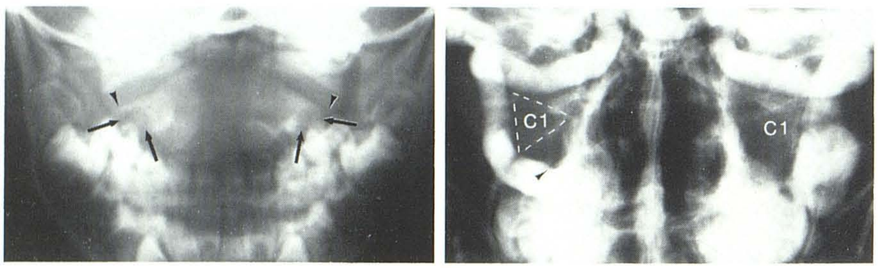
Pseudospread of the atlas is a common if not universal developmental phenomenon. Trauma is not a contributing factor. Rotation can produce various types of offset [6, 7] but was excluded in this study. In the past, children with pseudospread have been assumed to have unseen atlas fractures [8]. Some other authors have considered this finding to be normal [9, 10], but no documentation has heretofore been published. The pseudospread phenomenon has not been mentioned in descriptions of the development of the cervical spine in childhood [11].

Budin and Sondheimer [9] postulated a disparity in the growth rates of the atlas and the axis. Zaborowski [12] observed that "the width of the atlas shows higher growth dynamics during the first year of life compared with the axis." Our own data agree with these authors by showing a rapidly increasing prevalence of pseudospread during the first year, consistent with a faster atlas growth rate. This is a neural pattern [13], comparable to the growth of the skull. The subsequent disappearance of pseudospread indicates catch-up growth (a somatic pattern) by the axis during the third to sixth years. Delayed ossification and limited visualization of the lateral portions of the body of the axis, hollowed out and thinned by the vertebral artery canal (fig. 5), are contributing factors.

TABLE 3: **Trauma and Pseudospread, Ages 3.5 Months to 4 Years**

History	No. with Pseudospread (%)	Mean Spread (mm) ± 2 SD in Positive Cases	Atlas Spread Index CC/AA
No trauma	17/23 (74)	4.0 ± 1.8	0.50 ± 0.03 (n = 29)
Possible trauma	9/12 (75)	3.7 ± 1.3	0.50 ± 0.04 (n = 13)
Trauma, no fracture	25/36 (69)	4.3 ± 1.1	0.51 ± 0.03 (n = 34)
Skull fracture	10/12 (83)	3.5 ± 0.7	0.50 ± 0.04 (n = 13)

Note.—AA is the distance between the upper outer corners of the opposite lateral masses; CC is the distance between the most medial ossified points of the medial tubercles of the lateral masses.



A B

Fig. 5.—Vertebral artery canal through C2. **A**, 3½-year-old child. Vertebral artery canals (*arrows*) clearly seen immediately beneath articular surfaces of C2. Canal roof becomes thinner laterally (*arrowheads*) and may continue as cartilage for unknown distance. **B**, Vertebral arteriogram from 5-year-old child. As vertebral artery passes upward through C2 it turns sharply to run laterally directly beneath articular surface of C2. Bony roof of this canal terminates (*arrowhead*) well medial to lateral margin of C1 lateral mass (highlighted by dashed line).

TABLE 4: **Normal Ranges of Atlas Spread Indices**

Age	Mean Spread Index ± 2 SD*	
	I (CC/AA)	II (CC/BB)
0.5–6 mos	0.52 ± 0.06	0.63 ± 0.08
t test (2-tailed)	$p < 0.01$	$p < 0.001$
6^+ mos–2 yrs	0.50 ± 0.06	0.58 ± 0.07
t test (2-tailed)	$p < 0.01$	$p < 0.01$
2^+–4 yrs	0.48 ± 0.05	0.55 ± 0.07

Note.—AA and BB are the distances between the upper outer and lower outer corners of the opposite lateral masses, respectively; CC is the distance between the most medial ossified points of each medial tubercle of the lateral masses.
* 95% confidence interval.

Since bilateral lateral offset of C1 with respect to C2 in children is not an indicator of a spreading process of C1, other means of recognizing a Jefferson fracture without the misleading comparison with C2 would be desirable. CT demonstrates the atlas ring well, but this examination is limited by cost, additional time and radiation, and availability. The atlas spread index is an intrinsic estimator of C1 morphology, completely independent from the phenomenon of pseudospread. It may therefore be used as supporting evidence to exclude fracture in a child when a "funny looking atlas" is actually well within normal limits.

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