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A novel technique for sublaminar-band-assisted closure of pedicle subtraction osteotomy

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Keywords Sagittal imbalance · Pedicle subtraction osteotomy · Flat back · Sagittal balance restoration · Sublaminar bands

Learning targets

1. To illustrate the principles of surgical planning in sagittal imbalance.
2. To describe technical tips to perform the osteotomy on sclerotic bone adjacent to epidural scar tissue and to reproduce surgical planning.
3. To describe a novel, sublaminar-band-based technique to assist osteotomy closure.

Introduction

Sagittal imbalance is a spinal deformity with multifactorial etiology, associated with higher risk of low back pain, disability and poor health-related quality of life [1, 2]. Pedicle subtraction osteotomy (PSO) is the most commonly performed osteotomy to increase lumbar lordosis and gain a balanced spine on the sagittal plane in adults with sagittal imbalance [3, 4]. PSO is a technically demanding procedure and poses significant risk on the patient, especially in the elderly [5], including mortality from bleeding and perioperative complications. Insufficient correction has demonstrated to be a risk factor for poor results and reoperation [6–9].

Some key aspects for the successful execution of a PSO for sagittal imbalance are preoperative planning with calculation of the amount and site of needed correction, a team approach with advanced hemodynamic and neurophysiological intraoperative monitoring, adequate pelvic fixation, effective closure of the osteotomy, intraoperative measurement of the amount of correction obtained and adequate selection of the upper limit of instrumentation [10–15].

Though usually a combination of forces directly applied to the spine, bending of the table and application of forces through pedicle screws allows for straightforward closure of the osteotomy, in some cases a good reduction is difficult to obtain due to sclerosis of the vertebral body where the osteotomy is performed or bone fragility, with risk of implant failure when high modulus forces are applied through pedicle screws. In this paper, we present a novel technique based on application of forces through the osteotomy with sublaminar bands in help closure of the osteotomy and increase the stiffness of the final construct around the PSO.

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Fig. 1 Preoperative standing full spine (*left* and *center*) and lumbar (*right*) radiograms

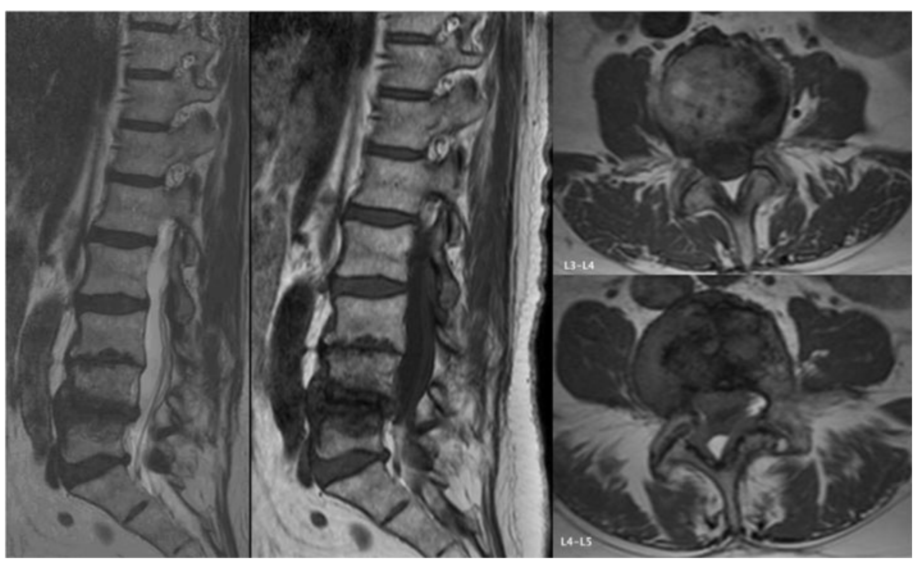

Fig. 2 Properative lumbosacral spine MRI: sagittal T2 (*left*), sagittal T1 (*center*), axial T1 of L3–L4 (*upper right*) and axial T1 of L4–L5 (*bottom right*)

Case description

A 74-year-old woman suffering from chronic low back pain radiating down both lower limbs and severe limitation in walking (maximum distance limited to 300 m, with crutches in a forward-bending position) was admitted to our Spine Surgery Division. Her Oswestry Disability Index (ODI) was 42 %, and

Fig. 3 Preoperative clinical images

numeric-rating scale for pain was 7/10 in her back and 9/10 in her legs. In 2007 she had undergone surgery for L3–L4 stenosis with fair mid-term results. Her radiological investigations showed (Fig. 1) a short and mild degenerative lumbar scoliosis, severe lumbar hyperlordosis, L4–L5 stenosis and severe discopathy in L3–L4 and L4–L5 (Fig. 2), associated to severe bone sclerosis in the L4 vertebral body. Her spinopelvic parameters were: pelvic incidence (PI) = 41°, pelvic tilt (PT) = 15°, lumbar lordosis (LL) = 28°, thoracic kyphosis (TK) = 38°, sagittal vertical axis (SVA) = 86 mm (Fig. 1). We calculated expected LL to be 53° and expected PT to be 8°. The clinical picture of the patient is presented in Fig. 3. Thus, preoperative planning dictated the need to increase the lumbar lordosis by 25°, with L4–L5 nerve root decompression and T10-ilium fixation and fusion. The thoracic spine was not included in fusion as thoracic kyphosis was below the expected value for her age group (expected TK = 43°), demonstrating ability to actively compensate in the thoracic region [16]. To achieve such a correction, a PSO performed at L4 was chosen.

Surgical procedure

Patient is positioned prone on a Jackson table with complete hip extension, abdominal decompression and the hinge of the table at the level of the osteotomy. A lateral X-ray of the lumbar and thoracic spine is performed to

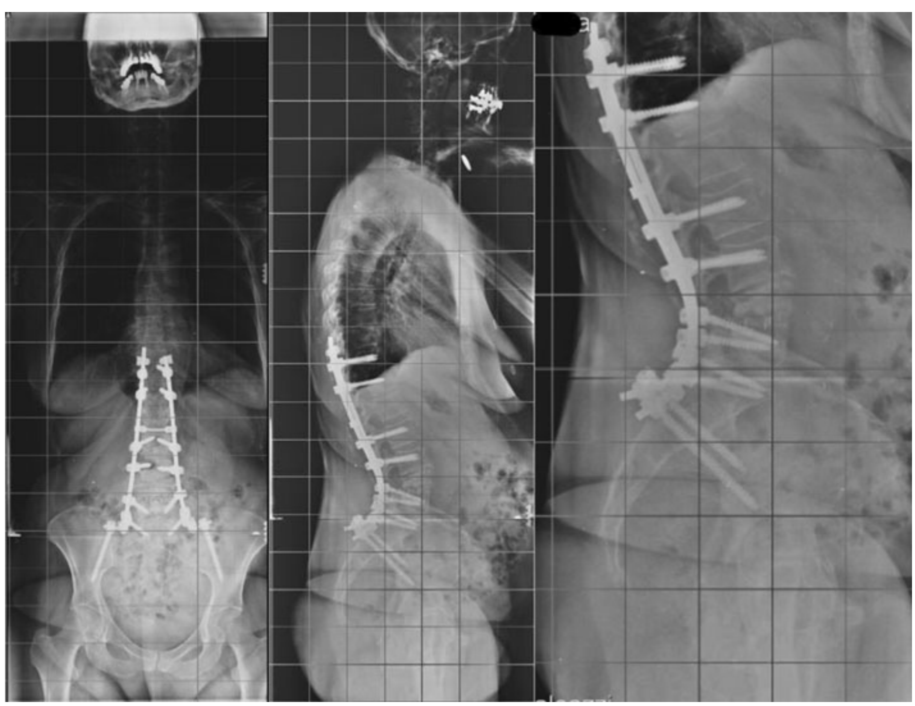

Fig. 4 Postoperative standing full spine (*left* and *center*) and lumbar (*right*) radiograms

measure the lumbar lordosis obtained with positioning. Careful preparation of the skin is performed in several steps with chlorhexidine and povidone-iodine solutions. The spine is subperiosteal exposed from T10 to S2 and both posterior-superior iliac spines are exposed. Meticulous bipolar haemostasis is done throughout exposure. After exposure, pedicle screws are placed between T11 and ilium at the selected levels. Fixation at T10 is performed with sublaminar bands to create a more elastic transition to the uninstrumented spine, thus expecting to decrease the risk of proximal junctional kyphosis. After this, a safety timeout is performed with the anaesthesiologist to make sure that the patient's condition permits proceeding with the osteotomy. During the timeout, the rod length is measured and rods are cut and prebent. A 5.5 mm rod in Co–Cr alloy is chosen due to higher resistance to load cycles compared to titanium alloy. A complete resection of the arch of L4 and the L3–L4 and L4–L5 facet joints is performed. L4–L5 interbody fusion with a peek TLIF cage and bone chips is performed. The base of the transverse process of L4 is cut bilaterally and the lateral wall of the vertebral body is carefully dissected of soft tissue. The canal is then explored and checked for mobility of the nerve roots. At L3–L4 significant adherences are found preventing full and safe mobilization of the dural sac and nerve roots. Thus, surgery proceeds with bilateral pedicle resection and decancellation of the vertebral body. The thinned posterior wall of the vertebral body is imploded with an impactor and the lateral walls are osteotomized with a bone chisel. At this point, the osteotomy is completed and the closure maneuvers are performed combining direct pressure on the spine, table reverse bend and reduction with cantilever maneuvers applied to the rod. A C-arm check identifies a failure to achieve adequate closure of the osteotomy, due to sclerosis of the vertebra that impedes osteoclasis. To overcome this difficulty, a coronal osteotomy of the upper L4 endplate is performed at ¾ of its length with chisels from the posterior osteotomy (from within the L4 vertebra). This maneuver is safer than blind osteotomy of the anterior and anterior-lateral walls of the vertebra. After this maneuver, closure of the osteotomy is facilitated by tensioning of sublaminar bands under the L2 lamina, connected to clamps placed in the rod between the S1 and the iliac screws. This tension band also reduces the load supported by the rod. A final C-arm lateral view verifies the osteotomy closure and enables measurement of the maximum lordosis, confirming that the procedure has met the goals of preoperative planning. Exploration of the roots and dura after the osteotomy, final haemostasis, preparation of the fusion bed, irrigation and bone grafting (with bone chips from the bone resection) are performed before routine closure.

Postoperative information and images

Postoperatively, the patient was kept in intensive care for 12 h. No new neurological deficit was identified. She was mobilized from bed on day 2 after surgery. In postop day 5 the patient was transferred to the rehabilitation department to continue treatment. Full standing spine X-ray (Figs. 4, 5) and clinical images (Fig. 6) were performed on day 30 and showed no complication; the achieved lumbar and global spine's sagittal profile correction was satisfactory and, in line with preoperative planning (PT = 13°, LL = 53°, SVA = 30 mm, TK = 53°). One month after surgery the patient's ODI had dropped to 24 %, and NRS for pain was 2/10 in her back and 3/10 in her legs. Three months after

Fig. 5 Postoperative standing full spine radiogram with SVA and lumbar lordosis (LL) measurement

Fig. 6 Postoperative clinical images

surgery, ODI dropped to 15.5 %, NRS for pain was 1/10 in her back and 0/10 in her legs. A three-point Jewett type brace is worn when the patient is out of bed for the first four postoperative months. Routine controls are performed at months 3, 6, 12, 24.

Conflict of interest None.

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