Radiology of postnatal skeletal development

XIII. C1–C2 interrelationships

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Abstract. Composites of C1 and C2 were analyzed in various roentgenographic projections to elucidate osseous interrelationships and the effect of overlap of different portions of these two vertebrae in standard radiographic projections during differing stages of postnatal chondro-osseous transformation. In anteroposterior projections the dento-central synchondrosis of C2 normally was located below the inferior rim of the C1 anterior ossification center. The upper extent of the dens ossification center was behind this anterior C1 center. The overlap made visualization of the ossiculum terminale difficult. The spinous process of C1 could be confused with the ossiculum. In transverse projections, the normal laxity characteristic of young children allowed considerable variation in rotational interrelationships. Various degrees of such instability are illustrated. In lateral views variation of the anterior contour of the dens was significant. Such variation must be considered developmental due to the location and direction of growth of the chondrum terminale and interactive modeling between C1 and C2 to allow extension at this particular joint.

Key words: Atlas – Axis – Rotatory subluxation – Displacement – Predens space

The developing atlas (C1) and axis (C2) may present significant diagnostic problems prior to skeletal maturation [8, 9]. While the interrelationships of these two vertebrae are relatively easily interpreted in standard lateral projections, there is still some question regarding the normality of configurations such as the predens space [1]. The assessment of anteroposterior and oblique projections often is difficult because of superimposed craniofacial components and air shadows within the oropharynx and nasopharynx. In previous publications the specific radiographic anatomy of the atlas and axis each were presented [10, 11]. This allowed a better appreciation of the detailed radiologic anatomy of each vertebra, without superimposition of multiple osseous elements. In this study the two vertebrae have been analyzed as a conjoint unit, but without superimposed craniofacial elements. Normal radiography and developmental variation (i.e., the predens space) have been assessed. Common disorders such as subluxation and hypermobility have been duplicated with these specimens for specific radiographic analysis.

Methods and materials

The cervical vertebrae were removed from 36 skeletally immature cadavers ranging in age from full-term neonate to 14 years. The atlas and axis (C1 and C2) usually were separated from the lower cervical vertebrae and dissected free of extraneous soft tissues (muscle, fat), while leaving ligaments intact. Each composite unit was radiographed intact in anteroposterior, oblique, and lateral projections, as well as views duplicating cross-sectional scanning (computed tomography (CT), magnetic resonance (MRI)). Similar cross-sectional radiography then was done with the two vertebrae either displaced laterally or in maximum rotation relative to each other. In selected vertebrae the dens was removed at the facet level to duplicate a hypoplastic dens. All radiographs were done with the vertebrae placed directly on the film cassette to negate distortion or magnification. In addition the first and second cervical vertebrae from 11 commercially prepared skeletons ranging in age from approximately 3 to 14 years were similarly analyzed.

Results

Anterior projections. Without the superimposition of the cranial and facial bones, the anatomy was better evident. By four to five years of age (Fig. 1) the synchondroses were closing. The proximal ex-
Fig. 1. A Anteroposterior view of C1 and C2 from a four-year-old. Note the multifocal ossification in the anterior portion of C1 (white arrows). The continuous dentocentral and neurocentral synchondroses (black arrow) are closing. B Anteroposterior view of C1 and C2 from a three-year-old. Note the paired neurocentral synchondroses of C1 (solid white arrow), juxtaposition of the inferior margin of C1 and the tip of the dens (open black arrow), and the neurocentral (open white arrow) and dentocentral (solid black arrow) synchondroses of C2.

Fig. 2. Anteroposterior view of C1 and C2 from an eight-year-old. The neurocentral synchondroses are completely closed and remodeled, while the dentocentral synchondrosis is still evident (straight arrow). The proximal dens has a V-shaped appearance behind a bifid anterior C1 ossification center (curved arrows).

Fig. 3. Anteroposterior views of C1 and C2 from two different 11-year-old children. Note the appearance of the ossiculum terminale behind the anterior ossification center of C1 (curved arrow). Also note the variable appearance of the closed dentocentral synchondrosis (straight arrow). In B the second and third vertebra are congenitally fused with the interspace having a radiographic appearance similar to the dentocentral closure above it.

Fig. 4. Anteroposterior view of C1 and C2 from a 14-year-old showing a well developed ossiculum terminale and physis (arrow) behind C1.

tent of dens ossification was at the lower margin of C1 anterior ossification. Variations in anterior ossification of C1 created irregular radiodensities. Similarly, the neurocentral synchondroses of C1 and C2 and the dentocentral synchondrosis of C2 created overlapping radiolucencies. Like any other growth plate, closure of these synchondroses was preceded by formation of a sclerotic line as the subchondral bone thickened (Fig. 1A). By eight to nine years the proximal dens ossification ex-