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Technical Report

A semiautomatic method to identify vertebral end plate lesions (Schmorl's nodes)

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Abstract

BACKGROUND CONTEXT: There are differences in the definitions of end plate lesions (EPLs), often referred to as Schmorl's nodes, that may, to some extent, account for the large range of reported prevalence (3.8%–76%).

PURPOSE: The purpose of this study was to develop a technique to measure the size, prevalence, and location of EPLs in a consistent manner.

STUDY DESIGN/SETTING: This study proposed a method using a detection algorithm that was applied to five adolescent females (average age, 15.1 [range, 13.0–19.2] years) with idiopathic scoliosis (average major Cobb angle, 60° [range, 55°–67°]).

METHODS: Existing low-dose, computed tomography scans were segmented semiautomatically to extract three-dimensional morphology of each vertebral end plate. Any remaining attachments to the posterior elements of adjacent vertebrae or end plates were then manually sectioned. An automatic algorithm was used to determine the presence and position of EPLs.

RESULTS: End plate lesions were identified in 15 of the 170 (8.8%) end plates analyzed with an average depth of 3.1 mm. Eleven of the 15 EPLs were seen in the lumbar spine. The algorithm was found to be most sensitive to changes in the minimum EPL gradient at the edges of the EPL.

CONCLUSIONS: This study describes an imaging analysis technique for consistent measurement of the prevalence, location, and size of EPLs. The technique can be used to analyze large populations without observer errors in EPL definitions.

Keywords: End plate lesion; Schmorl's node; Scoliosis; End plate irregularity; Computed tomography; Idiopathic Scoliosis; Vertebral end plate

Introduction

There is a general consensus that end plate lesions (EPLs), often referred to as Schmorl's nodes, can be defined as a herniation of intervertebral disc tissue into the vertebral body [1–5]. However, more specific definitions tend to differ. Constraints include indentations located

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centrally on the end plate [6], delineation by a thin sclerotic boundary [6], minimum size (distance from most anterior to most posterior edge of the EPL measured on sagittal images) [3], or the exclusion of smooth concave curvatures that have their center located at the posterior portion of the end plate (otherwise known as Cupid's bows) [3–5] because these are not considered to be pathological [7,8].

These differences may, to some extent, account for the large range of reported prevalence (3.8%–76%). Hilton et al. [9] analyzed 50 slab radiographs (cadaveric specimens, sliced sagittally into slabs that are individually radiographed) of thoracolumbar specimens (T9–S1) aged 13 to 96 years, finding that 76% had EPLs at 1 or more levels; also looking at slab radiographs (100 cadaveric thoracolumbar specimens, mean age, 68 [range, 43–93] years), Pfirrmann and Resnick [4] found that 58% of their specimens had at least 1 EPL; analyzing 372 contrast-enhanced magnetic resonance images (MRIs) of the thoracic and lumbar spine in subjects with a mean age of 53 years, Stäbler et al. [3] reported that EPLs were present in 38% of the subjects; and Sonne-Holm et al. [6] reported that at least one EPL was present in 3.8% of a series of 4,151 plain, lateral radiographs of lumbar spines in subjects aged 22 to 93 (median, 63) years.

The large discrepancies in reported prevalence could also be explained by the different imaging modalities used to observe EPLs. It has been suggested that observation of EPLs is more difficult on plain radiographs in comparison with MRI and slab radiographs [4,10] and that computed tomography (CT) scans may provide a more precise method of observing EPLs [6].

A number of studies have attempted to measure the location, size, and prevalence of EPLs. They are generally found at the thoracolumbar junction either centrally or posteriorly on the end plate but rarely anteriorly [2,4–6,9]. Two studies have found that EPLs are more common in the end plates on the caudal side of the vertebra in comparison with the cranial [4,9], but others have found no difference [2,6]. It is common for EPLs to be found at multiple levels in the same patient, and there is a tendency for successive vertebral surfaces to be affected with nodes of similar shape and position [2,4,6,9]. Pfirrmann and Resnick [4] found that EPLs had a mean diameter of 6 (range, 2–15) mm, a mean height of 3.3 (range, 1–9) mm, and a mean volume of 86 (range, 2–923) mm^3. Stäbler et al. [3] reported a slightly larger mean diameter of 8.2 (range, 4–20) mm; however, this could be accounted for by the fact that they excluded any EPLs with a diameter less than 3 mm, unfortunately depth and volume were not reported in this study.

Both the etiology and pathogenesis of EPLs are uncertain [6,9]. It has been postulated that they are either inert developmental or congenital herniations into weak areas of the end plate or that they are because of trauma, infection, osteoporosis, malignancy, or various bone diseases [1,6]. It has also been suggested that they form at locations that have been weakened because of incomplete resorption of the notochord or anomalies in the avascularization of the intervertebral disc during development [2,3]. The interaction between EPLs and disc degeneration remains unclear and controversial [10]; a number of studies have suggested that there is a link [5,9,11], whereas others have not been able to confirm this correlation [4,12]. A recent study comparing patients with lumbar symptoms with a control group found that EPLs are more likely to be found in patients with pain in the lumbar spine (EPLs were found in 9% of the control group and 19% of the symptomatic group) [12], although the relationship of EPLs to low back pain is still debated [6]. Similarly, the relationship between EPLs and race, gender, age, body weight, or exposure to heavy manual labor is uncertain [6].

End plate lesions have been observed in idiopathic scoliosis patients, but to the authors' knowledge, their prevalence, location, and size have not previously been reported. Buttermann and Mullin [13] analyzed MRIs of 60 consecutive pediatric and adult idiopathic scoliosis patients who had progressed to surgical treatment and found a correlation between EPLs and pain in pediatric scoliosis patients but not in adult scoliosis patients. A pilot investigation has also suggested that EPLs may potentially be a primary disturbance of growth plates that leads to the onset of scoliosis [14].

Given the previously mentioned variability in the definition of EPLs, the aim of this study was to develop an image analysis technique for consistent measurement of the prevalence, location, and size of EPLs. The wide range of reported prevalence of EPLs highlights the importance of a well-defined, repeatable, and reliable method to identify them. A semiautomatic approach will eliminate interobserver differences in EPL definitions and facilitate rapid comparison of multiple data sets. It is important that the vertebral tilt and rotation seen in idiopathic scoliosis patients are considered when detecting EPLs; therefore, we describe the tool development and application using a series of preoperative CT scans of idiopathic scoliosis patients.

Materials and methods

Imaging

Low-dose, CT scans, covering vertebral levels C7–S1, were taken for patients with adolescent idiopathic scoliosis (AIS) using a Toshiba Aquilion Multiscanner (Toshiba Medical Systems Corp., Tokyo, Japan). The scan used a 100 kV and 50 mA source with a 6-mm pitch and a 1 second rotation time, producing raw images with $0.6 \times 0.6 \times 1.0$ mm voxels. It is estimated that this scanning protocol exposed the pediatric patients to a radiation dose of 3.7 ± 0.74 mSv (estimate ± uncertainty) [15]. This is higher than the combined dose for full-length posteroanterior and lateral standing radiographs (approximately 1.0 mSv) but substantially lower than a typical adult chest CT scan (approximately 8 mSv [16]). At