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Evaluation of a semi-automated software program for the identification of vertebral fractures in children

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AIM: To assess observer reliability and diagnostic accuracy in children, of a semi-automated six-point technique developed for vertebral fracture (VF) diagnosis in adults, which records percentage loss of vertebral body height.

MATERIALS AND METHODS: Using a semi-automated software program, five observers independently assessed T4 to L4 from the lateral spine radiographs of 137 children and adolescents for VF. A previous consensus read by three paediatric radiologists using a simplified algorithm-based qualitative technique (i.e., no software involved) served as the reference standard.

RESULTS: Of a total of 1,781 vertebrae, 1,187 (67%) were adequately visualised according to three or more observers. Interobserver agreement in vertebral readability for each vertebral level for five observers ranged from 0.05 to 0.47 (95% CI: -0.19, 0.76). Intra-observer agreement using the intraclass correlation coefficient (ICC) ranged from 0.25 to 0.61. The overall sensitivity and specificity were 18% (95% CI: 14–22) and 97% (95% CI: 97–98), respectively.

CONCLUSION: In contrast to adults, the six-point technique assessing anterior, middle, and posterior vertebral height ratios is neither satisfactorily reliable nor sensitive for VF diagnosis in children. Training of the software on paediatric images is required in order to develop a paediatric standard that incorporates not only specific vertebral body height ratios but also the age-related physiological changes in vertebral shape that occur throughout childhood.

Introduction

Fractures are common in childhood and repeated fractures reflect the interacting effects of low bone mineral density (BMD) and/or physical activity.[1] Vertebral fractures (VFs) are a relatively common type of osteoporotic fracture.

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The detection of one or more vertebral compression (crush) fractures (identified by a 20% reduction in vertebral body height) is indicative of bone fragility irrespective of the reported BMD.[1] Although a lot of recent research has been conducted regarding the occurrence of osteoporotic VF in adults, relatively less attention has been paid towards paediatric VF, largely owing to the lack of an accepted standardised diagnostic technique in children.[2]

In the absence of major trauma, reduced BMD in children and adolescents is the major cause of VF; indeed, the finding of a VF is a main diagnostic feature of low BMD in children.[1] Low BMD may be primary (e.g., osteogenesis imperfecta) or secondary.[1,3] For example, the STOPP (Steroid-associated Osteoporosis in the Paediatric Population) studies have implicated glucocorticoids as a significant cause of secondary fractures in children and shown an incidence of VFs in those with a new diagnosis of acute lymphoblastic leukaemia of 16%.[4,5] Unlike osteoporotic fractures of the limbs, VFs are typically silent and if untreated may lead to progressive loss of vertebral body height and potential spinal deformity. If VFs are diagnosed early, however, bisphosphonate treatment can help to treat existing fractures and reduce future fracture risk.[6]

Assessment of VFs in children is performed using standard lateral spine radiographs and, currently, these are interpreted using a subjective visual assessment method to identify loss of height/change in shape consistent with VF. This approach is hampered by significant inter- and intra-observer variability,[2,7,8] which is likely to be reduced if a more objective assessment method is applied. Semi-automated software programs such as SpineAnalyzer (Optasia Medical, Cheadle, UK) may be the solution, but so far, limited studies have been carried out to evaluate these programs in children. The potential added value of these programs is that non-radiologists may be trained to use them, freeing up radiologists' time for more specialised tasks.

The purpose of this study was to assess the observer reliability and diagnostic accuracy in children and adolescents, of the semi-automated six-point technique developed for VF diagnosis in adults, using a semi-automated software program (SpineAnalyzer). This software records percentage loss of vertebral body height and classifies fractures based on the Genant system.[9]

Materials and methods

Study population

This study involved the retrospective analysis of images obtained as part of a larger prospective study of 250 children recruited between November 2011 and February 2014.[7] All images used in this study were of patients recruited from one centre. The mean age of the 137 patients at the time of image acquisition was 12 years (range 5–15) and 45 (33%) were male. The majority, 199 (80%), had suspected reduction in BMD (including children with osteogenesis imperfecta, inflammatory bowel disease, rheumatological conditions, cystic fibrosis, and coeliac disease). The remaining 51 (20%) patients were recruited from the spine clinic.

Local Research Ethics Committee approval was obtained for the main study from which the images were drawn, but was not separately required for this study. The study was registered with the Research and Innovation Department prior to commencement.

Lateral spine imaging

Lateral images of the thoracolumbar spine were acquired using one of two Phillips Healthcare machines (TH3 Digital or TH Bucky Diagnost, Guildford, UK) following European guidelines for imaging the spine in children as previously described.[7] The patients were asked to remain in the lateral decubitus position with flexed knees and hips. Depending on the size of each child being examined, thoracolumbar or separate thoracic and lumber spine images were obtained. As outlined in a previous study, the tube-to-film distance was set at 100 cm, and the films were centred at T7 and L3 for the thoracic and lumbar views, respectively.[10] The average exposures for thoracic, lumbar, and thoracolumbar spine radiographs were 75, 84, and 74 kV, respectively.

Image analysis

Lateral spine images were analysed independently by five observers (a radiologist, two radiographers, and two medical students), who attempted readings for all 137 cases, with each observer being blinded to the other evaluations. Prior to commencing the study, the four non-radiologists were trained to use the software by the radiologist, learning from non-study spine radiographs. A previous consensus arrived at by three paediatric radiologists using a simplified algorithm-based qualitative (ABQ) technique (i.e., with no software involved) served as the reference standard.[10]

As the first step in the semi-automated analysis using SpineAnalyzer, observers identify the T4 to L4 vertebral bodies by placing a point at or close to the centre of each vertebral body and indicating to the software the highest identified vertebral body (for example, T4). Having indicated T4, the software program recognises all identified vertebral bodies between T4 and L4 and automatically identifies six points corresponding to the four corners and the midpoints of the superior and inferior endplates of each vertebral body; observers modify the placement of these points as necessary. The software does not recognise vertebral bodies above T4 or below L4 (Fig 1).

Following placement of the six points, anterior, middle, and posterior vertebral heights are automatically determined by the software. With the help of these measurements, the anterior: posterior, middle: posterior, posterior: posterior^{+1}, and posterior: posterior^{-1} height ratios are calculated (+1 and −1 indicate the vertebrae immediately above [+1] and below [−1] the vertebra of interest). The vertebral bodies are then classified according to their height ratios, based on the scoring system developed by Genant (Table 1, Fig 1).[9]

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