

Current Surgical Strategies to Restore Proper Sagittal Alignment

Dr. Luiz Pimenta*

Clinical Study Coordinator, IPC - Instituto de Patologia da Coluna, Brazil

Mini Review

The lumbar lordosis is essential to the human spine, as it enhances biomechanical strength and facilitates the unique upright posture of the human species [1]. On average, 90% of the lumbar curve is attributed to the wedging of the discs, emphasizing the important contribution of them in maintaining lumbar lordosis [2]. In this way, minor changes in sagittal balance increase muscle activity and spinal load, that results in loss of disc height and facet arthrosis. In a degenerated spine, the neural arch can be responsible for up to 70% compressive force, as the disc load capacity is reduced by pathological alterations [3]. Consequently, humans have developed adaptive strategies to maintain a balanced spine due to degenerative changes. These include increased hip flexion, plantarflexion, increased cervical spine lordosis, pelvic retroversion, thoracic hyperkyphosis, bent knee and bent hip strategy similar to primates, all of them related to increased oxygen consumption [4]. The excessive energy expenditure is related to accelerate degenerative postural changes, also affecting adjacent joints, and evidences the need of an early intervention to keep intact the bipedal efficiency of the human spine.

Several studies have shown that lumbar spine surgery of sagittal alignment improves health-related quality of life parameters, as spontaneously restores compensatory strategies like pelvic retroversion and thoracic hyperkyphosis [5-9]. Schwab et al. [10] have shown that lumbar spine deformity is determined by the difference between lumbar lordosis (LL) and pelvic incidence (PI), being $LL = PI \pm 9^\circ$. Other utilized global radiological parameter of sagittal alignment is the sagittal vertebral axis (SVA), defined as the horizontal offset between the C-7 plumb line and posterior superior aspect of the S-1 vertebral body. The pelvis plays an important role in sagittal balance and the measured parameters are PI, pelvic tilt (PT) and sacral slope (SS). As the PI is a fixed measure, SS and PT are commonly affected by strategies utilized by patients with loss of lumbar lordosis, as pelvic retroversion and knee flexion.

Accordingly, the surgical goals must be alleviation of clinical symptoms and proper correction of sagittal alignment of the spine. The achieved C7-SVA must be less than 5cm and pelvic tilt less than 20° , while diminishing LL/PI mismatch. Degenerative changes of the spine, discs and ligaments can difficult the optimal lordosis restoration, and release maneuvers must be performed by posterior and/or anterior approach depending on the involved structures, while performing fusion in an operative position that recreates physiologic lordosis. The posterior approaches include resection of spinous processes, lamina and facetectomy, with soft tissues retractions, foraminotomy and intervertebral disc distraction performed by dilators and/or rods and screws. The anterior approaches include resection of the anterior longitudinal ligament, osteophytes, and complete discectomy. Also, the posterior longitudinal ligament can be released when necessary in anterior approaches [11].

Three-column osteotomies, like Pedicle subtraction osteotomy (PSO), are indicated for patients with rigid sagittal imbalances [12]. While being a demanding procedure and requiring excellent knowledge of the principles of sagittal balance, the technique consists of a posteriorly shortening of the posterior column respecting the length of the anterior column, with a mean gain of 20° to 40° of lordosis. However, complication rate can reach 45% of the patients, with a risk of

reoperation of 25% after 5 years. Massive blood loss has been reported in literature, reaching $>4,000\text{ml}$ and average percentage of total blood volume lost up to 55%, and neurological deficits are also frequent, reaching 15% of the patients [12,13]. Less invasive approaches or hybrid techniques come in order to mitigate some complications and allow corrective surgeries in elderly or poorer clinical condition population [14-16]. In general, as regard to the power of correction, less invasive approaches still are less powerful than hybrid and open techniques that have been shown to be similar to each other. In the other hand, complication rates are diminished with hybrid and even more with less invasive surgical options.

In an attempt to avoid these complications, the anterior approaches have been utilized to reconstruct sagittal alignment, while restores disc height and provides solid fixation of spinal segments. Up to date, anterior lumbar interbody fusion (ALIF) and lateral lumbar interbody fusion (LLIF) have shown promising results as they utilize large cages that redistribute spinal load [17]. Also, these techniques increase fusion potential as they are placed under direct compression whereas middle and anterior column provide more than 90% of the vascular osseous surface area [18]. However, ALIF presents some complications that must be taken in account for multilevel surgeries. Disadvantages of ALIF include the necessity of an access surgeon, high incidence of vascular injury and retrograde ejaculation. In addition, ALIF is associated with increased operating time and blood loss, as well as prolonged recovery time [19].

The LLIF presents as a minimally invasive option for multilevel degenerative conditions of the spine [20]. Minimally invasive surgical techniques have been demonstrated to provide a large number of benefits, which include less tissue trauma, preservation of normal anatomical structures and faster return to daily activities. LLIF consists of an anterior interbody fusion that realigns the endplates to a horizontal position through bilateral annular release and allows the placement of a large implant across the disc space reaching the ring apophysis bilaterally, maintaining intact all ligaments that play a role in ligamentotaxis, generating indirect decompression while stabilizing the motion segment [21]. Indications for the lateral approach are the same as those for any interbody fusion, with the limitation of access only disc levels above L5. For sagittal reconstructions, the technique involves complete anterior longitudinal ligament (ALL) and annulus release, with the use of hyperlordotic intervertebral cages. Early report shows that lateral LLIF has the ability to boasts equivalence to SPO correction of these global radiographic parameters while simultaneously creating additional disc height and correcting coronal imbalance [22].

In conclusion, lumbar lordosis is essential in human species as

*Corresponding author: Dr. Luiz Pimenta, Clinical Study Coordinator, IPC - Instituto de Patologia da Coluna, Brazil, Tel: 55 11 29368838; E-mail: luizpimenta@luizpimenta.com.br

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it allows less energetic expenditure to maintain bipedalism and is a consequence of pelvic parameters, spinal muscles, healthy intervertebral discs and vertebral wedging. Consequently, any changes in one of these features lead to sagittal mis alignment and alter load distribution over spinal structures. Surgical restoration of good sagittal alignment improves patient's quality of life and allows a painless and balanced position. Different strategies permits restoration of adequate lordosis, but less invasive techniques have been successfully introduced in the arsenal of surgical strategies for sagittal alignment of the spine, with less morbidity and improved clinical and radiological results.

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