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Review

Sagittal balance and pelvic parameters–a paradigm shift in spinal surgery

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ABSTRACT

It has become evident in recent years that global assessment of spinal sagittal balance is necessary for optimal management of the degenerate spine. Pelvic parameters have been developed which appear to correlate well with the natural history of degenerative spine disorders and outcomes from surgery. Although these parameters have a limited evidence base, they are now in widespread use by spinal surgeons and, in particular, spinal deformity surgeons. It is necessary for all surgeons treating spinal pathology to have a working knowledge of the principles of spinal sagittal balance, to be able to recognise sagittal imbalance and its compensatory mechanisms. In this article we outline the main concepts of spinal sagittal balance and pelvic parameters and how these concepts are leading to a paradigm shift in the surgical management of spinal disorders. We propose that analysis of pelvic parameters of sagittal balance will form an essential part of the evaluation of new surgical techniques for spinal conditions.

1. Introduction

The concept of sagittal balance has gained favour among spinal surgeons in the assessment and management of spinal conditions since 1985. Defining exactly what is meant by "sagittal balance of the spine" has been a controversial, and often elusive, task.[1] More recently, the importance of individual pelvic anatomy and assessment of pelvic parameters on sagittal balance has been recognised. These pelvic parameters have been correlated with severity of spinal pathology and with clinical outcomes following spinal surgery. The pelvis, forming the pedestal for the spine, is essential to the maintenance of normal sagittal balance. Abnormal pelvic parameters result in compensatory mechanisms by the pelvis and spine in order to try and maintain sagittal balance. It is necessary, therefore, for spinal surgeons to have an understanding of these parameters and a practical knowledge of how to assess and integrate these parameters in the management of spinal patients. Barrey et al. have proposed a three-step algorithm to analyse spinal balance which takes into account compensatory mechanisms and categorises sagittal balance into three stages: balanced, balanced compensated, and unbalanced.[2] Such algorithms provide a useful framework for which sagittal balance can be assessed reproducibly by clinicians in different centres and will lead to an expansion in our understanding of sagittal balance and its role in different spinal pathologies and their management.

2. Global sagittal balance

One of the most distinguishing and unique feature of humans (*Homo sapiens*) is that we are the only obligate bipedal primates. Although there are numerous theories regarding the circumstances in which bipedalism evolved, it is generally accepted that it evolved before the development of larger brains and the use of hand tools.[3] Unlike the C-shaped spine of facultative bipedal primates, the evolution of an ergonomic upright position in humans has necessitated three sagittal curves: lumbar and cervical lordoses and a thoracic kyphosis. These spinal curves are supported by the pelvis which, in humans has rotated vertically to act as the foundation of the vertebral column, the equivalent of the stylobate. The pelvis, in turn, sits upon the femoral heads, and an ergonomic upright position is effected with straight hips and knees.[4] Sagittal balance refers to this ergonomic arrangement whereby the centre of gravity of the body is balanced upon the pelvis. This is achieved by alliance of the lumbar lordosis and thoracic kyphosis such that the gravity line of the body passes through, or is slightly posterior to, the femoral heads (Fig. 1A). Extensive studies of the normal spine have revealed that the sagittal balance is achieved when the C7 plumb line (a line passing vertically from the centre of the C7 vertebral body) lies posterior to the gravity line (that is, posterior to the centre of the femoral heads.).[5,6] It is also possible to used angular methods of assessing global sagittal balance, for example, the spinosacral angle or spinal tilt.[7,8] The spinosacral angle is the angle between the sacral plateau and a line drawn from the centre of the C7 vertebral body and the centre of the upper S1 end plate, and spinal tilt is differentiated from this angle by substituting the sacral plateau with the horizontal line through

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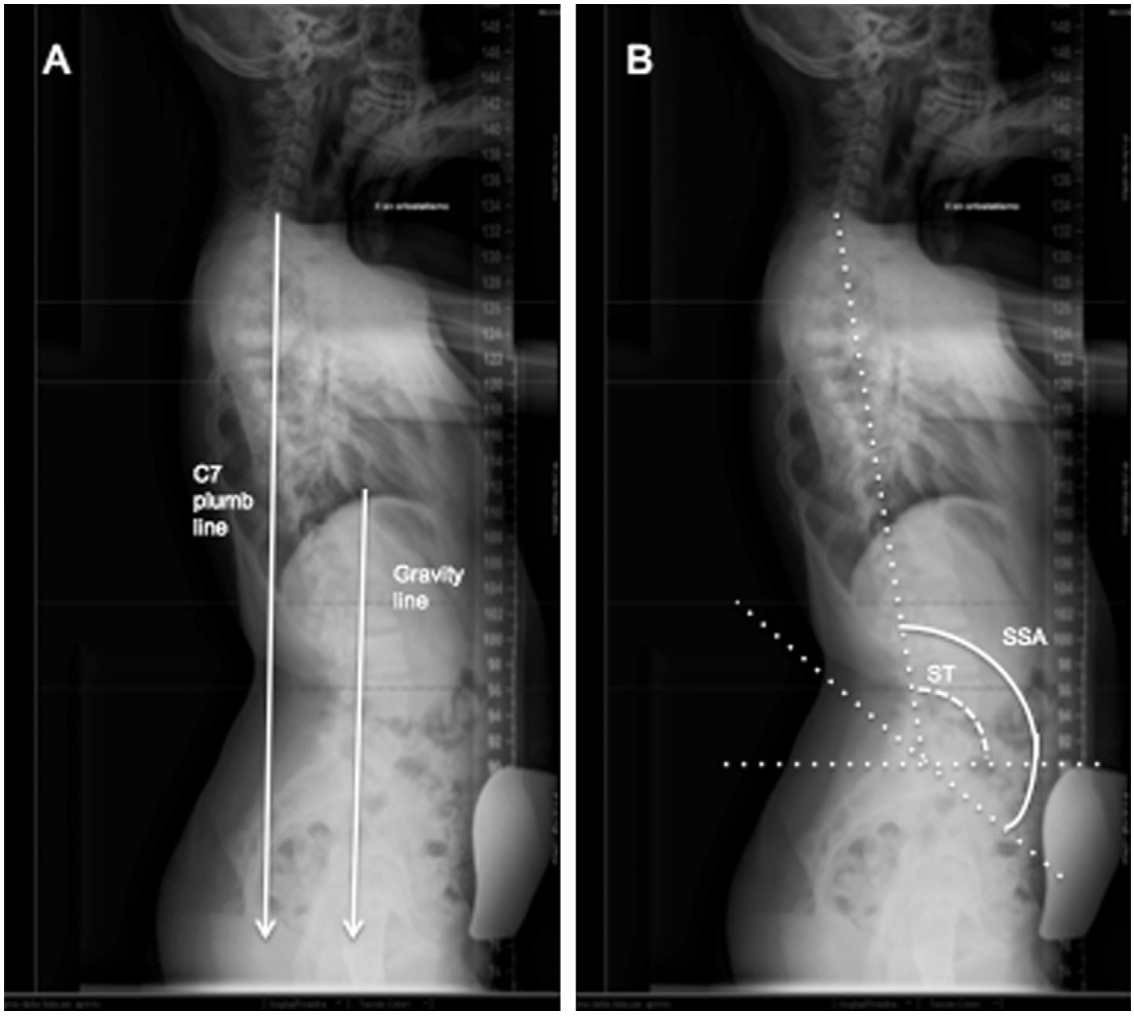

Fig. 1. Plain lateral radiographs showing the estimation of global sagittal balance of the spine and pelvis in the standing position. (A) In normal sagittal balance the C7 plumb line will pass behind the femoral heads. (B) The spinosacral angle (SSA) and spinal tilt (ST) may also be used as an overall measure of sagittal balance. When sagittal balance is normal, the weight of the body is ergonomically balanced through the spinal column and the pelvis is over the hips (head of the femurs).

the midpoint of the S1 upper endplate (Fig. 1B). Roussoully et al. analysed the spinosacral angle in 153 normal individuals and found a normative value of 134.7° ± 8.1 (SD).[7] An example of a patient with sagittal imbalance with a reduced spinosacral angle is shown in Fig. 2.

In general, the degree of lumbar lordosis and thoracic kyphosis will correlate with one another to achieve sagittal balance. Changes in the degree of lumbar lordosis, whether due to pathological changes or iatrogenic due to surgery, will result in a change in the thoracic kyphosis to maintain sagittal balance, and *vice versa*. These changes in the reciprocal spinal segment can occur only within the limits of flexibility and the increased stress on these spinal segments can lead to pain, deterioration, and instability. It is of major importance, for the spinal surgeon, therefore, to understand how conditions of the spine alter sagittal balance and the mechanisms that occur to compensate and restore this balance and the effects these may have on the spine.

3. Pelvic parameters

It is impossible to routinely assess the centre of gravity on each individual patient. Furthermore, modalities such as CT scans and MRI, which image patients in a supine position, are redundant in assessing sagittal balance. However, pelvic parameters measured on an erect lateral plain radiograph can be used as an indirect measure of sagittal balance. The importance of pelvic parameters in spinal balance was emphasized by Dubousset, who referred to the pelvis as the "pelvic vertebra".[9]

During et al. were the first to consider quantitatively how postural pelvic parameters correlate with the degree of lumbar lordosis: they described an angle, subsequently known as the pelvisacral angle, between the sacral plateau and a line drawn from the midpoint of the sacral plateau and the femoral heads and showed that this angle was significantly different between healthy volunteers and patients with spondylolysis (Fig. 3).[10] Jackson et al. also considered pelvic parameters and sagittal balance and showed that the pelvisacral angle (differing slightly from that of During et al. as the apex of the angle was drawn from the posterior margin of the superior S1 endplate rather than the midpoint of the sacral plateau) correlated strongly with lumbar lordosis and that alterations in sagittal balance were associated with pelvisacral rotation around the hips.[11] Legaye et al. defined the pelvic incidence, which is an angle formed at 90° to the pelvisacral angle described by During et al. In their seminal study comparing normal subjects with patients with scoliosis they found a strong correlation between pelvic incidence and sacral slope (the angle between the sacral plateau and the horizontal) and sagittal balance (Fig. 3).[12] Legaye et al. postulated that the pelvic incidence is the main pelvic parameter