ABSTRACT

This study presents details about the applicability of the new image acquisition system, called the biplanar imaging system, with three-dimensional capabilities (EOS®) to the treatment of spinal deformities. This system allows radiographic acquisition of the entire body, with a great reduction in the dose of radiation absorbed by the patient and three-dimensional (3D) stereoradiographic image reconstruction of bone structures, including the spine. In the case of adolescent idiopathic scoliosis, the analysis of the spinal deformity with 3D reconstruction allows better understanding of the deformity and surgical planning. In the case of adult spinal deformity, full-body analysis allows an evaluation of the spinopelvic deformity, including loss of sagittal alignment, in addition to an evaluation of compensatory mechanisms recruited by the individual in an attempt to maintain the sagittal balance. Level of evidence III; Descriptive Review.

Keywords: Radiography; Technology, Radiologic; Spine; Scoliosis; Bone Malalignment.

INTRODUCTION

The technology devised by Professor Georges Charpak,1 winner of the 1992 Nobel Prize in Physics, enabled the development of a new image acquisition system, known as the three-dimensional capacity biplanar imaging system (EOS®).2 Based on an ultrasensitive X-ray detector, the system is capable of limiting the dose of radiation absorbed by the patient, in addition to allowing simultaneous image capture in the anteroposterior (AP) and lateral (L) views.
two-dimensional (2D) planes of the entire body. Simultaneous acquisition of the image in two planes, when performed in a calibrated environment, also allows stereoradiographic reconstruction of the bone structures and of the spine in a three-dimensional (3D) image. With a biplanar imaging system, whole body image acquisition is performed rapidly, in around 30 seconds and with a dose of radiation about 10 times lower than for full spinal radiography. Another advantage is life-size imaging without magnification due to simultaneous capture by two X-ray sources. Finally, one of the main features of this imaging system is the ability to obtain images of bone structures with 3D reconstruction through acquisition in two planes. This capability depends on the software that uses algorithms based on statistical models and bone element shape recognition and a well-trained operator to identify key points in the shape of the bone elements in question.

The use of biplanar imaging has evolved considerably in recent years with increasing practical applicability, especially in the evaluation of spinal disorders. The objective of this article is an updated presentation and discussion of the benefits of skeletal imaging with the biplanar imaging system allowing evaluation of patients in the orthostatic position with exposure to radiation on the order of ten times lower than full-spine radiography. More recently, new protocols using micro-doses have allowed for examinations showing the simultaneous acquisition of frontal and lateral (biplanar) images during correction. The biplanar imaging system allows the analysis of all the two-dimensional parameters, (Figure 2) like conventional radiography, in addition to three-dimensional analysis through 3D image reconstruction. The measurement of radiographic parameters of interest in AIS demonstrates heightened accuracy when compared to measurement of images obtained via CT, considering the Cobb value, thoracic kyphosis, and axial rotation. Using this technology, Newton et al. were able to show the true positioning of the vertebrae in the sagittal plane. The authors evaluated the sagittal angulation of each vertebra in relation to its adjacent vertebra and observed that two-dimensional measurements tend to overestimate thoracic kyphosis measured between T5 and T12 by 11° on average. In addition to this information, which enables refinement in the surgical correction to the extent that the exact relationship between one vertebra and another are understood, they called attention to the impossibility of comparing preoperative thoracic kyphosis with the postoperative measurement, since derotation of the vertebrae of the soul of the curve is performed during correction. Besides the usual parameters already studied in radiographs, the biplanar imaging system allows the evaluation of several other parameters, both regional (maximum Cobb, coronal Cobb, sagittal Cobb, plane of maximum curvature (PMC), and the plane formed by the terminal-apical-terminal vertebrae), and local (wedging of the vertebra and disc, rotation in the transverse plane, and pelvic measurements). Additionally, new forms of presentation of the deformity have been developed based on these parameters, principally the plane of maximum curvature (PMC) measured using the orientation of the plane formed by the terminal-apical-terminal vertebrae to the proximal thoracic, main thoracic, and lumbar/thoracolumbar curves. In the patient with a normal spine, the orientation of the terminal-apical-terminal vertebrae is practically in the midline (zero degrees), since the physiological curves are thoracic kyphosis and lumbar lordosis, which are found in the sagittal plane. In order to facilitate visualization of the deformity in the axial plane, a graphical representation, called the “da Vinci” view, was developed, which allows evaluation of these planes in a more simplified manner. Demonstrating the importance of three-dimensional deformity assessment and its applicability to clinical practice, the Scoliosis Research Society (SRS) established a committee for the development of a 3D AIS classification system. Using data clustering techniques, they identified different curve forms, even among the curves...
classified as the same type using the Lenke classification. Although not yet available, the members of this committee believe that it will allow a better understanding of the aspects of three-dimensional deformity, better define how to correct these parameters, and improve the evaluation of postoperative outcomes.

Adult spinal deformity

The study of adult spinal deformity (ASD) is arousing interest in light of the aging of the population observed globally. This deformity is related to very severe functional disability comparable to chronic conditions such as diabetes, cancer, and respiratory and heart disease, and a considerable portion of patients seek surgical treatment. The evaluation of patients with ASD and treatment planning involve the assessment of well-established radiographic parameters, some of them used in the SRS-Schwab classification, which is the most widely used system and has proven clinical relevance. This classification system consists of a descriptive component of the type of deformity, including double coronal curve (thoracic and lumbar), thoracic curve, lumbar curve, and deformities without deformity in the coronal plane, in addition to three sagittal modifiers, according to the value of the radiographic parameters related to the sagittal alignment of the spine that are most highly correlated with functional disability, including the sagittal vertical axis (SVA), pelvic tilt (PT), and the discrepancy between pelvic incidence and lumbar lordosis (PI-LL).

All interest in the study of the relationship between sagittal vertebral alignment and pelvic alignment stems from the “cone of economy” concept introduced by Professor Dubousset, which is the narrow margin within which the body is able to remain in balance with minimal effort and without external support. A recent study sought to evaluate the “cone of economy” concept by investigating the relationship between the line of gravity (LG) of the body and the position of the foot, taking the radiographic parameters of sagittal vertebral alignment of the volunteers into account. It was shown that the anterior inclination of the trunk, represented by an increase in the SVA, leads to pelvic retroversion, with an increase in the PT angle and/or knee flexion, such that the location of the LG does not change in relation to the position of the foot. Thus, in order to maintain the center of body mass, represented by the LG, in relation to the position of the foot, maintaining the “cone of economy”, the loss of sagittal vertebral alignment is accompanied by the recruitment of compensatory mechanisms. The identification of these mechanisms allows for a true interpretation of the vertebral deformity and is essential to the planning of correction surgery in order to optimize postoperative alignment.

Many of the compensatory mechanisms are observed in the spine itself and in the pelvis, including cervical hyperlordosis, thoracic hypokyphosis, and pelvic retroversion, and can be assessed via a panoramic orthostatic radiograph of the entire spine. However, other compensatory mechanisms involving the lower limbs, including changes in hip, knee, and ankle position, cannot be contemplated with conventional spinal imaging exams. Evaluation of patients with ASD using the whole-body biplanar imaging system allows a better understanding of both spinopelvic deformity and recruited compensatory mechanisms, with a complete analysis of sagittal alignment.

Ferrero et al. conducted a study analyzing sagittal alignment according to whole-body evaluation with images obtained by the biplanar system. Considering a large sample of individuals with ASD, they observed that the loss of lumbar lordosis and the anterior inclination of the trunk (increase of the SVA and the T1 spinopelvic inclination angle), representing loss of spinal sagittal alignment, were associated with the recruitment of compensatory mechanisms, including pelvic retroversion (an increase in PT), posterior displacement of the pelvis and knee flexion. There was a statistically significant correlation between the radiographic spinopelvic parameters and the parameters considered in the evaluation of the compensatory mechanisms of the lower limbs, highlighting the role of these mechanisms in attempting to reduce loss of spinal sagittal alignment and all the associated functional disability.

Since the clinical impact of ASD is associated with the severity of intrinsic deformity in the spine and with the behavior of compensatory mechanisms, a new radiographic parameter was established that allows contemplation both of the loss of spinopelvic sagittal alignment and the compensatory mechanisms, called the global sagittal angle (GSA). In a
CONSIDEARIONS

The new technology for whole-body radiographic imaging with the capability of 3D reconstruction of bone elements allows a better understanding of spinal deformity with new perspectives for decision making in surgical planning for the treatment of spinal deformities compared with the use of biplanar X-rays. 

The following new findings are derived from this new technology: 3D reconstruction of the spine from biplanar X-rays using parametric models based on transversal and longitudinal inferences; measurement of the global sagittal angle (GSA), a radiographic parameter that permits contemplation of the loss of spinopelvic sagittal alignment and the simultaneous recruitment of compensatory mechanisms in the lower limbs; measurement of the radiographic parameters indicative of the compensatory mechanisms in response to loss of sagittal alignment: knee flexion angle (KFA), sacrofemoral angle (SAF), ankle flexion angle (AFA), and posterior displacement of the pelvis (PT).

All authors declare no potential conflict of interest related to this article.

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