Suarez-Monsalve S, et al., Int J Case Rep Ther Stud 2023, 4: 024
DOI: 10.24966/CRTS-310X/100024

HSOA International Journal of Case Reports and Therapeutic Studies

Case report

Pedicle Subtraction Osteotomy on a Patient with Severe Sagittal Imbalance Progression But Proportionate Gap Score Case Report and Lliterature Review

Silvia Suarez-Monsalve[1, 2*], Julian Alfonso Sierra-Peña[1], Jaime Eduardo Becerra-Ospina[3], Juan Carlos Perez-Rodriguez[3,4]

[1]*Neurosurgery Research Group, Medicine, Pontificia Universidad Javeriana Bogota Colombia*

[2]*Clinical Epidemiology Masters Degree, Pontificia Universidad Javeriana Bogota, Colombia*

[3]*Neurosurgery, Pontificia Universidad Javeriana Bogota, Colombia*

[4]*Spinal deformity surgery, Instituto Nacional de Traumatologia e Ortopedia Jamil Haddad, Rio de Janeiro, Brazil*

Abstract

Purpose: To demonstrate the successful surgical management of a patient with Degenerative Disc Disease (DDD) who underwent multiple surgeries but continued to suffer from severe sagittal imbalance despite a proportioned Global Alignment and Proportion Score (GAP) Score.

Methods: A case report was conducted on a patient diagnosed with a DDD that progressed to severely symptomatic positive sagittal imbalance but a proportionated GAP Score. Additionally, a literature review was conducted on indexed databases such as PubMed, Embase, and OVID, using MeSH terms such as “sagittal balance”, “GAP score” and “spinal column surgery”.

Results: Sagittal spine balance is crucial in evaluating patients with spinal deformities and determining the most appropriate surgical approach for each patient. The GAP Score is a validated method for determining ideal spinopelvic parameters for patients undergoing spinal column surgery. This score is an individualized method of analyzing the sagittal plane based on pelvic incidence, effectively predicting mechanical complications of surgery for adult spinal deformity. Unlike the GAP score, the Sagittal Vertical Axis (SVA) is a reference in this method, and instead, it is replaced by the Global Tilt, which can evaluate spinal and pelvic alignment.

Conclusion: This case report describes a DDD patient and severe symptomatic positive sagittal imbalance. The patient’s proportions were appropriate according to the GAP score, but the SVA was over 150 mm. A Pedicle Subtraction Osteotomy (PSO) at L3 was performed, resulting in lumbar hyperlordosis and correcting the SVA while significantly reducing the patient’s symptoms.

Keywords: GAP score; Pedicle subtraction osteotomy; Sagittal balance; Spine surgery

***Corresponding author:** Silvia Suarez-Monsalve. Medicine, Pontificia Universidad Javeriana Bogota. Cra. 7 No. 40-62, Colombia. Tel: (571) 3208320 - Ext. 2799. E-mail: silvia-suarez@javeriana.edu.co

Citation: Suarez-Monsalve S, Sierra-Peña JA, Becerra JE, Perez JC (2023) Pedicle Subtraction Osteotomy on a Patient with Severe Sagittal Imbalance Progression But Proportionate Gap Score Case Report and Lliterature Review. Int J Case Rep Ther Stud 4: 024.

Received: October 09, 2023; **Accepted:** October 25, 2023; **Published:** November 01, 2023

Introduction

The spinal column is a bone structure tasked with protecting the spinal cord, maintaining an erect posture, and executing movements without pain. In the human species, it also allows bipedalism and march without any external support. The latter was achieved by developing compensatory spinal column curvatures on the sagittal plane which conditions sagittal balance with minimum energy consumption [1]. Pathological changes with these curvatures may cause sagittal disbalance which requires musculoskeletal secondary compensation forces to balance functionality and posture, which also represents greater energy expenditure leading to pain, functional limitations, and quality of life deterioration [2,3]. Sagittal balance connects variables that relate the spinal column with the pelvis and lower limbs, which are denominated as spinopelvic parameters. These correspond to measurable values on a sagittal X-ray with a patient standing and looking to the front. When encountered with pathologies that disrupt the sagittal balance, restoring these parameters to recover the biomechanical relation between these structures is necessary to avoid patient complications [4]. At present there is a tool called the Global Alignment and Proportion score (GAP), which permits analyzing current sagittal balance to make a surgical plan looking forward to ideal biomechanical values and outstanding clinical outcomes [5]. We present the case of an adult male with spinal column disc degenerative disease with prior surgery. The patient progresses to severe sagittal disbalance requiring multiple surgical interventions, finally leading to Pedicle Subtraction Osteotomy (PSO). Although this procedure generates lumbar hyperlordosis, the patient can recover and tolerate bipedalism and march without any external support, drastically improving its functionality and quality of life.

Case Report

First surgical intervention

A male patient in his sixties, with a prior history of grade I obesity, consulting for lumbosacral pain of two years radiating to both lower limbs and associated with paraesthesia and hypoesthesia. Neurological exam evidenced pain to lumbosacral paravertebral touch and pain to axial movements. Preserved strength and sensitivity without signs of radicular stretch or facet stress. Lumbosacral MRI evidenced multilevel degenerative discal disease L2-L3 and L3-L4 Pffirmann III, and

L4-L5 and L5-S1 Pffirmann IV, associated with facet hypertrophy. Dynamic lumbosacral X-ray demonstrates diminished disc height for L2-L3 and L5-S1 (figure 1). Panoramic initial X-ray (March 2020) evidenced right convex 15-degree scoliosis with apex L4-L5. The patient underwent his first surgery via TLIF MIS L4-L5-S1 + T10 to S1 posterior simple instrumentation, correcting coronal disbalance without complications. Clinical follow-up documents pain persistence on the thoracolumbar region associated with lower limb paraesthesia. Post-op images show adequately placed arthrodesis material (figure 2).

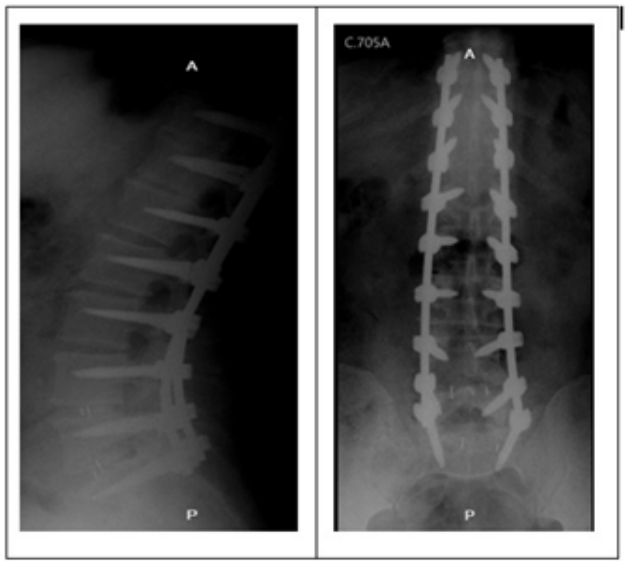

Figure 1: First post-op simple X-rays. Arthrodesis material adequately placed, pedicular screws fixation and intersomatic cages L4-L5 and L5-S1.

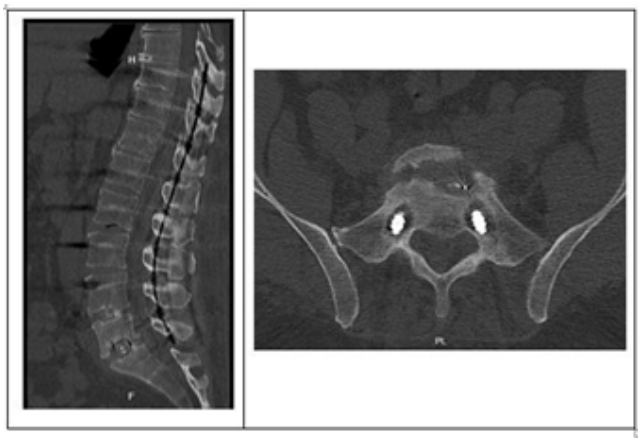

Figure 2: First Post-op CT: Intersomatic fusion mass without complete consolidation, sacroiliac joint vacuum in S1 instrumentation with left predominance.

Second surgical intervention

On the fourth-month post-op, due to symptom persistence despite surgical management a CT scan was ordered as a complementary study, showing a lumbosacral spine with vast foraminal decompression, however, the CT also reported fusion mass without complete consolidation (figure 3). An L5-S1 pseudoarthrosis was considered an adjacent segment disease. A revision, osteotomy, and inter-somatic cage removal TLIF were performed to further insert a new OLIF MIS cage and T5 to S2 iliac extension instrumentation considering the extension of DDD and facet hypertrophic.

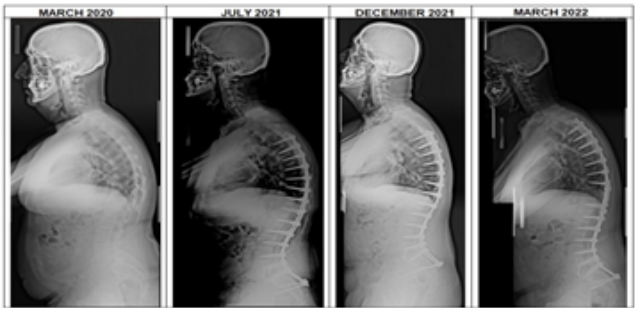

Figure 3: Panoramic radiographs in clinical follow-up.

Forwarding two months, the pain was relinquished to 2/10 on the analog pain scale, with sensitive symptom resolution and no motor deficit. The patient received rehab physical therapy.

Third surgical intervention

On the fourth-month post-op of the last surgical intervention, the patient persists with lumbar and left glute mechanic pain predominantly when standing up and with sacroiliac compression pain. Concatenating with CT these findings suggest post fusion sacroiliitis. The suggested procedure was a bilateral L5-S1-S2 radio frequency percutaneous neuro-ablation technique (DREZ). Likewise, a T5 screw change and Ponte T10-T11-T12-L1 osteotomy with satellite bar connector implantation as reinforcement. The next clinical follow up the patient persists with axial pain and functional limitations. New CT showed L5-S1 pseudoarthrosis signs with L5-S1 intersomatic fusion, and transpedicular screws inserted normally without loosening up. However, as the patient continued having pain, a new panoramic X-ray was taken, and every image taken was used as a comparison and to measure spinopelvic parameters (figure 4). These parameters were labeled as proportional according to GAP score [6], apart from sagittal balance (parameter not included in the GAP score) which showed severe progression overthrowing the 150mm of positive disbalance (figure 4). Severe sagittal disbalance made progressive and significant changes in the patient's posture, increasing his cervical lordosis to maintain eye gaze frontwards, inclining the pelvis backward, extending the hip, and flexing both knees while walking. This translated into an osteomuscular energy expenditure increase causing pain, fatigue, and medical absent leaves.

Figure 4: Double bar system L3 PSO day one post op X-ray. A posterior wall reduction is appreciated and lumbar lordosis gains.

Fourth Surgical Intervention

Knowing the severe sagittal disbalance and the patient's adaptive changes, despite adequate spinopelvic proportion classification, a fourth surgical intervention was decided to improve sagittal balance even though this can compromise other parameters (table 1). An L3 PSO was performed (figure 5) with the goal of diminishing posterior vertebral wall height, and overcorrecting lumbar lordosis which reduces sagittal deformity (figure 6). Intra-operatory findings demonstrate chromium-cobalt bar rupture on the distal segment, connecting with the great mechanical effort the patient made, requiring T3 instrumental extension and double bar lumbosacral reinforcement (figure 7).

Spinopelvic parameters	Initial	POP 1st surgery	POP 2nd surgery	POP 3rd surgery	POP Last-surgery
Pelvicincidence (PI)	**60º**	**62º**	**69º**	**69º**	**62.8º**
PelvicTilt (PT)	14º	20º	24º	22º	23.3º
SacralSlope (SS)	49º	47º	49º	47º	42.4º
Lumbar Lordosis L1-S1	59º	65º	70º	60º	72.8º
Lumbar Lordosis L4-S1	40º	46º	53º	42º	31.3º
Sagital vertical axis (SVA)	112 mm	113 mm	11 mm	165 mm	72 mm
Global Tilt (GT)	17.5º	26.2º	31.5º	30º	30º
Global Alignment and proportion (GAP) Score	1	0	1	1	2
MISMATCH (LL-PI)	-1	+2	+3	+9	+13.2

Table 1: Spinopelvic parameter comparisons while measuring on the follow up panoramic X-rays.

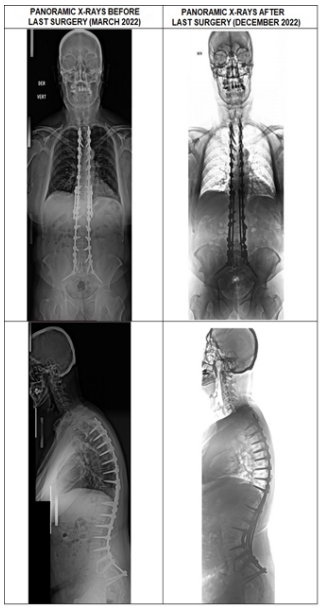

Figure 5: Coronal and Sagittal panoramic X-ray comparison from the last surgery.

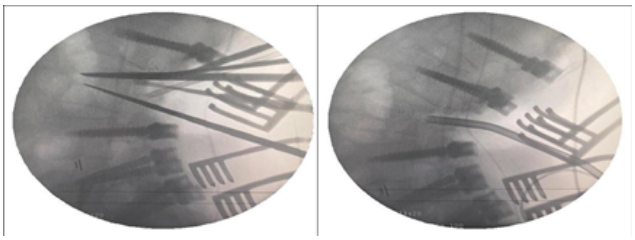

Figure 6: Intraoperative fluoroscopy X-rays. The left image shows osteotomes building wedges with the anterior vertex. The right image shows the wedge removed. An immediate lordosis gain is evidenced compared with previous bar implantation.

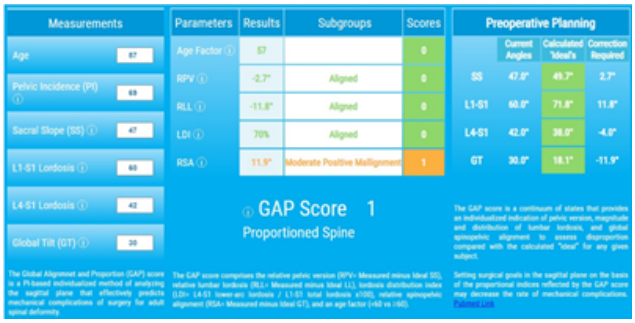

Figure 7: Patient GAP score before the last surgical procedure within proportions, calculated withhttp://www.gapcalculator.com/

From that point onwards, the patient began to show consistent clinica improvement. His posture changed, andhe continued to experience a significant recovery in his quality of life, which has remained consistent even after a year.

Discussion

Bipedalism in Homo sapiens stands as an evolutionary feat, liberating upper limbs during movement. However, this exchange, though advantageous, decreases sagittal balance stability compared to other mammals, increasing susceptibility to spinal degenerative diseases [7,8]. Unlike most primates, humans developed cervical and lumbar lordosis to counter thoracic kyphosis, preserving a forward head posture [7,9]. Spinal balance predominantly relies on sagittal plane curvature over coronal curvature [5]. Multiple pathologies can disrupt this balance, necessitating a comprehensive understanding of normal sagittal balance and compensatory mechanisms for effective therapeutic strategies.

Evaluating spinal balance is dynamic, often done using static exams like X-rays. However, this approach has limitations as it reflects the patient's position during the exam, constraining interpretation. To overcome this, a holistic approach analyzing body postures (sitting, standing, walking), forward head posture, horizontal gaze position, lower extremity adjustments, and upper limb support needs consideration [10,11].

The Sagittal Vertical Axis (SVA), measuring the distance between a line through half of C7's vertebral body and one from the sacrum's poster inferior corner, is a critical parameter for evaluating quality of life [12]. It widens with aging, although position-related variations introduce bias (2.5). Increasing sagittal imbalance increases pain and functional limitations, warranting surgical intervention.

The Global Alignment and Proportion score (GAP score), assessing sagittal balance against patient Pelvic Incidence (PI), predicts post-op complications (p-value <0.001, CI 0.85-0.98) based on parameters like pelvic version, lumbar lordosis distribution, and spinopelvic alignment (5). A proportional balance yields a 6% complication rate, contrasting 47-95% for moderate to severe disproportion [5]. Anterior deviation increases complications, especially with pelvic anteversion and hyperlordosis. Nevertheless, the GAP score's predictive capacity for mechanical failure remains debated [13-15].

Our case had a calculated GAP score but a notably positive SVA, complicating bipedalism, walking, and causing mechanical issues. SVA, excluded from the GAP formula, demands individual analysis for surgery. It's vital to customize each case, considering SVA's variation and its linkage to quality of life [12]. Descriptive parameters serve as guides, not rigid rules, varying with age, sex, and race.

Aging and spinal deformities evoke compensatory musculoskeletal shifts to maintain sagittal balance, including lumbar lordosis, thoracic spine flattening, pelvic retroversion, and knee flexion [16]. These adaptations seek bipedal posture and horizontal gaze with minimal energy expenditure. Correcting lower limb alignment, exemplified in our case, becomes a key therapeutic goal for spinopelvic surgery planning, yielding successful results [17-25].

Conclusion

Sagittal spinal column balance is achieved by maintaining harmony within its architecture, preserving constitutional curvature ranges. This allows us to maintain bipedalism equilibrium with a low energy expenditure. When patients have an affected sagittal balance, knowing about compensatory mechanisms, parameters and global evaluation is fundamental to making therapeutic decisions and reducing mechanical complications in spinal deformity surgical procedures. However, it is important to highlight that, while spinopelvic parameters are valuable reference values, at times, the patient`s clinical presentation takes precedence over these measurements. Even when a patient is classified as "proportionate" or with a GAP of 1, the may continue to exhibit symptoms that lead to multiple surgeries. In some cases, hyperlordosis generations is resorted to in order to compensate for their sagittal balance and alleviate symptoms. This underscores the importance of addressing each case on an invidivualized basis, considering both spinipelvic parameters and the patient's clinical experiences.

Ethical Considerations

This case corresponds to a patient with an age of majority, having all his cognitive qualities preserved. Who widely knows the nature, benefits, and risks of this research, as the academic interest of publishing his medical history. Informed consent procedures were undertaken according to the International Medical Ethics Committee´s directives.

Statements and Declarations

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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