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Review article

Surgical techniques for lumbo-sacral fusion

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ABSTRACT

Lumbo-sacral (L5-S1) fusion is a widely performed procedure that has become the reference standard treatment for refractory low back pain. L5-S1 is a complex transition zone between the mobile lordotic distal lumbar spine and the fixed sacral region. The goal is to immobilise the lumbo-sacral junction in order to relieve pain originating from this site. Apart from achieving inter-vertebral fusion, the main challenge lies in the preoperative determination of the fixed L5-S1 position that will be optimal for the patient. Many lumbo-sacral fusion techniques are available. Stabilisation can be achieved using various methods. An anterior, posterior, or combined approach may be used. Recently developed minimally invasive techniques are gaining in popularity based on their good clinical outcomes and high fusion rates. The objective of this conference is to resolve the main issues faced by spinal surgeons in their everyday practice.

1. Introduction

Lumbo-sacral fusion can be viewed as a biological process that ultimately produces a strong bony bridge between L5 and S1, at the selected site, in order to obtain complete ankylosis of the intervertebral joint. The goal is to relieve pain due either to exaggerated mobility or to an inappropriate position of the lumbo-sacral junction.

The chief objective is to permanently block one or more intervertebral joints at the lumbo-sacral junction. The architecture of the spine consists in three vertical columns [1]: an anterior column comprising the vertebral bodies and discs and two posterior columns composed of the facet joints and neighbouring structures. Fusion is induced at the intervertebral spaces, where spinal mobility occurs. The fusion site may be anterior, between two vertebral bodies; posterior, at the facet joints or inter-transverse region (posterolateral graft); or both anterior and posterior.

The lumbo-sacral junction has several unique characteristics. The lumbar spine is mobile, whereas the sacrum is lodged between the two iliac wings and therefore fixed. Thus, the lumbo-sacral junction is a zone where transitions occur in both anatomical structure and mechanical behaviour.

2. Specific characteristics of the lumbo-sacral junction

The lumbo-sacral junction is located at the distal end of the lordotic lumbar segment. Roussouly et al. [2] demonstrated that the lumbar spine can be divided into two segments, proximal and distal to the apex of the lordotic curvature. The apex is the most anterior point of the lumbar spine and is located on the vertical line tangent to the anterior lumbar convexity. Here, we will focus on the distal lordotic curvature, which normally prolongs the sacral slope (SS). Given this geometry and the strong correlation between distal lumbar lordosis and SS, L5-S1 fusion positioned in insufficient or excessive distal lumbar lordosis directly affects the SS value and, consequently, the position of the sacrum and pelvis in space when the patient assumes an erect posture.

The only radiographic parameter that predicts the optimal segmental lordosis at L5-S1 in patients with alignment abnormalities is pelvic incidence (PI). PI correlates strongly with lumbar lordosis and even more strongly with distal lumbar lordosis. Thus, the optimal amount of distal lumbar lordosis can be pragmatically estimated using two formulae: total lumbar lordosis = PI and distal (L4-S1) lumbar lordosis = 2/3 of total lordosis. This relationship is the starting point for the preoperative determination of the optimal amount of L5-S1 lordosis to be restored, since it is never modified, even in abnormal situations.

Two other unique features of the lumbo-sacral junction are considerable mobility and strong vertical forces produced by the weight of the torso. Both features may contribute to the high

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frequency at this level of disc disease, facet joint wear, and pain, which may require L5-S1 fusion.

3. Available methods for achieving L5-S1 fusion

Obtaining strong fusion in the optimal position is the main goal of fusion procedures. Regardless of the technique used, two requirements must be met if fusion is to be achieved:

- a substrate that features osteogenic, osteoinductive, or osteoconductive properties must be implanted, to contribute to the formation of the bony bridge;
- and the vertebrae must be stabilised in the optimal position by internal fixation material, to maximise the likelihood of fusion.

3.1. Substrates available for joint fusion procedures

There is no consensus regarding the best substrate. Furthermore, depending on the type of fusion, the choice of the substrate is often guided by surgeon preference and by the internal fixation material used.

Of the many available substrates, the most widely used are autologous bone harvested from the iliac crest or spinous processes and bone morphogenetic protein-2 (BMP2). Allogeneic bone and bone-marrow mesenchymatous cells are also used but have been less extensively evaluated in the literature.

3.2. Techniques available for lumbo-sacral fusion

3.2.1. Anterior lumbar inter-body fusion(ALIF)

ALIF is now performed using a minimally invasive approach. The technique is well standardised. The main challenge lies in determining that ALIF is the best option for the individual patient.

There are several prerequisites to performing an optimal surgical procedure with a simple postoperative course and outcomes that meet patient expectations. The surgeon must be conversant with the anterior approaches to the spine; if needed, the assistance of a vascular or gastro-intestinal surgeon may be obtained. Dedicated instruments and good lighting must be available. Preoperative CT angiography or magnetic resonance angiography should be performed to obtain a detailed map of the local anatomy. The risk of patient injury is greatest during mobilisation of the veins and, consequently, obtaining detailed information on the location of the left iliac vein (regardless of the side of the approach) and venous confluence is of the utmost importance.

The patient is in the supine position with the lower limbs aligned on the torso. The surgeon stands on one side of the patient. Alternatively, the patient may be supine with the legs abducted (i.e., in the "French position") and the surgeon standing between the legs and working in the axis of the spine: this position facilitates discectomy, preparation of the plateaus, and proper positioning of the inter-body implant. Either a midline sub-umbilical incision or a transverse Pfannenstiel incision is performed. The incision should be centred on the L5-S1 level, whose location is identified preoperatively.

3.2.1.1. There are three possible approaches (Fig. 1).

3.2.1.1.1. The left retro-peritoneal approach. The left retro-peritoneal approach is the oldest among them. The L5-S1 disc is approached in the arterial bifurcation and venous confluence. This approach is described in detail elsewhere [3,4]. It is now reserved for procedures at L4-L5 and revisions of procedures on L5-S1 performed through a right-sided approach.

3.2.1.1.2. The trans-peritoneal approach. The trans-peritoneal approach is the most direct route to the L5-S1 disc and is easy to perform in patients who are obese, have a history of abdominal surgery, or are undergoing a revision spinal procedure. A midline skin incision is performed. The linea alba must be opened. A midline incision is then performed. The abdominal contents are carefully displaced to expose the posterior parietal peritoneum, which covers the lumbo-sacral vessels and lumbo-sacral disc space. The posterior parietal peritoneum is opened, on the right side, starting 1 cm medial to the right of the common iliac artery. The pre-vertebral fat and hypogastric plexus are gently displaced from the right to the left to expose the anterior circumference of the L5-S1 disc. Blade retractors are then positioned on the vessels to retract and protect them.

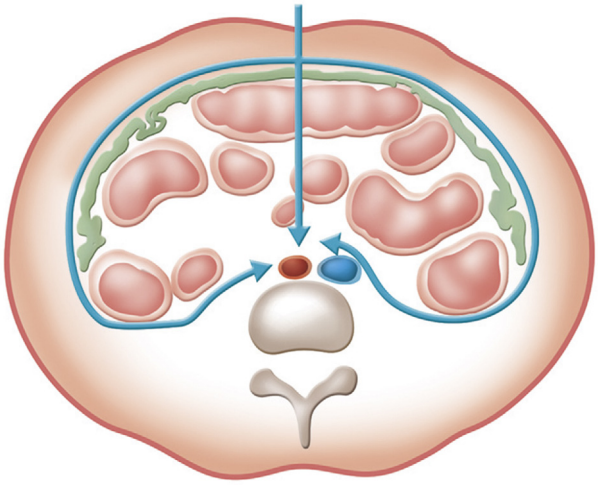

Fig. 1. Anterior approaches to the lumbo-sacral junction. Drawing: Anne-Christel Rolling.

Despite the many advantages of these approaches, the risk of vascular injury [5] and retrograde ejaculation [6] limits their use. Anatomical studies have established that the hypogastric plexus is located to the left of the L5-S1 disc space and that its left edge exchanges multiple anastomoses with the sigmoid plexus, so that injury is more likely to occur during a left-sided approach [7].

3.2.1.1.3. The right retro-peritoneal approach. The right retro-peritoneal approach is therefore preferred. In our opinion, this is the method of first choice for approaching the L5-S1 disc space. A vertical or transverse skin incision centred on the L5-S1 level is performed. On the right side of the lumbo-sacral region, the hypogastric plexus is very often absent or meagre, with only scant collaterals. This fact limits the risk of nerve injury by stretching, which can cause retrograde ejaculation in males or vaginal dryness and ovulation dysfunction in females.

In clinical practice, the left-sided approach is used in 40% of patients, due to contra-indications to the right-sided approach.

3.2.1.2. Discectomy. Discectomy is the first step of ALIF. Because this step is essential, an approach extending along the entire width of the disc, i.e., over nearly 50 mm, is warranted. The disc is one of the sources of pain and must therefore be removed as completely as possible, without damaging the subchondral bone. Freshening of the plateaus should be sufficient to promote bone formation yet cautious, since any excess would impair mechanical strength, inducing a risk of cage subsidence into the vertebral bodies.

The posterior part of the annulus must be completely exposed. If mobilisation of the space proves difficult, posterior release should be achieved by excising the posterior part of the annulus. The result is exposure of the posterior longitudinal ligament, which should be removed in the event of nerve root pain and difficulties distracting the inter-vertebral space. In the event of bleeding due to epidural

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