Clinical Imaging 40 (2016) 1182–1190

Contents lists available at ScienceDirect

Clinical Imaging

journal homepage: http://www.clinicalimaging.org

# "Children are not small adults": avoiding common pitfalls of normal developmental variants in pediatric imaging

Akshay D. Baheti *, Ramesh S. Iyer, Marguerite T. Parisi, Mark R. Ferguson, Edward Weinberger, A. Luana Stanescu

*Department of Radiology, Seattle Children's Hospital and the University of Washington, Seattle*

ARTICLE INFO

*Article history:*
Received 18 April 2016
Received in revised form 3 August 2016
Accepted 8 August 2016
Available online xxxx

*Keywords:*
Developmental variants
Normal variants
Anatomic variants
Physiologic

ABSTRACT

Imaging of children is complicated with a vast array of normal variants, congenital or developmental disorders, and age-dependent differential considerations. We present imaging findings of several common anatomic variants as well as physiological and maturational processes that occur in children. We compare and contrast them with pathological entities so that the reader can successfully distinguish them when interpreting pediatric imaging examinations. The content has been accrued from the authors' collective experience at a tertiary-care pediatric hospital, teaching and consulting with radiology trainees and clinicians, as well as a comprehensive review of the literature, and is intended to represent a useful error prevention tool for radiologists interpreting pediatric studies.



## 1. Introduction

Imaging of pediatric patients is complicated with a vast array of normal variants, congenital or developmental disorders, and age-dependent differential considerations. Children, after all, are not simply small adults, and it is vital to appreciate the specific imaging findings inherent to this young patient population to accurately interpret their diagnostic examinations.

The authors of this review work in an academic tertiary-care pediatric hospital and are responsible for teaching radiology residents and consulting with pediatric as well as nonpediatric radiologists around the region. Based on their feedback and queries, several challenges and misperceptions specific to pediatric imaging have been observed. Most of the confusion stems from difficulty in distinguishing age-related normal variant anatomy or physiologic differences from true pathological processes. Indeed, John Caffey, widely viewed as the father of pediatric imaging, stated that "most mistakes I've seen were not because one didn't know some disease, but because he didn't know he was looking at normal."

In this article, we present multimodality imaging findings of several common normal anatomic variants as well as findings related to physiological and maturational processes that occur in children. We compare and contrast them with pathological entities so that the reader can successfully distinguish them when interpreting pediatric imaging examinations. This article is intended to represent a useful error prevention tool especially for radiology trainees as well as nonpediatric radiologists.

## 2. Anatomic variants

### 2.1. Calvarial sutures

The major calvarial sutures include the coronal, sagittal, lambdoid, metopic, and squamosal sutures. All of these except for the metopic suture fuse in the late third decade of life. The metopic suture typically fuses between 3 and 9 months of age [1,2]. However, there can be multiple other accessory sutures present, usually involving the occipital or parietal bones since they arise from multiple ossification centers, six and two, respectively [3]. Similar to major sutures, accessory sutures may be identified on computed tomography (CT) by their corrugated or zig-zag morphology and sclerotic margins. They are usually bilateral and symmetric in appearance (Fig. 1A). This is in contrast to fractures, which are linear with nonsclerotic borders, may cross suture lines, and may be associated with sutural diastasis or subgaleal swelling [3] (Fig. 1B). Intrasutural or wormian bones represent an anatomic variant encountered most frequently along the lambdoid sutures. The inca (preinterparietal) bone is a large triangular wormian bone seen along the superior aspect of the occipital bone, delineated inferiorly by the mendosal suture that should not be confused with a fracture fragment (Fig. 1C) [4].

### 2.2. Cervical spine

The C1 vertebral body widens mediolaterally at a faster pace compared to C2 early in childhood. This allows the C1 lateral masses to exhibit apparent lateral offset with respect to C2 on the open-mouth odontoid view, simulating a C1 ring fracture [5,6] (Fig. 2). Up to 6 mm lateral offset of the lateral masses may be normally seen up to 4–7

* Corresponding author. Tel.: +1 206 987 2134; fax: +1 206 987 2341.
*E-mail address:* akshaybaheti@gmail.com (A.D. Baheti).

http://dx.doi.org/10.1016/j.clinimag.2016.08.008
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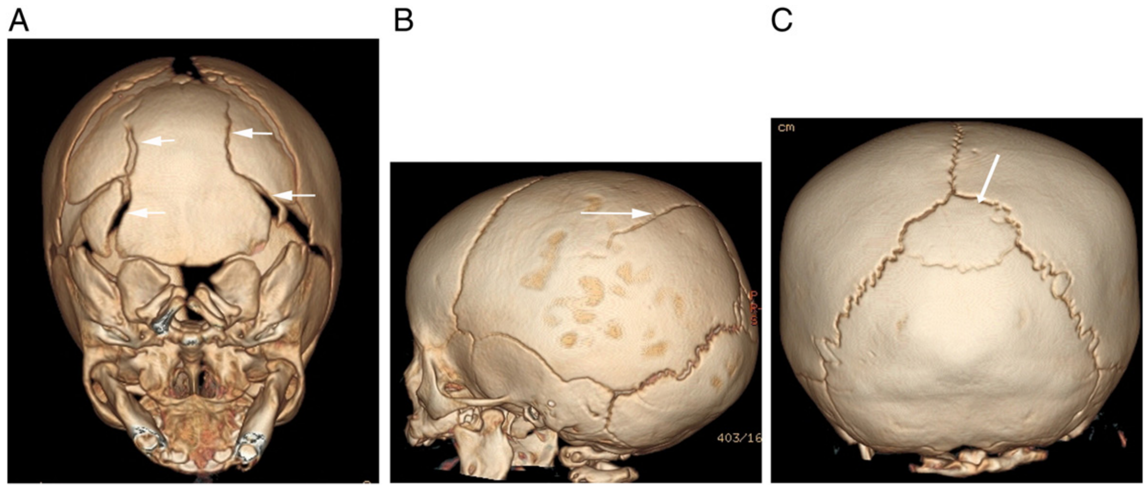


**Fig. 1.** Calvarial sutures versus fractures. (A) Nine-week-old female status post a fall. A noncontrast CT of the head was performed. Three-dimensional (3D) calvarial reconstruction demonstrates accessory sutures (arrows), which are seen frequently in the parietal and occipital bones, often symmetric, with a similar corrugated contour as adjacent sutures. (B) Six-month-old male status post a fall. 3D skull reformat of a noncontrast head CT shows a sharply marginated fracture of the left parietal bone (arrow) extending to the sagittal suture, demonstrating a regular, sharp contour as compared to adjacent sutures. Overlying soft tissue swelling is usually present in the acute and subacute phase. (C) Seven-month-old female status post fall. 3D skull reformat on a noncontrast head CT demonstrates the presence of the inca bone, a normal variant (arrow).

years of age, after which it gradually resolves due to increased proportional growth of the axis. This finding is called pseudospread of the atlas or pseudo-Jefferson fracture [5,6]. A true Jefferson (C1 ring) fracture is uncommon in this age group and should be suspected only in a suggestive clinical context and greater C1 lateral mass offset with associated prevertebral soft tissue swelling [5–7].

C2–C3 pseudosubluxation is another common finding in the pediatric cervical spine and mimics true anterolisthesis of C2 on C3. It was incidentally observed in 46% of children less than 8 years of age in a study of 160 patients and in 22% of children less than 16 years of age with history of polytrauma in another study of 138 patients [8,9]. In physiologic pseudosubluxation, the posterior cervical line (drawn along the anterior spinous processes of C1 and C3) touches or lies 1 mm anterior to the corresponding C2 spinous process in both flexion and extension [6,9]. If the distance is greater than 2 mm, it indicates the presence of a true injury [6]. It is of critical importance to identify pseudosubluxation as a normal variant in patients with a history of trauma or suspected child abuse (Fig. 3).

### 2.3. Thymus

Typically large at birth, the thymus gradually decreases in size after 2 years of age and is usually not visible on a chest radiograph after 8 years. While generally located in the anterior mediastinum, it may extend to the inferior thyroid pole superiorly and the diaphragm inferiorly [10]. It is usually seen on a chest radiograph as a unilateral or bilateral soft tissue density structure with smooth or wavy borders (the "wave sign") due to the impression of the anterior rib ends [10] (Fig. 4). It is often less dense than the underlying pulmonary vessels which can be seen through it. On ultrasound (US), the thymus is homogeneously hypoechoic with multiple internal linear and punctate echogenic foci that likely represent connective tissue septae and vessels [10,11]. On CT, the thymus is initially large and polygonal in shape with convex borders until about 5 years of age, and thereafter, it appears more triangular with straight or concave borders, reflecting the natural involution process [10].

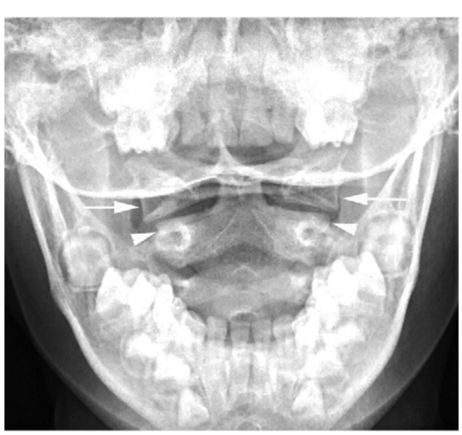

**Fig. 2.** Pseudo-Jefferson fracture. A 4-year-old female with neck pain post fall from a swing. Open mouth odontoid view radiograph shows the lateral masses of the atlas (arrows) extending laterally beyond the lateral margins of the axis (arrowheads). Up to 6 mm of displacement of the lateral masses is normal in children up to the age of 7 and is due to a faster transverse growth rate of the axis relative to the atlas early in life.

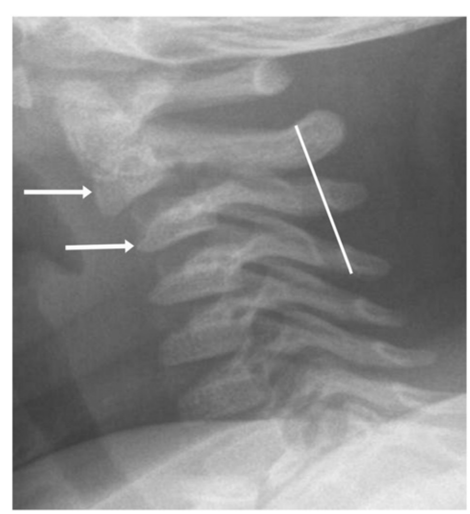

**Fig. 3.** Pseudosubluxation of C2 on C3 demonstrated on lateral radiograph of the cervical spine in a 2-year-old female. In children younger than 10, ligamentous laxity permits normal mobility of C2 on C3 (arrows). A normal posterior cervical line (marked with a white line) and the absence of prevertebral soft tissue swelling differentiate this normal variant from a true cervical spine injury.