Spondylosis Deformans

Spondylosis deformans principally consists of osteophytosis at the borders of the intervertebral discs. Degeneration of the posterior spinal facet (zygapophyseal) joints and cervical uncovertebral joints are often included under the general label of “spondylosis.” By middle age, these changes are almost universally present throughout the population, and may therefore be the cause of low back and radicular pain (Resnick, 1985; Schneck, 1985).

CONVENTIONAL AND FAST SPIN ECHO ACQUISITIONS

BASIC PROTOCOL

In general, the signal characteristics of the skeletal components of the vertebral column typically are best illustrated on the basis of spin-echo techniques. The margins of the osteophytosis associated with spondylosis deformans are generally well defined utilizing these acquisitions.

Table A8.3.1 lists the hardware necessary to perform the procedure, along with appropriate parameters. The available gradient strength will depend on the scanner, and the echo times (e.g., T_E) given in other tables will vary accordingly (i.e., the smaller the gradient strength, the longer the echo time for a particular scan).

NOTE: Be sure that technicians and nurses have immediate access to any emergency equipment that may be relevant to a given study, or that may be needed for a particular patient, such as crash carts or oxygen.

Set-up patient and equipment

1. Interview (screen) the patient to ensure that he or she has no contraindications such as cardiac pacemakers or other implants containing ferromagnetic materials. Also be sure to find out if the patient has any health conditions that may require the presence of special emergency equipment during the scanning procedure, or necessitate any other precautions.

2. If the procedure is a research protocol, have the patient sign any necessary consent form.

3. Have the patient remove all jewelry and change into a gown to eliminate any metal that might be found in clothing.

4. Inform the patient about what will occur during the procedure, what he or she will experience while in the magnet, and how to behave.

5. Have the patient mount onto the table. Either before or right after the patient lies down, set up any triggering devices or other monitoring equipment that is to be used.

Table A8.3.1 Equipment Parameters for Spine Imaging in Cases of Spondylosis Deformans

Coil type	Cervical, thoracic, lumbar: phase array surface coil (or other depending upon machine compatibility and availability)
Flow compensation	Any level (optional)
Peripheral gating	Thoracic spine only (optional)
Respiratory gating	Thoracic spine only (optional)
Use of contrast agents	No

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6. Center the coil over the region where the key information is desired.

   Make sure that the body is constrained to prevent motion, especially if high-resolution scans are to be run.

7. If needed, place a pillow or other support under the knees to make the patient more comfortable.

8. Use the centering light to position patient (cervical spine: thyroid cartilage; thoracic spine: nipple line; lumbar spine: iliac crests) and put him or her into the center of the magnet.

   Once this step has been performed, so long as the patient does not move on the table, the table itself can be moved and then replaced in the same position as before without jeopardizing the positioning of one scan relative to another.

9. If the patient is unable to hold still, provide an appropriate sedative.

Sequence 1: Rapid positioning pilot

10. To validate the patient's position, run the system's pilot (or scout) scan (sequence 1) to ensure correct location of the neck in three dimensions, using the imaging sequence given in Table A8.3.2 or similar parameters.

    This sequence usually consists of three orthogonal planes to allow subsequent localization. The images are often also used later to determine where to place the saturation pulses and to set up total coverage of the volume of interest.

Sequence 2: Sagittal T_1-weighted conventional spin echo

11. Set the imaging parameters as shown in Table A8.3.3.

Table A8.3.2 Primary Clinical Imaging Parameters for Sequence 1 (Pilot Scan)

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse, sagittal, coronal
Central slice or volume center	Laser light centered at cervical spine: thyroid cartilage; thoracic spine: nipple line; lumbar spine: iliac crests
Echo time (T_E)	As short as possible
Repeat time (T_R)	As short as possible
Flip angle (FA)	15°
Fields of view (FOV_x, FOV_y)	Cervical: 240 mm, 240 mm Thoracic: 340 mm, 340 mm Lumbosacral: 280 mm, 280 mm
Resolution (Δx, Δy)	Cervical: 0.94 mm, 0.94 mm Thoracic: 1.25 mm, 1.25 mm Lumbosacral: 1.09 mm, 1.09 mm
Number of data points collected (N_x, N_y)	256, 256
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	5 mm
Number of slices	3
Slice gap	Not applicable
Number of acquisitions (N_{acq})	1
Scan time	~10 sec

Table A8.3.3 Primary Clinical Imaging Parameters for Sequence 2 (T_1-Weighted Image)

Patient position	Supine
Scan type	Conventional spin echo
Imaging plane (orientation)	Sagittal
Central slice or volume center	Centered on: Cervical: 3rd cervical vertebra Thoracic: 6th thoracic vertebra Lumbar: 3rd lumbar vertebra
Echo time (T_E)	10 msec
Repeat time (T_R)	500 msec
Flip angle (FA)	90°
Fields of view (FOV_x, FOV_y)	Cervical: 240 mm, 240 mm Thoracic: 320 mm, 320 mm Lumbosacral: 280 mm, 280 mm (may use rectangular field of view, e.g., half or three-quarter field, if available, or tailor to region of interest)
Resolution (Δx, Δy)	Cervical: 0.94 mm, 0.94 mm Thoracic: 1.25 mm, 1.25 mm Lumbosacral: 1.09 mm, 1.09 mm
Number of data points collected (N_x, N_y)	256, 256
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	Cervical: 3 mm Thoracic: 3 mm Lumbar: 1 mm
Number of slices	As many as needed to cover region of interest
Slice gap	Cervical: 0.5 mm Thoracic: 1 mm Lumbar: 1 mm
Number of acquisitions (N_{acq})	4
Flow compensation	Yes (if available)
Saturation pulses	Yes; anterior cervical/thoracic/lumbar slabs to saturate larynx/vessels/heart
Slice series	Left to right or the reverse depending on preference
Scan time	~8 min

12. Use the pilot image to locate the spine in three dimensions to ensure coverage of the region of interest (e.g., cervical, thoracic, lumbosacral spine).

13. Let patient know you are ready, and begin the scan.

Sequence 3: Sagittal T_2-weighted fast spin echo

14. Review the pilot scans and ensure that the saturation pulse is correctly placed anterior to above the slab of interest.

15. Run sequence 3 according to Table A8.3.4.

Table A8.3.4 Primary Clinical Imaging Parameters for Sequence 3 (T_2-Weighted Image, FSE)[a]

Patient position	Supine
Scan type	Fast spin echo
Imaging plane (orientation)	Sagittal
Central slice or volume center	Centered on area of interest (as in Sequence 2, Table A8.3.3)
Echo time (T_E)	100 msec
Echo train length (ETL)	8
Repeat time (T_R)	4000 msec
Flip angle (FA)	90°
Fields of view (FOV_x, FOV_y)	As in Sequence 2, Table A8.3.3
Resolution (Δx, Δy)	Cervical: 0.47 mm, 0.47 mm Thoracic: 0.63 mm, 0.63 mm Lumbosacral: 0.55 mm, 0.55 mm
Number of data points collected (N_x, N_y)	512, 512
Display matrix (D_x, D_y)	512, 512
Slice thickness (Δz)	Cervical: 3 mm Thoracic: 3 mm Lumbar: 1 mm
Number of slices	Varies with spinal level
Slice gap	Cervical: 0.5 mm Thoracic: 1 mm Lumbar: 1 mm
Number of acquisitions (N_{acq})	1
Flow compensation	Yes (if available)
Saturation pulses	Yes; anterior cervical/thoracic/lumbar slabs anteriorly to saturate larynx/vessels/heart
Fat suppression	Yes: chemical saturation or STIR (short tau inversion recovery)
Slice series	Left to right or the reverse depending on preference
Scan time	~4 min

[a]FSE: fast spin echo.

Sequence 4: Transverse T_1-weighted conventional spin echo

16. Using the midline sagittal T_1-weighted image acquired in sequence 2, set the transverse acquisition parameters as follows:

    a. Cervical spine: 3 to 4 slices each, angled to plane of individual intervetebral discs, or stacked images throughout C1-T1.

    b. Thoracic spine: stacked images through levels of interest.

    c. Lumbosacral spine: 5 slices each, angled to the plane of the intervertebral disc at L3-4, L4-5, and L5-S1; one or more slices each, angled to the intervertebral disc at L1-2 and L2-3.

17. Supplement additional slices according to visible disease present or to clinical query.

18. Run sequence 4 according to Table A8.3.5.

Table A8.3.5 Primary Clinical Imaging Parameters for Sequence 4 (T_1-Weighted Image)

Patient position	Supine
Scan type	Conventional spin echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Centered on area of interest (as in Sequence 2, Table A8.3.3)
Echo time (T_E)	10 msec
Repeat time (T_R)	500 msec
Flip angle (FA)	90°
Fields of view (FOV_x, FOV_y)	As in Sequence 2, Table A8.3.3
Resolution (Δx, Δy)	Cervical: 0.94 mm, 0.94 mm Thoracic: 1.25 mm, 1.25 mm Lumbrosacral: 1.09 mm, 1.09 mm
Number of data points collected (N_x, N_y)	256, 256
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	Cervical: 3–4 mm Thoracic: 3–8 mm Lumbar: 4 mm
Number of slices	Varies with spinal level
Slice gap	Cervical: 1 mm Thoracic: 1–2 mm Lumbar: 1 mm
Number of acquisitions (N_{acq})	2
Slice locations	See text (Basic Protocol, step 16)
Flow compensation	Yes (if available)
Saturation pulses	No
Scan time	~4 min

Sequence 5: Transverse T_1-weighted fast spin echo

19. Using the midline T_1-weighted image acquired in Sequence 2, repeat the setup as in Table A8.3.6.

20. Run sequence 5 according to Table A8.3.6.

Sequence 6: Transverse T_2-weighted fast spin echo, fat suppressed (optional)

21. Using the midline T_1-weighted image acquired in sequence 2, repeat the setup as in Table A8.3.7.

22. Run sequence 6 according to Table A8.3.7.

GRADIENT RECALLED ECHO ACQUISITIONS

ALTERNATE PROTOCOL

With some machines, or according to preferences, gradient recalled echo acquisitions may be used in the sagittal and/or transverse planes to clearly distinguish between discs and soft tissue and to clarify the spinal neural foramen in the cervical region (Tsuruda et al., 1990; Van Dyke et al., 1989; Yousem et al., 1991).

Table A8.3.6 Primary Clinical Imaging Parameters for Sequence 5 (T_2-Weighted Image, FSE)[a]

Patient position	Supine
Scan type	Fast spin echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Centered on region of interest (as in Sequence 2)
Echo time (T_E)	100 msec
Echo train length (ETL)	8
Repeat time (T_R)	4000 msec
Flip angle (FA)	90°
Fields of view (FOV_x, FOV_y)	As in Sequence 2
Resolution (Δx, Δy)	Cervical: 0.94 mm, 0.94 mm Thoracic: 1.25 mm, 1.25 mm Lumbosacral: 1.09 mm, 1.09 mm
Number of data points collected (N_x, N_y)	256, 256
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	Cervical: 3 mm Thoracic: 3 mm Lumbar: 1 mm
Number of slices	Varies with spinal level
Slice gap	Cervical: 0.5 mm Thoracic: 1 mm Lumbar: 1 mm
Number of acquisitions (N_{acq})	2
Slice locations	See text (Basic Protocol, step 16)
Flow compensation	Yes (if available)
Saturation pulses	No
Scan time	~4 min

[a]FSE: fast spin echo.

Sequence 7: Sagittal gradient recalled echo

1. Run sequence 7 according to Table A8.3.8.

Sequence 8: Transverse gradient recalled echo

2. Run sequence 8 according to Table A8.3.9.

COMMENTARY

Background Information

Spondylosis deformans is represented by osteophytes that form in response to degenerative protrusive disc alteration along the ring margins of the vertebral bodies at or near the discovertebral margin. The bony vertebral excrescencies (i.e., osteophytes) appear and grow from the point of traction. Initially, the growth is horizontal but becomes more vertical as the process proceeds along the course of the outwardly protruding disc. These osteophytes form predominantly in the anterior and lateral aspects of the spine. Spondylosis, when present posteriorly and posterolaterally, may produce or contribute to the various forms of spinal stenosis, i.e., central spinal canal stenosis, lateral recess spinal canal stenosis, and neural foramen stenosis (Fig. A8.3.1).

Osteoarthrosis of the apophyseal posterior spinal (facet) joints of the spine consist of erosion or complete denudation of the articular cartilage, joint-space narrowing, bony eburnation, and osteophytosis. This may be accompanied by intra-articular osteocartilaginous loose bodies and hyperplasia of the synovial membrane. A combination of factors may result in

Table A8.3.7 Primary Clinical Imaging Parameters for Sequence 6 (T_2-Weighted Image, FSE, Fat Suppressed)

Patient position	Supine
Scan type	Fast spin echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Centered on region of interest (as in Sequence 2)
Echo time (T_E)	100 msec
Echo train length (ETL)	8
Repeat time (T_R)	4000 msec
Flip angle (FA)	90°
Fields of view (FOV_x, FOV_y)	As in Sequence 2
Resolution (Δx, Δy)	Cervical: 0.94 mm, 0.94 mm Thoracic: 1.25 mm, 1.25 mm Lumbrosacral: 1.09 mm, 1.09 mm
Number of data points collected (N_x, N_y)	256, 256
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	Cervical: 3 mm Thoracic: 3 mm Lumbar: 1 mm
Number of slices	As many as needed to cover region of interest
Slice gap	Cervical: 0.5 mm Thoracic: 1 mm Lumbar: 1 mm
Number of acquisitions (N_{acq})	2
Slice locations	See text (Basic Protocol, step 16)
Flow compensation	Yes (if available)
Saturation pulses	No
Fat suppression	Yes, fat saturation or STIR (short tau inversion recovery)
Scan time	~4 min

narrowing of the spinal neural foramen and entrapment/compression of the transiting spinal nerve root and, at some spinal levels (e.g., lumbar spine), the dorsal root ganglion. Those factors that produce neural foramen stenosis include a reduction in height of the neural foramen due to degenerative narrowing of the apophyseal joint space and intervertebral disc space, hyperplasia/redundance of the synovial membrane of the apophyseal joint, facet joint osteophyte formation, and posterolateral discogenic encroachment (e.g., intervertebral disc bulge/protrusion/extrusion, discogenic vertebral osteophytosis). These alterations may also contribute to concomitant stenosis of the central spinal canal and the lateral recesses of the central spinal canal. One other phenomenon that may cause stenosis of the neural foramina in the cervical region is osteoarthrosis of the uncovertebral articulations, or "joints of Luschka." These articulations are not evident in the cervical spine in all individuals, and when present are not found at all levels. Typically they are observed in the caudal five cervical vertebral bodies (i.e., C3 to C7). These articulations are formed from bony ridges that extend in a cranial direction from the superolateral margin of the vertebral body; these ridges are termed the uncinate or lunate processes. The uncinate processes form a modified articulation with the inferolateral surface of the suprajacent vertebral body. The modification is produced by fibrillation and fissuring of the marginal fibers of the interposed anulus fibrosus; the lining of the uncinate articulations are the cartilaginous end plates of the respective vertebral bodies. Although it simulates synovium-lined articulation, strictly speaking, this is not what it is. These articulations develop postnatally and undergo degenerative changes later in life.

Table A8.3.8 Primary Clinical Imaging Parameters for Sequence 7 (T_2^*GRE)[a]

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Sagittal
Central slice or volume center	Centered on the region of interest (as in Sequence 2, Table A8.3.3)
Echo time (T_E)	15 msec
Repeat time (T_R)	500 msec
Flip angle (FA)	10° to 20°
Fields of view (FOV_x, FOV_y)	As in Sequence 2
Resolution (Δx, Δy)	Cervical: 0.94 mm, 0.94 mm Thoracic: 1.25 mm, 1.25 mm Lumbosacral: 1.09 mm, 1.09 mm
Number of data points collected (N_x, N_y)	256, 256
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	3 mm
Number of slices	Varies with spinal level
Slice gap	1 mm or less
Number of acquisitions (N_{acq})	3
Flow compensation	Yes (if available)
Saturation pulses	Yes
Scan time	~6 min

[a]T_2^*GRE: T_2^* gradient recalled echo.

Table A8.3.9 Primary Clinical Imaging Parameters for Sequence 8 (T_2^*GRE)[a]

Patient position	Supine
Scan type	Gradient echo
Imaging plane (orientation)	Transverse
Central slice or volume center	Centered on the region of interest (as in Sequence 2, Table A8.3.3)
Echo time (T_E)	15 msec
Repeat time (T_R)	500 msec
Flip angle (FA)	10° to 20°
Fields of view (FOV_x, FOV_y)	As in Sequence 2, Table A8.3.3
Resolution (Δx, Δy)	Cervical: 0.94 mm, 0.94 mm Thoracic: 1.25 mm, 1.25 mm Lumbosacral: 1.09 mm, 1.09 mm
Number of data points collected (N_x, N_y)	256, 256
Display matrix (D_x, D_y)	256, 256
Slice thickness (Δz)	3–4 mm
Number of slices	Varies with spinal level
Slice gap	1 mm or less
Number of acquisitions (N_{acq})	1
Slice locations	See text (Basic Protocol, step 16)
Flow compensation	Yes (if available)
Saturation pulses	Yes
Scan time	~2 min

[a]T_2^*GRE: T_2^*gradient recalled echo.

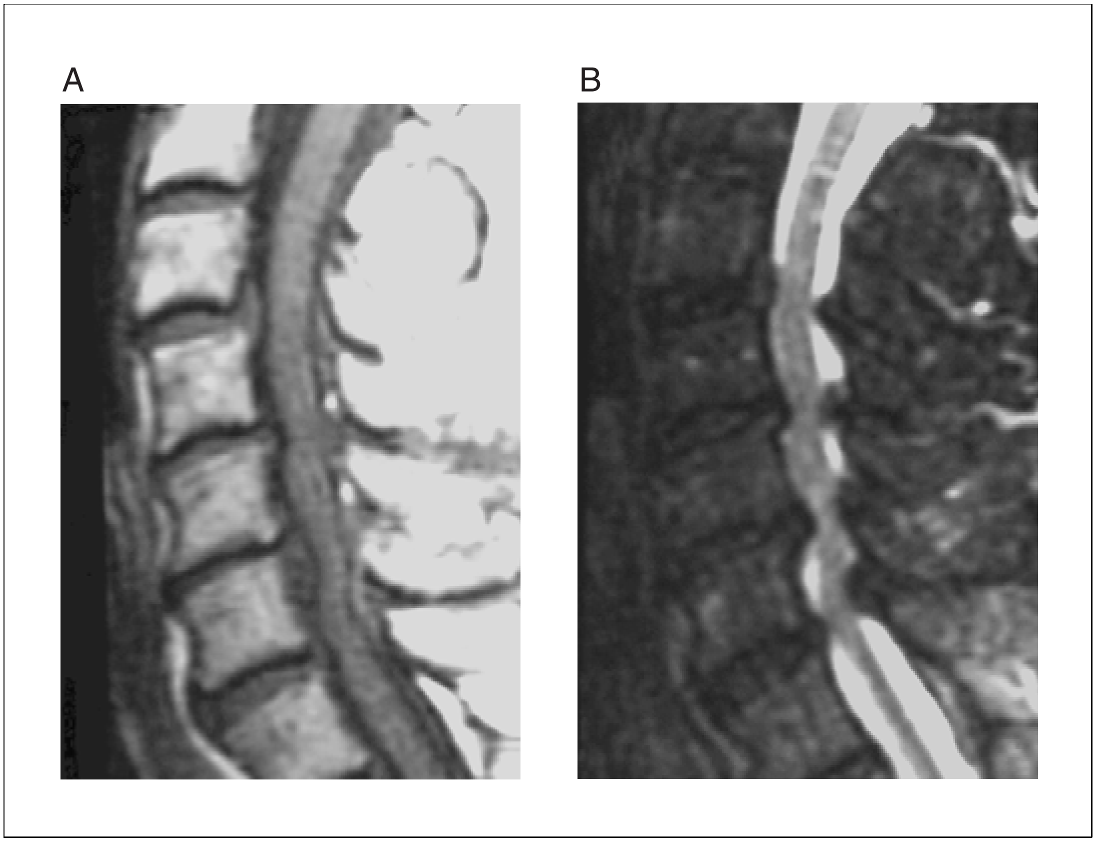

Figure A8.3.1 Cervical spondylosis. (**A**) Sagittal T_1-weighted (T_R = 500 msec, T_E = 10 msec) image shows diffuse cervical intervertebral disc space narrowing and posterior disc protrusions at multiple levels. (**B**) Sagittal T_2-weighted (T_R = 4000 msec, T_E = 100 msec) image with fat suppression shows the degenerative anterior and posterior protrusive changes at multiple levels.

Because they are cartilaginous articulations, degeneration of the uncovertebral articulations is referred to as osteoarthrosis. Uncovertebral articulation osteoarthrosis consists of narrowing of the articular space, erosion/denudation of the articular cartilage, and marginal osteophytosis. As noted above, this process may contribute to the narrowing of the spinal neural foramina at the levels of the cervical spine at which uncovertebral articulations exist.

Musculoligamentous and vertebral marrow edema may occur in association with these degenerative changes. These alterations can only be observed properly using MRI (Fig. A8.3.2).

Critical Parameters and Troubleshooting

Cerebrospinal fluid (CSF) flow, cardiac, laryngeal, body wall, and other sources of motion can produce artifacts that can on occasion significantly degrade the images. Proper spatial (e.g., prevertebral) saturation pulses and sometimes flow compensation pulses and/or cardiac/respiratory gating can reduce these artifacts significantly. In many instances these artifacts may be difficult or impossible to easily overcome from patient to patient.

Degenerative musculoligamentous and vertebral marrow edema are only properly demonstrated on MRI using fat suppressed techniques coupled with T_2-weighted imaging. The sagittal plane should be acquired in this manner; a similar acquisition may also be acquired in the transverse plane if desired.

Anticipated Results

The goal of studying the spine in patients with suspected advanced degenerative spondylosis is to reveal and document the presence, level, and severity of peridiscal, uncovertebral, and/or posterior spinal facet joint osteophytosis. These alterations in turn may lead to narrowing of the central spinal canal, lateral recesses of the central spinal canal, and spinal (intervertebral) neural foramen. The protocols in this unit will allow an accurate assessment of these phenomena.

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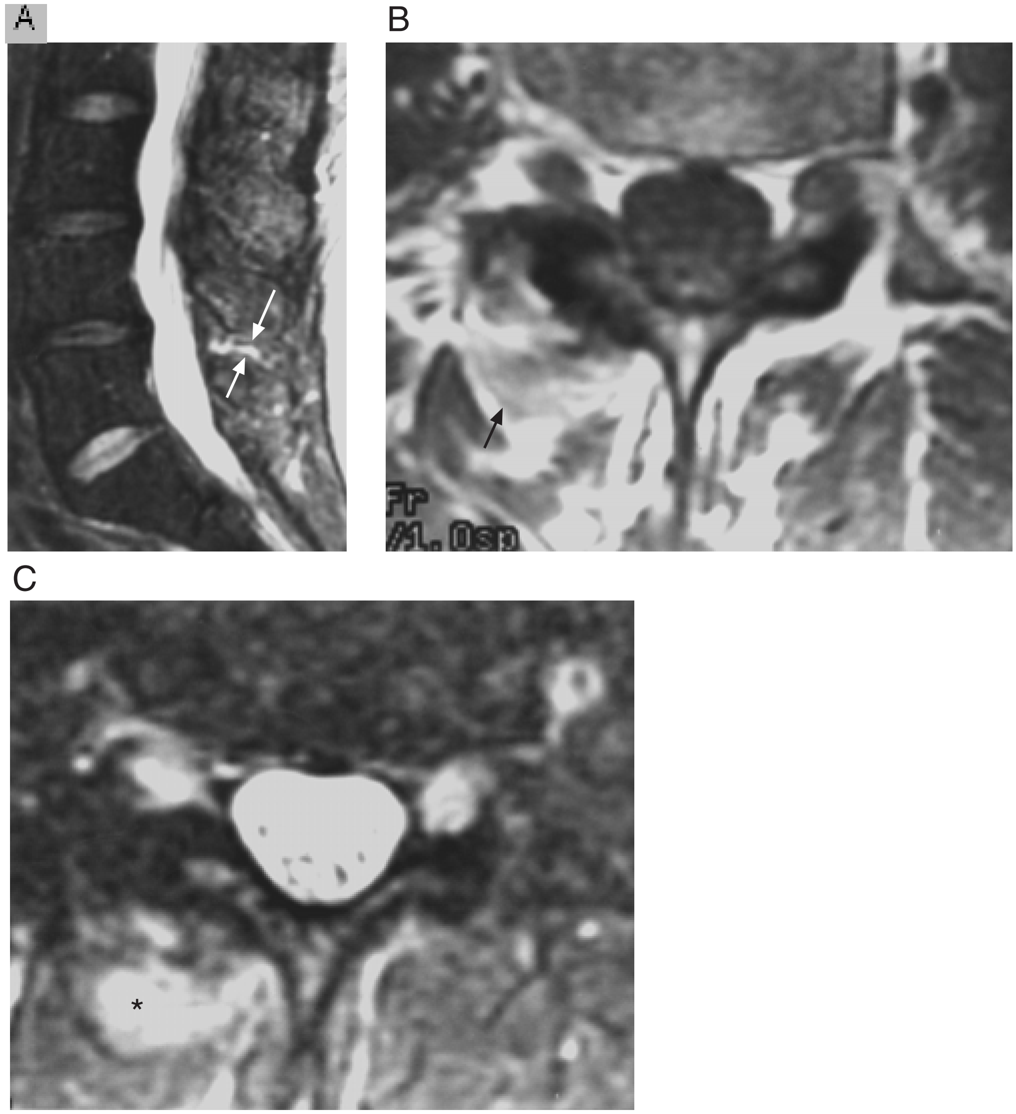

Figure A8.3.2 Degenerative spinal musculoligamentous alterations. (**A**) Sagittal T_2-weighted (T_R = 4000 msec, T_E = 100 msec) fat suppressed image shows interspinous ligament hyperintensity (arrows) indicating degeneration/rupture. (**B**) Transverse T_1-weighted (T_R = 500 msec, T_E = 10 msec) image shows the multifidus muscle (arrow) to be swollen and relatively hyperintense on the right side. (**C**) Transverse T_2-weighted (T_R = 4000 msec, T_E = 100 msec) fat suppressed image shows hyperintense degeneration of the multifidus muscle (asterisk) on the right side.

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