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Original article

Clinical and stereoradiographic analysis of adult spinal deformity with and without rotatory subluxation

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ABSTRACT

Introduction: In degenerative adult spinal deformity (ASD), sagittal malalignment and rotatory subluxation (RS) correlate with clinical symptomatology. RS is defined as axial rotation with lateral listhesis. Stereoradiography, recently developed for medical applications, provides full-body standing radiographs and 3D reconstruction of the spine, with low radiation dose.
Hypothesis: 3D stereoradiography improves analysis of RS and of its relations with transverse plane and spinopelvic parameters and clinical impact.
Material and methods: One hundred and thirty adults with lumbar ASD and full-spine EOS® radiographs (EOS Imaging, Paris, France) were included. Spinopelvic sagittal parameters and lateral listhesis in the coronal plane were measured. The transverse plane study parameters were: apical axial vertebral rotation (apex AVR), axial intervertebral rotation (AIR) and torsion index (TI). Two groups were compared: with RS (lateral listhesis > 5 mm) and without RS (without lateral listhesis exceeding 5 mm: non-RS). Correlations between radiologic and clinical data were assessed.
Results: RS patients were significantly older, with larger Cobb angle (37.4° vs. 26.6°, $P = 0.0001$), more severe sagittal deformity, and greater apex AVR and TI (respectively: 22.9° vs. 11.3°, $P < 0.001$; and 41.0° vs. 19.9°, $P < 0.001$). Ten percent of patients had AIR > 10° without visible RS on 2D radiographs. RS patients reported significantly more frequent low back pain and radiculalgia.
Discussion: In this EOS® study, ASD patients with RS had greater coronal curvature and sagittal and transverse deformity, as well as greater pain. Further transverse plane analysis could allow earlier diagnosis and prognosis to guide management.
Level of evidence: 4, retrospective study.

1. Introduction

Low back pain and radiculalgia are among the most frequent reasons for orthopedic consultation, at 2.5% in some countries [1]. There are many causes, of which spinal deformity is one. A recent study reported that the rate of spinal deformity can reach 68% in elderly populations (mean age > 65 years) [2]. Moreover, in degenerative adult spinal deformity (ASD) frontal deformity with vertebral rotation and sagittal malalignment is often associated with osteoarthritis and discal and ligamentous degeneration, inducing central or foraminal canal stenosis with radicular compression [3]. The combination of these phenomena causes pain and major disability [4,5].

To investigate the relation between symptoms and spinal deformity, several studies assessed correlations between radiologic parameters and quality of life scores [2,3,6–8]. Radiologic parameters most frequently found to be associated with symptoms were rotatory subluxation (RS) of the joint and loss of lumbar lordosis leading to global sagittal alignment defect, triggering compensation mechanisms in the pelvis, such as increased pelvic retroversion, or spine, such as flattening of the thoracic kyphosis [8]. Moderate but significant correlations were recently reported between clinical disability scores and sagittal spinopelvic radiographic parameters, demonstrating the contribution of global sagittal analysis to diagnosis, prognosis and management [5,9,10]. Coronal alignment

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parameters, on the other hand, seem to have little influence on the severity of pain and functional disability [5].

However, all of the literature regarding correlations between radiologic and clinical data has been restricted to 2D radiography, whereas adult spinal deformity is 3-dimensional deformity sometimes causing RS [11]. Radiographic assessment of vertebral rotation often uses pedicle projection on AP view [12–14]. However, in severe rotation the pedicle becomes difficult to identify [15]. MRI or CT may complete X-ray examination but are performed with the patient in supine position and do not allow analysis of anatomic factors underlying pain or loss of function in upright position. Stereoradiography, which was recently developed, provides full-body standing radiographs without distortion and with a low dose of radiation and shorter examination time, and allows 3D reconstruction at lower cost than MRI or CT [16–19].

Certain studies of adolescent idiopathic scoliosis using stereoradiography highlighted the importance of the axial plane for deformity analysis [17,18]. However, the literature on 3D analysis of adult spinal deformity remains sparse [20,21]. The present study therefore sought to analyze RS in ASD by 3D stereographic reconstruction, assessing correlations between axial plane and spinopelvic parameters on the one hand and pain and functional impairment on the other.

2. Materials and methods

2.1. Data collection

A retrospective study included patients between November 2012 and July 2014, after institutional review board approval. Inclusion criteria were: adult patient consulting for spinal deformity (Cobb angle > 10°) [22]. Exclusion criteria were: non-idiopathic or non-degenerative etiology, and history of spine surgery.

Demographic data comprised age, gender and body-mass index (BMI). Functional data comprised Oswestry Disability Index (ODI) and a visual analog scale (VAS), as well as low back and radicular pain. Radiography used the EOS® system (EOS Imaging, Paris, France), on a standardized protocol: patient upright, with horizontal gaze, and fingers on the clavicles to avoid superimposition on the arm on the spine [23].

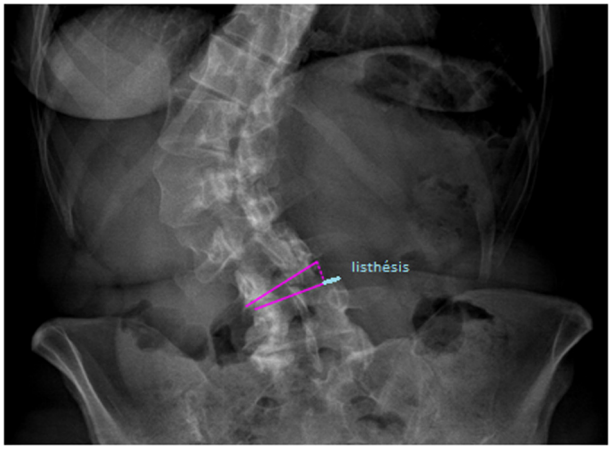

Fig. 1. Measurement method for rotatory subluxation (RS).

2.2. Radiographic analysis

Radiographic measurements were made by an experienced observer. 2D measurement on Surgimap software (Nemaris Inc., New York, USA) consisted in lateral listhesis alone: distance (in mm), on the convex side parallel to the cranial plate of the underlying vertebra, between the lateral edge of the underlying vertebra and the lateral edge of the overlying vertebra lowered perpendicularly to the plate of the underlying vertebra (Fig. 1). RS was defined as axial rotation associated with > 5 mm lateral listhesis in the coronal plane [24,25]. The patient cohort was thus divided into two groups: with (RS) and without ≥ 1 lateral listhesis exceeding 5 mm (non-RS).

3D spinal reconstruction used SterEOS® software, version 1.2.1 (EOS Imaging, Paris, France) (Fig. 2). To correct any pelvic rotation during acquisition, all parameters were measured with the patient-specific landmark defined by the Scoliosis Research Society (SRS) as the vertical plane through the acetabular centers [26]. Sagittal alignment assessment comprised global parameters (sagittal vertical axis [SVA], T1 spinopelvic inclination [T1SPi]) (Fig. 3), spinal parameters (T1T12 thoracic kyphosis, L1S1 lumbar lordosis [LL]) and pelvic parameters (pelvic incidence [PI], pelvic tilt [PT] and

Fig. 2. 3D reconstruction with SterEOS®.