ELSEVIER

The Spine Journal 14 (2014) 808–815

THE SPINE JOURNAL

Basic Science

Anatomic radiological variations in developmental lumbar spinal stenosis: a prospective, control-matched comparative analysis

Sameer A. Kitab, MD[a,b], Ali M. Alsulaiman, MD[a,b], Edward C. Benzel, MD[c,*]

[a]*Scientific Council of Orthopedics, Bab Almuadham 5116, Baghdad, Iraq*
[b]*Spine Health Unit, Orthopedics Department, Bab Almuadham 5116, Baghdad, Iraq*
[c]*Neurological Institute, Department of Neurosurgery, Cleveland Clinic, 9500 Euclid Ave. S-41, Cleveland, OH 44195, USA*

Received 20 December 2012; revised 30 July 2013; accepted 18 September 2013

Abstract

BACKGROUND CONTEXT: Developmental lumbar spinal stenosis is a maldevelopment of the dorsal spinal elements involving short pedicles and a trefoil bony spinal canal that increases the likelihood of neural compression at an earlier age.

PURPOSE: To identify radiographically the anatomic variations caused by the maldevelopment of the infrequently characterized dorsal spinal elements.

STUDY DESIGN: A prospective, control-matched comparative analysis.

METHODS: Magnetic resonance imaging (MRI) and anteroposterior (AP) plain radiographs of 66 patients (mean age, 40.7 years) selected and randomized prospectively and compared with images of 45, age- and gender-matched control subjects. Variables assessed included spinal canal cross-sectional area (CSA), thecal sac AP and transverse canal diameters (CSA), and interpedicular distance. All were expressed in ratios with vertebral body diameter (VBD), interlaminar angle, stenosis grade, and MRI evidence of disc degeneration.

RESULTS: In the stenosis cohort, global pathology and multilevel involvement with L3, L4, and L5 segments were involved more commonly and severely. Severe stenosis, at L1, L2, and S1 occurs infrequently. Multivariate analysis demonstrated a statistically significant reduction in spinal canal CSA-to-vertebral body CSA ratio, AP spinal canal diameter-to-VBD ratio on axial and sagittal magnetic resonance images, and plain radiograph interpedicular distance-to-VBD ratio at all levels. Interlaminar angle and the transverse spinal canal diameter-to-VBD ratio were reduced significantly in the stenosed cohort at all levels, except L1. No statistically significant difference regarding the incidence of disc degeneration on MRI between the two cohorts, as well as thecal sac CSA-to-spinal canal CSA ratios across all levels were observed, except for L3 and S1 ($p<.05$).

CONCLUSIONS: Three spinal canal morphologies were identified: (1) ''flattened'' canal with predominantly reduced spinal canal AP diameter, (2) spinal canal with predominantly reduced interlaminar angle, and (3) global reduction of all canal parameters. Early age at presentation and subtle spondylosis, although typical, should not be considered the identifying, differentiating factors.

Keywords: Developmental; Congenital; Stenosis; Lumbar; Spine; Canal; MRI

FDA device/drug status: Not applicable.

Author disclosures: ***SAK:*** Nothing to disclose. ***AMA:*** Nothing to disclose. ***ECB:*** Royalties: Elseiver (None), Thieme (None); Stock ownership: AxioMed (None), DePuy (None), OrthoMEMS (None), Turning Point (None); Consulting: AxioMed (None), OrthoMEMS (None); Board of Directors: AxioMed (None), Computational Biodynamics (None), Cervical Spine Research Society (None), OrthoMEMS (None), Turning Point (None), THINQ (None); Scientific Advisory Board: AxioMed (None), Computational Biodynamics (None), Cervical Spine Research Society (None), OrthoMEMS (None), Turning Point (None); Grants: OREF (F, Paid directly to institution/employer), Rawlings (F, Paid directly to institution/employer), Stryker (None).

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

* Corresponding author. Cleveland Clinic, 9500 Euclid Ave. S-41, Cleveland, OH 44195, USA. Tel.: (216)-444-7381; fax: (216)-445-9999.

E-mail address: benzele@ccf.org (E.C. Benzel)

1529-9430/$ - see front matter
http://dx.doi.org/10.1016/j.spinee.2013.09.012

Introduction

Developmental spinal stenosis is caused by a maldevelopment or growth disturbance of the dorsal spinal elements that result in an ''anatomic conflict'' between the available space in the spinal canal and its contents. This disorder manifests primarily after birth, hence the term *developmental* [1,2]. Patients may present with clinical symptoms at an early age, and with fewer degenerative hypertrophic changes than the more common degenerative cohort [1,3–6]. The anatomic radiologic variations in these patients has been characterized infrequently in the literature, and patients with developmental spinal stenosis are intermixed frequently with, and not distinguished from, degenerative or congenital varieties of stenosis [1–21]. Congenital anatomic changes or malformations (eg, an excessive scoliotic or lordotic curve) invariably characterizes the congenital type [1,7].

Early studies had linked developmental spinal stenosis traditionally to the trefoil-shaped bony spinal canal and further assessed spinal canal development from intrauterine to adult life [8–11]. Quantitative bony canal parameters defining developmental spine stenosis, however, are known to be of questionable significance [12]. As magnetic resonance imaging (MRI) has become the imaging standard for intraspinal pathology, several authors have attempted to define quantitatively and qualitatively the imaging parameters associated with spinal stenosis—the prevailing assessments being measurements of spinal canal or dural sac cross-sectional area (CSA) as assessed by either computed tomography or axial MRI sequences [13–18]. Regardless of the type of stenosis, spinal canal CSAs of less than 100 mm^2 or 75 mm^2 represent respectively relative and absolute central spinal stenosis [19,20]. The majority of cases evaluated in these studies, however, were of the degenerative type with hypertrophic degenerative changes [14,17–23]. Singh et al. [4], in a comparative study of 15 patients with congenital stenosis, specified quantitatively the radiographic parameters of congenitally stenotic spinal canals as having a shorter pedicle length (mean critical value, 6.5 mm), resulting in a smaller cross-sectional spinal canal area (mean critical value, 213 mm^2).

The importance of the imaging definition of this subgroup of patients with stenosis is clear. A more global pathology with possible multiple levels of involvement necessitates morphometric evaluation of the entirety of the lumbosacral vertebrae complex. The current study addresses specific imaging parameters based on axial and sagittal magnetic resonance (MR) images and anteroposterior (AP) plain radiographic comparisons of 66 symptomatic patients who were given a diagnosis of developmental stenosis. The images for this group were compared with the images of 45 asymptomatic age- and gender-matched control subjects without stenosis. To our knowledge, this is the largest patient series analyzed in a comparative study.

Materials and methods

Selection criteria for patients given a clinical diagnosis of developmental stenosis include patients younger than 50 years of age with neurogenic claudication symptoms for at least 2 months, with rest relief of symptoms and with minimum plain radiological degenerative manifestations. Patients in the developmental stenosis cohort were compared with a gender- and age-matched control group of 45 nonsmoking subjects who had undergone MRI for a single event of acute low back pain lasting no more than 7 to 10 days, which is within the population's prevalence for acute back pain events. Primary health-care records demonstrated no history of prior back pain or surgery, nor any history of claudication or gluteal, thigh, or leg symptoms. Although direct clinical comparisons are precarious, morphologic comparisons are not, and were examined in the current study. All patients were evaluated after informed consent was obtained according to institutional review board approval.

Sagittal and axial MR images at multiple levels from L1–S1, and AP lumbar plain radiographs were obtained for individuals in both cohorts. A reliable qualitative grading for the severity of lumbar spinal stenosis based on the morphology of the dural sac on axial MR images was used to evaluate study patients and control subjects (Table 1) [24]. Patients with deformity or radiographic evidence of instability were excluded from the study cohort. To minimize selection bias, patients with minor grade A radiologic stenosis (Table 1) were excluded. Ensuring that minor radiological spinal canal stenosis is the etiology behind clinical symptoms in patients in the grade A subgroup may prove difficult, and thus may introduce inclusion and selection bias.

From these stringent clinical and radiologic selection criteria, 66 patients (44 men [66.7%] and 22 women [33.3%]) with a mean age of 40.7 years (range, 17–50 years) were identified prospectively and compared with 45 control subjects (31 men [68.9%] and 14 women [31.1%]) with a mean age of 39.5 years (range, 16–50 years).

Patients given a diagnosis of developmental stenosis were treated with both surgical decompression (43% of

Table 1
Schizas qualitative grading for the severity of lumbar spinal stenosis based on the morphology of the dural sac [24]

Stenosis grade	Description
Grade A	CSF is clearly visible inside the dural sac, but its distribution is inhomogeneous.
Grade B	The rootlets occupy the entire dural sac, but they can still be individualized. Some CSF is still present, giving a grainy appearance to the sac.
Grade C	No rootlets can be recognized, with the dural sac demonstrating a homogeneous gray signal with no CSF signal visible. There is epidural fat present dorsally.
Grade D	In addition to no rootlets being recognizable, there is no dorsal epidural fat.

CSF, cerebrospinal fluid.