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Pitfalls in Spinal MR Imaging

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Summary

The purpose of this study is to present some pitfalls in the interpretation of spinal magnetic resonance (MR) images. Nearly 800 patients underwent spinal MR examination using a 0.5 tesla superconducting MR system. Pulse sequences were T 1- and T 2-weighted spin echo (SE) types. We encountered several pitfalls, which should be given careful attention; they can be roughly classified into two categories, i.e., those related to various are and those not so related. Artifacts in turn can be subdivided into two categories, those related to the patient himself (motional, metallic and chemical shift artifacts) and those related to the MR system (hardware and software). Pitfalls not related to artifacts are as follows: 1. partial volume averaging; 2. CSF flow void phenomenon; 3. lesions with few resonating protons; 4. lesions showing similar signal intensities. We must be aware of these pitfalls to avoid misinterpreting spinal MR images.

Keywords: Magnetic resonance imaging (MRI); Spinal cord lesions; Pitfalls in MRI; Image artifacts.

Introduction

Magnetic resonance (MR) imaging has revolutionized the spinal lesion diagnostic procedures due to its freedom from potential hazard, mutliplanar imaging capabilities and high tissue contrast. The superiority of MR imaging over conventional diagnostic modalities, including X-ray computerized tomography (CT), for spinal lesions has been well documented in recent papers[3, 7, 8, 10]. In the present diagnoses of spinal cord lesions we noticed several pitfalls, regarding which great care should be taken to avoid erroneous interpretation. The present paper details these pitfalls and discusses solutions thereto.

Materials and Methods

In the past two years, we examined nearly 800 patients for suspected spinal cord lesions. The MR scanner used was a 0.5 tesla superconducting system (Picker International, Cleveland, OH). Pulse sequences were T 1- and T 2-weighted spin echo (SE) types. Echo time (TE) and repetition time (TR) for T 1-weighted SE images were 40 and 600–1,000 msec respectively. TE and TR for T 2-weighted SE images were 120 and 2,000 msec respectively. The strength of the frequency-encoding (read-out) gradient was 0.985 milli-tesla/meter. Scan orientations were mainly sagittal and axial; coronal images were obtained if needed. Slice thickness was approximately 1.0 cm, field of view was 30 cm. Data matrix was 256 × 256; averaging: twice. Generally a body coil was used as transmitter and receiver antennas. Image reconstruction was via two-dimensional Fourier transformation.

Results

We noticed several pitfalls in the interpretations of the spinal MR images. These are listed in Table 1; detailed descriptions are given in discussion.

Table 1. *Pitfalls in Spinal MR Imaging*

A: Pitfalls related to artifacts
- a: Patient-related
  1. Motional artifact
     1. cardiac
     2. respiratory
     3. bowel movement
     4. swallowing
     5. flowing blood (Fig. 1)
  2. Metallic artifact
     1. large metal substances (Fig. 2)
     2. small metal particles (Fig. 3)
  3. Chemical shift artifact (Fig. 4)
- b: MR system-related
  1. Software-related
     center dot artifact (Fig. 5)
  2. Hardware-related
     dc field inhomogeneity
     gradient field nonlinearity

B: Pitfalls not related to artifacts
1. Partial volume averaging (Fig. 6)
2. CSF flow void phenomenon (Fig. 7)
3. Lesions with few resonating protons (Fig. 8)
4. Lesions showing similar signal intensities (Figs. 7 a, 9, 10)

Discussion

The pitfalls we noticed in spinal MR imaging can be divided generally into two groups, namely, those related to various artifacts and those not so related.

A. Pitfalls Related to Artifacts

Image artifacts themselves are of two types[5]: those related to the patient himself and those related to the MR system itself. The latter as well can be further subdivided into the type related to software, and that related to hardware.

A-a) Artifacts Related to the Patient

Artifacts related to the patient himself are motional, metallic and chemical (chemical shift misregistration effects).

1. Motional artifacts: Motional artifacts are caused by cardiac, respiratory and bowel movements, swallowing and rapidly flowing blood, and they degrade image quality.

Artifacts caused by cardiac and respiratory movements are minimized by gating. Although gating is time-consuming, it is often necessary with thoracic lesions. Bowel movements are reduced by the administration of glucagon. A surface coil is beneficial for these motional artifacts since it increases the signal-to-noise ratio, local signals from the spinal regions being enhanced much more than those from the heart, chest wall and bowels.

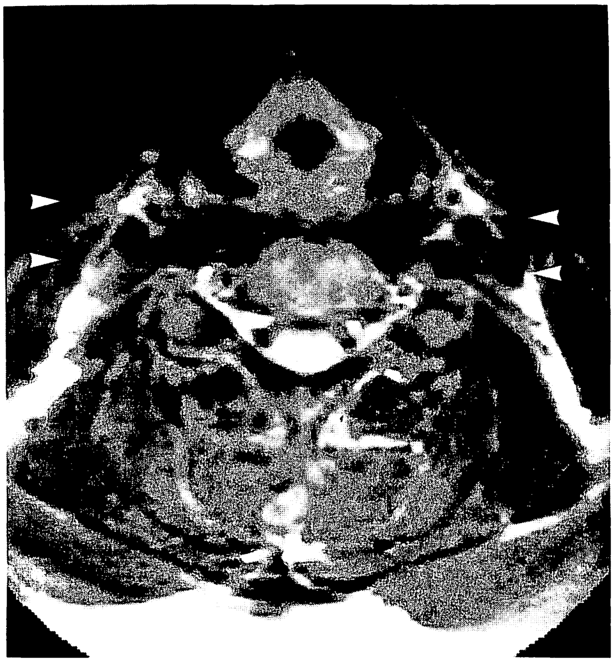


Fig. 1. Motion artifact (rapidly flowing blood). T1-weighted SE image. Artifact due to blood flow in the carotid artery and internal jugular vein. Arrowheads indicate line artifacts caused by blood flow. Due to the location of blood flow, image of vertebral canal contents are not degraded

Rapidly flowing blood causes line artifacts in the direction of the phase-encoding gradient (Fig. 1). It is sometimes necessary to interchange the directions of the phase-encoding and frequency-encoding (read-out) gradients to avoid line artifacts in the regions of interest (ROI). In the cervical regions, the carotid and vertebral arteries and the internal jugular veins may produce line artifacts. Fortunately, the spinal cord itself is usually out of range, due to the anatomical relations of these structures.

2. Metallic artifacts: Metallic artifacts are of two types: large metal substances such as dental fillings, surgical implants such as surgical clips (hemostatic clips and aneurysmal clips), surgical wires and orthopedic implants[9] (Fig. 2). Other metallic artifacts comprise the minute metal particles produced by short-term contact between a diamond drill and untempered operating instruments[4] (Fig. 3). A large metallic artifact can be seen as a local distortion of the image due to ferromagnetic material, which significantly distorts the static magnetic field, or as focal loss of signal due to non-ferromagnetic metal, which is caused by the presence of significant eddy currents induced in the object by the RF field[6]. Back-projection reconstruction accentuates these large metallic artifacts more than does two-dimensional Fourier transformation[9]. To reduce the small metallic artifacts, contact between operating instruments and diamond drill should be avoided as much as possible; irrigation of the operative field with saline may also reduce these artifacts.

3. Chemical shift artifacts: Chemical shift misregistration effect (chemical shift artifact) is seen usually at the junction of perirenal fat and renal parenchyma[12] and at the optic nerve in the orbit[1]. This shift is due to the different resonating frequencies of the protons in the fatty and non-fatty tissues. This chemical shift misregistration effect occurs not in the phase-encoding direction, but in the frequency-encoding (read-out) direction[12], the shift being proportional to the main magnet strength and inversely proportional to the gradient field strength. It is often seen at the junction of spinal epidural fat and thecal sac (Fig. 4). Epidural fat is usually seen around the thecal sac, mainly at the dorsal and lateral aspects of the sac, from the level of the low cervical region down to the lumbar region. The difference in the resonating frequencies of the fatty and

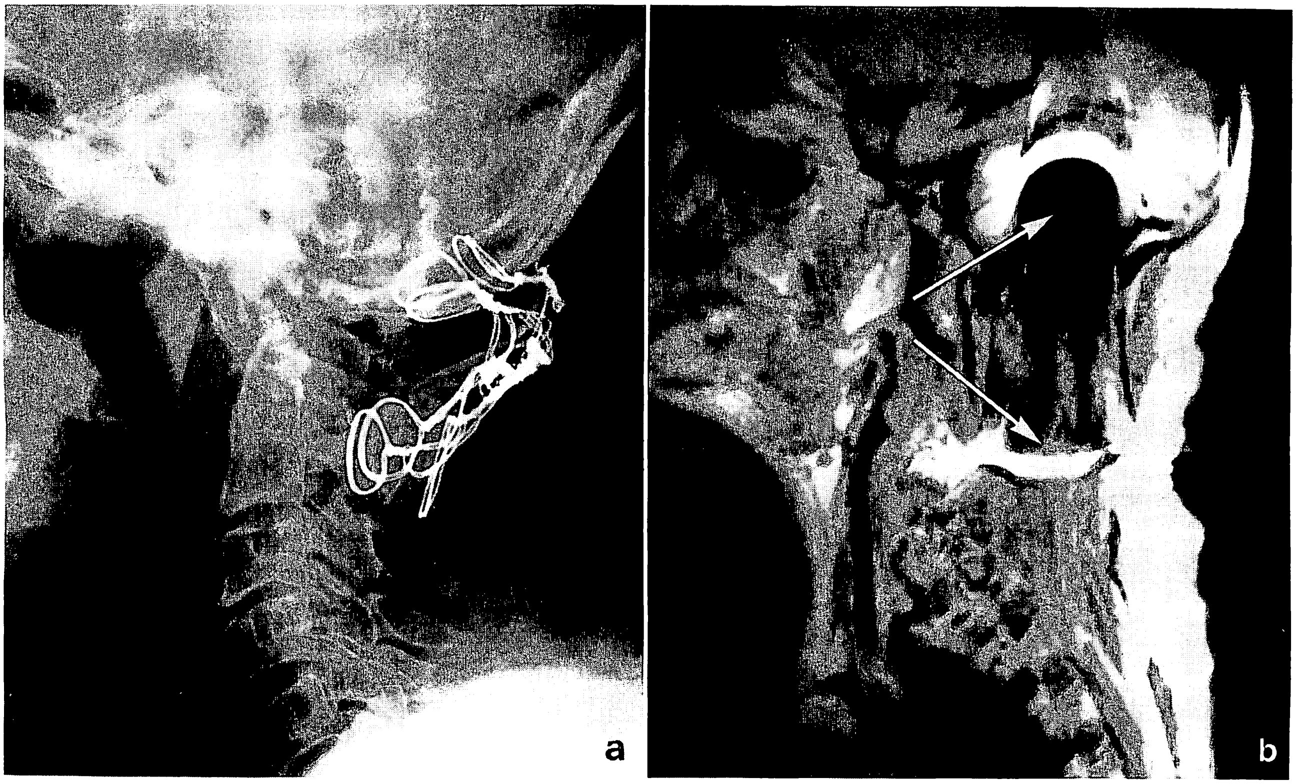


Fig. 2. Metallic artifact (large metal object). A 65-year-old male with atlanto-axial dislocation. Lamina of the axis was removed and iliac bone grafted for posterior fusion with surgical wires. a) A lateral cervical film. The grafted bone and surgical wires are noted. b) T 1-weighted SE image. Local image is markedly distorted by surgical wires (arrows)

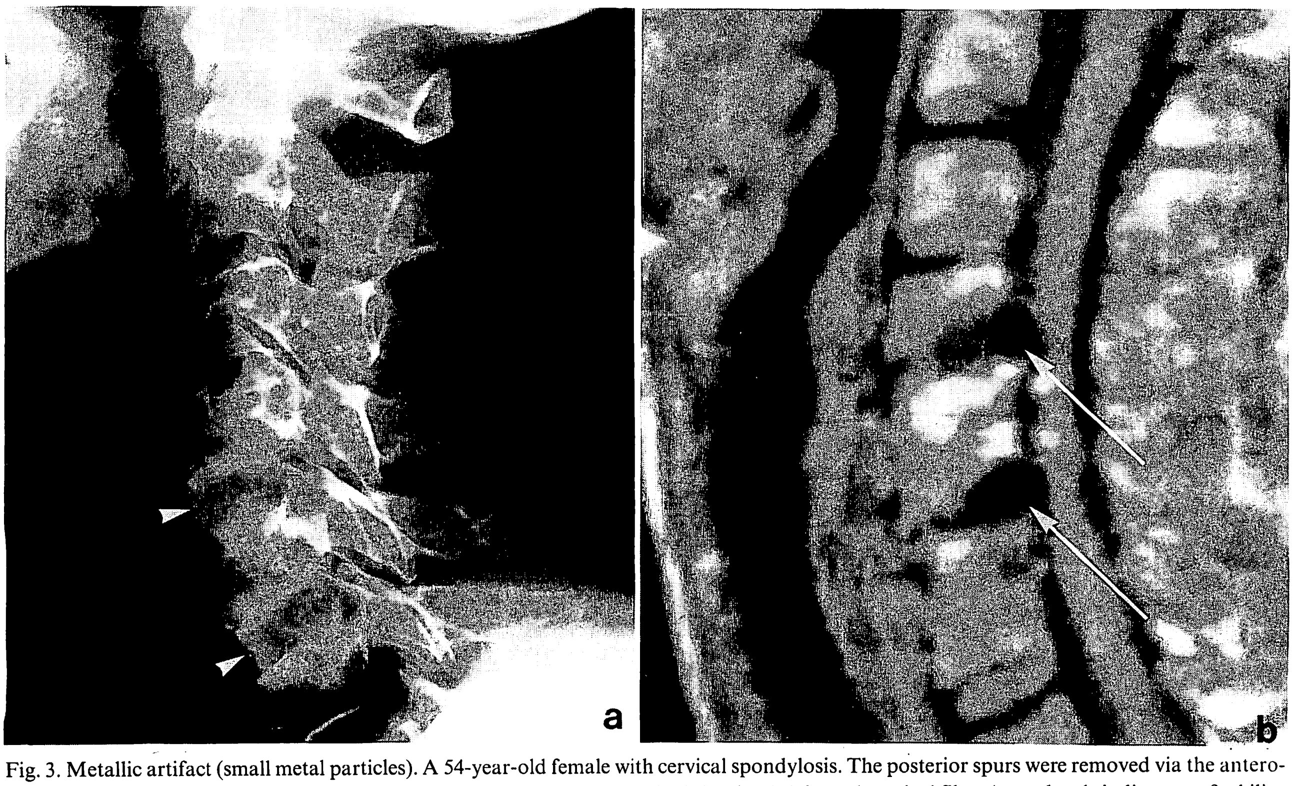
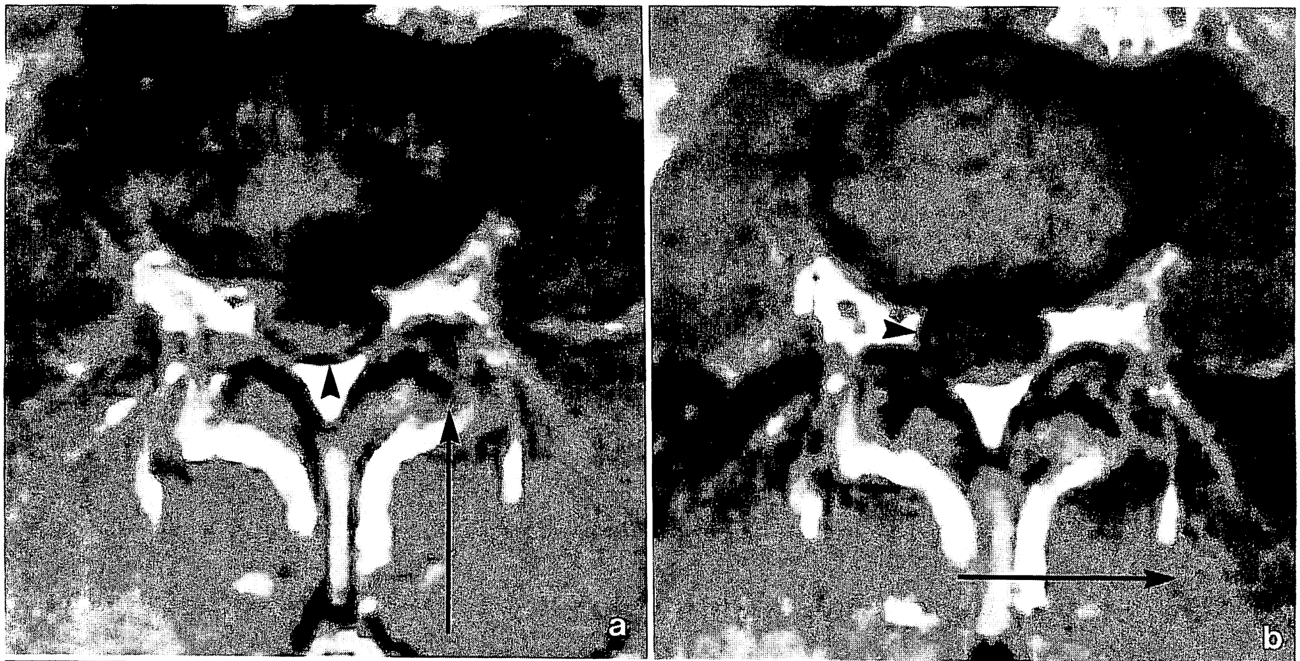


Fig. 3. Metallic artifact (small metal particles). A 54-year-old female with cervical spondylosis. The posterior spurs were removed via the antero-lateral approach using a diamond drill, with iliac bone grafts at C 4/5 and 5/6 levels. a) A lateral cervical film. Arrowheads indicate grafted iliac bones. b) T 1-weighted SE image. Local image (arrows) is obscured by small metal particles, remnants of operative procedures



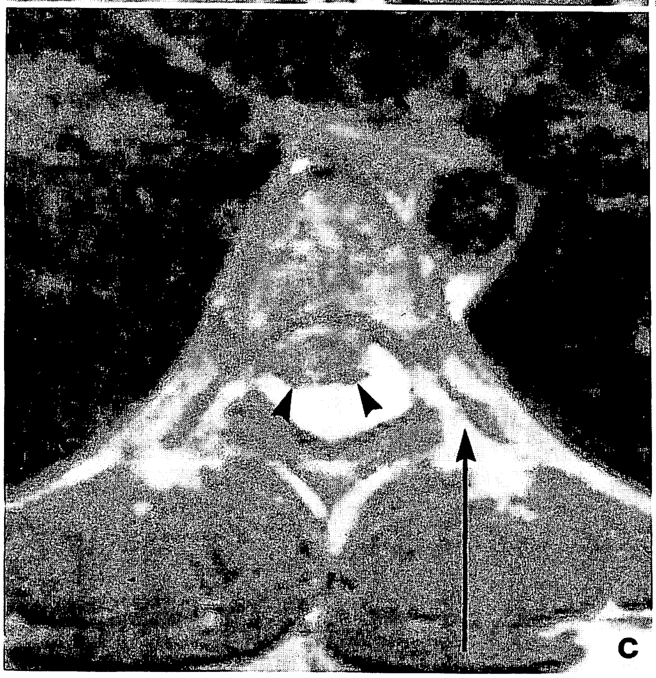


Fig. 4. Chemical shift artifact. T 1-weighted SE images. Arrows indicate direction of frequency-encoding (read-out) gradient. a) and b) Normal lumbar spine. Arrowheads indicate low intensity meniscuses attributable to chemical shifts of epidural fats. c) A 16-year-old male with lipoma. Surgery revealed that the lipoma was intradural and extramedullary and firmly attached to the spinal cord. Arrowheads indicate the chemical shift artifacts, which resemble a shadow of the dura mater

non-fatty tissues is about 3.0–3.5 parts per million (ppm). At 0.5 tesla, (21 MHz of the Larmor frequency), the separation of the resonant frequencies is about 63–73.5 Hz. In our MR system, pixel size is about 1.2 × 1.2 mm and pixel band width is about 50 Hz. This means that a "fat" image shifts about 1.3–1.5 pixels with respect to a "water" image, in the direction of the lower frequency-encoding gradient. The pixel misregistration of the epidural fat produces a low intensity meniscus (band) around the thecal sac in the direction of the lower frequency-encoding gradient. Lipoma

Fig. 5. Center dot artifact. T 1-weighted SE image of normal cervical spine. Arrowhead indicates center dot artifact, which could be a suspected pathological process if this image alone were available.

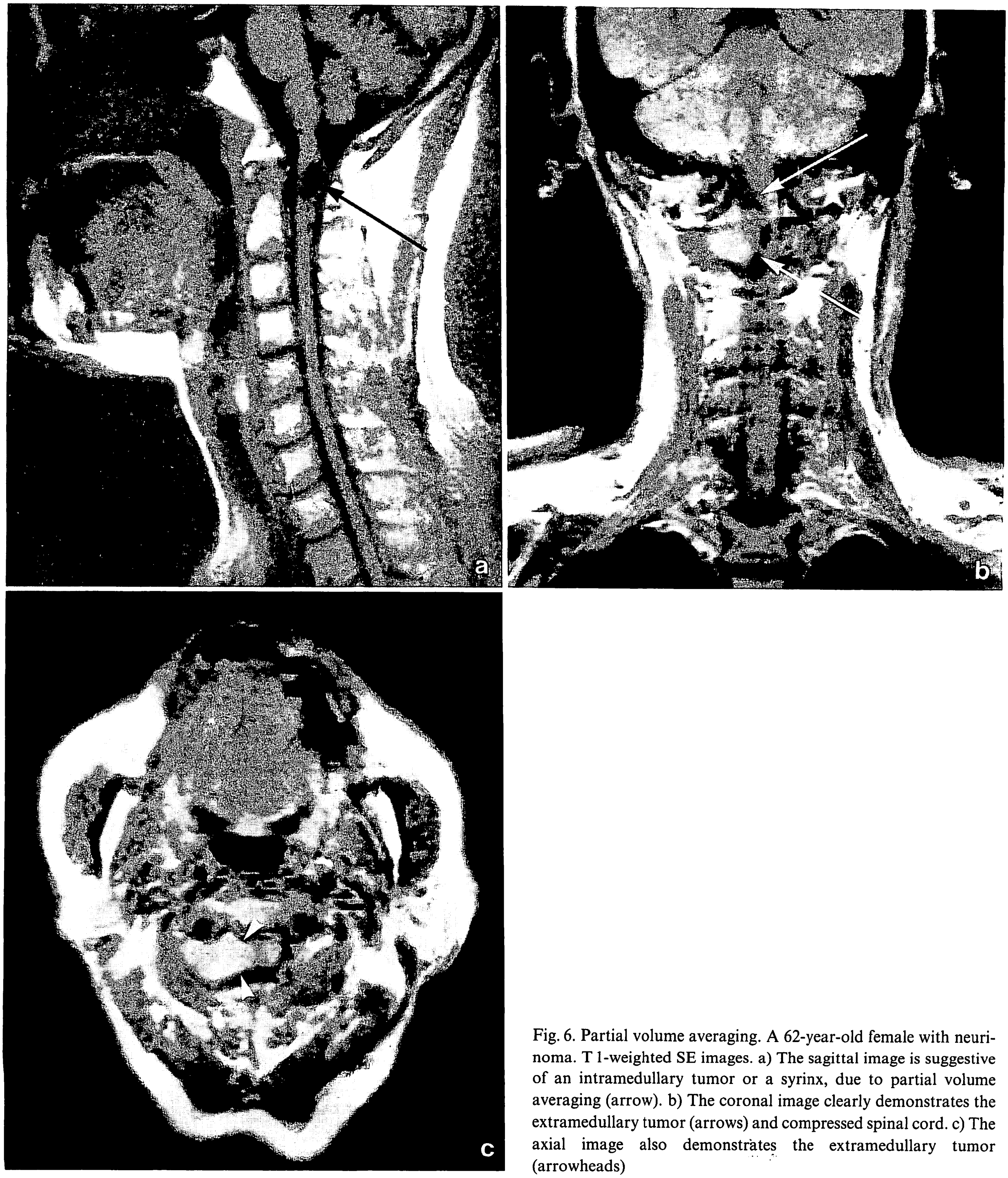


Fig. 6. Partial volume averaging. A 62-year-old female with neurinoma. T 1-weighted SE images. a) The sagittal image is suggestive of an intramedullary tumor or a syrinx, due to partial volume averaging (arrow). b) The coronal image clearly demonstrates the extramedullary tumor (arrows) and compressed spinal cord. c) The axial image also demonstrates the extramedullary tumor (arrowheads)

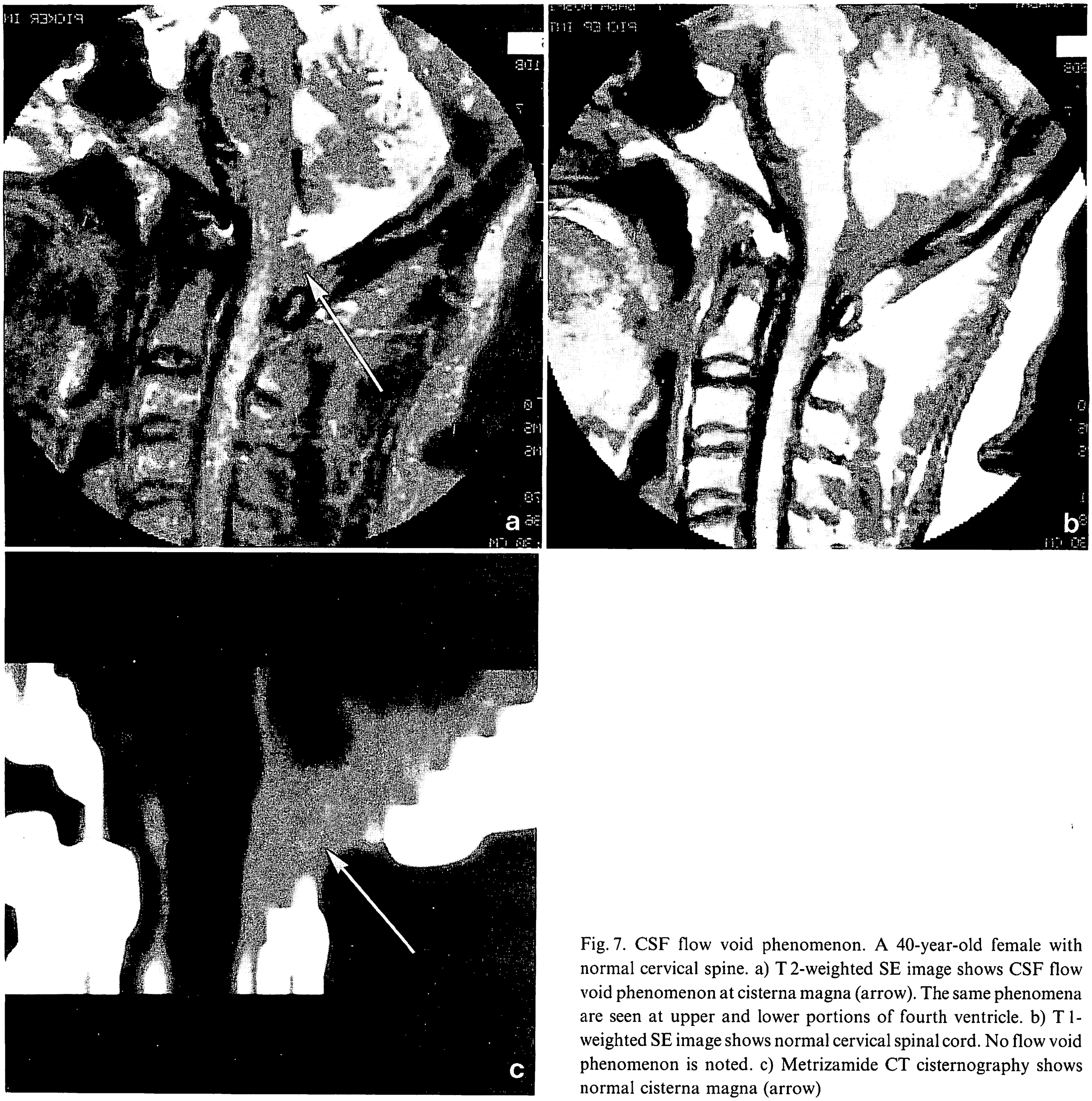


Fig. 7. CSF flow void phenomenon. A 40-year-old female with normal cervical spine. a) T 2-weighted SE image shows CSF flow void phenomenon at cisterna magna (arrow). The same phenomena are seen at upper and lower portions of fourth ventricle. b) T 1-weighted SE image shows normal cervical spinal cord. No flow void phenomenon is noted. c) Metrizamide CT cisternography shows normal cisterna magna (arrow)

yields a "fat" image and produces a chemical shift artifact like that of epidural fat. To identify the chemical shift artifact, it is useful to interchange the phase-encoding and frequency-encoding gradients or to change the polarity of the frequency-encoding gradient, this artifact always occurring in the direction of the lower frequency-encoding gradient.

A-b) Artifacts Related to the MR System

Artifacts related to the MR system itself are associated either with software or hardware.

1. Artifacts related to software. The center dot artifacts often encountered in MR images (Fig. 5), are products of the image reconstructive procedures. Both two-dimensional Fourier transformation and back-projection reconstruction produce these center artifacts. To avoid them, ROI should be placed slightly off-center of the field of view. If this center dot artifact is on the ROI, the patient must be moved a few centimeters off-center of the field of view.

2. Artifacts related to hardware. Image distortion and degraded image quality can be result from direct current (dc) field inhomogenities and gradient field

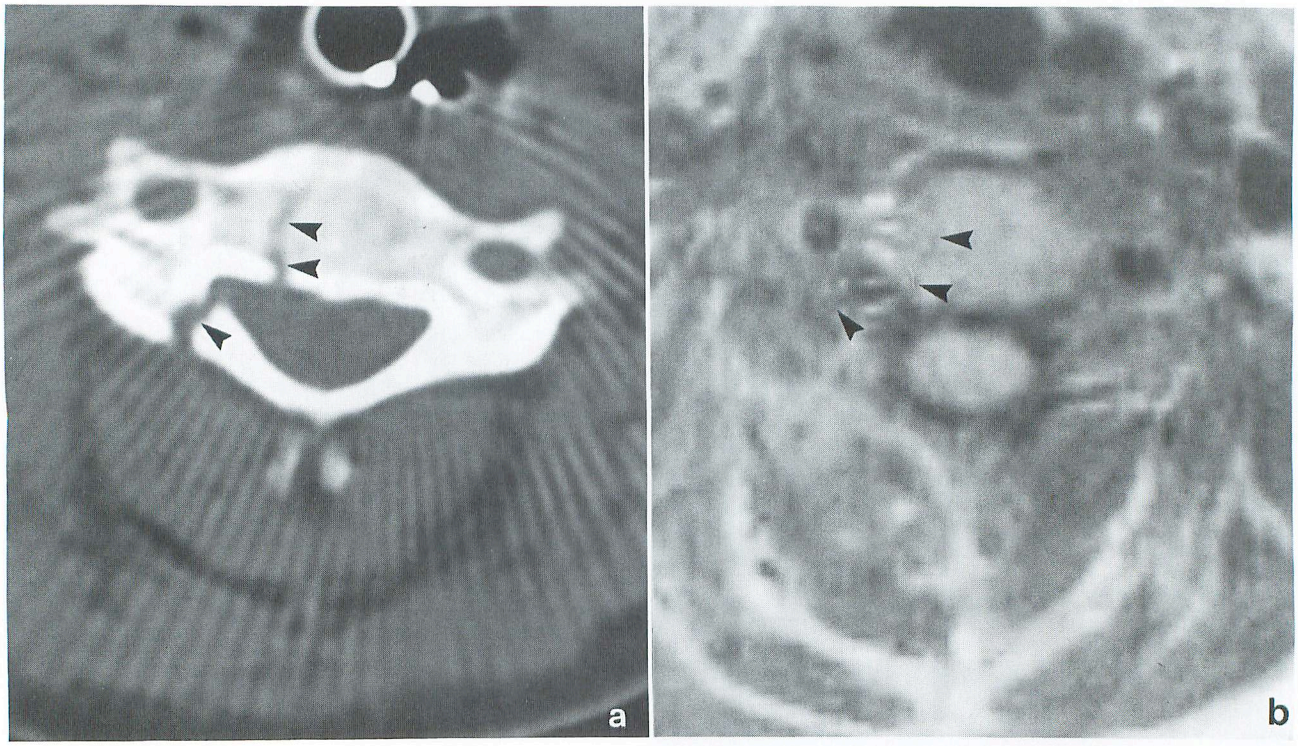


Fig. 8. A 26-year-old male with multiple cervical vertebral fractures. a) CT scan demonstrates fractures of C 4 body and lamina (arrowheads). b) T 1-weighted SE image poorly demonstrates the fractures (arrowheads) due to the scarcity of resonating protons in the cortical bones. It is almost impossible to diagnose the bony fractures with this MR image

nonlinearities, which are related either to the main magnet, gradient coils or shimming coils. Given the present technology, slight changes in the strength of the static magnetic field, both spacially and temporally, are unavoidable. A superconducting magnet produces a more homogeneous and stable static magnetic field than do resistive or permanent magnets.

B. Pitfalls not Related to Artifacts

1. Partial volume averaging. Partial volume averaging is a well-known phenomenon in X-ray CT scan. As in X-ray CT scan, MR exhibits the same phenomenon whether two-dimensional Fourier transformation or back-projection reconstruction are used for image reconstruction. Only when three-dimensional Fourier transformation is used for the volume scan is there no partial volume averaging phenomenon. In evaluating spinal disc diseases, the proper axial planes must be chosen for the involved disc using scout views. It is often the case that sagittal images alone cannot disclose the pathological lesions, due to partial volume averaging; multiplanar imaging is then necessary. Coronal images are sometimes necessary to demonstrate spinal cord tumors and to identify them as epidural, intradural-extramedullary or intramedullary (Fig. 6). Paraxial images are reportedly useful in demonstrating the spinal pathological process. Paraxial slices give detailed anatomical information not available from orthogonal plane images due to diminished partial volume averaging[2].

2. CSF flow void phenomenon. The cerebrospinal fluid (CSF) flow void phenomenon, the signal void of pulsatile to-and-fro CSF flows, is more often seen on T 2-weighted SE images than on T 1-weighted SE images (Fig. 7). It is frequently seen in the aqueduct of Sylvius, in the caudal fourth ventricle and in the third ventricle[11]. In spinal MR imaging, such phenomena must be kept in mind when evaluating low signal intensity areas, especially on T 2-weighted SE images, T 1-weighted SE images as well as other planar images being necessary for accurate interpretation. The CSF flow void phenomenon is not fully understood at present, but though it is often confusing, it can reveal flow information non-invasively, without the use of contrast media.

3. Lesions with few resonating protons. MR imaging is inferior to X-ray CT scan in demonstrating of bony changes such as bone fractures (Fig. 8) and bony neoplasms, due to the scarcity of resonating protons in the cortical bones. Vertebral bone fractures are difficult

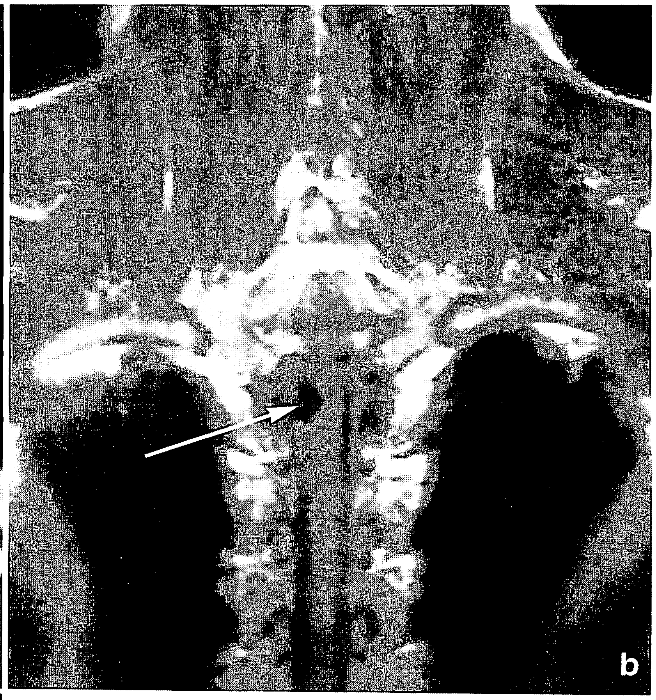


Fig. 9. A 52-year-old male with ossification of the yellow ligaments (OYL) at Th2 level. a) CT scan reveals the large OYL (arrowheads). b) and c) Coronal and axial T1-weighted SE images reveal a low signal intensity mass shadow (arrow or arrowhead), which resembles an extramedullary tumor

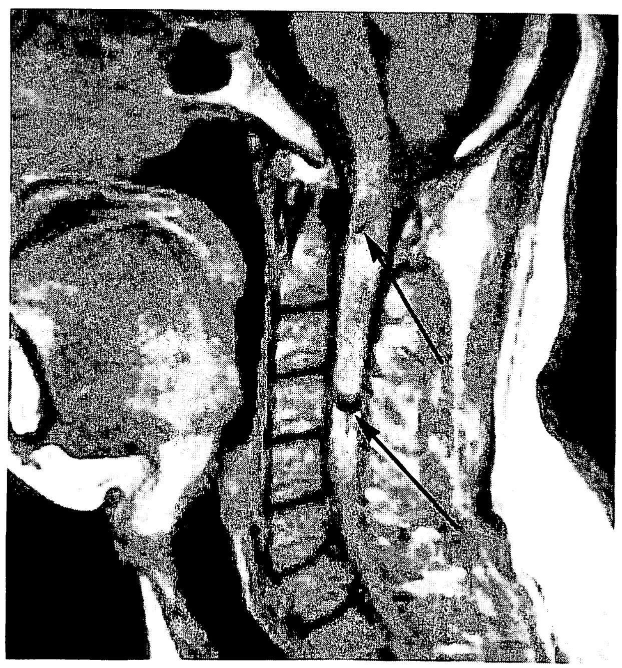


Fig. 10. A 44-year-old male with a cervical intramedullary ependymoma. T1-weighted SE image. Surgery revealed an old hematoma at the upper and lower poles of the tumor. Arrows indicate old hematomas in the intramedullary tumor; they must be differentiated from calcification and syrinx

to demonstrate using MR images. It is necessary to use X-ray CT scan to show bony changes, whereas compression of the spinal cord by disc tissues, osteophites and other pathological lesions are clearly demonstrated by MR. Ossification of the posterior longitudinal and yellow ligaments (Fig. 9), which show low signal intensities on both T1- and T2-weighted SE images, are less clearly demonstrated by MR than by X-ray CT scan.

4. Lesions showing similar signal intensities. It is sometimes confusing when low signal intensity lesions are noted. It may be calcification (Fig. 9), cortical bone, rapidly flowing blood, CSF to-and-fro flows (Fig. 7 a) or old hematoma (hemosiderin) (Fig. 10). These lesions show low signal intensity both on T 1- and T 2-weighted SE images. The syrinx usually shows to low intensity on T 1-weighted SE images and to high intensity on T 2-weighted SE images. However, we have experience of cases whose syrinxes showed low signal intensities both on T 1- and T 2-weighted SE images, findings which can be explained by the CSF flow void phenomenon. X-ray CT scan can differentiate calcification and cortical bone from other lesions; anatomical considerations will also help in such differentiation.

There being no known hazards in MR imaging, it is becoming increasingly popular as a modality for diagnosing spinal cord lesions. Knowledges of the above-detailed pitfalls will help avoid erroneous interpretation of pathological spinal cord lesions in MR imaging.

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