Lumbar spine fusion and stabilization: what the radiologist needs to know

Poster No.: C-2188
Congress: ECR 2012
Type: Educational Exhibit
Authors: S. Palmucci, L. A. Mauro, P. Costa, G. Barbagallo, F. Di Martino, G. Attinà, G. Cappello, P. V. Foti, G. C. Ettorre; Catania/IT
Keywords: Artifacts, Education, MR, Digital radiography, CT, Neuroradiology spine, Musculoskeletal spine
DOI: 10.1594/ecr2012/C-2188

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Learning objectives

To describe the role of imaging in the assessment of lumbar spine fusion and stabilization, in a series of patients treated in our hospital between November 2006 and November 2011; to identify type of devices implanted and recognize surgical procedures performed.
Background

"Biomechanics of the spine"

The spinal column is the structural support of the human body because it carries body weight and permits movements (flexion, extension, rotation and lateral bending). Biomechanics of the spine can be described considering three anatomical divisions: the anterior, middle and posterior columns. This simple method allows for an easy evaluation of spine stability in preoperative planning.

The anterior column includes the anterior longitudinal ligament and the anterior two-thirds of the vertebral body and annulus fibrosus; the middle column consists of the posterior one-third of the vertebral body, annulus fibrosus and nucleus polposus, and is limited by posterior longitudinal ligament; the posterior column includes the posterior elements - pedicles, facets, ligament flavum, interspinous ligament and supraspinous ligament [1].

At least two of these columns have to be healthy to permit column stability. Many diseases can produce loss of spine stability.

The most frequent causes are:

- **trauma**, with an annual incidence of 64 per 100,000 inhabitants
- **degenerative diseases**
- **infections**
- **tumors**
- **congenital anomalies** such as scoliosis, spondylolisthesis and degenerative arthritis.
"Spinal Fusion and Stabilization: surgical procedures and instruments"

Spinal fixation devices are used to provide spine stability, restore anatomical alignment and replace damaged vertebrae or disks. We can distinguish two kinds of procedure that are correlated and are often performed together: **spinal fusion** and **spinal instrumentation**.

**Spinal fusion** is a surgical procedure that promotes fusion between two or more vertebrae, preventing them from moving independently of each other.

**Spinal instrumentation** is a method of keeping the spine rigid after fusion surgery - using hooks, rods and wires anchored to the spine; its purpose is to aid fusion.

Currently it is quite common to combine bone grafting (spinal fusion) with the use of spinal fixation apparatus (spinal instrumentation): this combination improves fusion rates, permits mini-invasive surgery, provides immediate spine stability and allows rapid patient mobilization and rehabilitation [2].

Lumbar spinal fusion consists of the insertion of bone graft material with or without one or more interbody spacers and other devices to provide additional support and stability. Interbody spacers are filled after evacuation of the disk: they may be solid constructions - **ramps Fig. 1 on page 15** - or openwork structures filled with bone graft material - **cages Fig. 2 on page 15** - and may be used singly or paired (positioned side by side). Advantages of an interbody cage include the restoration of disc height and the enlargement of the neuroforaminal space. A cage is composed of a hollow, cylindrical structure with teeth on both sides for fixation to vertebral plates superiorly and inferiorly; the internal cavity is usually filled with autograft or allograft bone material to better fix the cage and provide later fusion. Cages are identified on radiographs by a small metallic marker outlining the margins of the latter [3]. An observation of a posterior marker located at least 2 mm anterior to the posterior vertebral body margin provides reassurance that the ramp is not protruding into the spinal canal (**Fig. 3 on page 16**).

On postoperative radiographs the outlines of radiolucent cages become increasingly apparent as the adjacent bone graft consolidates over time.

Graft material may herniate anteriorly or posteriorly (it depends on the approach used for the implant) and causes neurologic compromise.

Optimal screw placement is along the medial aspect of the pedicle; tips of pedicle screws should be embedded in the vertebral bone and should not reach the anterior vertebral body cortex, but there is no consensus on their optimal length. Sacral screws may be anchored in the anterior cortex of the sacrum for additional stability. Complications
include screw medial or lateral deviation, with penetration into the anterior cortex of the vertebral body. In Fig. 4 on page 17 cages, rods and screws are figured as they appear in reality and on radiograph and MDCT.

**Fig. 4**: Figure 4. This figure represents cages (A) and screws (B) mostly used in spinal fusion with instrumentation. Figure 4C shows A-P and L-L radiographs with the entire metallic structure of cage and instrumentation. We recognize screws (red asterisks), rods (red hashes) and metallic cage landmarks (white arrow). In Figure 4D a MDCT axial scan with maximum intensity projection protocol (MIP) shows metallic landmarks (white arrows) located anteriorly and posteriorly to the cage body and internal bone graft (white arrowhead); we also recognize correctly located pedicle screws (red asterisks) and rods (red hashes) that go through screw heads.

**References**: Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

Interbody fusion can be achieved through a variety of approaches, such as Posterior Lumbar Interbody Fusion (PLIF), Anterior Lumbar Interbody Fusion (ALIF) and Transforaminal Interbody Fusion (TLIF).
In ALIF, fusion of the disk space of the spine is obtained entering the front of the body through the abdomen; in this kind of surgical approach nerves and muscles in the back are not damaged or even touched but, on the other hand, there can be more serious complications such as vascular lesions and, in the lumbo-sacral junction, injury to the presacral plexus.

In PLIF, the surgical access is obtained by a posterior way: erector spinae muscles are stripped of the lamina of the affected vertebra to allow access to nerve roots, which are then retracted in order to remove disk material and replace it with a cage. A disadvantage of this technique is that it can produce more neurological complications, bleeding and subsequent scar formation within the spinal canal [4].

In TLIF the disk is accessed from a posterior incision on one side of the spine; the advantage of this procedure consists in avoiding the spinal canal exposition, since the cage is introduced unilaterally through the intervertebral foramen. The bone graft is placed into the intervertebral space from one side after emilaminectomy and complete removal of the facet joint on that side. **Fig. 5 on page 18** represents a patient treated with a bilateral TLIF approach.
**Fig. 5**: Figure 5. Patient treated with a bilateral TLIF surgical approach. AP (Figure 5A) and LL (Figure 5B) radiographs show the correctly located cages (red arrow) and posterior instrumentation (red arrowheads), also visible on MDCT MIP sagittal image (C). Axial MDCT scan identifies emilaminectomy and site of facet joint removal (red asterisks), hesitated to the surgical treatment (D). Surgical outcomes are better shown comparing with axial plane obtained in L3 (Figure 5E), where laminas and facet joints are undamaged. Surgical access site can be demonstrated by the presence of metallic staples in D (red hashes).

**References**: Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

Posterior spinal instrumentation is preferred in thoracic and lumbar regions, while the anterior approach is preferred in cervical regions because cervical vertebrae are smaller, as is the volume of the soft tissue, while implants used posteriorly are large. On the other hand, the posterior approach allows easier decompression and visualization of neural elements.

Rigid internal fixation after spinal fusion surgery is necessary in order to promote bone fusion, prevent pseudoarthrosis and restore anatomic alignment and functional biomechanics. It consists of fixation devices placed posteriorly. Three primary techniques are used to attach instrumentation to the posterior spine: sublaminar and interspinous wires or cables, laminar and pedicle hooks and pedicle screws. Transpedicle screws are the most used for attaching instrumentations and can be used both with plate and rod systems. Generally screws are angled medially so that they pass through the pedicle and into the vertebral body. They are screwed to rods or plates posteriorly. When correctly placed and if anchored into intact bone, they resist loads in all directions [5]. In some cases special fenestrated screws are used: through them cement can be injected directly in vertebral body just around the screw, permitting a better anchorage between screw and vertebral body bone (**Fig. 6 on page 19**).
**Fig. 6**: Figure 6. Osteoporotic patient treated with double-TLIF surgical approach, using cement injected inside vertebral body through fenestrated screws, in order to obtain a better screw fixation. In Figure 6A we see fenestrated screws (fenestrations are indicated by red arrows). Screws fenestration is also shown on axial MDCT scan (red arrow in B): here we identify cement (red asterisk). Axial T2-weighed MR scans (C and G), A-P (D) and L-L (E) radiographs and MIP sagittal MDCT reconstructions (F) show the placement of cement. Figure G shows screws as they can be seen in sagittal T2-weighed MR scan.

**References:** Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

"**Dynamic stabilization devices**"

One of the problems associated with lumbar fusion with instrumentation is that it is a rigid system. This induces increased loads acting on the adjacent segments and so may lead to accelerated degeneration. To prevent this, dynamic stabilization systems have been established [6]. They limit the stress placed on segments adjacent to the fusion and thus help prevent progressive degeneration. Dynamic stabilization may also be an alternative to fusion in some patients with back pain originating from chronic degeneration of the lumbar spine. In fact, interspinous implants are used for motion-preserving stabilization.
of primarily posterior lumbar pathologies, such as spinal stenosis or facet joint arthritis. They alone allow for the unloading of facet joints, restoring foraminal height and providing sufficient stability while still allowing motions in the treated segment [7].

Several dynamic stabilization devices are on the market today; they can be grouped in different categories: pedicle screws and artificial ligaments, such as Dynesis device or Graf ligament; interspinous process decompression devices - such as Wallis system, X-Stop, Coflex and Diam; posterior element replacement systems.

Interspinous process devices cannot be used at the level L5-S1 because of the lack of a distal anchorage point.

The most used are the Dynesys and Graf devices, the Diam implant and the X-Stop implant.

The Graf consists in a non-elastic band attached between pedicle screws; it limits flexion to within the normal range. The Dynesys device is similar to the Graf but it has an additional spacer around the band between the pedicle screws [8]. In addition to the band limiting flexion, the added spacer also limits extension, so that Dynesys restore biomechanics of the posterior annulus and face joints. In Fig. 7 on page 20 we show an example of Dynesis.
**Fig. 7:** Figure 7. Patient treated with Dynesis device, with TLIF surgical approach. Figure 7A shows A-P and L-L radiographs with well-visible titanium pedicle screws; we cannot recognize the polyester cords - the artificial ligament - between screws, that can be distinguished (white arrows) in sagittal MIP MDCT reconstructions (B), in axial intersomatic MDCT scan (D) and in coronal MIP MDCT reconstructions (E).

**References:** Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

Unlike Graf and Dynesys that are fixed to the vertebrae using pedicle screws, interspinous implants are floating devices: their advantage consists in limiting the possibility of loosening during motion [9]. Their aim is to avoid excessive extension and unload the posterior annulus. They can be compressible or non-compressible and are introduced through mini-invasive surgical approach.

The X Stop implant is composed of an oval interspinous spacer and two lateral wings which prevent its lateral migration; it is placed between adjacent spinous processes to hold spine in flexion. Wings are not crimped to the spinous process. It is made entirely of titanium. Only the interspinous ligament has to be pierced in order to be able to implant the X-Stop [10]. In **Fig. 8 on page 21** two patients treated with x-stop device and Coflex device are presented.
Fig. 8: Figure 8. Two patients treated with inter-spinous process decompression systems. Figures A, B and C show a X-Stop titanium device as it appears in L-L (Figure B) and A-P (Figure C) radiographs. Figures D, E and F show a Coflex device as it can be seen in radiographs (Figure E) and in a sagittal MDCT reconstruction. In Figure F we can also distinguish little metallic teeth (red arrow) that permit the device to anchor to the spinous process bone.

References: Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

The Diam implant is a H-shaped silicone interspinous spacer, held in place by a mesh band and suture. For this implant the supraspinous ligament can be left intact. Fig. 9 on page 22 shows an example of Diam implant, as seen in MDCT.
Fig. 9: Figure 9. Patient treated with Diam interspinous device. A shows the silicon H-shaped device. We can only see metallic landmarks in L-L radiograph (B) but we can directly recognize it (red hash) in CT scans, particularly in MIP sagittal (C) and coronal (D) MDCT reconstructions where we can exactly see the position of the device (red hash) with its metallic landmarks (red arrow), located between spinous vertebral processes (red asterisks).

**References:** Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

Total disk replacement is another surgical technique used for treatment of symptomatic degenerative disk disease. It includes removal of diseased disk and the insertion of disk prosthesis to restore normal disk space height, local normal lordosis and maintenance of motion; however, this type of surgical procedure is often followed by complications. The prosthesis is composed of two metal plates, which have metallic teeth in order to anchor plates to the adjacent vertebrae.

"Post-operative imaging" **Fig. 10** on page 23
<table>
<thead>
<tr>
<th>Role of Post-operative Imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Confirm correct positioning and integrity of instrumentation</td>
</tr>
<tr>
<td>2. Evaluate progression of bone fusion</td>
</tr>
<tr>
<td>3. Detect suspected complications, such as hematoma or infection</td>
</tr>
<tr>
<td>4. Identify the presence of new disease or disease progression</td>
</tr>
</tbody>
</table>

**Fig. 10**: Figure 10. The table shows the role of post-operative imaging in the assessment of lumbar spine fusion and stabilization.

**References**: Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

Post-operative radiography allows for evaluation of the degree of vertebral osseous fusion and to detect normal/abnormal position of devices (**Fig. 11 on page 24**);
**Fig. 11**: Figure 11. X-Stop device dislocated posteriorly with mild hematoma (red asterisk) in C. CT images show posterior dislocation of X-Stop behind spinous processes (red hashes).

**References**: Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

it also provides information about progression or stabilization of underlying disease.

Fusion success may be assessed by loss of radiolucency at the interface between cage and end-plate surface; other parameters assessed are the segmental motion stability or the height of disk.

MDCT represents the modality of choice in the assessment of vertebral osseous fusion. MR represents a useful diagnostic tool used in cases of infections or fluid collections; it offers the possibility of studying signal intensity changes in vertebral body and of evaluating the spinal cord.
Fig. 1: Figure 1. A sample of interbody rampe.

© Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT
**Fig. 2:** Figure 2. A sample of interbody cage.

© Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT
**Fig. 3:** Figure 3. Normal localization of cage: an observation of a posterior marker located at least 2 mm anterior to the posterior vertebral body margin provides reassurance that the ramp is not protruding into the spinal canal.

© Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT
**Fig. 4:** Figure 4. This figure represents cages (A) and screws (B) mostly used in spinal fusion with instrumentation. Figure 4C shows A-P and L-L radiographs with the entire metallic structure of cage and instrumentation. We recognize screws (red asterisks), rods (red hashes) and metallic cage landmarks (white arrow). In Figure 4D a MDCT axial scan with maximum intensity projection protocol (MIP) shows metallic landmarks (white arrows) located anteriorly and posteriorly to the cage body and internal bone graft (white arrowhead); we also recognize correctly located pedicle screws (red asterisks) and rods (red hashes) that go through screw heads.

© Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT
Fig. 5: Figure 5. Patient treated with a bilateral TLIF surgical approach. AP (Figure 5A) and LL (Figure 5B) radiographs show the correctly located cages (red arrow) and posterior instrumentation (red arrowheads), also visible on MDCT MIP sagittal image (C). Axial MDCT scan identifies emilaminectomy and site of facet joint removal (red asterisks), hesitated to the surgical treatment (D). Surgical outcomes are better shown comparing with axial plane obtained in L3 (Figure 5E), where laminas and facet joints are undamaged. Surgical access site can be demonstrated by the presence of metallic staples in D (red hashes).

© Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT
Fig. 6: Figure 6. Osteoporotic patient treated with double-TLIF surgical approach, using cement injected inside vertebral body through fenestrated screws, in order to obtain a better screw fixation. In Figure 6A we see fenestrated screws (fenestrations are indicated by red arrows). Screws fenestration is also shown on axial MDCT scan (red arrow in B): here we identify cement (red asterisk). Axial T2-weighted MR scans (C and G), A-P (D) and L-L (E) radiographs and MIP sagittal MDCT reconstructions (F) show the placement of cement. Figure G shows screws as they can be seen in sagittal T2-weighted MR scan.

© Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT
**Fig. 7:** Figure 7. Patient treated with Dynesis device, with TLIF surgical approach. Figure 7A shows A-P and L-L radiographs with well-visible titanium pedicle screws; we cannot recognize the polyester cords - the artificial ligament - between screws, that can be distinguished (white arrows) in sagittal MIP MDCT reconstructions (B), in axial intersomatic MDCT scan (D) and in coronal MIP MDCT reconstructions (E).

© Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT
Fig. 8: Figure 8. Two patients treated with inter-spinous process decompression systems. Figures A, B and C show a X-Stop titanium device as it appears in L-L (Figure B) and A-P (Figure C) radiographs. Figures D, E and F show a Coflex device as it can be seen in radiographs (Figure E) and in a sagittal MDCT reconstruction. In Figure F we can also distinguish little metallic teeth (red arrow) that permit the device to anchor to the spinous process bone.

© Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT
**Fig. 9:** Figure 9. Patient treated with Diam interspinous device. A shows the silicon H-shaped device. We can only see metallic landmarks in L-L radiograph (B) but we can directly recognize it (red hash) in CT scans, particularly in MIP sagittal (C) and coronal (D) MDCT reconstructions where we can exactly see the position of the device (red hash) with its metallic landmarks (red arrow), located between spinous vertebral processes (red asterisks).

© Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT
### Role of Post-operative Imaging

1. Confirm correct positioning and integrity of instrumentation
2. Evaluate progression of bone fusion
3. Detect suspected complications, such as hematoma or infection
4. Identify the presence of new disease or disease progression

**Fig. 10:** Figure 10. The table shows the role of post-operative imaging in the assessment of lumbar spine fusion and stabilization.

© Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT
Fig. 11: Figure 11. X-Stop device dislocated posteriorly with mild hematoma (red asterisk) in C. CT images show posterior dislocation of X-Stop behind spinous processes (red hashes).

© Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT
Conclusion

Radiologists should be familiar with the morphological appearance of lumbar spine after surgical procedures of fusion and stabilization; the recognition of devices helps identify the type of treatment performed.
Personal Information

Stefano Palmucci, MD
Operative Unit of Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico-Vittorio Emanuele" Via Santa Sofia 78 - 95123, Catania, Italy
spalmucci@sirm.org

Letizia Antonella Mauro, MD
Operative Unit of Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico-Vittorio Emanuele" Via Santa Sofia 78 - 95123, Catania, Italy
mauroletizia@tiscali.it

Piero Costa, MD
Operative Unit of Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico-Vittorio Emanuele" Via Santa Sofia 78 - 95123, Catania, Italy
costa.p1@gmail.com

Giuseppe Barbagallo, MD
Department of Neurosurgery
University Hospital "Policlinico-Vittorio Emanuele" Via Santa Sofia 78 - 95123, Catania, Italy
giuseppebarbagal@hotmail.com

Federica Di Martino, MD
Operative Unit of Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico-Vittorio Emanuele" Via Santa Sofia 78 - 95123, Catania, Italy

defedericadimartino@hotmail.it

Giancarlo Attinà, MD
Operative Unit of Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico-Vittorio Emanuele" Via Santa Sofia 78 - 95123, Catania, Italy
gianco82t@hotmail.it

Giuseppina Cappello, mD
Operative Unit of Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico-Vittorio Emanuele" Via Santa Sofia 78 - 95123, Catania, Italy
giuseppina.cappello@gmail.com

Pietro Valerio Foti, MD
Operative Unit of Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico-Vittorio Emanuele" Via Santa Sofia 78 - 95123, Catania, Italy
pietrofoti@hotmail.com

Giovanni Carlo Ettorre, Professor
Operative Unit of Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico-Vittorio Emanuele" Via Santa Sofia 78 - 95123, Catania, Italy
g.ettorre@unict.it
References