Interpretation of radiology images in invasive and minimally invasive spinal surgeries for spinal fusion and decompression

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Purpose

The main objective of this article is to make the radiologists familiar with the common techniques, surgical approaches and instrumentation used in spinal fixation and fusion procedures. At the same time it is to emphasize the vital role of radiologist in evaluating the position of implants and potential complications associated with the operative approaches and spinal fixation devices. The choice of a particular interbody fusion device affects the assessment of fusion progression on imaging modalities. This review outlines the advantages and disadvantages of commonly used imaging methods based on the best yield for each modality and how to overcome the problematic issues associated with the presence of metallic hardware during imaging.
Methods and Materials

SPINAL FUSION PROCEDURES

INTRODUCTION:

Interbody fusion devices increase the stability of the operated segment or segments by restoring and maintaining disk space height with normal sagittal lordosis along with deformity correction and pain relief. It not only limit the movement and permit fusion to develop but also causes indirect decompression of the foramina (1,2). An annular window for total diskectomy achieves clean bleeding endplates for an optimal environment for fusion to occur and distraction of the disk space causes indirect decompression of the foramina. Due to this fusion success requires both mechanical stability and adequate graft material to provide a favorable biologic environment for fusion to occur. That is basis for transition from early fusion procedures to more successful approaches using structural graft.

Table 1

| Bone graft or posterior pedicle screws | femoral ring allograft, threaded cortical bone dowels, cylindrical metal fusion cages, tapered fusion cages (metal and composite) |

TYPES OF INTERBODY FUSION:

Posterior/posterolateral/transforaminal/spinal fusion and instrumentation

- Anterior instrumentation and fusion
- Inter-body grafts and implants
- Vertebral body replacement (corpectomy)
- Total disk replacement

Each technique can stand alone or can be accompanied by supplemental segmental posterior instrumentation (3,4,15,16)(posterior rods and pedicle screws most commonly FIG 1,2). The time from implantation of an interbody fusion device to solid arthrodesis is variable, but it is usually a minimum of 6-12 months (22,23,24,36)

FIG 1 Proper endplates preparation

FIG 2 Insertion of the device

METHODS:

1-A posterior approach is usually used when posterior decompression is required in addition to fusion as in degenerative spinal disease common in dorsal and lumbar regions.
as it is easier and adequately visualizes neural elements. It is mostly avoided in the cervical region for cord manipulation risks at that level[4,5].

Posterior fusion uses autografts placed along decorticated facets, partially cut laminae and/or transverse processes. In PLIF, afterdiskectomy bone graft material is packed into the anterior disk space before the insertion of one or two interbody spacers; placed side by side; and packed with graft material FIG 3

The bone graft material is placed laterally (between transverse processes) rather than anteriorly (between vertebral bodies), for posterolateral spinal fusion. Rods are commonly used for long segment spinal fixations e.g., in scoliosis, as they can be individually cut and molded as required to facilitate maintenance of sagittal alignment, while plates are favored for short segment fixations e.g., in traumatic and degenerative etiologies. (20,21,13)FIG 4,5,6

(Fig3) radiographs of the lumbosacral spines with PLIF showing LV3 through LV5 levels laminectomies with fine posteriorly located bone chips

2- Anterior fusion procedures are indicated for discogenic pain where removal of degenerative disk material and replacement for disk height is performed along with anterior osseous fusion for immediate stability. The presence of facet joint disease contra-indicates these procedures.

Anterior instrumentation may use either rod-screw or plate-screw systems to form a spinal construct. The anterior approach is generally preferred in the cervical spine (commonly known as anterior cervical diskectomy and fusion or ACDF) because of the risk of cord manipulation associated with a posterior approach at this level. In the thoracic and lumbar levels it is less indicated owing to significant morbidity, related to going through the chest and abdominal cavities, and delayed recovery is associated with this approach.

3- Inter-body grafts and implants

These are a group of materials that have compressive strength and aim mainly to preserve disc space and/or spinal motion .. They can be biologic substances like iliac bone grafts (Fig4) and fibular grafts in cervical regions and femoral grafts where more spinal axial loads are present as in the lumbar region. Synthetic materials such as stainless, titanium and carbon polymers can be used in threaded and solid forms. (5,6)

(Fig 4)Immediate post-operative antero-posterior (A) and lateral radiographs (B) of the lumbosacral spines with posterior lumbar interbody fusion showing LV4-LV5 levels laminectomies with iliac bone graft at LV4-5 disc level

(Fig5) Antero-posterior (A) and lateral radiographs (B) of the cervical spines showing metallic markers of CV4-5 intervertebral disc spacers
**4- Vertebral body replacement (corpectomy)**

Spinal diseases of neoplastic, infective or traumatic processes may necessitate resection of one or more vertebral bodies under certain circumstances, known as corpectomy or vertebral body replacement. Maintaining the lost spinal segment height is mandatory to preserve functionality and avoid further neural related complications. For corpectomy procedures large strut grafts are used with added spinal hardware fixations. Femoral strut allografts are used in the lumbar or thoracic spine, while fibular strut allografts or tricortical iliac crest grafts are used in anterior cervical corpectomy.

**5- Total disk replacement**

Total disk replacement, also known as disk arthroplasty, is performed in patients with discogenic pain with no nerve root involvement, spinal stenosis or spondylolisthesis. At least 4 mm of residual disk height and a lack of significant endplate degeneration to provide satisfactory anchorage for the replacement device are pre-requisites. The presence of spinal instability, facet joint degeneration, osteoporosis and/or infection contraindicates total disk replacement. These are classified into four categories: (1) low-friction sliding surface; (2) spring-and-hinge systems; (3) contained fluid-filled chambers; and (4) discs comprised of rubber or other elastomers. The materials used by different manufacturers have many different combinations of metals and polymers.

**6- Spinal dynamic stabilization**

Spinal fusion procedures reduced pain clinically, but the increased stress on the adjacent segments. Dynamic stabilization may be an alternative to for low back pain originating from chronic degeneration of the lumbar. The concept of dynamic stabilization relies upon altering load bearing and controlling abnormal motion. This limits the stress placed on the segment adjacent to the level of fusion and thus helps prevent progressive degeneration. A wide variety of dynamic stabilization devices may be broadly grouped, into the following categories: (1) pedicle screws and artificial ligaments; (2) inter-spinous process decompression devices; and (3) posterior element replacement systems.

**DEVICES:**

Most pedicle screw systems currently use titanium implants so degradation of anatomic detail on postoperative imaging is not as severe as in the past when stainless steel implants were used. These devices have varying geometric configurations, wall thicknesses and materials. First-generation devices were cylindrical and could be placed via a posterior and anterior lumbar interbody fusion approach (FIG 7). Subsequent
second-generation devices offered improved shapes and sizes to fit within the disk space and improve alignment and fusion. (7,8,9)

**FIG 7** Two types of cages most commonly used in the US. On the left is the Ray titanium threaded cage. The cage in the model spine on the right is the BAK cage

- Titanium
- PEEK (polyether etherketone) and other polymers,
- Human allograft bone dowels
- Allograft bone spacers

1- Metal Devices:

First-generation:

cageBAK (Bagby and Kuslich) Cage.

This first-generation cage is a cylindrical, hollow, porous, square-threaded, titanium alloy cage that is screwed into position within the disk space (Fig8) It is thicker than subsequent generations of cages and produces more severe artifacts on MR and CT imaging (17,18,19)

**FIG 8**

A, BAK cage (Zimmer Spine).

B, Ray Threaded Fusion Cage (Stryker Spine).

C, LT-CAGE.D, INTER FIX device

E, Harms cage (DePuy Spine).

F, PEEK cage (Medtronic SofamorDanek).

G, JAGUAR I/F CAGE (Brantigan Device; DePuy Spine). H, BOOMERANG.

I, Bone Dowel.

J, Femoral Ring

Second-generation:

1-Ray Threaded Fusion Cage.

A second-generation cage is a cylindrical, hollow, titanium, threaded device that contains less metal than the BAK cage due to which the Ray cage produces fewer artifacts on imaging studies.
2-INTER FIX Threaded Fusion Device and the INTER FIX RP Threaded Fusion Device.

The INTER FIX and the INTER FIX RP are second-generation cylindrical, fenestrated, titanium cages that permit improved CT imaging because of the decreased wall thickness (Fig 1D). These devices can be implanted through anterior lumbar interbody fusion or posterior lumbar interbody fusion approaches. Advantages versus allograft are similar to the aforementioned devices.

Third-generation

**LT-CAGE Lumbar Tapered Fusion Device.**

Most widely used LT-CAGE is a thin-walled, threaded cage trapezoidal configuration and the shape allows increased surface area for bone growth and tapered configuration facilitates restoration of lordosis.

**Harms Cage.**

Harms cage a surgical titanium mesh cage, with 1-mm wall thickness to provide axial strength has an open diamond configuration to maximize the area of bone graft and allow for load sharing.

2- Composite Devices

**PEEK Cage.**

PEEK refers to polyetheretherketone, a plastic substance similar to those of cortical bone. It is radiolucent on CT and XRay, while well visualized on MR images. As it is radiolucent, small metallic markers are usually placed at both ends of the device to allow monitoring of position.

**JAGUAR I/F CAGE (Brantigan Device).**

The JAGUAR I/F CAGE is a carbon fiber-reinforced polymer rectangular-type cage driven into a disk space, and can be machined to any size and shape. Being radiolucent markers are placed though fewer artifacts on CT and MR images.

**BOOMERANG II Device.**

The BOOMERANG II second-generation device is a bow-shaped implant with biconvex surfaces is radiolucent and lacks artifacts on CT imaging. Markers are placed to allow visualization on plain radiographs.

3- Biologic Devices
**Bone Dowels/Femoral Rings.**

The advantage of these devices is absence of imaging artifacts and the placement of a completely biologic device. Disadvantages are risk of disease transmission and fracture potential when inserted with an impactor.

**Bone Graft Substitutes**

*Recombinant Human Bone Morphogenetic Protein (rhBMP-2), Commercially Available as INFUSE Bone Graft.*

INFUSE Bone Graft substance is recommended for use only with the LT-CAGE. INFUSE Bone Graft being radiolucent reflects new bone formation by increased attenuation within the disk space.

**FIG 9 Normal progression of interbody fusion. A, On a coronal reformatted CT image, obtained 6 months after surgery, new bone formation is evident within (black arrow) and adjacent to (white arrow) the LT-CAGE devices. B, Ten months after surgery, reformatted CT image shows additional new bone formation, especially lateral to the fusion devices (white arrows), with bony bridging across the disk space**

**Radiology Evaluation Of Interbody Fusion:**

Baseline radiographs are essential as they are the primary point for evaluation of future studies should patients develop symptoms suggesting possible complications. They may justify further imaging workup with computed tomography, magnetic resonance and/or nuclear medicine studies as the evaluation of a patient with a spinal implant involves a multi-modality approach.(12,13,14)

**Plain Radiographs**

Baseline radiographs or CR images are essential for evaluating spinal construct position and serve as a starting point for evaluation of future studies. At the same time they help to assess intervertebral space, fusion and its progression, allograft resorption/replacement, graft incorporation, change in position or instrument failure on plain films. (fig 10,11,12,13) Antero-posterior (AP), lateral, oblique, and motion studies (flexion, extension, or lateral bending) images are usually adequate projections (10,11,19,20).

**Accurately placed graft :**

- Anterior plates are anchored to the underlying vertebral bodies with screws. Fig 10
- Screws should enter the anterior cortex of each vertebral body and.
- These should be seated in the posterior cortex without impinging on the cord.
• This firm purchase of the screws promotes posterior graft material compression and enhance bony fusion.
• The screws should not enter an adjacent end plate and should be at least 2 mm from the superior and inferior end plates

**FIG 10** - Pre-operative lateral lumbosacral x-ray showing collapse of the L5-S1 disc space. **B:** Intraoperative x-ray of the same patient showing increase in the disc height at L5-S1 after cage placement. **C:** Long term (approximately 2 years) postoperative x-ray of the same patient showing continued maintenance of the increased disc space height at the L5-S1 level (site of cage insertion)

**FIG 11** - Antero-posterior (A) and lateral radiographs (B) showing well positioned spinal lumbar construct with pedicular screws central within the pedicles and not violating the cortices or adjacent endplates

**Limitations Of Radiographs:**

• Measurement accuracy is also largely dependent on obtaining true lateral views and suboptimal radiographs are often obtained.
• Interbody space itself remains difficult to view without properly oriented radiographs.
• Plain radiographs is further complicated by the difficulty in judging fusion progression or bony bridging across the disk space.
• Metal devices obscure the central bone graft to assess graft maturity remodeling
• The choice of bone graft material may impact the radiographic assessment of interbody fusion

**Table 1**

Ray’s criteria for evaluation of spinal bony fusion

<table>
<thead>
<tr>
<th>Ray’s criteria for radiographic assessment of bridging osseous fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 3 degrees of inter-segmental position change on lateral flexion and extension views</td>
</tr>
<tr>
<td>No lucent area around the implant</td>
</tr>
<tr>
<td>Minimal loss of disk height</td>
</tr>
<tr>
<td>No fracture of the device, graft, or vertebra</td>
</tr>
<tr>
<td>No sclerotic changes in the graft or adjacent vertebra</td>
</tr>
<tr>
<td>Visible bone formation in or about the graft material</td>
</tr>
</tbody>
</table>
**MR Imaging**

Recent MRI advances and newer magnetically inert polymers used for the manufacture of spinal hardware elements allowed higher resolution images of clinical diagnostic value. MRI has become an integral part of evaluating the hardware implants particularly patient with pain, where clinical findings are non-focal, and laboratory diagnosis is negative for infection.

MRI is sensitive for detecting fractures, pseudo-arthrosis, and infections. It depicts cancellous bone marrow well compared to cortical bone. MR imaging in its current application is considered inadequate for the assessment of interbody fusion.

**Distortions due to metal :**

Magnetic resonance imaging (MRI) is potentially the best imaging modality for diagnosing patients with metallic implants, due to its superior soft tissue contrast. However, MRI near metallic implants is hampered by severe artifacts, which stem from large metal-induced field inhomogeneities as mentioned below. Paying attention to patient positioning, choosing adequate imaging parameters and selecting different pulse sequences will help to reduce MR susceptibility artifacts associated with the spinal hardware and optimize the clinical value of MRI in such patient groups.(35,36)

Based on the directions along which spatially dependent artifacts exist, the artifacts are grouped into through-plane distortions and in-plane distortions. Fig17 These two types of distortions occur at different stages in a pulse sequence: through-plane distortions result from a distorted excitation profile during the slice-selective excitation, while in-plane distortions are due to disrupted frequency encoding during the readout.(25,37)

**Fig17 T1W SE image (A) demonstrating magnetic resonance susceptibility artifact of metallic hardware are mainly the sum of signal loss within the metallic object and high signal intensity appearing around the metallic object caused by altered both phase and frequency of local spins leading to read-out misregistration. This is more obtrusive on T2-gradient images (B)**

**Parameters to overcome the metallic artefacts:**

Following are the parameters to overcome the metallic artefacts in MRI. However the details of eradicating metal artefacts are beyond the scope of this article.(23,24)

- Non-ferromagnetic titanium and polycarbon-enforced implants
- Smaller the implant size the more obtrusive the artifact will be
- Alignment of the longitudinal axis of the hardware device parallel to the direction of the main magnetic field (z-axis of the scanner)
- High-field-strength magnets produce larger magnetic susceptibility artifacts increased distortion effects of a higher main magnetic field strength could be offset by higher gradient strengths
• Use of a small field of view, high-resolution matrix (e.g., 256 × 256 or 512 × 512), thin section, and high gradient strength
• Shortening the echo time (TE) and decreasing voxel size to minimize intravoxel dephasing
• Use of a 180° refocusing pulse with SE and FSE sequences
• FSE images with decreased inter-echo spacing (#TE) in the same echo-train duration
• For fat suppression use of short inversion time inversion recovery imaging
• View angle tilting technique to decrease metallic artifacts by the application of a "compensatory gradient" (fig 18,19)
• Single-point imaging (SPI)

**Fig 18** Schematic diagram of the SEMAC sequence for imaging near metallic implants. The VAT compensation gradient suppresses in-plane distortions, while the additional z-phase encoding steps are included to resolve distorted excitation profiles that cause through-plane distortions

**Fig 19** Comparison of techniques metallic fixation device. As compared to the SE and the VAT-SE row sequences, the SEMAC technique greatly suppresses the metal-induced distortions. (27,28)

**Protocols:**

**Table 2**

<table>
<thead>
<tr>
<th>Common parameters</th>
<th>Sequences</th>
<th>TE/TR 95-105/5500 ms;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Matrix</td>
<td>256×224 sagittal, 384×256 axial</td>
</tr>
<tr>
<td></td>
<td>FOV</td>
<td>28×28 cm sagittal , 24×24 cm axial</td>
</tr>
<tr>
<td></td>
<td>Number of slices</td>
<td>2 sagittal, 2 axial- total 20-40 Slices</td>
</tr>
<tr>
<td></td>
<td>Slice thickness;</td>
<td>4 mm</td>
</tr>
<tr>
<td></td>
<td>Receive bandwidth</td>
<td>±125 kHz.</td>
</tr>
</tbody>
</table>

**Additional parameters for SEMAC**

| Processing | ZPE 10-16; partial Fourier; scan time 4-8 min. |

**Additional parameters for 2D FSE**

<table>
<thead>
<tr>
<th>Acquisition</th>
<th>NSA 2; no phase wrap; slice flow compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan time.</td>
<td>2-5 min</td>
</tr>
</tbody>
</table>

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No parallel imaging  Due to the orientation of the coil and acquisition geometry

**CT Imaging**

The use of CT for monitoring the progression of interbody fusion is now common and preferred method of assessing interbody fusion. Hardware artifacts can compromise CT; however, later-generation metallic fusion devices using titanium result in less degradation by artifact compared with earlier stainless steel implants. (29,30) Moreover, scatter effect from metal devices has not been found to be a significant obstacle with thin-section CT. Thin-section reconstructed CT scans, with reformatted coronal and sagittal images, showsLfig 20,21,22,

- Fusion maturation and degree of osseous fusion
- Failure of device fixation and nonunion
- To some extent for true arthrodesis
- Positioning of pedicle screws
- Spinal and construct alignment

**CT Protocol & Technique**

CT protocols have been developed to monitor periodically the progress of interbody arthrodesis (tab 3). CT scans are normally obtained 3, 6, 12, and 24 months after a fusion procedure or until solid arthrodesis has been obtained. These scans may be obtained without plain radiographs. Fig 22 23, 24) The following is a summary of the typical findings for each assessment period

**Table 3**

**Suggested CT scanning protocol**

<table>
<thead>
<tr>
<th>Suggested CT scanning protocol*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient orientation</td>
</tr>
<tr>
<td>Gantry tilt</td>
</tr>
<tr>
<td>Region of interest</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Kernel/algorithm</td>
</tr>
<tr>
<td>Milliamperage (mA)</td>
</tr>
<tr>
<td>Kilovoltage (kV)</td>
</tr>
<tr>
<td>Field of view (FOV)</td>
</tr>
</tbody>
</table>
Matrix 512 × 512
Volume acquisition slice collimation 1.0 mm
Image reconstruction progression

Step 1 Reconstructed axial 3.0-mm-thick sections; entire scan volume

Step 2 Reconstructed axial 1.0-mm-thick sections at 0.5-mm increments (overlapped); region of interest only

Step 3 Reformatted images in 3 planes; region of interest; 1.0 mm axial (parallel to the disc); 3.0 mm coronal and sagittal

Window and level settings 2000-3000/350-400

**CT Interpretation**

The radiologist interpreting a CT scan on a patient who has undergone interbody fusion should evaluate the following points(32,33,34)

1-**Scout Radiographs/Topograms.**

Reviewing anteroposterior and lateral scout radiographs enables the radiologist to appreciate:

- Fusion level or levels involved
- Approach whether anterior, posterior, or both
- Type of fusion device used and vertebral alignment
- Probable cause of the patient's problem necessitating the fusion e.g. spondylolisthesis, discogenic pain
- Scout radiographs will alert the radiologist to any surgical procedure eg, adding posterior rods and pedicle screws, occurred since the prior study.

2-**Vertebral Body Alignment.**

Is anterolisthesis, retrolisthesis, or scoliosis visible?

3-**Disk Space Preservation.**

Significant disk disease visible at levels other than those fused

Re-establishment of normal disk space height at the level or levels fused

4-**Anterior Versus Posterior Approach.**

Location of a fusion device or devices within the disk space anterior or posterior
5-Number of Fusion Devices at Each Level Fused.
Are the fusion devices single or paired?

6-Type of Fusion Device Used.
Were Bone Dowel, femoral ring, metallic cage, carbon fiber device, and so forth used?

7-Change in Device Position.
Evidence of device movement since the previous CT scan
Images for this section:

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Fig. 2: Radiology, Dubai Bone & Joint Centre, Dubai UAE

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Fig. 4: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3386531/

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Fig. 6: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3386531/

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Fig. 17: http://cds.ismmr.org/protected/11MProceedings/files/423.pdf

Fig. 18: http://cds.ismmr.org/protected/11MProceedings/files/423.pdf

Fig. 19: http://cds.ismrm.org/protected/11MProceedings/files/423.pdf

Results

Plain Xrays

After evaluation of normal implant complication could be accurately assessed

**Hardware failure**:

It happens if implant breaks, or dissociates from the underlying bone and showing rod migration or dislodgement, rod breakage, hook cutout or disengagement, wire breakage, screw cutout. In some instances, fluoroscopically positioned images may be needed to judge better alignment of the hardware or osseous structures

**Fig 12** Antero-posterior (A) and lateral digital radiographs (B) of the lumbosacral spines with short-segment posterior fixation spanning LV5 and SV1 levels with fracture of left lower pedicular screw of the construct representing hardware failure.

A precedent to hardware failure is aseptic loosening where instability due to pseudoarthrosis and/or infection is thought to be an etiologic factor. Loosening of pedicle screws appear as a rim of lucency around the screw threads (or any hardware) especially when the lucency exceeds 2 mm or increases in size on X-ray **Fig 4**

**Fig 13**. Antero-posterior digital radiographs of the lumbosacral spines with posterior lumbar interbody fusion showing LV3 through SV1 levels laminectomies with peri-screw lucency seen around the last screws representing aseptic loosening

CT SCANS

Progression of patient activity levels

CT scans play an important role in the progression of patient activity levels, in particular the decision regarding return

Three Months.

At 3 months,

- Early bone healing is occurring (**Fig 2A**).
- Obvious peri hardware lucencies that would indicate loss of fixation are noted.
- Subsidence, or sinking of the implant into the vertebral body above or below, should also be noted.
Subsidence has direct impact on ligamentotaxis and therefore reflects a partial loss of structural stability to work.

Six Months.

Presence of findings is indicative of delayed union, with direct implications regarding return to work and the predictability of successful fusion.

- Bony arthrodesis nearing completion at 6 months
- Evidence of bridging trabecular bone seen lateral to the implant and may also be noted within the implant
- Initial bone formation between the lateral aspect of the fusion device and the annulus.
- Exclude cystic lucencies adjacent to the implant
- Exclude linear defects through the bridging bone

**Fig20 Normal progression of interbody fusion. A, On a coronal reformatted CT image, obtained 6 months after surgery, new bone formation is evident within (black arrow) and adjacent to (white arrow) the LT-CAGE devices. B, Ten months after surgery, reformatted CT image shows additional new bone formation, especially lateral to the fusion devices (white arrows), with bony bridging across the disk space**

Twelve Months.

Findings at 12 months are similar to those with the 6-month CT scan. Trabecularization should be more mature with obvious bridging bone between vertebral bodies.

Twenty-four Months.

- CT is performed only if solid arthrodesis is not present at 12 months.
- Consolidation of disk space more completely
- Filling of trabecular bone around the implants.
- Absence of lucency or cystic changes at the device margins
- Lucent lines through the fusion mass is an indicator of nonunion, or failed fusion.

Subsidence

Subsidence is defined as a fusion device sinking into one or both of the adjacent vertebral bodies. It is significant because by a technically satisfactory interbody fusion procedure, a tight solid construct (ligamentotaxis) results. With subsidence, however, the ligaments are no longer tight and results in an increased incidence of failed fusion because the loss of mechanical structural support allows the fusion device or bone graft material to shift or dislodge.
**FIG 21.** Subsidence of LT-CAGE devices at L5-S1. Sagittal (A) and coronal (B) reformatted CT images demonstrate subsidence of the LT fusion devices (small arrows) through the L5 inferior endplate into the vertebral body. The sagittal image demonstrates new bone formation (large arrow) posterior to the fusion device with bony bridging taking place across the disk space.

Lucency at the Fusion Device or Pedicle Screw Margins.

Lucency suggests movement at the operated level and loosening of the device or screw. Such lucency is associated with delayed or failed fusion.

**Fig 22** Lucency at fusion device margins. Coronal (A) and sagittal (B) reformatted images at L5-S1 demonstrate lucency (arrows) at the margins of both LT CAGEs, suggesting delayed or failed fusion.

**Fig 23** Lucency surrounding pedicle screws. Coronal reformatted image at L5-S1 demonstrates lucency (large white arrows) surrounding the pedicle screws at S1 and subtle lucency around the L5 screws (small white arrows), signifying instrumentation loosening and fusion failure. Note the fusion devices (black arrows) within the disk space.

Cystic Changes Within the Endplates Adjacent to the Implant.

Cystic changes are seen on axial views adjacent to the implants and are good markers for failed fusion (Fig 6). These changes will resolve if arthrodesis occurs.

**Fig 24** Cystic changes within the endplates adjacent to the implants. A, Five months after surgery, CT scan shows cystic changes (arrows) in the endplates at the L5-S1 level on an axial image. B, Twenty-one months after the application of posterior instrumentation, CT scan shows that the cystic changes are much less prominent as the fusion is progressing to solid bony union.

New Bone Formation Within or Adjacent to the Fusion Devices.

New bone, typically encouraged by the inclusion of rhBMP-2-impregnated collagen sponge must achieve solid bony bridging across the disk space in a successful fusion. New bone formation within or adjacent to the fusion device is typically seen:

- By 3 months after the fusion procedure and
- Usually progresses for 18-24 months.
- Best appreciated on the coronal and sagittal reformatted images.
Abnormalities at Levels Other Than the Fused Level or Levels.

CT protocol initially covers T12 to the midsacrum. It is important for the radiologist to review carefully the images at levels rostral or caudal to the fused level to identify a herniated, foraminal stenosis or facet arthropathy as potential causes for a patient's residual or recurrent symptoms after a fusion.

Location and Integrity of the Surgical Hardware.

A fractured posterior rod or pedicle screw may be more easily appreciated on scout radiographs than on axial CT images however, a medially directed pedicle screw that has penetrated the medial cortex of a pedicle in the vicinity of the adjacent nerve root is better delineated on axial images

Fig 25 Broken pedicle screw. CT scan shows the fractured right S1 pedicle screw (white) A Bone Dowel (black) is present in the L5-S1 disk space

Fig 26 Medial orientation of pedicle screw. In a 48-year-old man, an axial image demonstrates that the left L4 pedicle screw (arrow) has penetrated the medial cortex of the pedicle in the vicinity of the L4 nerve root

CT Features of Delayed or Failed Fusion

This lucency represents osteolysis secondary to device (screw) motion, which develops with bone resorption secondary to device motion Relative indicators of loss of fixation that may lead to failure include a change in fusion device position and device subsidence . CT feature is cystic changes within the endplates adjacent to the implant.

Linear defects (fracture) can be seen through intradiskal new bone within or adjacent to the fusion device parallel to the endplates (fig 28,29)

Fig 27 Linear lucency parallel to the endplate in new bone formation in. Coronal (A) and sagittal (B) reformatted images at L5-S1 demonstrate irregular linear lucency (arrows) through new bone formation within the disk space, indicating failed fusion

Fig 28 Dislodged fusion device. Axial (A) and coronal (B) reformatted images at L5-S1 demonstrate the left-sided mesh titanium fusion device (straight white arrow) displaced laterally within and lateral to the intervertebral foramen in the vicinity of the left L5 dorsal root ganglion and nerve. A Bone Dowel (curved white arrow) is noted in the midline in the disk space. Bony bridging (arrowheads) across the disk space is evident
MAGNETIC RESONANCE IMAGING (MRI)

It can accurately comment on:

- Congruity of device in disc space Fig14
- Any collapse of the bone graft in the disc space,
- Reabsorption of the graft Fig16
- Pseudo-arthrosis.
- Extrusion of the graft and nerve root compression with radicular deficit
- Soft tissue evaluation and any superadded infrection Fig15

Fig14 Antero-posterior (A) and lateral digital radiographs (B) of the lumbosacral spines showing aberrant pedicular screw violating LV3 superior endplate and protruding into LV2-3 disc, T2W (C) and T1W (D) sagittal magnetic resonance images showing aberrant pedicular screw violating LV3 superior endplate and protruding into LV2-3 disc.(27,30)

Fig15 Sagittal T2W SE image (A), axial T1 pre-contrast (B) and post-contrast SE MR images (C) in a post-operative patient showing localized encysted collection within the operative bed with appreciable contrast enhancement of the encysted collection following IV gadolinium administration representing a post-operative infection with abscess formation

Fig16 T2W SE (A) and T1W (B) sagittal magnetic resonance images showing multiple vertebral body collapse targeting LV1, DV11 and DV8 levels in osteoporotic patient predisposing to hardware failure

Future Advances

Radiolucent Fusion Devices.

Radiolucent devices, such as those made of carbon fiber material, have a significant advantage over metallic devices in that they produce relatively little artifact on postoperative CT and MR imaging studies. Thus, monitoring the fusion and appreciating any postoperative complication become easier for the radiologist. fig 28,29

Disk Prosthesis (Artificial Disk).

Future treatment for low back pain will include use of a disk prosthesis because;

It will allow stabilization of the disk space but will maintain motion. Height will be preserved with restoration of lordosis while permitting relatively normal mobility of the vertebral
segments. The drawback of all disk prostheses currently under investigation is that their composition is predominantly chrome cobalt, which produces artifacts on CT and MR images.

**Fig 29 Intervertebral disk prosthesis.** Lateral scout view (A) demonstrates a Maverick-type chrome cobalt disk prosthesis (Medtronic SofamorDanek) within the L4-5 intervertebral disk space in a 33-year-old woman. Coronal (B) and sagittal (C) reformatted images demonstrate artifact related to the device, degrading anatomic detail at this level.
Fig. 12: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3386531/

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**Fig. 14:** http://cds.ismrm.org/protected/11MProceedings/files/423.pdf


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Conclusion

Interbody fusion has become a reliable and frequent procedure and is the treatment of choice for a number of lumbar spinal disorders, including discogenic pain. Radiologists are required to be familiar with the instrumentation and operative options used in spinal fixation and fusion procedures to properly assess outcome.

CT provides better evaluation of fusion progression and status than dynamic radiography and is becoming the preferred method of monitoring patients who have undergone interbody fusion (22,23). MRI has become an integral part of evaluating the patient with painful hardware implants. MRI is sensitive for detecting fractures, pseudo-arthrosis, and infections. It depicts cancellous bone marrow well compared to cortical bone. Radiologist should be familiar with the common interbody fusion devices, its potential complications, approach and normal appearance.
References


3- Foley KT, Holly LT, Schwender JD. Minimally invasive lumbar fusion. Spine. 2003;28[suppl]:S26-S35Medline#


5- Burkus JK, Dorchak JD, Sanders DL. Radiographic assessment of interbody fusion using recombinant human bone morphogenetic protein type 2. Spine 2003;28:2372-2377


31- ]


33- Jinkins JR, Van Goethem JW. The postsurgical lumbosacral spine. Magnetic resonance imaging evaluation following intervertebral disk surgery, surgical


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