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Original Article

Computed Tomography and Magnetic Resonance Imaging in the Differentiation of Osteoporotic Fractures From Neoplastic Metastatic Fractures

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Abstract

Determining whether a low-intensity vertebral fracture in an older person, particularly one with a history of cancer, is due to osteoporosis (OP) or is the result of a metastasis, is a not infrequent clinical problem that has important prognostic and therapeutic implications. The 2 types of fracture are usually indistinguishable on plain radiographs and require higher order imaging for diagnosis. Magnetic resonance imaging is the modality of choice because of its unique ability to depict the bone marrow, which becomes transiently edematous in an acute OP fracture. Preservation of at least part of the normal marrow signal, the visualization of a fracture line parallel to the end plates, the presence of an intravertebral cleft, lack of pedicle involvement, and no extra-osseous mass all favor a benign OP fracture. Absence of the preceding signs, particularly if there is complete replacement of the normal bone marrow and a convex posterior contour of the vertebral body, favors a fracture of malignant origin. Non-routine magnetic resonance sequences using diffusion-weighted imaging and/or chemical shift imaging may be helpful in difficult cases.

Key Words: Vertebral fractures; Osteoporotic; Metastatic; Magnetic Resonance Imaging; Computed Tomography.

Introduction

Computed tomography (CT) and magnetic resonance imaging (MRI) play essential roles in the diagnosis and management of many conditions that affect the vertebral column. A spine weakened by osteoporosis (OP) is susceptible to not just fragility fractures resulting from low-intensity trauma, but also the broader range of conditions that can afflict a non-osteoporotic adult spine. In this article, we focus on the use of CT and magnetic resonance (MR) in the differentiation of fractures due to OP from those due to metastatic disease.

CT and MR

CT uses ionizing radiation to generate images that result from the differential absorption of X-rays by the tissues being radiated, a concept that is familiar to the clinical bone densitometrist. The information is acquired and displayed in axial (cross sectional) planes, but modern scanners incorporate software programs that permit multiplanar reformation to produce sagittal and coronal views, as well as three-dimensional reconstructions. CT provides better visualization of the cortical bone of the spine than does MRI, and CT images can be acquired rapidly, making it an ideal modality for the evaluation of acute high-intensity vertebral trauma. CT is also used in the evaluation of, among other conditions, degenerative disc disease and infectious processes *(1)*.

MR image reconstruction is distinctly different from, and more complex than, other imaging modalities. MR images, which are a display of the radio-frequency signals emitted by tissues that have been magnetized in the strong magnetic field of the scanner, do not require ionizing radiation for their generation *(2)*. MR provides better contrast differentiation of the soft tissues than CT, its images can be acquired directly in the sagittal and coronal planes, and it is the only clinical imaging modality that enables depiction of the bone marrow with high spatial resolution *(3)*. MRI also demonstrates

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exquisitely the epidural and paravertebral extension of osseous lesions, as well as the degree of spinal cord compression. These properties, especially visualization of the bone marrow, render MR the indisputable modality of choice for determining whether a fracture is of benign or malignant origin and, parenthetically, identifying the edema accompanying acute OP fractures. However, for assessment of many other spinal disorders, CT and MRI are best regarded as complementary modalities. Patients with MR-incompatible implanted metallic devices cannot undergo MR imaging, and a small percentage of individuals require moderate sedation for the scan because of claustrophobia *(4)*.

Pathophysiology

Fragility fractures due to OP may share clinical and imaging features with those resulting from neoplastic metastatic disease. The latter are often called ''pathologic fractures,'' although osteoporotic fractures are also by definition pathologic, in that they occur in bone weakened by disease *(5)*. Both entities tend to occur in older adults; have a predilection for the thoracic and lumbar spine; may coexist; can result from normal physiological stress *(6)*; and may present with acute, painful vertebral deformities that are indistinguishable from one another on standard radiographs. In such instances, higher-order sectional imaging with MRI is often required for diagnosis so as to enable prognostic and therapeutic decision-making.

The reported burden of vertebral metastases is dependent on the intensity of our diagnostic scrutiny. It has been estimated that about 10% of patients with cancer will develop a symptomatic spinal metastasis *(7)*, whereas autopsy studies may demonstrate macroscopic vertebral body metastases in approximately 30% of patients dying from cancer *(8)*. Although almost any malignancy can metastasize to the spine, the most common primary solid organ sites are lung, breast, and prostate, and the common hematopoietic lesions are myeloma and lymphoma *(9)*. Prostate cancer tends to produce osteoblastic metastases that are not usually confused with OP, but other malignancies may produce osteolytic lesions leading to vertebral collapse that can look identical to an OP fracture. As a confounder, some cancer treatment regimens, such as aromatase inhibitor therapy for breast cancer and androgen deprivation therapy for prostate cancer, may accelerate age-related bone loss and lead to secondary OP fractures *(10)*. For clinical purposes, it is assumed that fractures above the level of T4 are not due to OP *(11)*.

Many investigators have strived to refine the imaging characteristics that enable the differentiation of OP from metastatic fractures *(12–16)*. The broad basis for their distinction rests on some general pathological observations *(17)*, with the caveat that these are not always pathognomonic.

(1) Older individuals typically have spinal bone marrow that is dominated by yellow marrow, which is hematopoietically inactive and largely composed of fat *(18)*. Metastases replace the marrow fat of the vertebral body with tumor cells and tend to impart a convex posterior border to the dorsal aspect of the body. By the time that the vertebral body has been weakened sufficiently to collapse, the tumor has often spread dorsally into the pedicles and neural arch. In addition, once the vertebra has fractured, extra-osseous tumor is often found anterolaterally in the paravertebral soft tissues and posteriorly in the epidural space.
(2) In an acute OP fracture, the marrow cavity is filled with blood and fluid, which are gradually replaced by granulation and fibroblastic tissue as the fracture heals. This reparative tissue is in turn reabsorbed over time, restoring the normal fatty marrow. A well-defined fracture line and/or a vacuum cleft that are parallel to the vertebral end plate may be found within the vertebral body, the latter representing osseous failure at the junction between the subchondral bone of the end plate and that of the more central vertebral body, so-called Kummel's disease *(19,20)*. If the posterior aspect of the body is fractured, there is a retropulsed fragment with sharp or angular (non-convex) margins. Extra-osseous reactive changes leading to paravertebral soft-tissue masses are minimal or absent.

MR Protocol/Sequences

The standard MR protocol to assess vertebral fractures should include the following: (1) a fast or turbo spin echo sagittal T1-weighted sequence, (2) a sagittal T2-weighted sequence with fat saturation or short-tau inversion recovery to cause fat suppression, and (3) an axial T2-weighted sequence. The T1-weighted sagittal sequence is useful to assess the morphology of the fracture and the cellular content of the marrow fat *(21)*. The T2-weighted fat-suppressed sagittal sequence increases the conspicuity of bone marrow lesions *(22)*. The T2-weighted axial image allows assessment of the vertebral and paravertebral soft tissues.

Intravenous paramagnetic contrast medium is generally not helpful in the differentiation of OP from neoplastic vertebral fractures because contrast enhancement occurs in the acute healing phase of a benign fracture and in a fracture of malignant origin. It may be helpful in specific situations, such as the identification of lesions that have spread to the epidural space and are causing cord compression *(3)*. The use of dynamic contrast-enhanced perfusion MRI, which monitors tissue enhancement and wash out after the intravenous injection of a bolus of contrast medium has been studied in the context of benign compared with malignant spinal fractures. Although differences were found between the time-intensity curves in patients with the 2 types of fracture, the sensitivity for the detection of an acute benign fracture was low *(23)*.

In general, the morphological information provided by the standard MR sequences is highly predictive of whether a fracture is of benign or malignant origin, but it is not absolute, and the use of additional of non-routine MR techniques