Benign or Pathological? Imaging of Spontaneous Vertebral Fractures

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Introduction

Spontaneous vertebral compression fractures are extremely common, particularly in elderly patients. Most result from osteoporosis and occur after minimal or even unrecognized trauma. However, a vertebral fracture may also be the manifestation of malignancy, particularly metastatic disease or multiple myeloma. Less commonly, infection or another underlying bone disorder may weaken the vertebra and produce a pathological fracture.

The distinction between a benign osteoporotic fracture and a malignant pathological fracture is therefore one of the most important diagnostic problems in spinal imaging. In many patients, radiographs, CT and MRI provide a straightforward answer. In others, however, the distinction can be remarkably difficult because acute benign fractures produce marrow edema, enhancement and even paravertebral soft-tissue changes that may simulate malignancy. Conversely, malignant fractures may occasionally retain areas of apparently normal marrow.

The diagnosis should consequently never rely on a single sign. The radiologist should integrate vertebral morphology, bone marrow pattern, cortical integrity, posterior-element involvement, soft-tissue abnormalities and the appearance of the remainder of the skeleton.

First question: is the fracture recent?

Before determining its cause, the radiologist should establish whether the fracture is acute/subacute or chronic. Healed osteoporotic fractures usually demonstrate restoration of fatty marrow signal and disappearance of edema on MRI. Recent benign fractures typically demonstrate bone marrow edema, with decreased signal on T1-weighted images and increased signal on fluid-sensitive fat-suppressed sequences. This distinction is important because the major diagnostic difficulties occur with recent fractures. An acute osteoporotic fracture can replace much of the normal fatty marrow with edema and therefore resemble tumor infiltration. Conversely, persistent or progressive marrow abnormalities beyond the expected healing period should raise concern for an alternative diagnosis.

Comparison with previous examinations is consequently one of the simplest and most powerful diagnostic tools.

Preserved normal marrow is reassuring

One of the most useful MRI features of a benign osteoporotic fracture is preservation of areas of normal fatty marrow within the compressed vertebral body. The fracture-associated edema may have a band-like or geographic distribution, frequently adjacent to the fractured endplate, while part of the vertebral body retains normal high T1 signal.

Malignant infiltration more often produces diffuse replacement of normal marrow, resulting in homogeneous or extensive low T1 signal. However, this distinction is not absolute. Severe acute benign fractures can produce extensive edema involving nearly the entire vertebral body, while some malignant lesions remain focal. The important question is therefore not simply whether T1 signal is low, but does the marrow abnormality resemble edema surrounding a mechanical fracture, or does it resemble replacement of marrow by tissue?

Look for the fracture line

A visible fracture line strongly supports a mechanical process. On MRI, a benign fracture may demonstrate a linear low-signal band, frequently parallel to an endplate. This corresponds to trabecular impaction or the fracture itself.

CT is particularly useful for demonstrating cortical disruption, trabecular impaction and fracture lines. The relationship between the fracture and the endplate can be especially informative. Osteoporotic compression fractures frequently originate from endplate failure and produce a relatively organized pattern of vertebral collapse. By contrast, malignant fractures may produce more irregular destruction because tumor weakens the vertebra independently of normal mechanical stress pathways.

The fluid and vacuum signs

Intravertebral clefts are important clues to benignity. A vacuum cleft within a collapsed vertebral body, best demonstrated on CT or radiographs, strongly favors a benign osteoporotic fracture and may reflect osteonecrosis and abnormal mobility of the fractured vertebral body. On MRI, the cleft may contain vacuum with signal void and/or fluid and appear hyperintense on T2-weighted or fluid-sensitive images—the so-called fluid sign. These findings are particularly associated with delayed post-traumatic vertebral collapse or Kümmell-type changes. Fluid sign is by far less specific for a benign fracture than the vacuum sign. Although not absolutely specific, an intravertebral vacuum phenomenon in the appropriate morphological context is strongly supportive of a benign mechanical fracture.

Posterior vertebral contour: convex or concave?

The posterior wall provides another useful clue. Malignant infiltration can expand the vertebral body and produce a convex posterior vertebral border extending toward the spinal canal. Benign osteoporotic fractures more commonly produce retropulsion of a discrete bony fragment while maintaining an otherwise non-expansile vertebral contour.

This distinction reflects different mechanisms. Osteoporotic fractures result from mechanical collapse and fragmentation and , in the absence of a solid tissue like a metastasis, there is no or limited vertebral wall bulging. In malignant fracture, the vertebral body contains a solid tissue that unlike red marrow can not be compressed , with subsequent vertebral wall buldging.

Posterior elements: useful but not absolute

Abnormal marrow signal within the pedicles and posterior elements has traditionally been considered suspicious for malignancy. This remains a useful observation, particularly when posterior-element involvement is extensive or associated with a soft-tissue mass. However, acute benign fractures can produce reactive edema extending into the pedicles. Therefore: pedicle edema is not synonymous with tumor.

The morphology of the abnormality matters. Diffuse marrow replacement, cortical destruction or a focal mass is considerably more concerning than isolated edema associated with an otherwise typical osteoporotic fracture.

Paravertebral and epidural soft tissues

A focal or mass-like epidural or paravertebral soft-tissue component strongly raises suspicion for malignancy. Tumor may extend through the vertebral cortex into the epidural space or paravertebral tissues, producing a relatively well-defined soft-tissue mass.

Benign fractures may also produce paravertebral abnormalities, particularly hematoma or edema, but these tend to be less mass-like and more closely related to the fracture. In benign fracture, there is no focal soft tissue bulging.

Cortical destruction versus cortical fracture

CT also plays an essential role as first line imaging technique or complementary to MRI. In a benign fracture, the cortex is fractured but remains recognizable as bone. Cortical fragments, endplate impaction and trabecular compression can often be identified.

Malignant disease more commonly produces cortical destruction rather than simple fracture. This conceptual distinction is useful: benign fractures break bone; aggressive lesions replace and destroy bone.

Of course, a malignant vertebra can subsequently fracture, producing both processes simultaneously. Nevertheless, recognizing permeative destruction, focal lysis or an associated soft-tissue component should immediately raise concern.

Multiple fractures do not necessarily mean metastases

Multiplicity can be misleading. Multiple vertebral compression fractures are common in osteoporosis and therefore should not automatically suggest metastatic disease. The distribution and morphology of the fractures are more important. Multiple vertebrae demonstrating similar compression deformities, preserved marrow between fracture zones and typical osteoporotic morphology strongly favor benign disease. Conversely, multiple focal marrow-replacing lesions involving fractured and non-fractured vertebrae strongly suggest malignant disease. Always inspect the entire imaged skeleton rather than concentrating exclusively on the collapsed vertebra. A second lesion without a fracture may provide the clue that establishes the diagnosis.

Multiple myeloma: the great mimic

Multiple myeloma deserves particular attention because it can closely mimic osteoporosis. Patients may present with apparently spontaneous vertebral compression fractures without an obvious focal mass. Bone density may appear reduced, and vertebral collapse may initially seem osteoporotic. MRI may reveal diffuse, focal or heterogeneous marrow infiltration, but marrow abnormalities can occasionally be subtle. The radiologist should therefore maintain a low threshold for considering myeloma when fractures are numerous, disproportionate to apparent osteoporosis, occur in unusual circumstances or are associated with other suspicious skeletal findings. Clinical and laboratory correlation is essential.

Diffusion-weighted imaging: useful but not decisive

Diffusion-weighted imaging (DWI) has been investigated extensively for differentiating benign from malignant vertebral fractures. Malignant tissue frequently demonstrates restricted diffusion because of increased cellularity, whereas benign edema may show relatively less restriction. However, substantial overlap exists. Hemorrhage, edema, necrosis and technical

factors can alter diffusion signal. ADC values should therefore not be used as an isolated discriminator. DWI is best regarded as an additional piece of evidence rather than a diagnostic referee. The same principle applies to contrast enhancement. Both acute benign fractures and malignant fractures may enhance substantially.

Do not forget infection

Not every pathological fracture is malignant. Spondylodiscitis can weaken vertebral bodies and produce collapse. Involvement of adjacent vertebral endplates, abnormal disc signal, paravertebral inflammatory changes or abscess formation should suggest infection. However, the disc may initially appear relatively preserved, particularly in certain infections. When morphology does not fit either a typical osteoporotic fracture or malignant infiltration, infection should remain in the differential diagnosis.

Watch out for trauma

The signs used to differenciate benign from malignant vertebral fracture may not apply in post traumatic vertebral fractures in which extensive bone destruction and asymmetrical soft tissue mass can be encountered.

A practical reading strategy

When evaluating a spontaneous vertebral fracture, a systematic approach is helpful.

- First, look at the whole spine. Is this an isolated fracture or part of a generalized process?
- Second, assess the fracture morphology. Look for endplate impaction, fracture lines, cortical fragments and intravertebral clefts.
- Third, analyze the marrow. Is normal fatty marrow partially preserved, or is there diffuse marrow replacement?
- Fourth, inspect the posterior wall and posterior elements. Is there simple mechanical retropulsion or an expansile/destructive process?
- Fifth, search for epidural or paravertebral soft tissue.
- Finally, look elsewhere. Additional marrow lesions, pelvic lesions, lymphadenopathy or a primary tumor may solve the diagnostic problem.

If uncertainty persists, comparison with previous imaging, short-interval follow-up, CT, PET/CT or biopsy may be appropriate depending on the clinical situation.

Conclusion: Combine signs rather than to look for a single sign

No single MRI or CT feature provides perfect differentiation between benign osteoporotic and malignant vertebral fractures. The most convincing benign pattern combines endplate-related collapse, a visible fracture or impaction line, partial preservation of normal marrow, an intravertebral cleft, absence of destructive cortical change and absence of a mass-like epidural or paravertebral component.

Conversely, diffuse marrow replacement, expansile convexity of the posterior vertebral border, destructive cortical changes, convincing posterior-element tumor involvement, an epidural or paravertebral mass and additional non-fractured marrow lesions increase concern for malignancy.

The essential diagnostic principle is therefore not to search for a single "malignant sign." Instead, ask whether the vertebral morphology tells the story of mechanical failure of weakened but otherwise normal bone, or whether it suggests bone that has been replaced and destroyed by disease before it fractured.