DOI: 10.21608/pajn.2022.108045.1040

Case Report

Two-stage operative therapy of L5 vertebra spondyloptosis (Surgery technique introduced by R. Gaines) Clinical case

Bulatov Aleksandr Vasilievich,[1] Evsyukov Aleksey Vladimirovich,[2] Kubeckiy Yuliy Evgenyevich,[1] Rzaev Jamil Afet oglu[1]
[1]Federal Neurosurgical Center, Federal State Budgetary Institution under the RF Ministry of Healthcare, city of Novosibirsk, RUSSIA
[2]The Russian Ilizarov Scientific Center for Restorative Traumatology and Orthopaedics, Federal State Budgetary Institution under the RF Ministry of Healthcare, city of Kurgan, RUSSIA

Received: 26 November 2021 / **Accepted:** 24 January 2022 / **Published online:** 21 December 2022

BACKGROUND: Grade V spondylolisthesis or spondyloptosis is a clinical state quite rare for the population, of less than 1%.The main aspects of operative improvement are rather few in number. One-stage spondyloptosis treatment involves in situ fixation, partial reduction and stabilization. Another option, when the surgical aid includes a multi-stage approach for this pathology, for example, by L5 vertebrotomy with L4 - S1 interbody fusion development, was described by R. Gaines. But this procedure is accompanied by a high complications risk described by the author himself.

CASE PRESENTATION: Herein a case of surgical treatment of 27 years old young man, who complained of severe lumbar pain and pain in both legs is observed. In particular, L5 vertebra spondyloptosis was detected. The patient has undergone a two-stage R. Gaines surgery, including L5 vertebrotomy, L4 vertebra repositioning over S1, L4-S1 interbody fusion with mesh cage and L3-L4-S1-S2- alar transpedicular fixation. 12 months later, after bone block shaping at L4-S1 level, a part of screw attachment system was removed. L5 vertebra dislocation (100% dislocation) was measured, and the parameters of sagittal modifiers: (PI, PT, LL, L4- S1, SS, TK, SVA) were assessed. Clinical outcomes were monitored using VAS, ODI and MacNab scales. After 18 months, the patient was able to resume his working activity associated with hard physical labor.

CONCLUSION: Surgical technique introduced by R. Gaines is a reliable, complex and by no means a powerful instrument for vertebral column repair and lumbar spine sagittal balance improvement in spondyloptosis.

KEYWORDS: Surgery technique introduced by R. Gaines, Spondyloptosis, High grade spondylolisthesis, L5 Vertebrotomy, Vertebral column shortening, Vertebral-pelvic balance.

INTRODUCTION

For the first time ever the term "Spondylolisthesis" was introduced by Killian in 1854; etiology and healing techniques were widely debated, but treatment of rare cases of spondyloptosis became the real issue for everyone. Grade V spondylolisthesis or spondyloptosis (Pursuant to H.W. Meyerding's classification of 1932, augmented by J. Junge and F. Kuhl in 1956) is a rare clinical status, the treatment of which requires an individual approach in each particular case. Spondyloptosis shall be defined as ventral dislocation of L5 vertebral body ventraly and caudally to S1 vertebral body. Frequency of high-grade spondylolisthesis (Higher than 50% of vertebral body dislocation) is rated at no more than 5% of the total number of detected spondylolisthesis; wherein spondyloptosis appears in less than 1% of cases.[1,2,5] One-stage spondyloptosis treatment involves in situ fixation, partial reduction and stabilization.[3,4] Weaknesses of surgical techniques used for spondyloptosis treatment (In situ fixation, partial reduction and stabilization) reside in the fact that they do not reduce deformity (LL, L4-S1) and besides being associated with a very high level of pseudoarthrosis (28-45%).[4,6] On top of that, this surgical technique is associated with the risk of neurological deficit increasing (18 -29%),[3,7] and requires a long period of bed rest.[3,6,7] Unsatisfactory results encouraged search for new surgical techniques.

R. Gaines was the first one who developed and reported a two-stage L5 vertebraectomy technique and L4 to S1 repositioning in spondyloptosis in 1985; in the year of 2005, he provided the data on satisfactory results obtained from 30 patients in the long-time perspective. Global literature statistics revealed only 9 publications that have been published over 35 years (4 of them were by R. Gaines).

Over the past decade, in the course of treatment of spondylolisthesis, the analysis of sagittal balance and vertebral-pelvic relationship has become increasingly important.[8] Without conducting osteotomy, none of the applied approaches can improve biomechanical situation by reducing lumbosacral kyphosis and lumbosacral lordosis restoring.[6]

The present article describes a case history of patient's

Correspondence:
Bulatov Aleksandr Vasilievich
Federal Neurosurgical Center, Federal State Budgetary Institution under the RF Ministry of Healthcare, city of Novosibirsk, Russia
Email: bulatov-av@mail.ru

treatment with a rare state of spondyloptosis (Persistent vertebral pain syndrome and vertebral column deformity). Two-stage surgery technique according to R. Gaines' procedure was carried out successfully. This intervention is complicated and currently used in exceptional cases.

Study design: Case-control. Evidence level – 4 (UK Oxford, 2009 revision).

Case history

A 27-year-old patient presented to the clinic with A 27-year-old patient presented to the clinic with complaints of constant pain in lumber spine, pain along posterior and exterior hips' surfaces. The pain increased with daily activities and partially decreased during rest. Such clinical signs disturbed the patient for 8-years period with gradual progression. Conservative therapy did not produce any desired effect.

On admission lumbar hyperlordosis and sacropelvic kyphosis were presented in the patient; L-spine: flexion-extension movements' inactivation. Clinical signs were assessed using a visual analogue pain scale (VAS) questionnaire, Oswestry Disability Index (ODI) questionnaire. VAS back - 8, VAS legs – 6, ODI: 68 points.

Complete preoperative neurological examination revealed hyperesthesia along L5 and S1 dermatomes in the right lower limb, ambilateral Achilles reflex depression. No affection of motor power weakness Power paresis was not observed. Positive LL stretch symptoms (up to 450).

Full-length X-ray of vertebral column revealed L5 vertebra spondyloptosis located below S1 superior endplate, as shown in **(Fig. 1).**

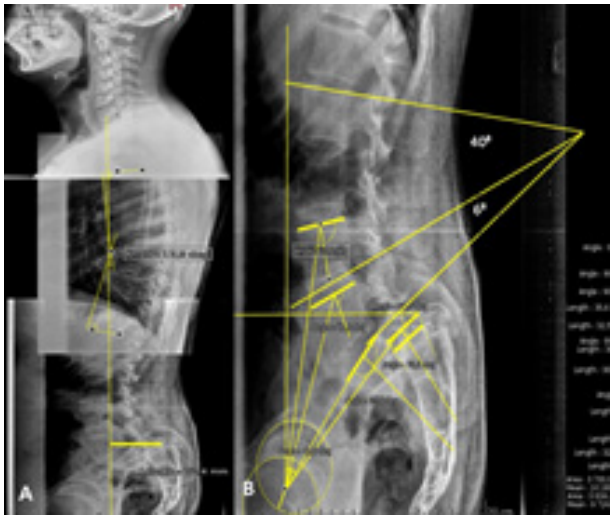

Fig: 1 Side X-ray images of the vertebral column (A – entire vertebral column, B – lumbar spine). Ventral dislocation of L5 vertebra followed its caudal migration and rotation in the sagittal plane is to be determined.

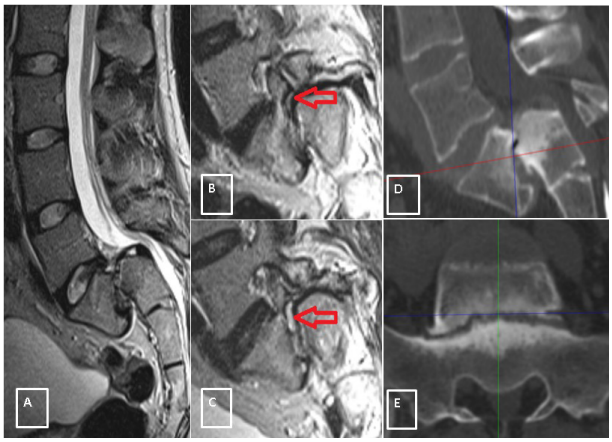

Fig 2: MRI and MSCT of L-spine before surgery. T1 mode in sagittal (A) plane; B – L5-S1 foramen stenosis from the left, C - L5-S1 foramen stenosis from the right); (D) and (E) Sagittal & Axial reconstruction of CT scans at L5-S1.

L5 vertebra not only moved forward and descended into the pelvis area, but also turned in the sagittal plane along transverse axis, so that the lower L5 endplate faces the anterior S1 body surface **(Fig. 1)**. In addition, a defect in interarticular arch section from both ends, dysplasia of facet joints and domed sacral bone were revealed. Assessment of the sagittal balance parameters was carried out: PI = 79°, L5I = 86°, L4I = 42°, L3I = 21°, PT = 42°, SS = 37°, L4-S1 = 6°, LL = 40°, TK = 18°, SVA = 72 mm (Fig. 1). These changes may be interpreted as follows: in-place disorder with respect to local lumbar lordosis, following lower (And the whole) lumbar lordosis angle sharp decrease, accompanied by expansion of not only compensatory changes - thoracic hyperkyphosis reduction and pelvis retroversion, but also the development of global sagittal imbalance, manifested in SVA increase. According to SDSG-classification,[9] the above concerns high grade spondylolisthesis with sagittal imbalance development, type 6 - High grade spondylolisthesis, unbalanced spine. Vertebral-pelvic indices, associated with an increased risk of dislocation progression, were as follows: slip angle 116° (Normal: 10° to 0°),[10] lumbosacral angle Dubousset,[11] 61° (Normal: 90° to 110°), SDSG lumbosacral angle 20°.12 Ambilateral foramen stenosis at L5-S1intervertebral foramen level was revealed using magnetic-resonance imaging and computed tomography **(Fig. 2).** Based on the results of computed tomography reconstruction, one can state the absence of the bone block at L5 vertebral body level - first sacral vertebra dislocation.

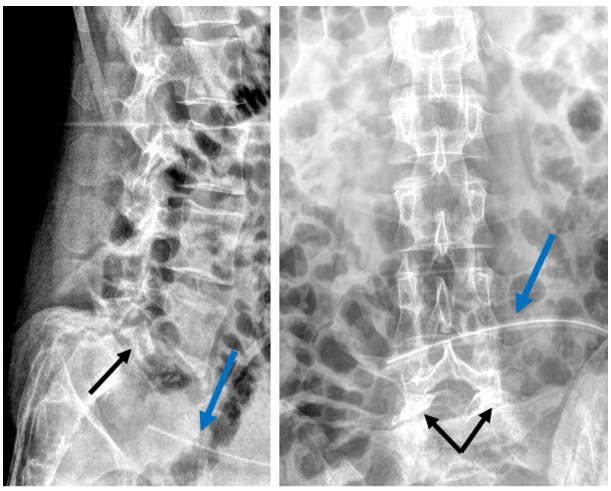

Fig 3: Survey radiographs of the L-spine (A-lateral, B-anterioposterior) after the first stage of operative therapy. Indicated by arrows: black arrow – part of vertebral pedicles, blue arrow – drain inserted into the surgical site.

The patient was considered for various treatment options such as: in situ fixation, partial reduction and posterior approach stabilization, L5 vertebraectomy/transpedicular stabilization two-stage treatment (surgical technique introduced by R. Gaines). It has been also reported on potential technical difficulties, risk of neurologic deficit, lower paraplegia development and pelvic organs' malfunction. Taking into consideration the rarity of the pathology and possible development of intraoperative complications, a two-stage surgery technique divided approach, stage II: median posterior approach, consent was taken for the intervention.

Surgical technique

Description of the surgical technique may be found in writings by R. Gaines and W. Nichols.[1] The surgery was carried out in two stages: from anterior approach and posterior approach and the time limit between the 2 stages was made up 1 week. In the first stage, resection of L5 vertebral body together with L4-L5 and L5-S1 discs were removed from anterior retroperitoneal approach. The location of the L5 body was caudally to the caval bifurcation between common iliac veins. The vessels were mobilized and pulled apart and the lowest part of L5 body, lying on the anterior S2 surface was identified. L4-L5 disc was removed and complete L5 corpectomy up to the base of pedicles was carried out and L5-S1 intervertebral cartilage was removed. The posterior longitudinal ligament was visualized and repositioning was not carried out. The duration of the surgery was 125 minutes, while the blood loss was 350 ml.

Extent of the surgery intervention has been confirmed by postoperative X-ray follow-up, **(Fig. 3).**

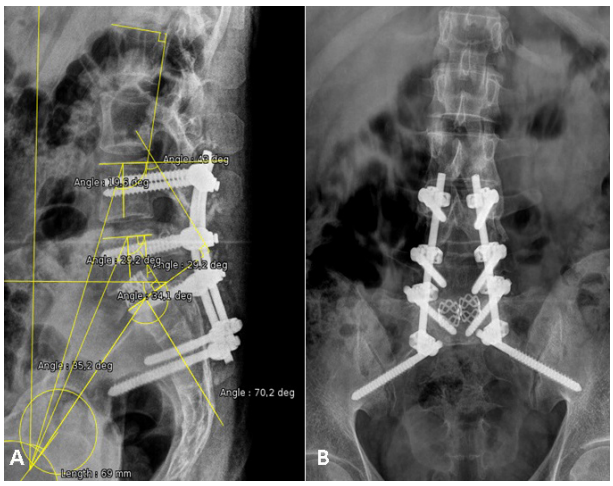

Fig 4: Survey subsequent radiographs of the L-spine (A-lateral, B-anterioposterior) taken after operative therapy of the patient in an upright position.

Based on the control X-ray examination it's already possible to report about the L5 vertebra remnants' repositioning and partial restoration of spinal-pelvic relationship. During the post-surgical period, the patient did not undergo verticalization. After 7 days the second stage was carried out through a standard posterior approach along the midline. Screws were installed transpedicular into L3, L4, S1 pedicles, S2 – iliac wings on either side. Laminectomy, facetectomy and resection of L5 vertebra pedicles' remaining portion and cranial portion of S1 vertebra dome were carried out. Visualization and mobilization of L4, L5 and S1 roots. In consequence of the applied manoeuvre, L4 and L5 spinal roots were localized at L4-S1 reconstructed foramen level. The L4 vertebra–S1 repositioning was carried out using interjacent rods. L4-S1 interbody fusion was carried out by means of two Mesh implants (Diameter: 14 mm, height: 15 mm) filled with bone flap resulting from bone resection. For the achievement of lordosis after repositioning two rods were set. Transpedicular fixation was mounted and screw compression was undertaken.

Motor evoked potentials were monitored throughout the surgery and the duration of the surgery was 300 minutes while the blood loss was 750 ml.

Post-surgical period

The patient was brought into verticalization 2 days after completion of the second stage. An occurrence of neurological deficit manifested as grade 3 weakness affecting the along L5 roots on both sides. On the background of rehabilitation measures, paresis regressed to full recovery within 8 weeks, demonstrating no loss of sensitivity. Postoperative wounds healed by primary intention. Subsequent radiographs were taken after the patient's verticalization and activization, **(Fig. 4).**

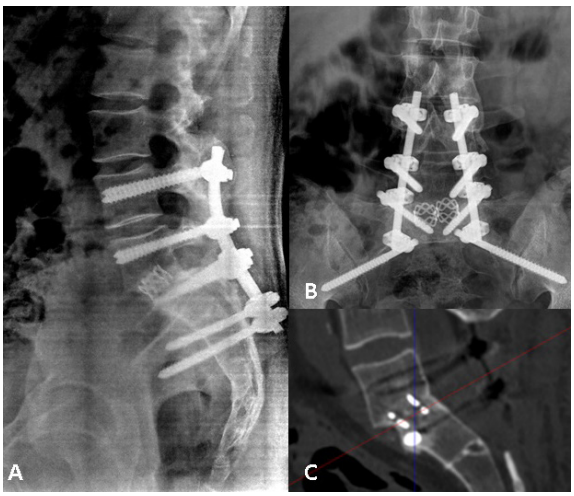

Fig. 5: X-ray radiography (A-lateral, B- anterioposterior) and (C) sagittal reconstruction of CAT scans at the formed bone block level between L5 and S1 12 months after the surgery.

The two-stage operative therapy made it possible to significantly improve lumbopelvic relationships. Owing to resection of the sacral bone dome, the index of pelvis inclination (PI) have been decreased up to 70°, which, combined with reduction of L4 vertebra, made it possible to increase lower lumbar lordosis (L4-S) 1 up to 29°, with an improvement in the range of 20 degrees and the entire lumbar lordosis (LL) up to 40°. In addition, the sacral bone tilt had been changed accordingly, SS = 37°; the pelvis tilt (PT) had been decreased up to 35°. The surgical intervention made it possible to significantly improve spinal-pelvic indices, but the ideal ones for the given patient were not achieved.

The recommendations for the patient were restrictive orthopedic regimen for the period up to 6 months.

One year after the surgery the patient returned to standard daily activities, experiencing absence of back and legs' pain. Control X-ray radiography and MSCT examination, **(Fig. 5)**, displayed the bone block formation (according to classification introduced by K. H. Bridwell[13] at L4-S1 level; retention of the sagittal balance indicators in terms of the achieved improvement: PI = 70°, PT = 35, SS = 35°, L4-S1 = 29°, LL = 43°.

Considering the so formed bone block at L4-S1 level of intervention **(Fig. 5)** and relatively young age of the patient, it was decided to remove proximal and distal structural elements. **(Fig. 6).**

After the patient's management during 18 months the following results were achieved: Complete neurological deficit restoration, return to work and active lifestyle; VAS-back - 0, VAS-legs - 0, ODI - 8 points. The sagittal balance achieved targets: PI = 70°, PT = 35, SS = 35°, L4-S1 = 29°, LL = 51°, SVA - 45 mm.

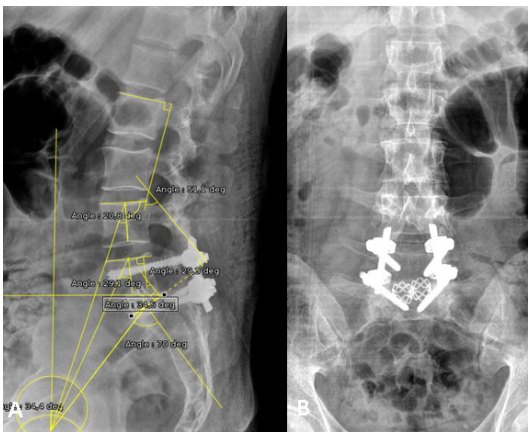

Fig 6: Survey radiographs (A-lateral, B- anterioposterior) of the L-spine taken after 18 months.

DISCUSSION

Spondyloptosis turns out to be the most severe form of spondylolisthesis, where L5 vertebra body is shifted below S1 upper part. Unprompted block formation between L5 and S1 vertebrae occurs with almost 50% of patients suffering spondyloptosis.[14] The goal of operative therapy unless natural bone block was formed concerns pain management, progression prevention, vertebral column orthosis and sagittal balance improvement. Clinical indications towards operative therapy of spondyloptosis include vertebral pain syndrome, spinal deformity progression and neurological disorders such as mono-radicular nerve root syndrome or polyradicular cauda equina root syndrome with pelvic organ dysfunction.[2,5,6]

The best treatment procedure with respect to this rare pathology is still a matter of argument. A great deal of surgeons recommend in situ posterior fixation.[3,7,15] But such interventions exclude vertebral column orthosis and sagittal balance improvement, thus resulting in disease progression and vertebral pain syndrome preservation. Patients with in situ fixation and suffering spondyloptosis have been reported about frequent complications, such as: Pseudoarthrosis high index (60%), deformity progression of the lumbar spine region with sagittal imbalance aggravation (45%).[14] For example, Boos et al. described a number of cases of L5 vertebra partial repositioning using only posterior metal fixation and consequently reported on a great number of pseudoarthrosis.[16] Some surgeons follow another approaches and offer partial reduction of spondyloptosis using extended metal structures from the posterior approach with minimal sagittal balance improvement. Reduction of L5 vertebra degree of separation is possible level of S1 upper vertebral end plate or higher. In severe cases reduction is carried out via osteotomy of the sacral bone dome.[5] As for our clinical case study, the L5 upper vertebral end plate was positioned below the S1 vertebra upper plate; reduction was problematic owing to a high risk of neurological complications; therefore, osteotomy of the sacral bone dome was obligatory and thus changed spinal-pelvic relationship.

Surgical technique proposed by R. Gaines in 1985 seems to be a revolutionary one with respect to operative treatment of spondyloptosis.[1] The author pointed out an important advantage of his shortening vertebrotomy technique, because of sagittal balance restoration and pelvis retroversion reduction, one can speak on improvement of the sagittal balance compensatory mechanisms, restoration of lordosis and lumbar-femoral rigidity phenomena disappearance. As concerns our particular case, the patient's sagittal balance compensatory mechanisms before surgery were: (PI = 79°, L5I = 86°, L4I = 42°, L3I = 21°, PT = 42°, SS = 37°, L4-S1 = 6°, LL = 40°, TK = 18°, SVA = 72 mm). The sacral bone and pelvis were turned backwards (retroversion), thoracic hyperkyphosis was reduced – as a compensatory mechanisms they illustrated lumbar lordosis sharp decrease.[17] However, compensatory reactions were not sufficient, thus giving rise to the vertebral column imbalance progression which is confirmed by the SVA-indicator equal to 72 mm. After the surgery we noted improvement of the sagittal balance indicators: PI decreased up to 70° (Due to resection of the posterior part of the S1 vertebra dome), LL changed up to 43° and L4-S1 changed up to 29°. Some real changes of the sagittal balance improvement were "absorbed" by an increased tilt of the sacral bone after the surgery (PT = 35, SS = 34°) and segmental decrease at each level. But the said improvement actually corresponded to the new PI parameters and was sufficient for stabilization and reduction of load on compensatory mechanisms. The above led to a complete pain management and the patient's vocational rehabilitation. Finishing surgery, that involved hardware shortening, made it possible to further improve lumbar lordosis (LL) up to 51°; however, at this stage of monitoring, we may observe persistent pelvis tilt (PT) up to 34°.

During first surgeries done according to R. Gaines' technique,[1] the L4 vertebral body was straightforwardly connected to S1 superior end, providing direct bone-to-bone fusing between L4 and S1 vertebrae bodies, thus resulting in absence of lordosis between the L4 and S1 vertebrae bodies. All of that impedes the possibilities for sagittal balance improvement. In addition, two nerve roots (L4 and L5) pass between the pedicles L4 and S1, coming out through common passages that are subject to compression, since no implant is used between L4 and S1 vertebrae bodies.

Paresis along the L5 root turned out to be the most common complication attributed to all these surgeries As for R. Gaines study, neurological deficit occurred in 12 (75%) cases out of 16 patients. Most of these neurological manifestations regressed, and in 25% of cases persistent neurological deficit (weakness in one or both legs) remained. In some later study, R. Gaines reported informed of the following: paresis along the L5 root during post-surgery period occurred in 23 out of 30 patients. With In the midst of the ongoing rehabilitation (within the period from 6 weeks up to 3 years), 21 out of 23 patients showed complete neurological deficit response.5 In our clinical case, neurological deficit in the patient occurred during post-surgery along L5 roots on both sides, but within 8 weeks it was completely recovered.

Experience gained by R. Gaines when performing vertebrotomy of L5 vertebra for spondyloptosis makes it possible to overcome the problem of iatrogenic syndrome of cauda equina roots' radiculopathy with pelvic organs dysfunction, but temporary affection deficiency of the L5 root is still possible affected by tension and because of vertebrae position improvement.[13] Total resection of L5 vertebra structure and its ligaments, maximum mobilization of the roots with their minimal distraction under intraoperative neurophysiological control seem to be the key to minimizing the risk of neurological disorders and adequate repositioning achievement.

The present article deals with only one case of vertebrectomy of the L5 vertebra for spondyloptosis (Type 6 according to SDSG-classification), since this pathology occurs in only 1% of all high grade spondylolisthesis cases. Surgical technique introduced by R. Gaines is a fairly complicated procedure; despite the development of anesthesiology and resuscitation, practical application of intraoperative neuroimaging and neurophysiological control, the said technique is rarely used. Based on literature and in the course of patient questioning, despite the emerging neurological deficit, an extremely high degree of satisfaction with the performed surgery and the achieved result in terms of improvement of the quality of life were revealed.

CONCLUSION

The Surgical technique introduced by R. Gaines is a reliable, complex and by no means a powerful instrument for vertebral column repair and lumbar spine sagittal balance improvement in spondyloptosis. Even with high morbidity of neurological complications, the technique represents a safe treatment option with proven long-term effect. Patients shall be advised about high risks associated with neurological, vascular and abdominal complications. Such complex and multi-stage repair of vertebral column requires solid grounding of the surgical team.

List of Abbreviations

LL: Lumber Lordosis.
MSCT: Multi Slice Computerized Tomography.
PT : Pelvic Tilt.
SS: Sacral Slope.
SL: Segmental Lordosis.
SVA: Sagittal vertical axis.
SDSG : Spinal Deformity Study Group.
TK: Thoracic kyphosis.
PI: Pelvis inclination.
ODI: Oswestry Disability Index.

Disclosure

The authors report no conflict of interest in the materials or methods used in this study or the findings specified in this paper

Funding

The authors received no financial support for the research, authorship, and/or publication of this paper.

Informed Consent

An informed consent was taken from the patient.

REFERENCES

1. Gaines RW, Nichols WK. *Spine.* 1985;10:680-6.
2. Passias PG, Poorman CE, Yang S, et al. Boniello AJ, Jalai CM, Worley N, et al. Surgical treatment strategies for high-grade spondylolisthesis: A systematic review. *Int J Spine Surg.* 2015;9:50.
3. Bohlman HH, Cook SS. One-stage decompression and posterolateral and interbody fusion for lumbosacral spondyloptosis through a posterior approach. Report of two cases. *J Bone Joint Surg Am.* 1982;64:415-8.
4. Junge, H. /Bruns. Beitr. Klin. Chir. Appearance and significance of neural symptoms in lumbar spondylolisthesis and indications for operative management. 1956;193(N1):39–58.
5. Gaines RW. L5 vertebrectomy for the surgical treatment of spondyloptosis: Thirty cases in 25 years. *Spine.* 2005;30(Suppl):66-70.
6. Lehmer SM, Steffee AD, Gaines RW Jr. Treatment of L5–S1 spondyloptosis by staged L5 resection with reduction and fusion of L4 onto S1 (Gaines procedure). *Spine.* 1994;19:1916–25.
7. Peek RD, Wiltse LL, Reynolds JB, et al. Thomas JC, Guyer DW, Widell EH. In situ arthrodesis without decompression for grade-III or IV isthmic spondylolisthesis in adults who have severe sciatica. J Bone Joint Surg. *Am.* 1989;71:62-8.
8. Bridwell KH, Lenke LG, McEnery KW. et al. Anterior structural allografts in the thoracic and lumbar spine. *Spine.* 1995;(20):1410-1418.
9. Labelle H. Spino-Pelvic Sagittal Balance of Spondylolisthesis: A Review And Classification. *Eur Spine J.* 2011;20(Suppl 5):S641–S646.
10. Hu SS, Bradford DS. Spondylolysis and spondylolisthesis. In: Weinstein SL (ed) The pediatric spine principles and practice. Lippincott Williams & Wilkins, *Philadelphia.* 2001:433-451.
11. Dubousset J. Treatment of spondylolysis and spondylolisthesis in children and adolescents. *Clin Orthop.* 1997;337:77–85.
12. O'Brien MF, Kuklo TR, Blanke KM, et al. Spinal Deformity Study Group. Radiographic measurement manual. *Medtronic Sofamor Danek.* 2004.
13. Petraco DM, Spivak JM, Cappadona JG, Kummer FJ, Neuwirth MG. An anatomic evaluation of L5 nerve stretch in spondylolisthesis reduction. *Spine (Phila Pa 1976).* 1996;15;21(10):1133-8; discussion 1139.
14. Seitsalo S, Osterman K, Hyvarinen H, Schlenzka D, Poussa M. Severe spondylolisthesis in children and adolescents. A long-term review of fusion in situ. *J Bone Joint Surg Br.* 1990;72: 259-65.
15. Molinari RW, Bridwell KH, Lenke LG, Ungacta FF, Riew KD. Complications in the surgical treatment of pediatric high-grade, isthmic dysplastic spondylolisthesis. A comparison of three surgical approaches. *Spine (Phila Pa 1976)* 1999;24:1701-11.
16. Boos N, Marchesi D, Zuber K, Aebi M. Treatment of severe spondylolisthesis by reduction and pedicular fixation: A 4-6-year follow-up study. *Spine.* 1993;18:1655-61.
17. Lamartina C, Berjano P. Classification of sagittal imbalance based on spinal alignment and compensatory mechanisms. *Eur Spine J.* 2014;23(6):1177-89.