Spine metastasis imaging: review of the literature

Imagerie des métastases vertébrales : revue de la littérature

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Abstract Any malignant neoplasm possesses the capacity to metastasize to the musculoskeletal system. Because the spine is the most frequent site of bone metastasis, imaging must be discussed in cases of cancer. Bone marrow is the main interest in imaging the metastatic process by magnetic resonance, while X-rays allow the study of cortical involvement. This article presents our experience, and a review of the literature, in an overview of the different imaging techniques—X-rays and magnetic resonance—with emphasis on the many difficulties that can be encountered in the diagnosis and monitoring of spinal metastases, allowing a management strategy for diagnosis and follow-up.

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MOTS CLÉS
Rachis ;
Métastases ;
Tassement vertébral ;
Imagerie rachidienne ;
IRM

Résumé Toute pathologie néoplasique est susceptible de donner des métastases musculosquelettiques. Parce que le rachis constitue le site métastatique le plus fréquent, son imagerie doit être envisagée en cas de cancer connu. L'imagerie par résonance magnétique est particulièrement utile pour explorer la moelle osseuse et le contenu du canal rachidien, alors que le scanner apprécie au mieux l’atteinte corticale. Cet article rapporte notre expérience confrontée à une revue de la littérature, en mettant l’accent sur les difficultés rencontrées dans le diagnostic et la surveillance des métastases rachidiennes.

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**General considerations**

Bone is a common site of metastases for many primary malignant tumors; indeed, it is the third location after liver and lung. Metastases are the most frequent cause of bone tumors, initiating 25% of cases [6,29]. Furthermore, the spine represents the most frequent site of skeletal metastasis. The majority of metastatic lesions in the skeleton are encountered in middle-aged and elderly patients. Carcinomas of the breast, prostate, kidney and thyroid, in order of decreasing frequency, account for 80% of skeletal metastases. Anatomical studies have shown that 84% of bone metastases derive from carcinomas of the breast and prostate, while 50% are from thyroid, 44% are from lung and 37% are from kidney cancers [4,5].

Metastatic cells pass easily through the basal membrane, that is why vertebral bodies are generally affected on their posterior aspect before the posterior arch, rarely involved alone [27]. Spongiform bone is invaded first. Cortical involvement occurs later, leading to fracture, vertebral instability, an extravertebral, growing mass and compression of the spinal cord. In this chapter, the roles of magnetic resonance imaging (MRI), computed tomography (CT) and the still-important plain film for the diagnosis and follow-up of metastases is discussed. The fundamental usefulness of nuclear medicine imaging techniques, such as scintigraphy, single photon emission computed tomography (SPECT) and positron emission tomography (PET) will be described in another chapter.

**Plain films**

The poor sensitivity of roentgenograms in the early detection of osseous destruction cannot be denied, and a careful and thorough analysis of radiographs is essential for detecting lesions. It is generally agreed that a variation of almost 50% of normal bone tissue mass is necessary for detection [13, 17]. Thus, in breast carcinomas, radiographic signs are visible six months later than those seen on scintigraphy [20].

The most frequent features observed in metastases are pure osteolytic lesions. Lodwick [22] has identified three different types. “Geographical” osteolysis refers to focal destruction of bone tissue by tumor. "Moth-eaten" osteolysis refers to the appearance of multiple small holes. Pervious osteolysis, characterized by smaller, millimeter-sized holes, reduces the visibility of bone on film. However, there are other suggestive features to look for:

- Blurred outlines on a vertebral body means cortical involvement. Because of the high specificity of this sign for tumor involvement, it should be sought first;
- Loss of cortical bone in the posterior wall of the vertebral body, as well as its posterior convexity, are also highly specific signs of tumor involvement (Fig. 1). Conversely, concavity with backward angulation is highly specific for osteoporosis.

Vertebral collapse is frequently observed. Common metastatic causes of such collapse include, in order of decreasing frequency, carcinomas of the breast, lung and prostate [14]. More than one vertebral body may collapse sequentially or simultaneously. Collapse of the vertebral body is also seen in osteomalacia, osteoporosis and plasma cell myeloma. Several patterns are indicative of a malignant lesion: one-sided damage; angular or irregular distortion of the vertebral endplates; involvement of the upper thoracic spine; and associated soft-tissue mass or pedicle destruction. A noteworthy finding, useful for differentiation of a malignant tumor from spondylitis, is preservation of vertebral disc height.

Homogeneous or inhomogeneous sclerotic areas detected on one or more vertebral bodies is another indication of possible metastatic disease from prostate and stomach tumors, plasma cell myeloma and lymphoma [29].

**Computed tomography**

By combining X-rays and tomographic rotational slices, CT offers images with a density resolution ten times higher...
than plain films, allowing for a precise study of trabecular bone, and without superposition. With contrast intravenous injection, intra or extracanalar spread of the tumor can be easily studied. Helicoidal scanning with a small rebuilding field, 2- to 3-mm-slice thicknesses with 1.5- to 2-mm pitch, and frontal and sagittal 2-D reconstructions are good parameters for studying images using two filters, one for soft tissue and another for bone.

Sensitivity and specificity of CT are high. In cases of vertebral collapse, porotic or tumor-like patterns have been described and are presented in (Tables 1 and 2) [21].

Usually, a lytic mass will replace normal spongiform bone tissue such as trabeculae; the resultant lesion (which may be very small, with low visibility) can be seen with better delineation on CT than on plain films (Fig. 2). Depending on lesion evolution, some trabeculae may remain visible. Sometimes, necrosis and, more rarely, calcifications can be seen as well as cortical or pedicular destruction, epidural involvement or a paravertebral mass.

To determine tumor origin, one of the main criteria is cortical involvement. Osteolysis of almost always cortical, anterolateral or posterior, and helpful for diagnosis [21]. Cortical involvement may be visible only by notching of the inner surface. In two-thirds of cases, the posterior wall of the vertebral body is also involved. Pedicular involvement is observed in half of the cases, and foraminar involvement from pedicular lesions can be clearly seen on sagittal images.

Following intravenous contrast-media injection, CT can demonstrate soft-tissue masses in two-thirds of cases. A “double-bag” configuration (see further delineation) may also be noted in cases of epidural encroachment.

Being located above the seventh cervical vertebrae and collapse of a single vertebra are highly suggestive of malignancy. Conversely, porotic collapse may be a sign of cortical fracture, with bursting and fragments of different sizes creating a puzzle-like appearance. Backward angulation is another specific sign [21] (Fig. 3), observed in one-third of cases. In addition, spongiform-bone osteolysis may be pre-

<table>
<thead>
<tr>
<th>Table 1 Osteoporotic vertebral body (VB): statistical value of CT findings (21)</th>
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<tbody>
<tr>
<td>CT findings</td>
</tr>
<tr>
<td>Cortical fracture on VB side</td>
</tr>
<tr>
<td>Cortical fracture on posterior aspect</td>
</tr>
<tr>
<td>At least one cortical fracture</td>
</tr>
<tr>
<td>Cortical fragment inside medullary canal</td>
</tr>
<tr>
<td>Fracture inside VB</td>
</tr>
<tr>
<td>Circular fracture</td>
</tr>
<tr>
<td>Vacuum sign</td>
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<tr>
<td>Circular thickness of soft tissues &lt; 8 mm</td>
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<table>
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<tr>
<th>Table 2 Malignant vertebral body (VB) collapse: statistical value of CT findings (21)</th>
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<tr>
<td>CT findings</td>
</tr>
<tr>
<td>VB side cortical destruction</td>
</tr>
<tr>
<td>Posterior VB cortical destruction</td>
</tr>
<tr>
<td>At least one VB cortical destruction</td>
</tr>
<tr>
<td>VB spongiform bone destruction</td>
</tr>
<tr>
<td>At least one pedicle destruction</td>
</tr>
<tr>
<td>Soft tissue mass</td>
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<tr>
<td>Epidural mass</td>
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</table>

Figure 2. CT. Three types of osteolytic process of vertebral bodies replacing normal bone trabeculae and cortical involvement of posterior wall: pervious (a); moth-eaten (b); and geographical (c).

Figure 2 TDM : Trois types de processus lytiques de corps vertébraux remplaçant les trabéculations normales de l’os et une érosion corticale: ostéolyse perméative (a), « mitée » (b) et géographique (c).
sent in 30% of cases. Finally, in 40% of cases of recent collapse (less than two months), there is a slight thickening of the soft tissues surrounding the vertebral body (less than 8 mm).

Sclerotic lesions, rarely observed, show up as a high-density structure (although less than a cortical lesion), and are heterogeneous, with blurred boundaries with spongiform bone as well as a periosteal reaction. Bony trabeculae are no longer visible. Cortical involvement and a paravertebral mass are seldom observed in such cases.

CT is of great value in making therapeutic decisions. Thus, thorough examination of the pedicles may guide the choice between a transpedicular or posterolateral approach for vertebroplasty [8] (Table 3).

Magnetic resonance imaging

Based on the magnetic resonance of protons, the most abundant constituent of water and, thus, the human body, MRI has become an elective procedure for soft-tissue investigations. Changes in bone-marrow are fundamental to the sensitivity of MRI in the detection of sites of skeletal metastases. Identification of such sites using this technique requires the observer to recognize normal age-related marrow changes, particularly in the spine [30]. These changes relate to the predictable and orderly conversion of red (hematopoietic) to yellow (fatty) marrow cells that occurs during growth and development [38]. Over the age of 25 years (adulthood), the red marrow is concentrated predominantly in only a few sites, including spinal vertebrae, with a partial localization in adipocytes that increases with age [29].

The specific abnormalities seen on MRI in relation to spinal (and paraspinal) metastatic foci are dependent, overall, on the particular imaging parameters employed.

On T₁-weighted imaging, normal bone marrow appears hypointense in children, becoming progressively more iso- and hyperintense in elderly people. Signals for intravertebral lesions are of low intensity, and may be extremely low for sclerotic metastases (Fig. 4). Such images can be useful for demonstrating spinal-cord compression. In rare cases, the

<table>
<thead>
<tr>
<th>MRI findings</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VB posterior angle recession into medullary canal</td>
<td>16</td>
<td>100</td>
</tr>
<tr>
<td>VB partly hypointense on SE T₁-weighted imaging</td>
<td>68</td>
<td>93</td>
</tr>
<tr>
<td>Homogeneous signal of VB on post-contrast T₁-weighted imaging</td>
<td>84</td>
<td>82</td>
</tr>
<tr>
<td>Normal signal of VB or linear hypersignal under fracture on T₁-weighted imaging</td>
<td>85</td>
<td>90</td>
</tr>
</tbody>
</table>

Table 3 Osteoporotic vertebral body (VB) collapse: statistical value of MRI findings (10)
presence of, for example, methemoglobinemia or melanocytes (hemorrhagic metastasis of melanoma) that affect $T_1$ imaging may cause the vertebrae to appear hyperintense.

Intravenous gadolinium administration can vastly improve metastatic foci visibility, especially when they are extravertebral. However, the degree of tumor enhancement may be marked, slight or absent (in cases of sclerotic metastases). Furthermore, enhancement may be random, initially peripheral with subsequent central spread, or homogeneous. In cases of highly fatty bone marrow, fat suppression or short tau inversion recovery (STIR) may be necessary.

However, considering the risk of equalization of the signals from both the metastasis and bone marrow on post-contrast sequences, $T_1$-weighted images without gadolinium should be performed initially. Likewise, in cases of fat suppression on $T_1$-weighted images, it will be necessary to administer gadolinium. STIR ($T_2$) sequencing is more sensitive than $T_1$- and $T_2$-weighted images for detecting metastases but, on the other hand, it is less sensitive for identifying extravertebral involvement [9,23].

On $T_2$-weighted imaging, the signal characteristics of intravertebral lesions are variable, although an increase in signal intensity is most usually encountered [29]. In some reports [35], $T_2$-weighted images have been considered better than $T_1$-weighted images for appraising the subarachnoid space in the absence of cord compression.

Because fast or turbo spin-echo sequencing results in high signal intensity of fat, causing metastases to become isointense in adult bone marrow, fat saturation or STIR is generally used to improve lesion visibility (Fig. 5). One exception is the richly hematopoietic bone marrow in children’s spinal vertebrae, where the hyperintensity of abnormal bone marrow becomes evident on spin-echo sequences via the flip-flop sign [31]. On gradient-echo sequences, the normal appearance of the vertebra is hypointense because of the magnetic susceptibility effect due to the bone/marrow interface. However, the appearance of spinal metastases is highly influenced by the choice of imaging parameters (such as echo and repetition times, and flip angle) [27,29], with high signal intensity of metastatic foci, in this case, due to diminution of the magnetic susceptibility effect caused by trabecular bone destruction by tumor. However, susceptibility and metal-related artefacts may induce false images of metastatic involvement in patients with cancer (Fig. 6).

To improve $T_2$-weighted imaging, increased contrast between normal bone marrow and tumor can be obtained by using ultrasmall superparamagnetic iron oxide (USPIO) particles [12,27,34]. Their specificity for reticuloendothelial-system cells induces localized high fields in bone marrow (the so-called “superparamagnetic effect”), speeding up phase displacement of water protons. This shortens normal bone-marrow $T_2$ signal intensity, leading to decreased signal intensities for both yellow and red bone marrow, making bone metastases more apparent as they remain hyperintense.

Daldrup-Link et al. [11] have shown that STIR sequencing is more sensitive than $T_1$- and $T_2$-weighted TSE images for demonstrating bone-marrow signal-intensity changes after iron-oxide infusion. A strong signal decline is observed for normal and hypercellular bone marrow 45–60 min after iron-oxide administration, whereas no, or only minimal, signal decline of neoplastic bone-marrow lesions is observed. In the end, recent studies [37,40] suggest that histograms provided by quantitative apparent-diffusion-coefficient (ADC) mapping may provide valuable information for differentiating benign vertebral fractures and metastatic lesions. Zhou et al. [40] found a mean ADC value of benign lesions 68% higher than that of metastases. On the other hand, qualitative diffusion-weighted imaging, as previously described by Baur et al. [3], has demonstrated that benign compression fractures are hypo- to iso-intense compared with adjacent normal vertebral bodies, and that metastatic compression fractures are hyperintense. However, this offers no advantages over conventional non-enhanced MRI in the detection of vertebral metastases, as shown by Cas-

**Figure 4**  Sclerotic metastases: MRIs, $T_1$-weighted (a) and $T_2$-weighted (b) images show low signal intensity corresponding to hyperdensity on CT scan (c).

**Figure 4**  Métastases sclérotiques. L’aspect IRM sur les images pondérées en T1 (a) et en T2 (b) montre un hyposignal correspondant à l’hyperdensité sur l’image TDM (c).
In addition, lesions with a high water content and low cellularity may demonstrate high signal intensity on T2-weighted imaging and hypointense signal on diffusion-weighted imaging, owing to the T2 shine-through effect.

Both osteolytic and sclerotic lesions may be present in the same patient from the same cancer. Mixed lesions (sclerotic/lytic) are often retrieved because of constant low signal intensity on all sequences for the sclerotic component, and nodular high signal intensity on post-contrast T1-weighted images [27,29] (Fig. 4). The presence of both a pure sclerotic metastasis and mixed lesions creates a striped effect.

Features to help discriminate between vertebral fractures caused by metastasis (or other tumors) and osteoporosis [10] on MRI are presented in (Tables 4 and 5). The usual MRI appearance is low signal intensity on T1-weighted images, hypersignal on T2-weighted images and heterogeneous hypersignal on T1-weighted images with gadolinium (Fig. 7). Thus, MRI allows study of the entire spinal column at the same time when searching for other metastatic foci. It also allows assessment of morphology and signs of collapsed vertebra. In fact, 65% to 88% [29, 39] of malignant collapses are accompanied by images suggesting the presence of metastatic foci on adjacent vertebrae.
Intradural-extramedullary and intramedullary sites may be involved in metastasis, even without primary bone involvement, as shown by Kamholtz and Sze [18].

The great majority of metastases involving the epidural space relate to bone involvement. The pattern is known as the “double-bag” configuration (Laredo et al. [21]), with the same signal as tumor on different sequences (Fig. 8). This particular appearance is due to the high resistance of the common posterior vertebral ligament to bulging as the tumor progresses. Gadolinium administration can enhance visualization of tumor extending into the epidural space. On T1-weighted images, mottling of the fat near the thecal sac is indicative of epidural metastasis (Fig. 8). On post-contrast T1-weighted images, linear streaks of enhancement along the dorsal or ventral surface of the spinal cord may represent sites of pial metastases.

**Table 4** Malignant vertebral body (VB) collapse: statistical value of MRI findings (10)

<table>
<thead>
<tr>
<th>MRI findings</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backward convexity of VB posterior wall</td>
<td>70</td>
<td>94</td>
</tr>
<tr>
<td>Epidural mass</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>Pedicle hyposignal on SE T1-weighted imaging</td>
<td>80</td>
<td>94</td>
</tr>
<tr>
<td>All VB hyposignal on T1-weighted imaging</td>
<td>77</td>
<td>81</td>
</tr>
<tr>
<td>Heterogeneous hyposignal of VB on T2-weighted imaging</td>
<td>85</td>
<td>100</td>
</tr>
<tr>
<td>VB heterogeneous or diffuse hyposignal on post-contrast T1-weighted imaging</td>
<td>77</td>
<td>100</td>
</tr>
</tbody>
</table>

**Table 5** MR Signal intensity of spinal components on different sequences

<table>
<thead>
<tr>
<th>MRI</th>
<th>Fat</th>
<th>Bone</th>
<th>Marrow</th>
<th>CSF</th>
<th>Muscle</th>
<th>Tumor</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2</td>
<td>Hyper</td>
<td>Hypo</td>
<td>Iso</td>
<td>Hyper</td>
<td>Iso</td>
<td>Isohyper</td>
</tr>
<tr>
<td>STIR</td>
<td>Hypo</td>
<td>Hypo</td>
<td>Iso</td>
<td>Hyper</td>
<td>Iso</td>
<td>Hyper</td>
</tr>
<tr>
<td>T2*</td>
<td>Hyper</td>
<td>Hypo</td>
<td>Iso</td>
<td>Hypo</td>
<td>Iso</td>
<td>Isohypo</td>
</tr>
<tr>
<td>T2+Gd</td>
<td>Hyper</td>
<td>Hypo</td>
<td>Iso</td>
<td>Hypo</td>
<td>Iso</td>
<td>Hyper</td>
</tr>
<tr>
<td>T1Gd/FATSAT</td>
<td>Hypo</td>
<td>Hypo</td>
<td>Isohypo</td>
<td>Hypo</td>
<td>Iso</td>
<td>Hyper</td>
</tr>
</tbody>
</table>

Figure 7 Malignant vertebral collapse on STIR-T2 weighted imaging (a) and ST T₁-weighted imaging before (b) and after gadolinium administration (c). Images show heterogeneous high signal intensity of the vertebral body on T₂-weighted imaging, and low signal intensity on T₁-weighted imaging that dramatically increased on T₁-weighted imaging after gadolinium administration, backward convexity of the posterior wall of the vertebral body, epidural extension and no evidence of disc damage.

Figure 8 Intracanalar extension: axial slices with T₁-weighted imaging are mandatory for clear delineation of epidural involvement, with a typical "double-bag" configuration (a) (arrows), and arachnoid and pia mater invasion (b,c) (arrows).
In intradural-extradural metastases, MRI provides inconsistent diagnostic results due to the lack of contrast between tumor and the surrounding cerebrospinal fluid, the absence of surrounding edema and motion artefacts because of cerebrospinal-fluid pulsations [1,24,29,39].

On the basis of previous considerations, the following pattern of investigations is proposed:

- Sagittal spin-echo T₁-weighted images of the entire spinal column;
- Sagittal STIR T₂ images, at least of the pathological zone;
- Sagittal post-contrast spin-echo fat-sat T₁-weighted images of the whole spine;
- Axial post-contrast spin-echo T₁-weighted images of pathological spinal levels.

(Table 5) presents the signals of each spinal component on different sequences as previously delineated [27].

Post-therapeutic aspects

After radiation therapy, MRI appears to be a powerful tool for differentiating post-therapeutic changes from tumor recurrence.

In the former, areas of increased signal intensity during certain imaging strategies are consistent with either an absolute or relative increase of fatty tissue whereas, in the latter, low signal intensity is more characteristic. During the two first weeks, marrow edema and areas of necrosis are more visible on STIR sequencing than on spin-echo. USPIO may also be useful [12]. Between 3 and 6 weeks, fatty bone-marrow conversion allows homogeneous high signal intensity on T₁-weighted images for all vertebrae included in the radiation field [39] (Fig. 9), thus increasing the visibility of new lesions. Medullary conversion arises in the periphery, allowing a banded appearance with central high signal intensity on T₁-weighted images [36]. Marrow recovery depends on the age of the patient. A recent study [12] performed on animals (rabbits) suggests that late post-contrast images may significantly and positively enhance T₁ imaging of normal bone marrow. Also, a subsequent increase of irradiation due to increased reticuloendothelial-system activity allowed reliable identification of irradiation-induced changes in bone-marrow physiology.

Drug side-effects on osseous tissue can be observed; altered bony remodeling, osteopenia, coarsening of trabeculae and secondary neoplasia may be encountered. Vascular lesions may also be present, leading to ischemia and fractures. A thorough examination of MRIs allows tumor evaluation and avoids the assumption of metastatic spreading. These effects can be observed even after five years [15]. According to some authors [16,29], radiation would have a protective effect on marrow against tumor cell invasion.

Chemotherapy can produce a striped appearance on MRI after a few weeks, following aplasia. Thus, on STIR sequences, low signal intensity will follow high signal intensity. After growth-factor administration, marrow hyperplasia can present as nodes, which can be difficult to differentiate from metastases as they both appear hyperintense on T₁-weighted images.

For evaluation of vertebral tumors, MRI allows the best visualization of the metastatic process. Necrosis, tumor volume and epidural extension are well demonstrated. In practice, discrimination between hemorrhagic metastases and necrosis may be delicate [32].

Development of a faint sclerotic rim at the periphery of sclerotic lesions is the best sign of a healing response. Progressive bone sclerosis from the outside towards the center, from focal areas of osteolysis to a uniform osteosclerotic zone, sometimes followed by shrinking prior to total disap-
pearance, is the usual pattern of progressive healing. However, in some instances, healing of an osteolytic lesion may be accompanied by progressive ossification at the periphery that leads, even on MRI, to a well-defined and sometimes expanded appearance [2,25]. In this case, CT and plain films can be useful.

On occasions, a successful response to therapy is demonstrated by vertebral sclerotic zones in vertebrae that were initially normal in appearance, suggesting the presence of undetected osteolytic lesions. In fact, an osteoblastic reaction suggestive of a successful response to therapy can lead to a dramatic increase in both the size and number of tumor foci, findings that could easily be interpreted as disease progression [28,29].

In contrast, in sclerotic lesions, a decrease in the size and number of osteoblastic foci is thought to characterize the healing process. For tumors such as carcinomas of the prostate, sclerotic areas may remain unchanged rather than decrease in size during tumor remission [28,29]. Thus, correlation of these radiographic changes with clinical and biological data will allow for better interpretation of the patient’s true condition. Regarding mixed lesions, a successful therapeutic response would be a continuous evolution towards a uniformly sclerotic area. Subsequent patterns of healing are identical as with osteolytic lesions. For reducing artefacts due to materials after surgery, fast spin-echo sequences are recommended [26].

Considering that radiographic manifestations of progression or healing at the site of skeletal metastases are fairly constant from one region of the body to another, an abbreviated or short version of the survey examination may be sufficient when monitoring the tumor’s response to therapy.

**Management of imaging**

The strategy will be different according to clinical manifestations and staging of illness. At the stage of detection and diagnosis of osteophilic neoplastic processes, and even in the absence of clinical manifestations, scintigraphy (bone scanning) can be systematically performed, with or even replaced by SPECT, which will greatly improve the predictive value of the bone scan in the diagnosis of vertebral metastases [33]. When positive, MRI is also performed. In fact, SPECT is considered to produce results comparable and complementary to MRI [19]. MRI imaging has an equal or greater sensitivity in the detection of osseous metastases than bone scintigraphy, and has greater specificity. Plain films and CT remain a constant part of patient evaluation.

Plain films are useful, and easy to perform for monitoring metastases. They offer a good survey of cortical involvement and, thus, the risk for fractures and neurological complications. Treatment efficacy, as reflected by the number and size of metastases and staging of rebuilding (or the progression of destruction), can also be determined. CT is not used routinely during follow-up, but may be necessary for surveying pure osteoblastic or mixed lesions. MRI is also useful for paravertebral masses and epidural extension. However, although MRI does have limitations for imaging tumor necrosis and bone-marrow changes, it remains mandatory for post-treatment monitoring. In this case, diffusion-weighted sequences may allow for better delineation of diagnosis.

**Conclusion**

The diagnosis and monitoring of spinal metastases have been highly improved with MRI. A clear description of the performance and limitations of each type of investigation are discussed in this chapter, as well as their complementarity with isotope techniques. Moreover, these imaging techniques, especially those using magnetic resonance, are still being developed to provide better detection of lesions. The radiologist needs to remember that X-ray findings can be suggestive of a diagnosis without being truly pathognomonic. Searching for bone metastasis should be part of any investigation of any clinical manifestation suggestive of spinal disease, even in patients not known to have cancer.

**References**


Spine metastasis imaging: review of the literature