14 L5 Vertebrectomy with Reduction of L4 onto S1 for the Surgical Reconstruction of Lumbosacral Spondyloptosis

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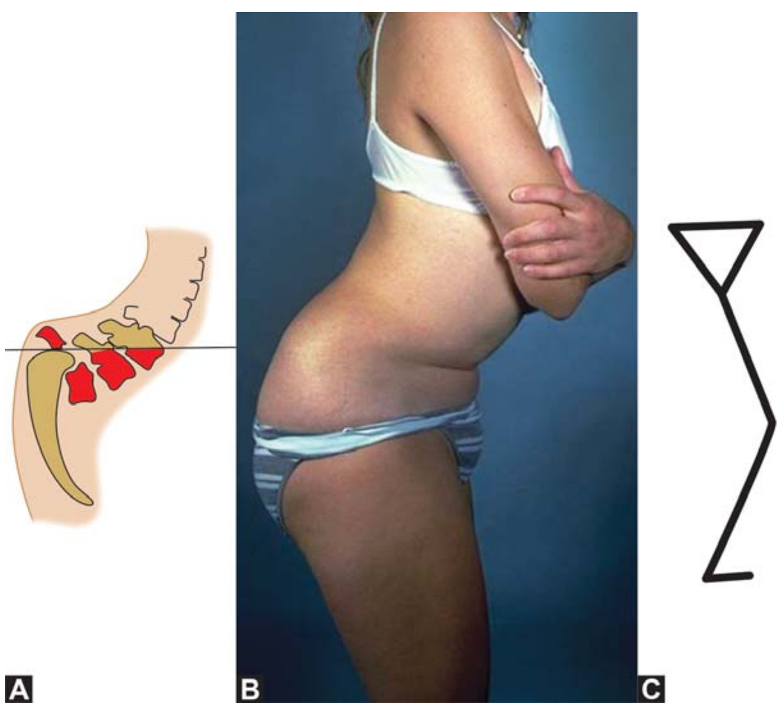
Introduction

A high grade slip is classified as spondyloptosis when the entire vertebra of L5 lies completely below a horizontal line drawn across the top of S1 on a lateral standing X-ray (Figs 14.1A to C). It is not a congenital deformity. Progression to spondyloptosis occurs during the years of rapid growth.

Dysplasia of the posterior elements of the sacrum, pars interarticularis defects, wedging of L5 and L5-S1 disk degeneration have been identified as risk factors for progression of spondylolisthesis.[5] Severe endplate and growth plate damage in the immature proximal sacrum, either manifesting as a growth disturbance or an epiphyseal slippage, or both, results in proximal sacral rounding (PSR) (Fig. 14.8A) This epiphyseal damage to the upper sacrum seems to be the central etiologic factor that allows spondyloptosis to occur. [4]



Figures 14.1A to C: (A) Spondyloptosis exists when the entire vertebral body of L5 lies caudal to a line drawn across the top of S1 on a standing lateral X-ray of the lumbosacral junction. (B) The most severely involved patients show severe sagittal plane decompensation with a crouch gait and stance as seen in a case and (C) Diagrammatic

Clinical Features

Occasionally, a patient with spondyloptosis presents with minor symptoms in adult life, with spontaneous fusion between L5 and S1. However, all the children the authors have ever seen with spondyloptosis have crippling disability from a combination of:

1. Disk-related lumbosacral pain
2. Pain, weakness or numbness from single or multilevel root compression and/or cauda equina syndrome and/or,
3. Thoracolumbar fatigue due to muscle imbalance in the sagittal plane.

The patient's body weight, the severity of the sagittal plane malalignment, and especially the L5-S1 slip angle, affect the findings of the physical examination.[1]

Patients who have the most severe ptosis of L5 into the pelvis, with the highest slip angle, have a deep crease across the abdomen, even if they are overweight. The patients with higher slip angles have more and more prominence of the posterior iliac crests and more sagittal plane decompensation becomes visible. Also, when the slip angle rises, the lumbar lordosis also increases. In the most severe cases, the lumbar lordosis extends itself, to try to maintain sagittal plane compensation, to T3 or T4, so the patient's physical examination shows "total spinal lordosis" above their spondyloptosis at the lumbosacral junction.

CROUCH GAIT AND STANCE (FIGS 14.1A TO C)

The "crouch gait and stance" occurs because of the spino-pelvic malalignment from the spondyloptosis. The pelvis retroverts during the development of the spondyloptosis. As the pelvis rotates posteriorly, the femoral head extends in the acetabulum to maintain the upright posture. Since normal hip extension, in normal individuals, is rarely greater than 15 degrees, that is the maximum retroversion of the pelvis the hip joint can accommodate with the femur still perpendicular to the floor. When pelvic retroversion is greater than 15 degrees, the iliofemoral ligament becomes taut and no further hip extension is possible. For that reason, as the pelvis rotates in greater amounts of retroversion, and the spine falls into the pelvis the femoral shaft loses its right angle orientation to the floor and the patient loses the normal stance and gait. The hip joint is in 'apparent flexion' and the knee joint flexes to maintain upright stance. The composite of all these changes is manifest when the patients stands and walks in a crouched position.

There are some patients who have more flexible hip joints. If and when they develop spondyloptosis, they do not crouch, since the femoral head can extend beyond 15 degrees in the hip joint.

Surgical resection of L5 and stabilization of L4 on S1 restores the pelvic retroversion toward normal. Restoration of the normal position of the pelvis, and thereby the hip joint, relaxes the iliofemoral ligament and permits the return of the trunk and knee flexion to normal. Hence the "crouched gait" returns to normal without the need for any therapy.

The presence or absence of nerve root tension can be noted by the patient's response during the sitting straight leg-raising test. Creation of "nerve root pain" during straight leg raising suggests nerve root tension. Creation of "hamstring tension-type pain" suggests myostatic contracture. Some spondyloptosis patients have both, myostatic contracture from limited hamstring growth, and also nerve root tension—as well as a crouch gait due to limited hip extension. However, only very rarely is the treatment of all three necessary. Usually, just restoring proper spinal alignment addresses the crouch.

When neurologic deficit occurs, particularly in patients who have had previous surgery, root related sensory or motor deficit or cauda equina syndrome may coexist.

Patients with bowel and bladder paralysis (cauda equina syndrome), without back and leg pain, have been identified during childhood, due to spondyloptosis. Their diagnosis was delayed, and recovery of bowel and bladder function was incomplete because of their delayed diagnosis.

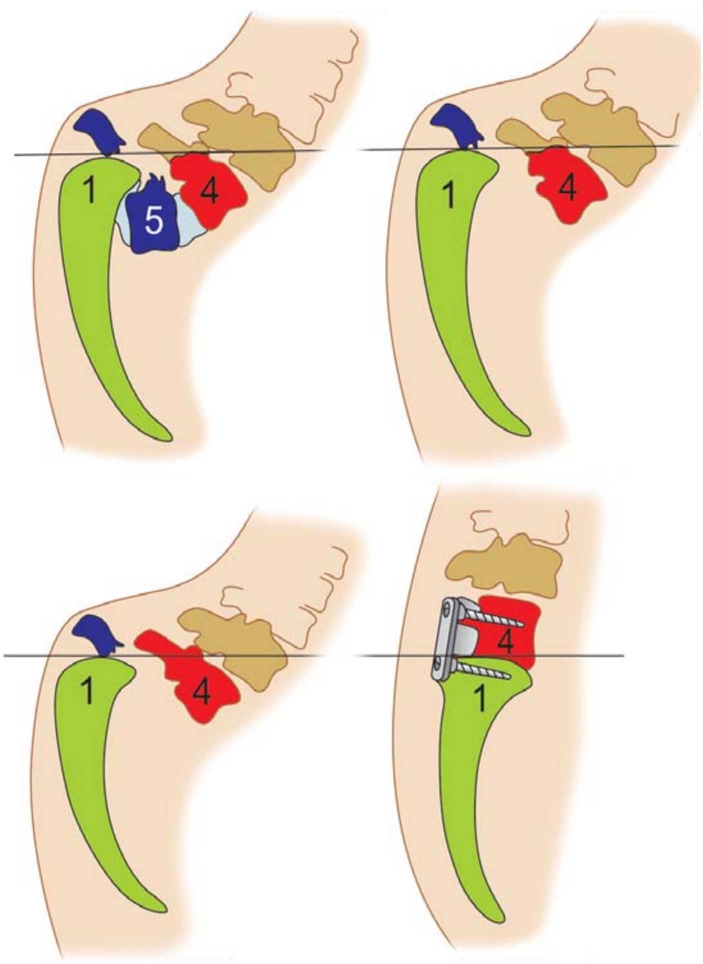
Surgical Procedure[2,3]

FIRST STAGE PROCEDURE (FIG. 14.2A)

It is imperative for the operating surgeon to have adequate spinal exposure for the anterior resection. He must be attended by three experienced surgical assistants. The resection procedure is one of the very most difficult spinal reconstructions which exists. Only the very most experienced spinal reconstructive surgeons should attempt the procedure.

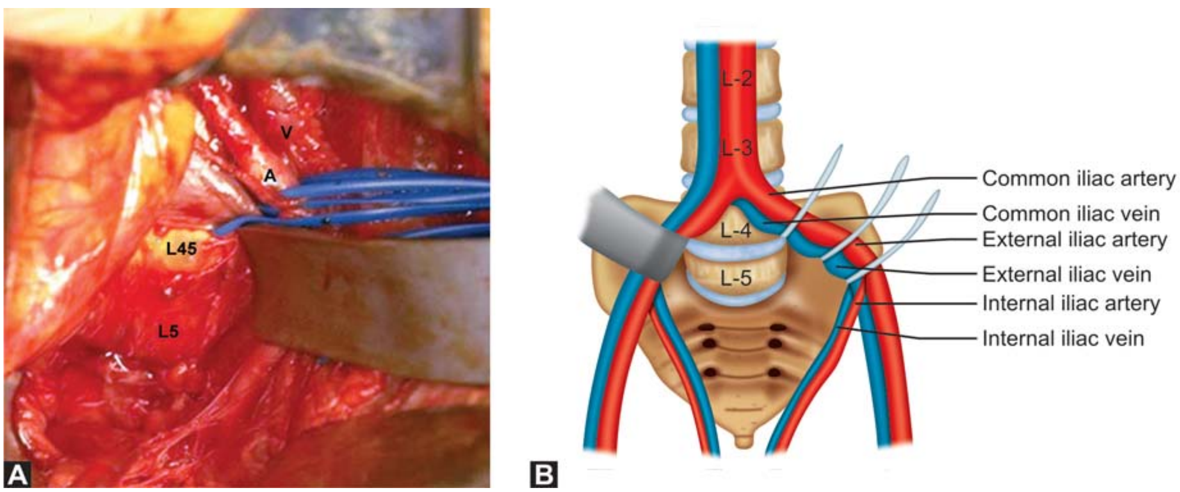
To perform the L5 vertebrectomy and total removal of the L4-5 and L5-S1 disks, the surgeon makes a transverse abdominal incision completely transecting one rectus abdominis muscle and going through at least half of the contralateral rectus abdominis muscle (Figs 14.5A and B). Retroperitoneal dissection then completes the exposure of the spine.

Regardless of the severity of the slip angle, the body of L5 is always deep in the pelvis—and always caudal to the bifurcation of the great vessels. Both internal and external iliac arteries, both internal and external iliac veins, the aorta and the vena cava must be identified and carefully protected. The middle sacral artery and veins are ligated. Epidural veins around the L4-5 and L5-S1 intervertebral foramina must be handled gently. The vertebral body of L5 lies caudal to the bifurcation of the vena cava, between



Figures 14.2A and B: (A) The first stage of the resection procedure removes the entire vertebral body of L5, and the L4-5 and L5-S1 disks (B) The second stage of the procedure removes the pedicles and posterior elements of L5 and the upper cartilage endplate of S1. Pedicle screws are placed into L4 and S1, and then L4 is reduced onto S1. Both the L4 and L5 nerve roots then proceed through a reconstructed L4-S1 foramen. "Bone-on-bone" apposition is necessary for proper healing of L4 onto S1. No cage or extra bone graft is appropriate or necessary

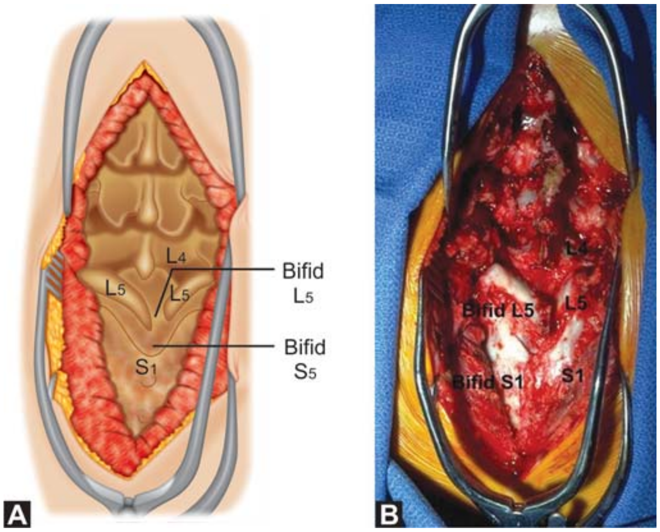
Figure 14.3: The incision used for the anterior approach transects the left rectus muscle, and as much of the right rectus muscle as is necessary to ensure good visibility for the entire surgical team and an extensile approach for the pelvic vessels. This very wide exposure makes the resection safe



Figures 14.4A and B: (A) Retroperitoneal exposure is used to expose L5. The L5 vertebral body always lies very deep in the pelvis, caudal to the bifurcation of the vena cava and aorta. The iliac arteries (A) and veins (V) must be identified and protected. The proximal exposure visualizes the vertebral body of L4, and usually the L3-4 disk. A shelf lies underneath the vertebral body of L5 where a malleable retractor can be placed to help the exposure (B) A diagrammatic representation of the pelvic vascular anatomy

the common iliac veins. If the iliac veins and arteries can be mobilized widely enough, the resection can be performed with each side retracted simultaneously. If simultaneous retraction of the iliac veins puts undue tension on the inferior portion of the bifurcation of the vena cava, the resection can be performed one side at a time by retracting one iliac vein, removing one side of L5, and then retracting the opposite side vessels, and removing the opposite side of the vertebral body.

Before beginning the vertebrectomy, the iliopsoas muscle is dissected laterally, bilaterally, so that the intervertebral foramen can be identified on each side—by gently placing a tiny curved curette into the foramen. If a little epidural bleeding occurs, a piece of thrombin-soaked Gelfoam is placed into the foramen. This will stop this epidural ooze.



Figures 14.5A and B: The patient is then placed in the prone position and the posterior elements are exposed subperiosteally. The dural sac is almost subcutaneous in spondyloptosis patients, so care to avoid injury during the exposure is necessary. Subperiosteal exposure of L2 to S1 is necessary. L4, L5, and S1-3 are commonly bifid, so care to identify these uniquenesses are important (A) Diagrammatic representation and (B) Intraoperative picture demonstrating the bifid posterior elements

This dissection must clearly define the L5 pedicle and the intervertebral foramina of L4-5 and L5-S1 bilaterally. These structures define the posterior margin of the first stage resection. The L5 root can occasionally be identified during the exposure, though its identification is not essential during this part of the procedure.

Inferiorly, the deepest part of the L5 body is identified lying on the anterior surface of S2-3. A medium malleable retractor is placed underneath the vertebral body of L5 while it is being excised. Once the entire body is removed, the place for the retractor is gone, and long-handled Wylie vein retractors are used by the assistants.

Before beginning the vertebrectomy, the surgeon must assure that each assistant is comfortable, and that he has good vision of the operative field. Each assistant must actively participate during the entire procedure for the surgeon to maintain proper visualization of the operative field. Uninterested assistants do not function well during this procedure.

The anterior 80% of the L4-5 disk is removed first—back to the posterior annulus. The anterior 80% of the L5 body is then excised back to the posterior cortex of the vertebral body of the L5 body. Bone bleeding is controlled by local pressure and gelfoam. As the vertebral body is removed back to the posterior cortex, the body becomes thinner and narrower in the cephalocaudal dimension. Once only the posterior cortex of L5 remains, the posterior cortex is removed like a laminectomy—with curettes, and Kerrison Rongeurs. Epidural bleeding always occurs. The epidural bleeding is controlled with Gelfoam and local pressure. Patience is necessary during this portion of the procedure. The surgeon must never lose control of the bleeding, and must tailor the operative procedure to achieve the resection, but also protect the patient. The L5 roots can be identified at this point in the dissection for some patients, but it is not mandatory to identify them. Once the entire vertebral body of L5 is gone, the L5-S1 disk tissue is removed. Generally, there is not much tissue to be removed, since most of it has been spontaneously resorbed by the disease process.

After completing the L5 vertebrectomy, the cartilage endplate on the inferior surface of the L4 vertebral body is removed. However, the subchondral bony endplate of L4 is maintained and is not decorticated.

Gelfoam is left in the resection gap. No attempt at reduction of the deformity is attempted. The wound is not closed until it is absolutely dry, and the bleeding is completely controlled. Drains are not necessary and are not used. The wound is closed.

The patient is nursed by "log-rolling" if the procedure is performed in stages.

If the bleeding has been easily controlled and the patient is thin, and surgically stable, and the operative team is rested, the procedure can be performed in a single stage, during a single anesthetic. However, most patients are operated in two stages—not a single stage.

SECOND STAGE PROCEDURE (FIG. 14.2B)

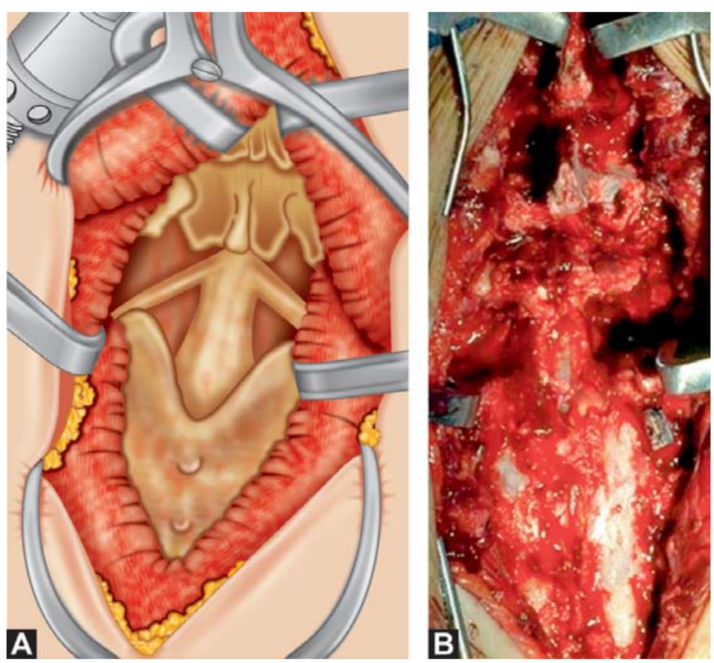
Second stage reduction of L4 onto S1 is also done very similarly to the way it was first performed in 1979.

In spondyloptosis the bifid upper sacrum and L5 are virtually subcutaneous, and the dural tube immediately underneath the subcutaneous fat. Therefore, in making the skin incision, one must carefully avoid lacerating the dura. Once the skin incision is made, the posterior elements of L3 to S2 are exposed subperiosteally, very delicately. They are generally close to paper-thin (Figs 14.5A and B).

If desired, gentle distraction of the L4-S1 interval can be performed with Harrington outriggers between the L2 or 3 laminae and the sacral ala. This can bring the transverse process and pedicle of L5 (underneath the ala of the sacrum in spondyloptosis patients) into the surgeon's view so they can be removed (Figs 14.6A and B).

Once the laminae and transverse processes of L4-S1 are clearly exposed, pedicle screws are then placed bilaterally into L4 and S1. The pedicle screws in S1 are placed into the vertebral body. Two well placed bicortical S1 screws are all the distal fixation necessary for the reconstruction. When the pedicle screws are satisfactorily placed, then the posterior elements, transverse processes and pedicles of L5 are removed. These structures can either be removed en bloc, or piecemeal. Great care must be used during this removal, since the L5 nerve roots lie immediately adjacent to the L5 pedicles. The L5 roots must be identified and carefully protected before the L5 pedicles are removed. Once the pedicles are totally removed, then the dural tube is lifted dorsally so the cartilage endplate of S1 can be removed. It is generally no more than 2-3 cm in diameter—much smaller than the endplate of L4. This leaves the S1 subchondral bony endplate exposed and ready to dock with the endplate on the inferior aspect of the L4 vertebral body (Fig. 14.7).

To reduce L4 onto S1, the Harrington outrigger is removed, and the L4 and S1 pedicle screws are approximated with a plate or a rod system. L4 is apposed to the



Figures 14.6A and B: Harrington hooks and outriggers are applied across the sacral ala and the posterior elements of L2. Gentle distraction on the outriggers allows the L5 pedicles to come into view, in patients with a high slip angle. In severe cases the pedicles are hidden under the ala. Mild distraction is usually adequate. Overdistraction must be avoided to prevent undue traction on the L5 nerve root. (A) Shows a diagrammatic representation with the distractor *in situ* (B) Intraoperative photograph showing the L5 roots

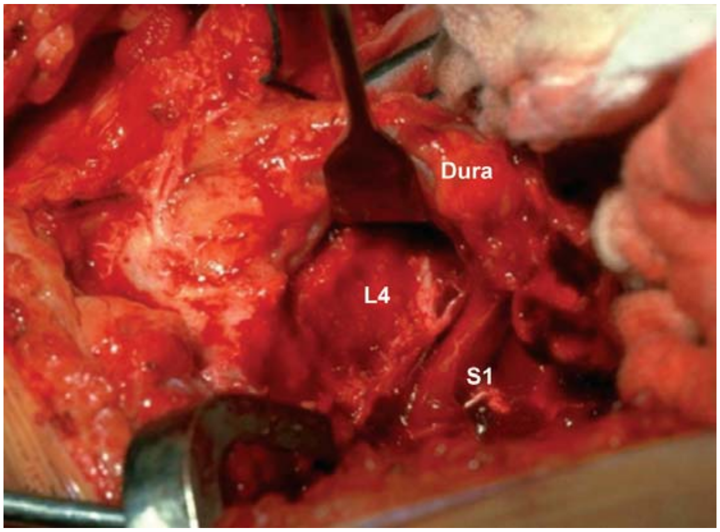


Figure 14.7: The dome of the sacrum is then exposed, and the cartilage endplate of S1 is removed. The bony endplate is not damaged or decorticated. The inferior end plate of L4 body is then docked on the superior surface of S1. The intraoperative view shows the retraction of the dural tube allowing a good view of the docked surfaces. A Penfield #4 elevator is used to confirm apposition between the vertebral bodies of L4 and S1 following the reduction

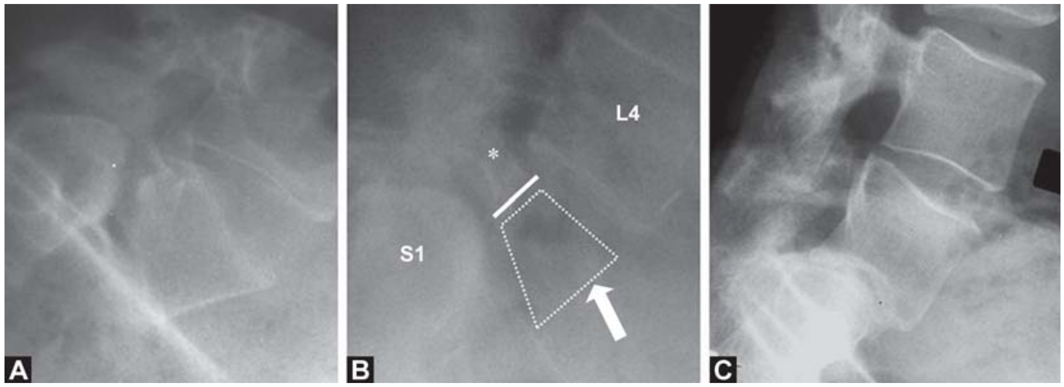
endplate of S1 to achieve "bone-on-bone" apposition to achieve healing of the osteotomy/ resection. No attempt to influence lordosis at the L4-S1 interval is pursued. Apposition for healing is paramount—not lordosis. Interbody implants are inappropriate and unnecessary, since their use delays healing and hinders spinal shortening.

Cancellous bone from the L5 vertebrectomy is placed in the lateral gutter to produce an intertransverse fusion between L4 and S1—in addition to the spontaneous anterior fusion between L4 and S1. Graft is placed at any intervertebral gaps between the bodies of L4 and S1. BMP is unnecessary. The reduction proceeds and the spinal implants are readjusted until there is palpable impingement (load-sharing) between the bony endplate of L4 and the bony endplate of S1. This impingement is palpated, underneath the dural tube with an instrument, like a Penfield-4 dissector. The L4 and L5 roots then proceed through the reconstructed L4-S1 foramen. Once all the posterior elements and pedicle of L5 are removed and the ligamentum flavum is removed from the spinal canal at the L4-5 and L5-S1 levels, there is plenty of room for two nerve roots in the reconstructed L4-S1 intervertebral foramen. There must be no residual tension or compression on these roots. Great care and direct observation of the dural tube and nerve roots is essential during the reduction to minimize nerve root injury. Despite extraordinary care, for many patients (60–70%) a little L5 nerve root injury may occur. Generally, for virgin patients, the nerve root deficit which occurs from root retraction recovers during the weeks or months after the reconstruction. A very few will have some very mild residual sensory and/or motor deficit, though not pain, since there is no tension on the roots. Neurontin, manual or ice massage or other medications may be used to treat patients whose dysaesthesias require conservative management.

Postoperative Care

Patients remain in bed for 4-6 weeks following the surgery. Logrolling is used to avoid skin problems. Since the use of pedicle screw fixation, postoperative bracing has not been used during the period of bed rest. After the period of bed rest patients, may begin walking and start rehabilitation. Generally a lumbosacral corset is suggested when the patient is ambulating. Serial tomography is taken every 6-8 weeks, until interbody healing occurs between L4 and S1. The brace may then be removed.

In the historical descriptions of this procedure, routine re-exploration of the fusion mass was suggested and routinely performed. One nonunion—the very first case— was regrafted in since the first 3 cases had internal fixation with Harrington compression



Figures 14.8A to C: (A) Preoperative lateral radiograph. Radiograph following the first stage resection demonstrates the resection gap that remains after the 1st stage. S1 demonstrates the proximal sacral rounding (B) The asterisk lies over the resected stump of the pedicles and the arrow points to the gap created by the resection of L5. (C) Lateral radiograph 11 years postoperatively, showing a good fusion. The implants have been removed

rods and a spica cast—very poor internal fixation by current standards. The first case healed after regrafting, and a little correction was lost, but the final functional outcome is superb.

Since, the use of pedicle screw fixation has become routine (for the subsequent 40 cases), routine re-exploration of the fusion mass has been discontinued—except for the very most difficult cases—when nonunion is most likely.

Tips and Pearls

STAGE 1

1. Two or three very experienced assistants that are comfortable and have a good vision of the operative field at all times.
2. Transecting the entire rectus on one side to aid anterior access.
3. The vena cava and iliac arteries and veins must be widely mobilized to allow adequate retraction so the spinal anatomy can be totally identified and operated.
4. Iliopsoas is elevated on both sides to the level of the neural foramina.
5. Visualization of the L5 nerve roots is not essential. However, removal of ALL of the two disks and the entire vertebral body of L5 is ESSENTIAL.
6. L4 inferior cartilage end plate is removed, but the bony endplate is not damaged or decorticated at all. The S1 cartilage end plate is removed. The bony end-plate is also not decorticated.

STAGE 2

1. L5 and sacrum posterior elements frequently bifid, hence care during exposure to avoid dural laceration
2. Outrigger distraction between L3 and S1 to ease the L5 nerve roots from under the ala into the operating field.
3. L5 roots identified under the L5 pedicle and protected throughout the procedure.
4. Complete excision of the pedicles on both the sides is imperative to allow the reduction of L4 onto S1.
5. Good L4 on S1 apposition is paramount for prompt interbody union.
6. Avoid spacers between L4 and S1. “Bone on bone” apposition allows for prompt healing and shortening of the spinal column to avoid nerve root stretching.
7. Ensure there is no residual L4 or L5 nerve root tension or compression at the end of the procedure.

Illustrative Case

Figures 14.9A to F: This is a 18-year-old female that underwent the resection nine years earlier. (A and B) Preoperative clinical pictures showing posterior pelvic rotation, crouch gait and stance and coronal (a) and sagittal (B) decompensation (C) Mid sagittal T2-weighted preoperative MRI scans (D) Postop lateral xray shows a good sagittal plane restoration (E and F) Postoperative clinical pictures showing a good restoration of the coronal (E) and sagittal (F) balance

Conclusion

The L5 vertebrectomy reconstruction remains a predictable option for those patients with spondyloptosis who have severe lumbopelvic deformity and sagittal plane imbalance.

The dramatic improvement in the spinopelvic alignment results in prompt resolution of the "crouch stance and gait," for those patients who have it.

The resection remains the procedure of choice for patients with spondyloptosis, when the deformity is fixed, on a lateral "stretch" film of the lumbosacral junction.

Less "fixed" deformities can be managed by anterior and posterior partial reduction and arthrodesis.

Table 14.1: Benefits of L5 spondylectomy over a partial reduction of a high grade spondylolisthesis

Parameter	*Comments*
Pros:	
Sagittal alignment	Improved translation and kyphosis
Reduction of deformity	Complete reduction achieved
Secondary compensation	Normal lumbar lordosis and pelvic anteversion are restored
Union	Large footprint for bony contact; more predictable union rates; 2 fibrous nonunions in our series without loss of correction.
Hardware problems	Better anterior column load sharing; pedicle screw based systems require fewer levels to be fused
Progression	No progression in our series
Rehabilitation time	Much shorter with the pedicle screw based reconstructions
Spinal column shortening	Shortening is tolerated by neural structures better
Gait and stance	Restored after reconstruction
Neurologic deficit due to progression	Shortening of the spinal column and restoration of the sagittal alignment prevents future damage to the cauda equina and the L5 nerve roots
Cons:	
Iatrogenic neurologic injury	Potential for injury to L5 nerve root
Surgical time	Longer than a partial reduction procedure
Blood loss	Higher blood loss; need for staged procedure and blood salvage procedures when performing a L5 spondylectomy
Surgeons learning curve	Steep learning curve
Dysesthesia	Usually recover in 6-8 weeks; due to L5 root intraoperative traction injury

The healing of the osteotomy reconstruction is very predictable, and the surgical complications are manageable. The longevity of the reconstruction, once it has healed, seems to provide a life-long solution for the patients.

Prevention of this severe deformity by early surgery of predisposed patients is certainly a preferred surgical option.

Although a technical challenge, this procedure has a significant number of advantages over a partial reduction as performed for a high grade spondylolisthesis. We have suggested some key elements of the surgical procedure that we feel would help surgeons achieve a better result in Table 14.1.

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