Instrumented spine: what the radiologists should know

Poster No.: C-1915
Congress: ECR 2013
Type: Educational Exhibit
Authors: E. Santos Armentia\textsuperscript{1}, N. Silva Priegue\textsuperscript{2}, M. González Vázquez\textsuperscript{1}, R. Prada Gonzalez\textsuperscript{3}, R. Oca Pernas\textsuperscript{1}, G. Tardáguila\textsuperscript{1}; \textsuperscript{1}Vigo/ES, \textsuperscript{2}Vigo (Pontevedra)/ES, \textsuperscript{3}Vigo, MG/ES
Keywords: eLearning, MR, CT, Trauma, Neuroradiology spine
DOI: 10.1594/ecr2013/C-1915

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 different types of spinal instrumentation including interbody, anterior and posterior fusion devices, their correct position, radiological appearance and potential complications

Background

Treatment of back pain is the third most common indication for surgical procedures. Decompression and occasional arthrodesis with instrumentation are frequently performed. Postoperative imaging is used to assess disease progression, positioning of instrumentation, possible complications and the extent of bone-graft fusion.

Knowledge of the advantages and limitations of different imaging modalities is necessary for optimal evaluation of patients with spinal instrumentation.

Radiologists should be familiar with the different surgical methods used in spinal fusion, types of instrumentation and potential complications to properly appraise postoperative images.

Imaging findings OR Procedure details

There must be adequate fixation to immobilize the spine while the bone graft heals to the vertebral segments.

The purpose of the spine instrumentation is to provide stability and reduce deformity and pain during the fusion process, and should be keep in mind that is not designed to replace the bony elements of the spine.

Spinal instrumentation may eventually fail unless bone fusion takes place.

Over the past decades, spinal instrumentation techniques have significantly increased.

Various diagnostic imaging techniques play an important role in the assessment of pre-operative and post-operative patients.

After spinal surgery, imaging studies are performed to:

• Ensure the progression of bony fusion.
• Confirm the proper position and integrity of the instrumentation.

• Identify complications.

• Detect new disease or disease progression.

Fusion between bone graft and the intersomatic cage or osteosynthesis material is crucial to provide additional support and stability to the spinal instrumentation.

SPINAL IMPLANTS:

Spinal implants are made of many different materials, shapes and sizes. It is not the objective of this paper to review all them, so just a wide review is done.

Spinal implants can be summarized into several groups:

1. Screws.
2. Wires.
3. Plates.
4. Rods.
5. Bone graft.
6. Interbody Cages.

1. Screws

Screws can be used as fixation directly or can provide strong anchorage points where rods can be attached.

Screws can be placed in different ways:

- Transpedicular screws. Fig.3.

In a study (1), 915 patients with 4790 transpedicular screws were reviewed, finding:

- Complications related to screws: 2.4%
- Contact with the anterior cortex: 2.8%
- Exceed the cortex: 1.4%
- Pedicle fracture: 0.6 to 2.7%
- Dural Tear: 1%
- Nerve root irritation: 1% (medial or inferior position)
- Broken screw: 0.5 to 2.2%;
- Pseudoarthrosis incidence: 65%
• Late onset pain secondary to pseudarthrosis or screw placement, which requires removal of the instrumentation.

-Translaminar screws.
  • The screws are placed through the facet joints.
  • The end of the screw should ideally be positioned within the lateral masses of C1.

-Transarticular screws.
  • Typically used in odontoid fracture.
  • Only the distal portion has notches for thread, so that a rigid fixation occurs when force is applied between the screw head and the threaded end region.

-Fixation screws. Fig.4.
  • They are used in odontoid fracture. Just the distal part of the screw is threaded; so a rigid fixation is achieved between the head of the screw and the lag distal part when tighten.

2. Wires. Fig.5.

Wires are placed as a tension band, converting the tensile forces in compression forces.

They can be used alone, mostly used in cervical spine to stabilize posterior vertebral elements and support bone graft, or in combination with other devices to provide stability.

3. Plates. Fig.6.

Often used in the cervical spine.

Plates are manufactured to conform to the contour of the spine and are held in place by screws set into adjacent vertebrae.

  • ANTERIOR: They are used in the cervical spine, and should have a low profile. Plates are fixed with screws, which must be at least 2 mm from the plates
  • POSTERIOR: Generally used in trauma.

4. Rods. Fig.7.

Rods are used, along with hooks and screws, to immobilize and to contour the spine into correct alignment. There are different types:
• Posterior fixation with screws
• Harrington rod
• Growth rods: expansible
• Luque rods: usually attached with sublaminar wires

5. Bone graft. Fig. 8.

Typically used in conjunction with other instrumentation techniques.

The solid fusion of the bone graft can be radiologically identifiable usually after 6-9 months.

The complete stabilization is not achieved until bone fusion occurs.

CT is the technique of choice to assess graft fusion.

Different types of graft may be used:

• Autologous.
• Allogeneic.
• Demineralized bone matrix.
• Bone morphogenetic proteins (BMP).

6. Interbody Cages. Fig. 9.

Most often placed between two vertebral bodies.

They are openwork structures filled with bone graft material to promote bone growth between the adjacent vertebrae.

Cages are used to restore lost disc height resulting from a collapsed disc and to relieve pressure on nerve roots.

INTERSOMATIC FUSION TECHNIQUES Fig. 10.

All the mentioned techniques are intended to:

• Restore and maintain the disc space height.
• Maintain normal sagittal alignment.
• Increase the stability of the operated segment.

When intersomatic space height decreases, results in:

• Narrowing of the conjunction foramen.
- Root compression.
- Loss the stability of the posterior longitudinal ligament (PLL).

When intervertebral fusion occurs Fig.11:

- Intersomatic space increases.
- Decompress the foramina.

Correct fusion is achieved when:

- Lateral plain film in flexion and extension demonstrates:
  - Absence of movement or
  - Less than 3° change at intersegmental position.
  - Absence of radiolucent area surrounding the implant.
  - Minimum loss of disc space height.
  - No implant, graft or vertebra fracture.
  - No sclerosis affecting the graft or the adjacent vertebra.
  - Bone formation is visible in the cage or around it (2).

**FAILED BACK SURGERY SYNDROME**

Failed back surgery syndrome (FBSS) is a persistent low back pain following spine surgery.

The etiology of failed back surgery can be a failure to recognize adequately the initial focus of pain, incorrect diagnosis, suboptimal selection of surgery, poor technique, failure to achieve surgical goals (pseudarthrosis), and/or recurrent pathology.
**Fig. 1**: Failed Back Surgery Syndrome

**References**: Radilogy, Povisa - Vigo/ES

**SIMPTOMATIC PSEUDOARTHROSIS**
1. Inadequate surgical technique:

-Lumbar spine Fig. 12:

Implant malposition has an estimated incidence of 5-41% in lumbar spine.

Screws can scroll:

- Medially # Invade the spinal canal
- Laterally # Invade conjunction foramina
- Anterior or laterally# Invasion of the retroperitoneum

-Cervical spine Fig. 13:

Screws should be close to the cortex but not beyond it.

When placing an anterior plate, screws can:

- Withdraw and protrude on soft tissues (eg. great vessels, trachea or esophagus)
- Completely surpass posterior cortical and protrude on the spinal cord.

2. Instrumentation failure:

-Migration of the osteosynthesis material Fig. 14, 15:

The posterior margin of the cage must be placed # 2 mm from the posterior margin of the vertebra

Multiple causes:

- Osteosynthesis material is overdimensioned.
- Material placed too anterior #Rule out aortoiliac invasion.

-Fractures: Fig. 16,17,18

Usually due to fatigue and repetitive stress occasioned by spinal movements.
The fracture does not always indicate instability, but is associated with greater mobility, instability and pseudoarthrosis.

The prominence of the instrumentation can lead chronic tissue irritation, causing pain, formation of a bursa and even pressure pain and tissue necrosis.

Could be an indication of removing the osteosynthesis material.

Some intersomatic spacers require, for their insertion, to perform one groove in the vertebral bodies.

Fractures associated with the insertion of these devices have been described, probably due to weakness in the endplate where the keel of these devices is positioned.

-Metallosis: Metallosis occurs when abrasion of metal components produces metallic debris which builds up in the periprosthetic soft tissues. **Fig.19.**

**3. Bone resorption:**

-Collapse of implant **Fig. 20:**

Vertebral fractures usually affect the cranial endplate because it is thinner and supported by less-dense trabecular bone.

The concave central portion of the endplate is weaker than the peripheral zone.

Therefore, there is higher risk of collapse if the implant is not large enough to anchor the stronger peripheral ring.

**It is called migration** when the cage sinks ≤ 3 mm in the adjacent vertebra

There’s no a well-known correlation between the implant sinking and clinical symptoms. If collapse is too large may bulge:

- Posteriorly # on the thecal sac and roots.
- Anteriorly # on the great vessels.

David reported a collapse rate of 9%. (4) Van Ooij et al (5) reported collapse in 18 of 27 patients, with underestimation of the size of osteosynthesis material in 10 of the 18.
Osteolysis: Bone resorption around the screw or implants which are in close contact with bone. Fig. 21, 24.

- Bone weakness
- Predispose to fracture
- Leads to hardware failure.

4. Facet joint arthrosis.

- Dooris et al (6) found that the location of the prosthesis in the disc space contributes to the development of osteoarthritis.
- Especially, when the material is placed too anterior, facet joints support a load 2.5 times greater than if the material was well placed.
- In 2005 Lemaire et al (7) described osteoarthritis facet 11 of 107 patients in which, on sagittal images, the osteosynthesis material was placed too anterior.

5. Adjacent segments arthrosis. Fig. 22.

- Huang et al (8) demonstrated a correlation between the range of mobility of treated levels and the rate of degeneration of adjacent segments.
- 42 patients were evaluated:
  - 10 patients (24%) developed arthrosis with intersomatic space loss, anterior osteophyte formation or both.
  - Further analysis revealed that patients who had a range of mobility # 5° not develop degenerative changes, suggesting that it is a protective factor for degenerative changes in adjacent spaces.
- Risk factors for development of adjacent segment disease (3)
  - Advanced age (>60 years)
  - Postmenopausal status
  - Osteopenia/Osteoporosis
  - Preoperative degeneration at the adjacent level
  - "Floating" fusion
  - Long fusion segment
  - Altered coronal or sagital alignment
  - Injury to the adjacent segment facet joint.

The development of facetary arthrosis is influenced by the location of the prosthesis in the disc space.
HETEROTOPIC OSSIFICATION:

- No correlation with clinical symptoms.
- Lemaire et al. (4) showed that ossification in the lateral face of the osteosynthesis material leads to fusion, whereas lateral ossification produces continuous mobility.
- They thought that ossification occurs after the 5th year after implant placement.
- Ossification of the anterior longitudinal ligament occurs most frequently when the anterior plate is placed closely to nonfused disc space.
- It can be avoided by placing a plate whose length exceeds the vertebral margin # 5mm.

COMPLICATIONS:

- LATE: Migration, Loss of instrumentation, Loss of instrumentation, Fractured or failed instrumentation.

<table>
<thead>
<tr>
<th>COMPLICATION</th>
<th>INCIDENCE RATES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudoarthrosis</td>
<td>5- 32%</td>
</tr>
<tr>
<td>Instrument failure</td>
<td>2- 15%</td>
</tr>
<tr>
<td>Neurologic</td>
<td>3- 11%</td>
</tr>
<tr>
<td>Implant removal</td>
<td>7- 25%</td>
</tr>
<tr>
<td>Removal for pain</td>
<td>2- 3%</td>
</tr>
<tr>
<td>Iatrogenic flat back syndrome</td>
<td>2- 3%</td>
</tr>
<tr>
<td>Infection</td>
<td>1- 2,4%</td>
</tr>
</tbody>
</table>

Cervical spine:

Fountas et al. (5) in a retrospective study of 1015 patients with anterior cervical discectomy, described as most frequent complications:

- Dysphagia (9.5%)
- Postoperative hematoma (5.6%)
- Recurrent laryngeal nerve palsy (3.1%)

**Infection. Fig. 23,25:**

- Incidence: 0.6 to 2%.
- Staphylococcus epidermidis and Propionibacterium acnes (4)
• During surgery
• During the immediate postoperative period
• During the late postoperative period.

The instrumentation should be removed if infection occurs after the first year since surgery and fusion is already well established.

IMAGING TECHNIQUES:

Different imaging techniques may be used in the evaluation of the spinal instrumentation

- **Plain films:**
  - It is essential to perform preoperative and immediately postoperative plain films which are used as starting point for comparison in later controls.
  - Instrumentation failure or migration can be easily evaluated with serial plain films.

- **Nuclear medicine techniques:**
  - Useful for the evaluation the surgical site for a year or even more.

- **Ultrasound:**
  - Rarely used, especially for evaluation of superficial collection or abscess.

- **RM:**
  - Less used due to metal artifacts (use titanium reduces metal artifacts)

- **CT:**
  - Very useful. It is able to demonstrate the position of the instrumentation, the alignment, the spinal canal and possible complications such as pseudoarthrosis.
  - CT is the gold standard, however, the occurrence of metal artifacts is its main handicap.
  - In order to reduce artefacts caused by instrumentation and improve image quality, various strategies have been developed:
    • Optimize technique:
      • Lower pitch.
      • Higher current tuve(230-350 mAs)
      • Higher peak kilovoltage(140 Kv).
    • Optimize reconstruction algorithms:
• Using soft tissue reconstruction filters rather edge-enhancing algorithms.

• Dual energy images **Fig. 26**:
  - Dual energy techniques also can improve image quality reducing metal artifacts.
  - Images are obtained at different kilovoltage (80 and 140 kV).
  - High kilovoltage images (140Kv) better depict soft tissues and show lower metal artifact than conventional images, so a better assessment of the hardware can be done.

**Images for this section:**

**Fig. 3**: Axial CT (A), lateral plain film (B) and picture (C) showing the correct position of transpedicular screws in the axial plane in A. In the sagittal plane, screws should be parallel between them and to the superior endplate, as in L4 and L5, and should not touch the endplate as in L2 (arrow).
**Fig. 4:** Odontoid fracture fixation: Placement of the drill guide tube through the odontoides (A). The fixing screw is inserted over the guide wire (B), up to the required location (C). Fixing screw and guide wire (D). Lateral (E) and anteroposterior (F) cervical plain films and coronal (G) and sagittal (H) CT images showing a fixing screw through the odontoid process.

**Fig. 5:** Sagittal CT image (A) and volumetric reconstruction (B) demonstrate multiple fractures (brace) affecting posterior elements in C2-C6 (arrows) and C2 body (arrow) which conform a craniocaudal distraction injury of the atlanto-axial articulation. Lateral (C) and anteroposterior cervical plain films showing a wire fixing posterior elements of C1-C2 (arrowhead) that solves the previously existent atlanto-axial distraction.
**Fig. 6:** Lateral and frontal radiographs demonstrate cervical fixation using an anterior plaque and screws (arrows, image C) between C4 and C6 and intersomatic cage (arrowheads) in space C6-C7.

**Fig. 7:** Intraoperative picture showing the placement of a dorsal Luque rod (A); postoperative CT: sagittal image (B) and volumetric reconstruction (C) of the Luque rod.
Frontal (D) and lateral (E) spinal plain films demonstrate a patient with thoracic scoliosis, convex to the right, bridged by a Harrington rod.

Fig. 8: Bone graft evolution. Just after surgery (A) it has a fine gravel appearance, and temporal evolution (B, C and D) shows it consolidation in a new bone pillar formation. Just operated patient with bone graft (E) and 1-year-follow up of the same patient (F) showing the consolidation of the bone graft into a new bone column.
Fig. 9: Multiple types of intersomatic cages (A). Bone graft is placed inside the intraosseous cage (B). Plain films show intersomatic cage placed in lumbar spine (arrowhead in C) and cervical spine (arrow in D). Coronal (E) and sagittal (F) CT images and volumetric reconstructions show a different model of cage placed in C5-C6 space.
**Fig. 10:** Lateral plain film in cervical spine (A) shows the use of different material for osteosynthesis: a screw in the odontoid process (arrow) and an anterior plate and screws, fixing the vertebral bodies in C5-C6 (arrowhead). Plain radiograph of the dorsolumbar spine (B) shows a intersomatic cage (arrow) between L1-L3 bodies used in combination with rods (arrowheads).

**Fig. 11:** 1-Intersomatic space narrowing 2-Loss of stability of the posterior longitudinal ligament (PLL). 3-After placement of the intersomatic cage, the disc space height and PLL stability are recovered.
Fig. 12: Coronal CT images (A) and volumetric reconstructions (B, C) show malpositioned right transpeduncular screw (arrows) which surpasses the anterior pedicular cortex and protrudes into the retroperitoneum. Right screws surpassing the anterior sacral cortex (D) and the vertebral cortex (E) are shown in axial CT images; both screws are located close to the right iliac vessels (arrowheads). Left vertebral screw displaced medially, invading the spinal canal (arrow in F).
**Fig. 13:** Lateral radiograph of the cervical spine (A): degenerative changes can be observed, mainly affecting the space C3-C4 (green arrow). Lateral radiography (B), CT images (C,D) and volumetric reconstruction (E) just after instrumented surgery with plate and screws, where malposition of the screws (located in the C4-C5 space) can be observed (yellow arrows). The same patient is reoperated the next day. Images of CT (F,G) and volumetric reconstructions (H,I) shows again malposition of the screws, which are located outside the vertebral body, and the plate, that is rotated. After the third surgery, hardware was finally well positioned (not shown).
Fig. 14: Serial radiographs of the cervical spine showing progressive anterior displacement of the intersomatic cage (arrows) located in the space C6-C7.
Fig. 15: Lateral radiograph of the cervical spine demonstrating two intersomatic cages in C5-C6 space and in C4-C5 which is malpositioned, showing anterior displacement.
Fig. 16: Lateral radiography of lumbar spine and enlarged detail (A) showing screw fractures (black arrows). Left sacral screw left screw is disarticulated from the rod is seen in axial CT image (red arrow in B).

Fig. 17: Left pedicle fracture secondary to instrumentation is shown in axial CT image (arrowhead in A). Certain devices (B), due to the embedded metallic keel (red arrow) can produce split fractures in the vertebral bodies.
**Fig. 18:** Axial ans sagittal CT images showing diastatic left facet joint with fracture of the articular process (arrows)
**Fig. 19:** Axial (A) and sagittal (B) CT images, showing metallosis: abrasion of right rod (arrowhead) with deposition of metal debris in ossified soft tissues (arrows).
Fig. 20: Diagram depicting implant collapse into the endplates. Serial lateral radiographs showing a normosituated cage in the space L4-L5 (A) which is collapsed in (B). The same collapsed implant is seen in the sagittal (C) and coronal (D) CT images.
**Fig. 24:** Same patient of Fig. 23. Late postoperative CT images demonstrate erosions (arrows) between the graft and the adjacent vertebrae consistent with lack of consolidation.
**Fig. 21:** CT images (A, B,C) and plain films (E,F,) showing bone resorption around vertebral screws(arrows).
Fig. 22: Sagittal and lateral CT images of lumbar spine with instrumentation showing degenerative changes in adjacent space L2-L3 (arrows).
**Fig. 23:** Sagittal CT (A) and coronal (B) images of the cervical spine showing bone graft placed in space C6-C7 (red arrows). This graft was necessary after a corporectomy because of a spondylodiscitis with a prevertebral abscess, shown in T2 weighted (C) and postcontrast T1 (D).

**Fig. 25:** Complication of lumbar spine instrumentation with bone infection. CT images showing sclerosis and erosion in L3-L4, affecting the endplates and vertebral bodies (arrows).
Fig. 26: High kilovoltage CT image (140Kv) show lower metal artifact than low kilovoltage image (80Kv).
Conclusion

Adequate understanding of various surgical techniques and instruments, coupled with improved awareness of the possible complications, are vital when interpreting postoperative studies.

Radiologists should be familiar with postoperative spinal images obtained on various modalities and the knowledge of how certain situations contribute to failed back surgery syndrome, and should arrive at a precise diagnosis, permitting appropriate treatment and minimizing patient suffering.

References


(3) David T. Lumbar disc prosthesis: 5 years follow-up study on 147 patients with 163 SB Charité prostheses. Presented at the fourth annual meeting of the Spine Society of Europe, Nantes, France, September 11-14, 2002.


(7) Huang RC, Tropiano P, Marnay T, Girardi FP, Lim MR, Cammisa FP Jr. Range of motion and

(8) J.D. Auerbache et al. Lumbar instability adjacent to a previous fusion. Seminars in Spine Surgery Volume 17, issue 4, Pages 267-276, December 2005


**Personal Information**

Eloísa Santos Armentia  
Radiology Department  
Povisa Hospital  
Salamanca Street number 5  
Vigo (Pontevedra) , Spain  
mail: esantosar@povisa.es  
esantos@povisa.es

Noelia Silva Priegue  
Radiology Department  
Povisa Hospital  
Salamanca Street number 5  
Vigo (Pontevedra) , Spain  
mail: noesilpri@hotmail.com