A Novel Vertebral Numbering System Using EOS Imaging

Rachael Weesner, MS4; Clay Hoffman, MS4; Christopher Kleck, MD; Shahbaaz Sabri, MD; Renzo Laynes, MD; Nathaniel Stringer, DO; Joseph C Chavarria, MD; David Ou-Yang, MD; Evalina Burger-Van Der Walt, MD

Anschutz ORTHOPEDIC RESEARCH

Background

- Congenital spinal abnormalities include anomalies of the cervical region, unilateral failure of vertebral segmentation, greater or less than 12 ribbed segments, and lumbosacral transitional vertebrae[1-4]
- Failure to detect congenital spinal anomalies can lead to inconsistencies with vertebral numbering[5]
- Vertebral numbering inconsistency, mislabeling, and errors can have devastating implications for patients, including catastrophic intraoperative events such as wrong-level spinal surgery[6-7]
- Variation in detection methods, regions of the spine imaged, and patient populations have prevented radiologists and surgeons from reaching a consensus on how best to identify and label anomalous spinal anatomy
- EOS (whole spine) imaging may allow more comprehensive detection all patients with congenital cervical, thoracic, and lumbosacral anomalies of the spine, allowing us to generate a method that can easily and accurately applied to segmental radiographs when full-body EOS imaging is not available[8]

Research Questions

1. How common are congenital rib and vertebral anomalies and in what patterns do they most often occur in EOS full-length spine imaging?
2. What vertebral counting method best accounts for transitional anatomy of the spine and can provide the lowest error when utilizing limited imaging of the spine?

Methods

- Retrospective, single institution, image analysis study of 3250 images from patients >18 years old who obtained full-length EOS spine imaging at UCH
- 5 labelers; Discrepancies in 63 images resolved by musculoskeletal radiology attending
- Counting and Labeling Criteria (determined by musculoskeletal radiologists, neurosurgical spine surgeons, and orthopedic spine surgeons)
  - The sacrum (S1) considered to be the endpoint of mobile segments
  - Starting at the skull base, count caudaully until reaching the sacrum to identify # of pre-sacral mobile segments
  - In normal (absence of transitional) anatomy, there are 24 pre-sacral mobile segments (L5 being the last)
  - Identified first and last ribbed segments
  - Recorded hypoplastic, incomplete, and unilateral ribs, in addition to failure of formation or failure of segmentation

Results

Incidence and Patterns of **Vertebral Anomalies** of the 3147 images analyzed:

- 8.8% had Lumbosacral Transitional Anatomy (LSTA); of these, 62.4% had 25 pre-sacral mobile segments and 37.3% had 23 pre-sacral mobile segments
- No patients had an abnormal number of cervical vertebrae
- *All observed transitional anatomy was lumbosacral*

Incidence and Patterns of **Congenital Rib Anomalies** of the 3147 images analyzed:

- 5.4% had an abnormal number of ribs (> or < 12); of these, 83.6% had 11 ribs and 16.4% had 13 ribs
- 3.5% had incomplete or hypoplastic ribs
- **Location of first ribbed vertebrae**: at the 8th pre-sacral mobile segment for 99.6%; remainder at the 7th or 9th
- **Location of last ribbed vertebrae**: at the 19th segment (normal anatomic level) in 94.7% of patients, 4.5% at the 18th segment, 0.76% at the 20th segment

Vertebral Counting Method in the Setting of Transitional Anatomy

- 1.8% had both LSTA and a rib anomaly (either rib number or rib location)

  In this subset:
  - 67.9% had 23 pre-sacral mobile segments + abnormal number of ribs; 30.4% had 25 pre-sacral mobile segments + abnormal number of ribs
  - 70% had LTSA + 11 ribs; 30% had LTSA + 13 ribs
  - Three patients had both LSTA and **abnormal rib location** (not abnormal rib #) first ribbed vertebrae at the 7th (opposed to 8th) pre-sacral segment

Patients with four non-ribbed lumbar pre-sacral segments were more likely to have 23 pre-sacral mobile segments and 12 ribs (2.1%) than 24 pre-sacral segments and 13 ribs (0.3%).

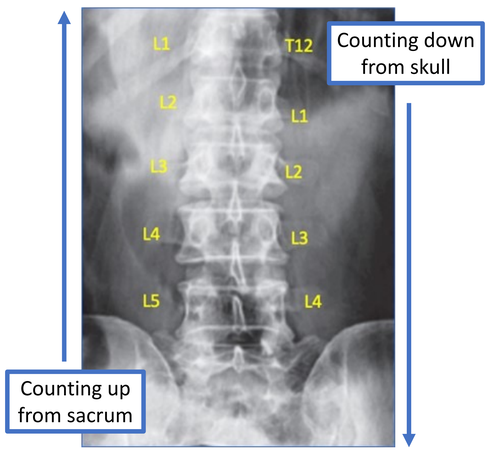

Figure 3. An AP lumbar radiograph demonstrating four non-ribbed pre-sacral lumbar segments numbered in two different ways. The method on the right accounts for the more common abnormality (having 23 pre-sacral mobile segments) rather than the less common abnormality (having 13 ribs).

Patients with six non-ribbed lumbar pre-sacral segments were more likely to have 25 pre-sacral mobile segments and 12 ribs (5.0%) than 24 pre-sacral segments and 11 ribs (3.3%).

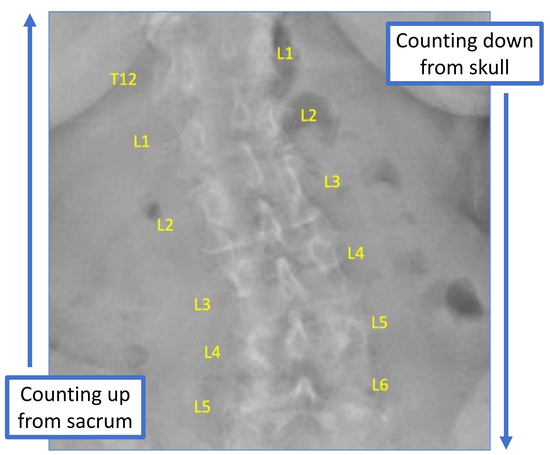

Figure 4. An AP lumbar radiograph demonstrating six non-ribbed pre-sacral lumbar segments numbered in two different ways. The method on the right accounts for the more common abnormality (having 25 pre-sacral mobile segments) rather than the less common abnormality (having 11 ribs).

Limitations

- Single-institution study
- Images analyzed were obtained in a population being seen in a clinical setting for evaluation
- None of our patients had extra cervical vertebrae contributing to their transitional anatomy

Discussion

- While classification systems exist that describe different anomalies, they do not aid in accurate labeling of vertebral levels in the setting of variable anatomy[9]
- Conventional methods of counting and numbering vertebrae do not consistently account for patients with congenital rib and vertebral anomalies[10-12]
- They inaccurately assume that the most caudal pre-sacral segment in the lumbar spine is indeed L5 and that patients will always have 12 ribbed vertebrae (not always the case in patients with congenital spinal anomalies)
- Our study shows that patients with < or > 5 nonribbed (traditionally called “lumbar”) vertebrae are more likely to have an abnormal total number of pre-sacral mobile segments (23 or 25) than to have an abnormal number of ribs (11 or 13)
- New method for when EOS is not available: label first non-ribbed vertebrae as the first segment of the lumbar spine (L1)
- Then, if four or six lumbar segments are identified, they label the spine in a manner that accounts for the most likely form of congenital anomaly: one with an abnormal number of lumbar vertebrae, not an additional or missing ribbed segment

Conclusions

- Transitional lumbosacral anatomy is more common than ribbed vertebral body anatomic variations
- **New numbering system**: count in a cranial to caudal direction, with the first ribbed vertebra labeled as thoracic (T1) and the first non-ribbed vertebra in the lumbar spine labeled as lumbar (L1)
- **Goal of the new method**: improve consistency between radiologists and surgeons and decrease the risk of wrong level surgery in the setting of transitional anatomy
- **Future directions**: test this method at multiple institutions beyond UCH

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