Vertebroplasty and Spinal Tumors

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11.1 Introduction

The spine can be affected by several primary or secondary tumors, with progressive osteolysis of each part of the vertebra (i.e., posterior arch, pedicles, body), causing unsustainable local pain and motor impairment secondary to vertebral collapse [1]. In the last decade, prolongation of life expectancy in patients affected by neoplastic disease has been responsible for an increase in vertebral metastases, particularly in the case of cancer of the breast, lung, kidney and prostate cancer [2]. Approximately 70% of patients with secondary lesions have at least one vertebral lesion [3] (Table 11.1). Moreover, because of the improvement in survival related to implementation of cancer treatment, most methods (including vertebroplasty) have changed from being end-of-life palliative care to become part of management of chronic disease [4].

Pain is the main symptom related to vertebral tumors, not only related to bony weakness of the vertebra, but also to the local periosteum and paravertebral tissues. In general, the pain is: drug-resistant; unrelated to mechanical distress; present even in the resting position. It usually precedes extravertebral spread of the tumor as well as radicular and spinal cord syndrome related to compression fracture.

11.2 Diagnosis

Symptoms of spinal metastases are the initial presentation of the disease in ≥20% of patients affected by neoplastic disease [5]. Despite care-

Table 11.1 Classification of spinal tumors

Benign	Malignant
Hemangioma	Solitary
Osteoid osteoma	Chordoma
Aneurysmal bone cyst (ABC)	Chondrosarcoma
Osteochondroma	Ewing's sarcoma
Osteoblastoma	Plasmacytoma
Eosinophilic granuloma	Multiple
Hemangiopericitoma	Multiple myeloma
Giant cell tumor	Lymphoma
	Leukemia

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ful evaluation of clinical findings such as motor and sensory impairment, abnormal reflexes and pain can be useful if one suspects neoplastic involvement in the spine [6]. The correct diagnosis is usually achieved using conventional computed tomography (CT) and magnetic resonance imaging (MRI), particularly in patients with a known history of cancer, with vertebral bone biopsy being undertaken in case of solitary lesions with equivocal radiological findings. Detailed history-taking, physical examination, bone scintigraphy and total-body CT enables the primary disease to be identified in 85% of cases; additional bone biopsy can bring this figure up to 93% [7]. Thanks to more precise selection of the targeted area required for analyses, CT-guided biopsy enables the correct histological diagnosis to be reached in 93% of cases [8]. Plain radiographs are not considered appropriate for the diagnosis because lesions are detected in only 30% of cases [9]. CT, despite excellent accuracy in the detection of bony abnormalities, shows moderate sensitivity (about 66%) [10], but remains fundamental for planning vertebroplasty. In fact, the size and location of lytic lesions is important to assess the risk of vertebral collapse in patients with vertebral disease. Hence, careful evaluation in multiple planes of the vertebra affected by the tumor is fundamental for CT studies, if augmentation with polymethylmethacrylate (PMMA) is being considered. According to Taneichi and coworkers, the risk of sudden collapse of a vertebra at the thoracic level is higher in the case of vertebral body (VB) involvement (>60%) and in the case of 30% destruction of the VB if there is involvement of the costovertebral joint. In patients with lumbar involvement, lesions involving 35–40% of the VB, and those with only 20–25% VB destruction associated with involvement of the posterior arch and/or pedicle are considered to be at high risk rate for vertebra collapse [11]. MRI is the ideal method for demonstrating neoplastic involvement of the spine, with a sensitivity and specificity of 98.5% and 98.9%, respectively [11]. Hence, study of the entire spine, including T1-weighted spin echo (SE) and T2-weighted short T1 inversion recovery (STIR), is preferred in cases of suspected neoplastic disease [6], with enhanced imaging to be added if extravertebral tumor spread is suspected.

11.3 Conventional Treatment

Management of spinal tumors includes medical therapy (corticosteroids, chemotherapy), radiotherapy and surgical treatment. Therapy is according to the histological type as well as the location and size of the tumor. Even though pain relief can be achieved in ≤71% of treated patients [12], chemo-radiotherapy has delayed efficacy [13] and surgery is not always possible. Moreover, despite the high prevalence of success in reduction/resolution of tumor size with chemotherapy and/or radiotherapy, the immediate risk of vertebral fracture remains. Despite being palliative in the case of metastatic disease, surgical management of spinal tumors is proposed for compression of the spinal cord (laminectomy, corpectomy, *en bloc* resection), spinal instability and severe pain [14].

11.4 Augmentation Treatment

Vertebral augmentation has been validated as an excellent procedure for increasing spinal stability if spine osteolysis occurs. The pain resolution observed with vertebral augmentation is almost immediate. With respect to the safety, feasibility and efficacy of vertebroplasty, it should be considered to be part of conventional analgesic treatment [15], thereby reducing narcotic use for all stages of the disease [16]. With regard to surgery, augmentation procedures should be carried out before chemo-radiotherapy [17] to reduce tumor size and to allow the patient to better tolerate anti-tumor therapies [4]. Pain relief after vertebroplasty has been reported to 84–92% [18], with asymptomatic paravertebral leakage accounting for 4–9.2% [19, 20].

Augmentation in the case of an osteolytic vertebral tumor has two aims: mechanical stabilization of the vertebra (preventing creep deformation of the VB and complications related to neural compression) and resolution of the focal

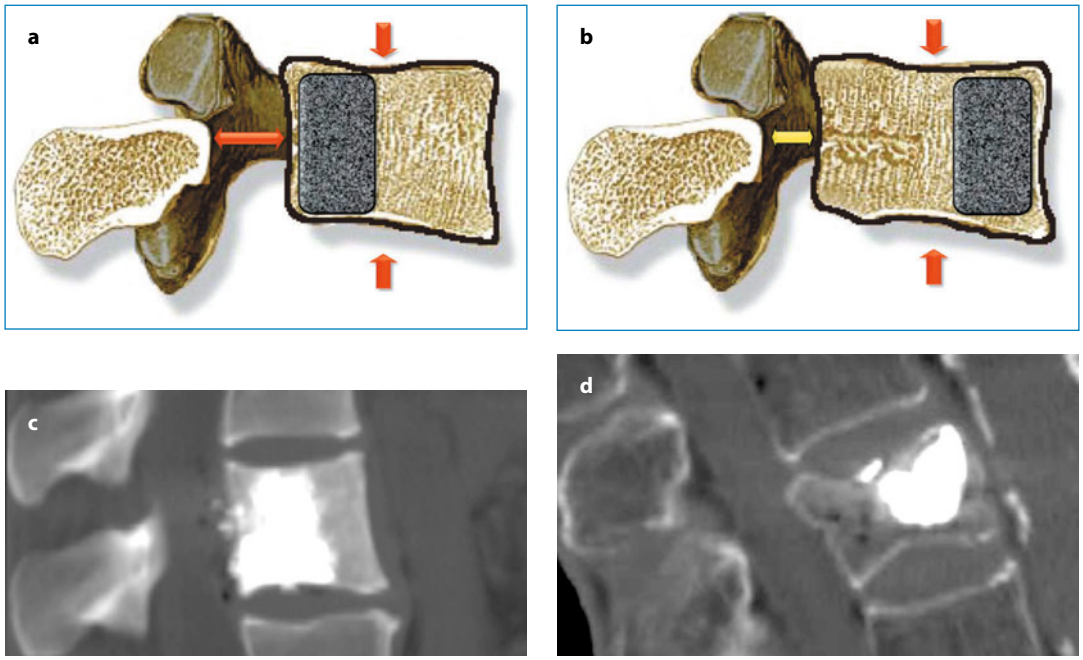


Fig. 11.1 Best position to obtain vertebral stability. When PMMA is introduced into the posterior-third of the vertebral body (**a** and **c**), the variation of the spinal canal under compression is minimal in comparison with augmentation undertaken in the anterior-third (**b** and **d**)

pain related to the disease. According to recent biomechanical studies on metastatic spinal tumors, mild-to-moderate reduction in size of the spinal canal (with a consequent risk of increasing compression of the spinal cord) has been demonstrated in the case of compression of a vertebra augmented in the anterior-third only. Hence, the best position for PMMA injection for reaching vertebral stability is the posterior-third of a neoplastic VB [21] (Fig. 11.1).

Different mechanisms (i.e., thermal ablation of the vertebral nerve plexus or neurolytic actions of the monomer used) have been advocated for the explanation of pain relief [22], but mechanical stabilization seems to be the main mechanism. Recently, increasing interest in biological-bioactive cements has become evient in the literature [23]. Osteoconductive material as an association between alpha-calcium sulfate and hydroxyapatite [24] has been proposed in the attempt to obtain bone regrowth in focal osteolytic areas, with the original tumor being removed by conventional chemo-radiotherapy (Fig. 11.2).

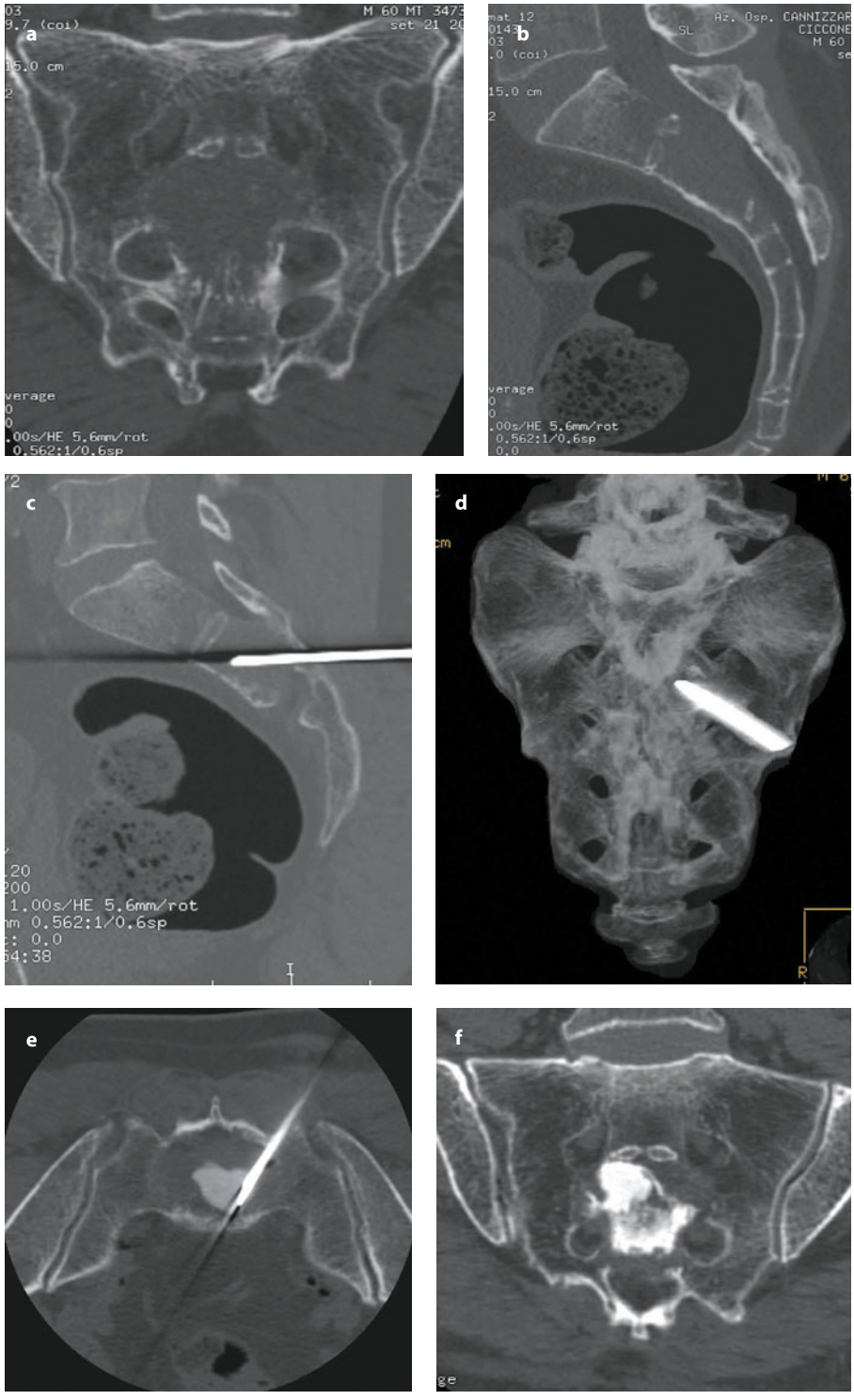


Fig. 11.2 Osteoconductive augmentation of the sacrum. A large sacral defect into the S2 body is observed in a patient previously affected by multiple myeloma (**a** and **b**). A 11-G needle is placed into the sacrum (**c** and **d**) and a small amount of osteoconductive material introduced using a X-ray–CT-guided technique (**e**). After 45 days, regrowth of new bone into the sacrum is observed (**f**)

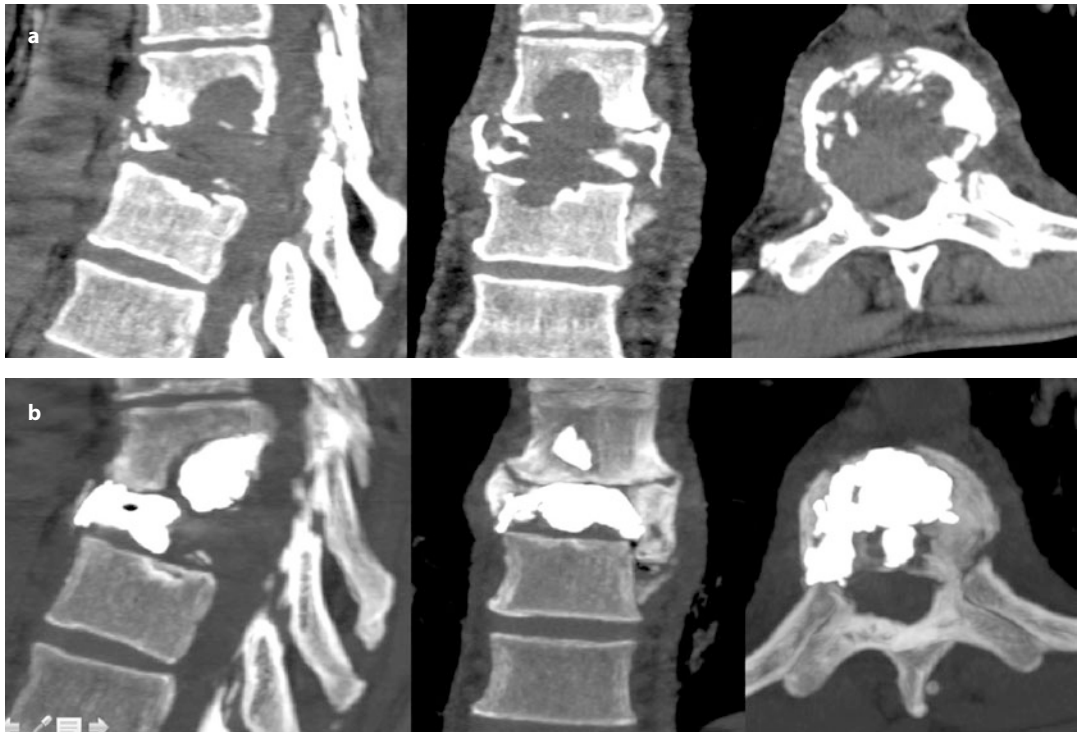


Fig. 11.3 Vertebral augmentation using radiofrequency-applicable PMMA. Severe T7 vertebral collapse with erosion of the posterior wall is observed in a 56-year-old male with by multiple myeloma (**a**). After slow injection of very dense PMMA, reduction of kyphosis related to vertebral augmentation with partial restoration of vertebral height, and respecting the posterior wall profile, is observed (**b**)

11.5 Vertebroplasty and the Posterior Wall

If vertebroplasty is planned in the case of neoplastic vertebral erosion, discontinuity of the posterior somatic wall and/or epidural tumor involvement has been referred as severe contraindications to the procedure [25] because of the presumed risk of dislocation of tumor tissue into the spinal canal [26]. Some authors suggest that pre-vertebroplasty treatment (chemo-radiotherapy or embolization-radioablation of the tumor [27–29]) should be carried out to reduce the size of the tumor, and to carry out PMMA augmentation with concurrent myelography to monitor epidural changes during kyphoplasty/vertebroplasty [30]. Recently however, new trends related to technical considerations have been reported. First, according to a biomechanical study by Pollintine et al. on PMMA spreading into a VB [31], cement distribution is strongly influenced by the physical property of material injected and hardening behavior. Hence, the use of polymers with radiofrequency-controlled hardening could be useful in augmentation of tumor VBs with defects in the posterior wall [32, 33] (Fig. 11.3). Moreover, stress distribution in the VBs can be normalized using repeated injections of small volumes of PMMA (Fig. 11.4) to reduce the risk of epidural leakage [34–38]. Hence, despite not being indicated for epidural compression [39, 40], augmentation procedures can be undertaken cautiously even in patients with severe erosion of the posterior wall (Fig. 11.5) and/or epidural extension of the tumor [41]. This is because worsening neurological symptoms after vertebroplasty have not been described in patients with symptomatic epidural compression 42 (Figs 11.6 and 11.7).

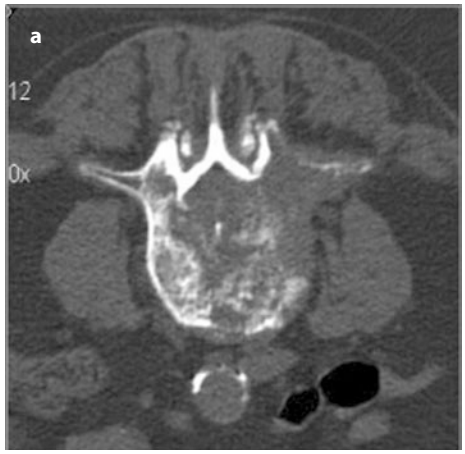
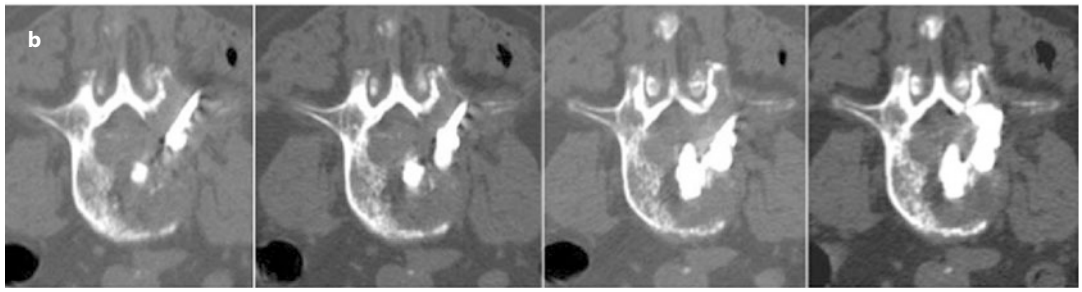


Fig. 11.4 Small-volume injections of PMMA in pedicle reconstruction in a patient with severe osteolysis secondary to a breast lesion of the right pedicle (**a**). Using multiple injections of small amounts of PMMA, careful reconstruction of the pedicle and tranverse process is achieved (**b**)



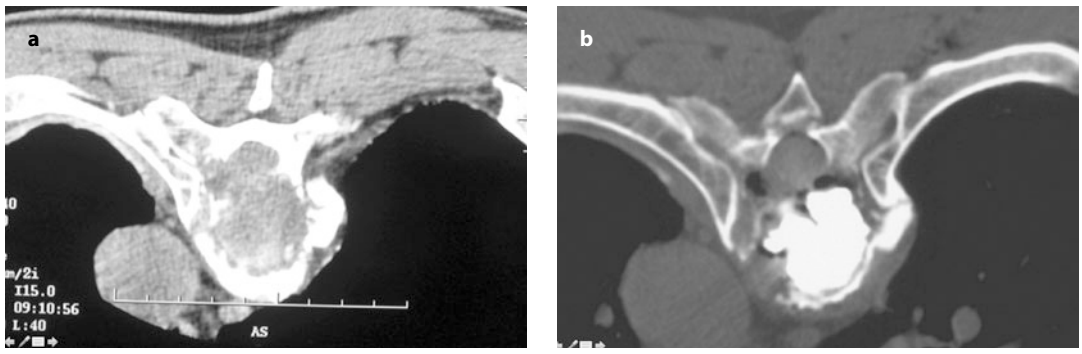


Fig. 11.5 Vertebroplasty in a patient with erosion of the posterior wall secondary to metastases due to primary lung carcinoma. Before treatment, a large defect at the level of the posterior wall of T9 can be seen (**a**). After treatment, subtotal augmentation of the vertebral body without epidural leakage can be achieved (**b**)

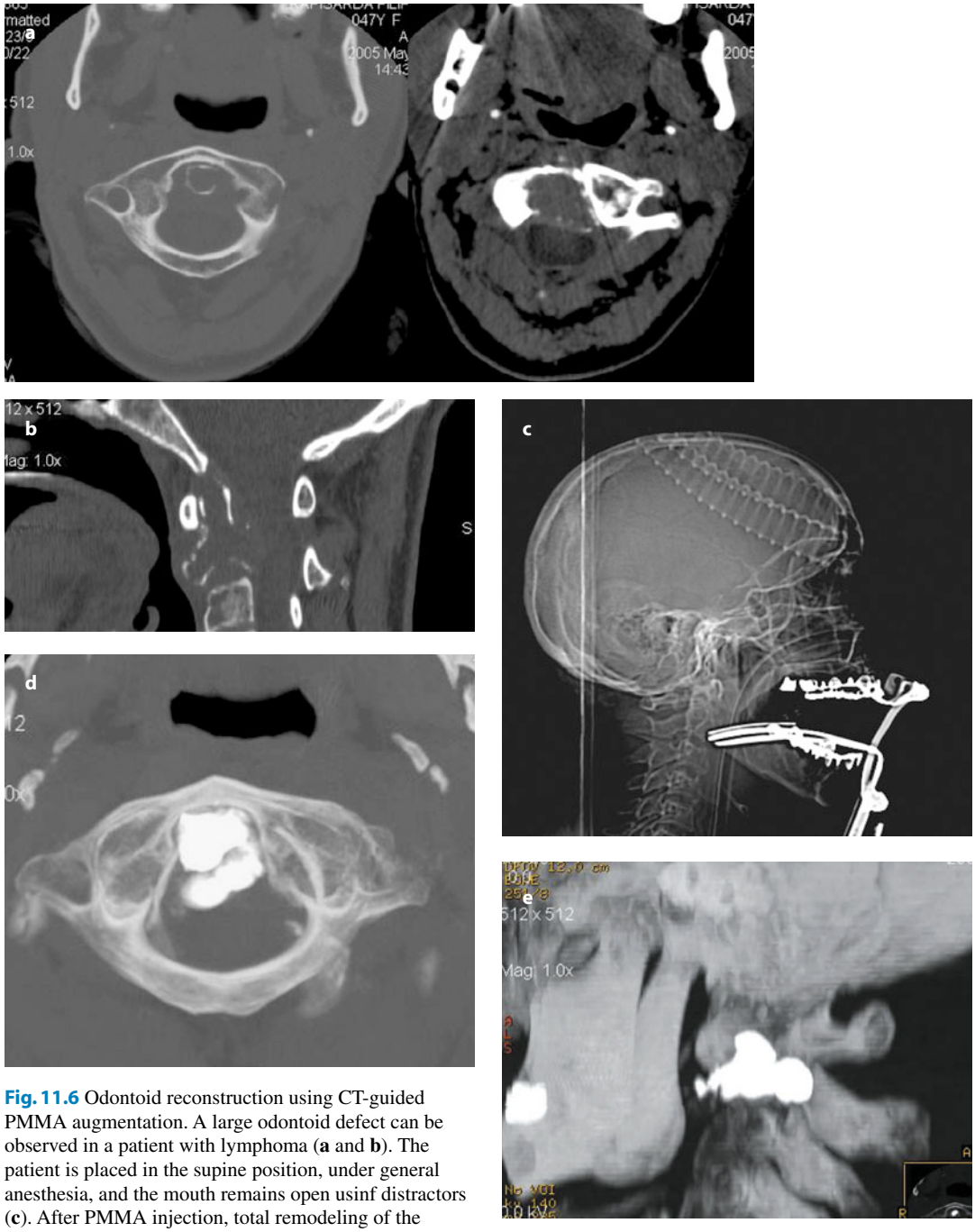


Fig. 11.6 Odontoid reconstruction using CT-guided PMMA augmentation. A large odontoid defect can be observed in a patient with lymphoma (**a** and **b**). The patient is placed in the supine position, under general anesthesia, and the mouth remains open usinf distractors (**c**). After PMMA injection, total remodeling of the odontoid process recreating the C1–C2 articulation is demonstrated (**d** and **e**)

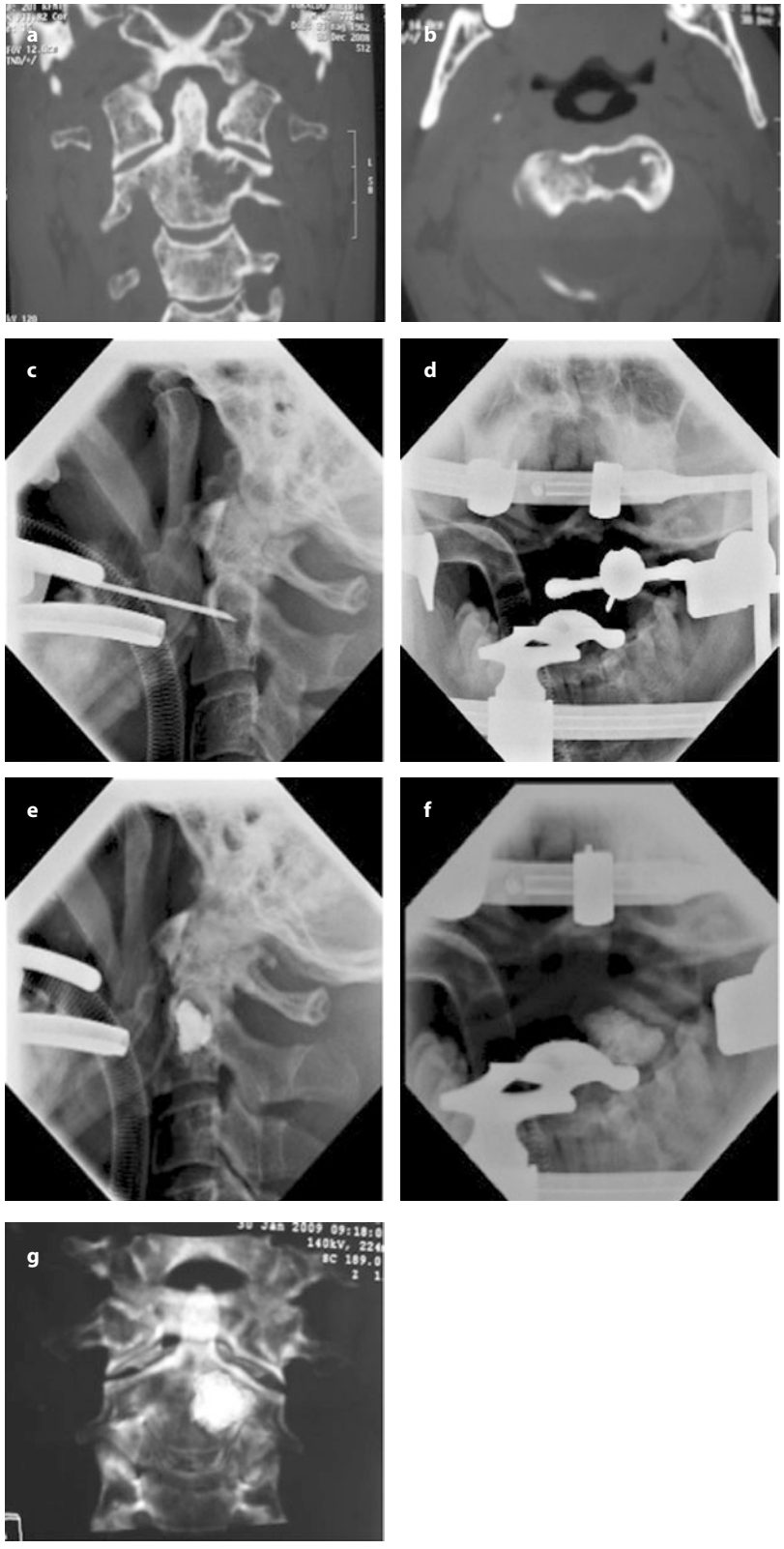


Fig. 11.7 C2 vertebroplasty. Multidetector-row computed tomography (MDCT) coronal and axial MP reconstruction at the cervical level show a multiple myeloma lesion at C2 (**a** and **b**). The patient is placed in the supine position under general anesthesia. The mouth remains open by the use of distractors (**c** and **d**). Left lateral and anteroposterior views under fluoroscopic control after PMMA injection show good distribution of cement into the lesion without leakage (**e** and **f**). Three-dimensional volume-rendered MDCT shows good distribution of the PMMA (**g**)

11.6 Vertebroplasty and Extravertebral Tumors

Another point to consider is whether conventional vertebroplasty can be carried out in cases of a neoplastic vertebra with an extravertebral soft-tissue tumor. Previously, an extravertebral tumor was considered to be a contraindication for vertebroplasty (especially in cases of severe epidural extension). Even though severe compressive myelopathy remains an indication for conventional open surgery to decompress the spinal cord, an increasing number of studies focusing on the "emboligenous" effect of injected PMMA has been published [43–45], and the procedure has become used widely (even in cases of epidural involvement of the disease) with very low prevalence of complications [15]. Ischemic changes of paravertebral tissue immediately after vertebral augmentation can be demonstrated by contrast-enhanced CT or MRI, and persistent regression of the tumor can be documented in follow-up studies (Figs 11.8–11.10). Even though the cause of spontaneous regression of extravertebral extension of metastatic disease after vertebroplasty remains unknown, several mechanisms have been proposed. Deramond et al. suggested that the thermal effect related to PMMA could be responsible for the observed cytolytic effects [46], but this does not seem probable considering the low-temperature hardening PMMA that is commonly used. Kayamura et al. suggested that the regression could be related to the activation of messenger ribonucleic acid (mRNA) by PMMA, with new synthesis of tumor necrosis factor (TNF) [47]. However, considering the size reduction detected a few days after augmentation, this mechanism do not seems feasible. Considering the embolic effect of PMMA injection demonstrated in the literature [44], ischemic changes could be considered to be the main cause of immediate reduction in tumor size after vertebroplasty [45].

11.7 Vertebroplasty and the Neoplastic Posterior Arch

The pedicle and posterior arch are crucial for spinal stability. At the thoracic level, ≥60% involvement of the VB is considered to suggest the risk of vertebral collapse. However, if the pedicle/posterior arch is involved, 25% erosion of the VB is sufficient to cause vertebral creeping [48]. Moreover, the entire posterior arch is considered to be a very sensitive area for local pain. Several authors have demonstrated neoplastic involvement of elements of the posterior arch to be associated with severe local pain, and local infiltration in case of persistent pain after vertebroplasty has been suggested [49, 50].

Previously, neoplastic involvement of the posterior arch was considered to be a contraindication to vertebroplasty. This was mainly because of the difficulty in visualizing PMMA distribution during injection into the pedicle using the C-arm assisted procedure, as well as the consequent risk of PMMA leakage into the spinal canal. However, if a CT-guided technique is employed, use of a small-gauge needle (13–15 G) and multiple mini-injections of PMMA can be used to reconstruct almost every part of the posterior arch, thereby sparing the spinal canal (Figs 11.11–11.15).

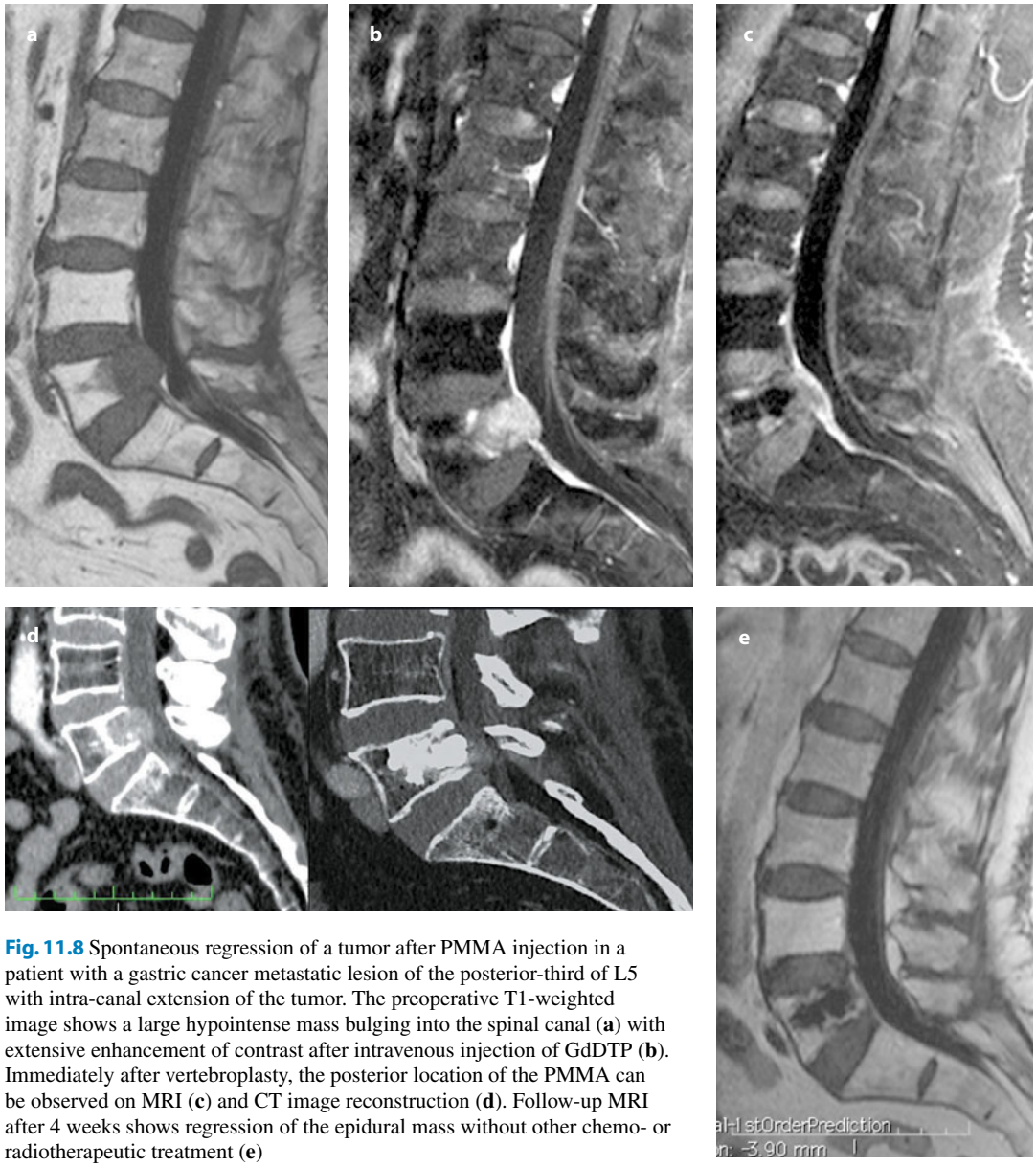


Fig. 11.8 Spontaneous regression of a tumor after PMMA injection in a patient with a gastric cancer metastatic lesion of the posterior-third of L5 with intra-canal extension of the tumor. The preoperative T1-weighted image shows a large hypointense mass bulging into the spinal canal (**a**) with extensive enhancement of contrast after intravenous injection of GdDTP (**b**). Immediately after vertebroplasty, the posterior location of the PMMA can be observed on MRI (**c**) and CT image reconstruction (**d**). Follow-up MRI after 4 weeks shows regression of the epidural mass without other chemo- or radiotherapeutic treatment (**e**)

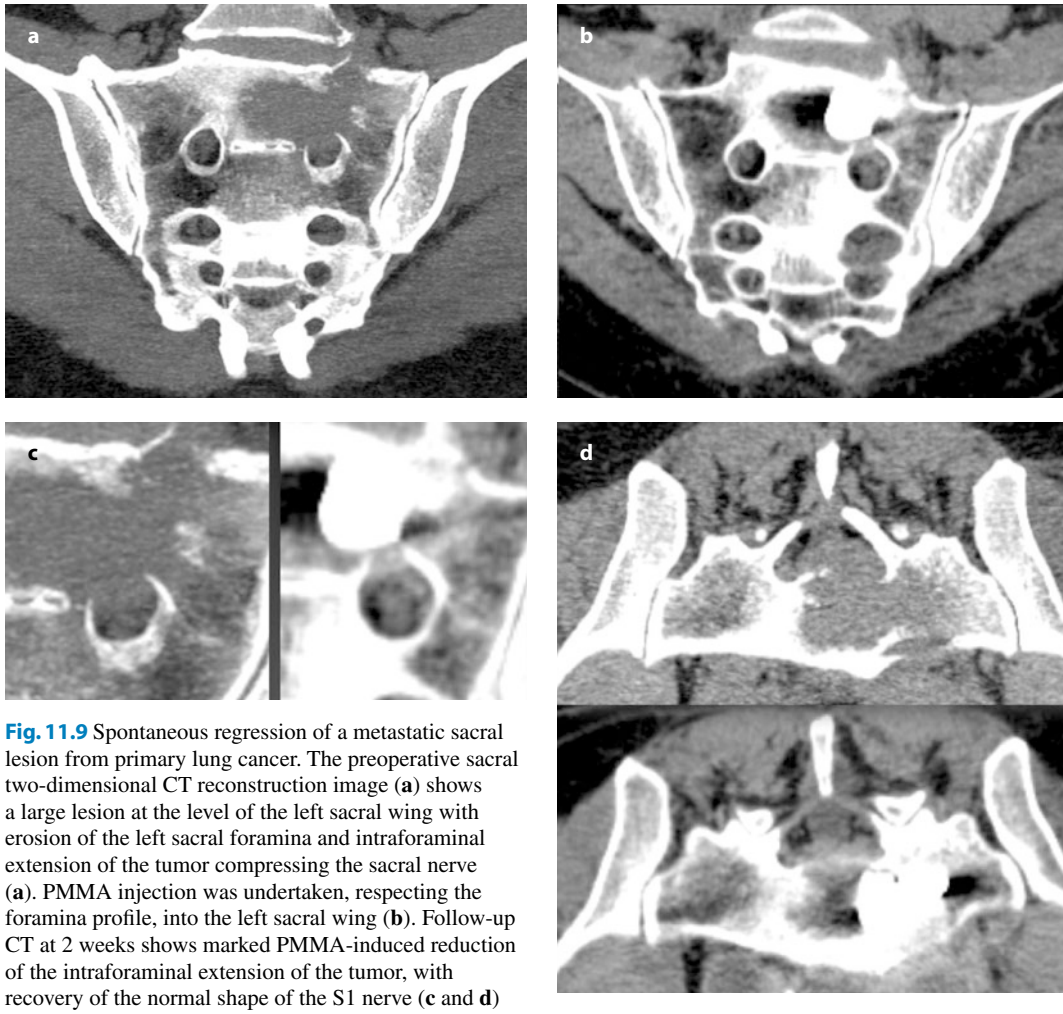


Fig. 11.9 Spontaneous regression of a metastatic sacral lesion from primary lung cancer. The preoperative sacral two-dimensional CT reconstruction image (**a**) shows a large lesion at the level of the left sacral wing with erosion of the left sacral foramina and intraforaminal extension of the tumor compressing the sacral nerve (**a**). PMMA injection was undertaken, respecting the foramina profile, into the left sacral wing (**b**). Follow-up CT at 2 weeks shows marked PMMA-induced reduction of the intraforaminal extension of the tumor, with recovery of the normal shape of the S1 nerve (**c** and **d**)

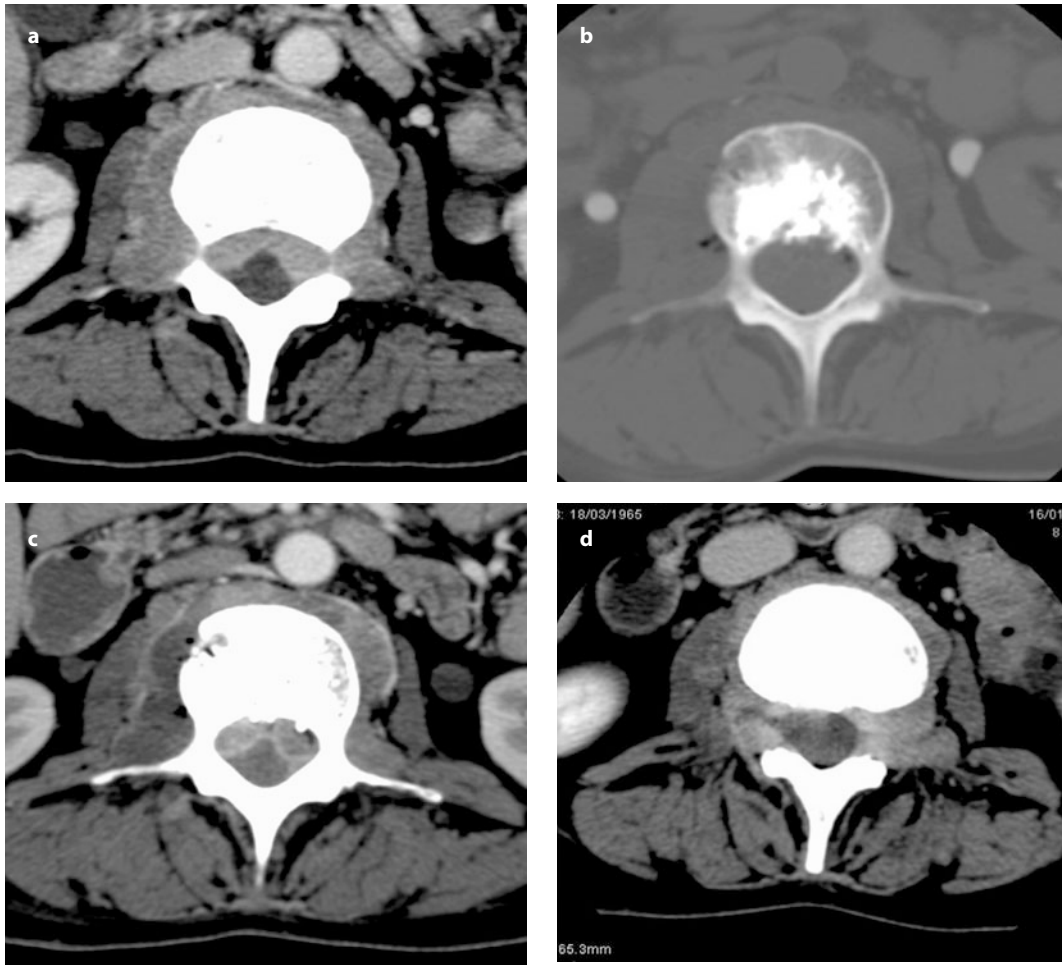


Fig. 11.10 Spontaneous regression of epidural tumor extension in a female with T11 involvement due to breast cancer metastasis and paraparesis. The preoperative contrast-enhanced CT study shows tumor extension into the perivertebral space and spinal canal with spinal-cord compression (**a**). PMMA augmentation is undertaken involving mainly the posterior-third of the vertebral body of T11 (**b**). Upon immediate contrast-enhanced follow-up, no enhancement of the epidural intrathecal lesion and paravertebral lesion on the right side can be seen, which is probably related to ischemic chances induced by PMMA augmentation (**c**). At 4-week follow-up, the paraparesis has resolved and no recurrence of the tumor can be seen in the spinal canal (**d**)

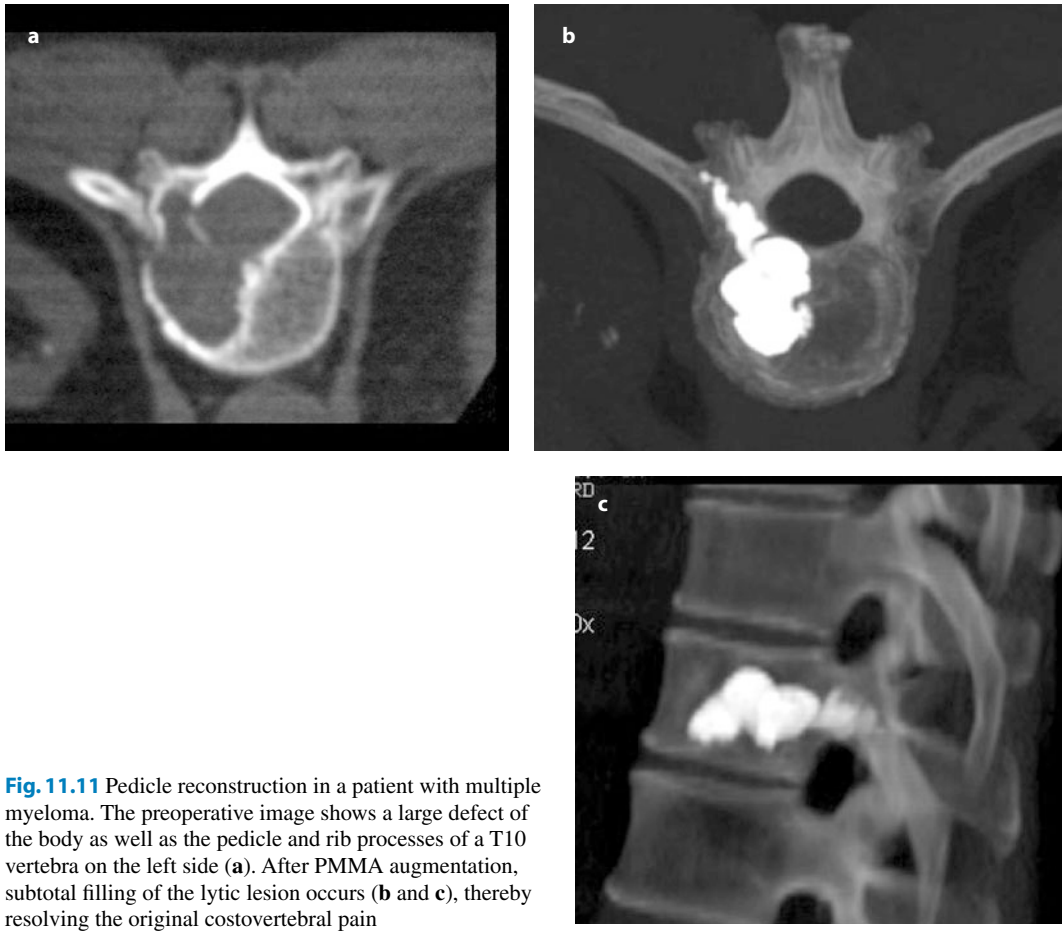


Fig. 11.11 Pedicle reconstruction in a patient with multiple myeloma. The preoperative image shows a large defect of the body as well as the pedicle and rib processes of a T10 vertebra on the left side (**a**). After PMMA augmentation, subtotal filling of the lytic lesion occurs (**b** and **c**), thereby resolving the original costovertebral pain

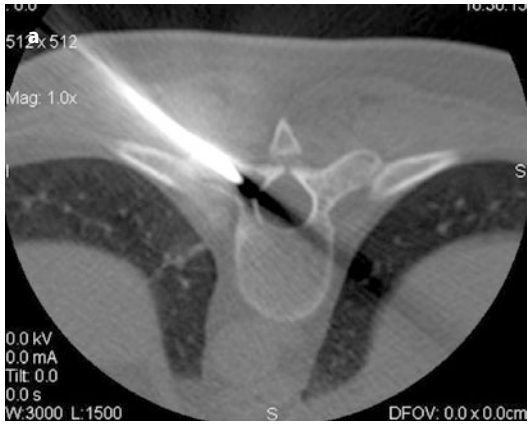
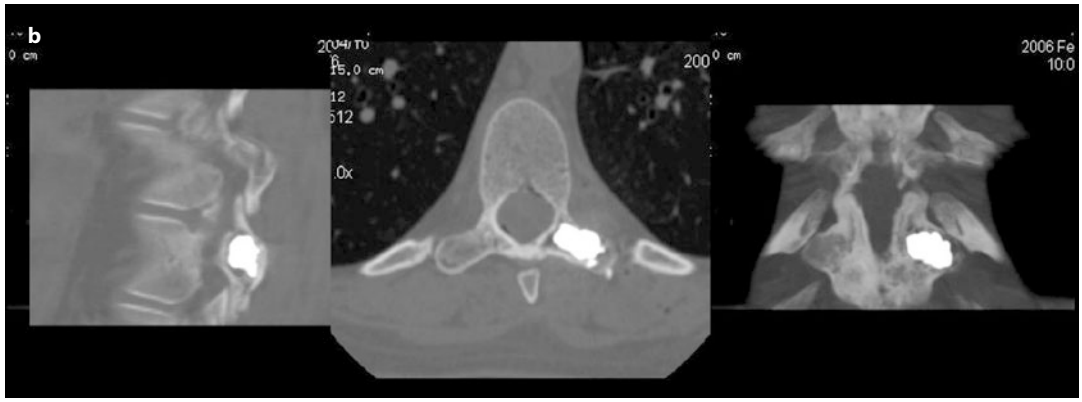


Fig. 11.12 Pedicle augmentation in a female with painful focal left pain at the T6 level. Before augmentation, a lytic lesion of the left transverse process related to localization of breast cancer metastases can be seen (**a**). After PMMA injection, total filling of the left transverse process can be observed on axial, sagittal and coronal CT reconstruction, with resolution of the pain (**b**)



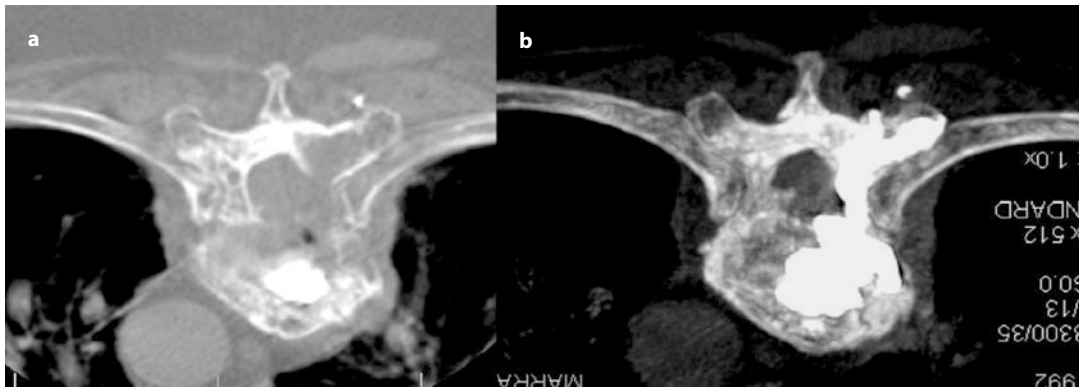


Fig. 11.13 Reconstruction of the body, pedicle and transverse process in a patient with T12 lung cancer metastases. Before PMMA injection, a large painful osteolitic lesion can be seen involving the left pedicle and transverse process of the T12 vertebra (**a**). After PMMA injection, full remodeling of the vertebra can be seen, recreating the missing left pedicle and articular process (**b**)

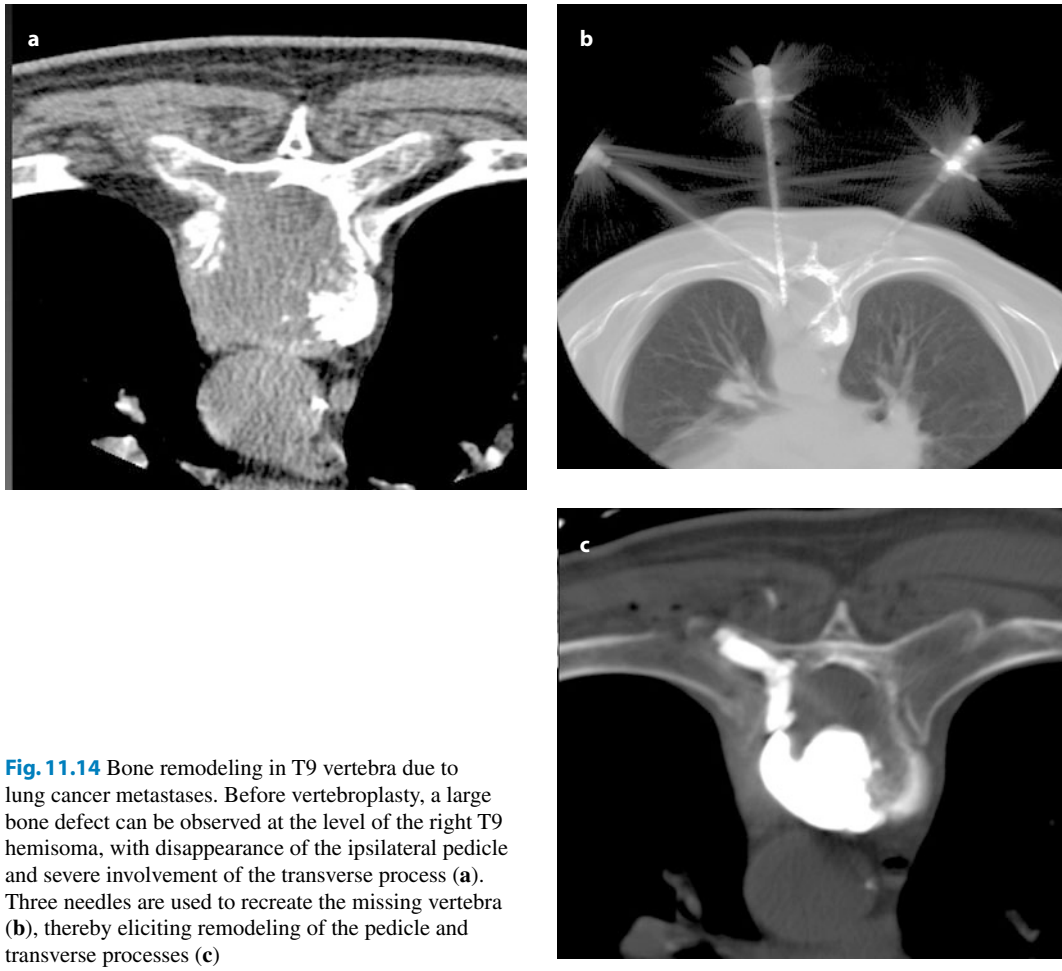


Fig. 11.14 Bone remodeling in T9 vertebra due to lung cancer metastases. Before vertebroplasty, a large bone defect can be observed at the level of the right T9 hemisoma, with disappearance of the ipsilateral pedicle and severe involvement of the transverse process (**a**). Three needles are used to recreate the missing vertebra (**b**), thereby eliciting remodeling of the pedicle and transverse processes (**c**)

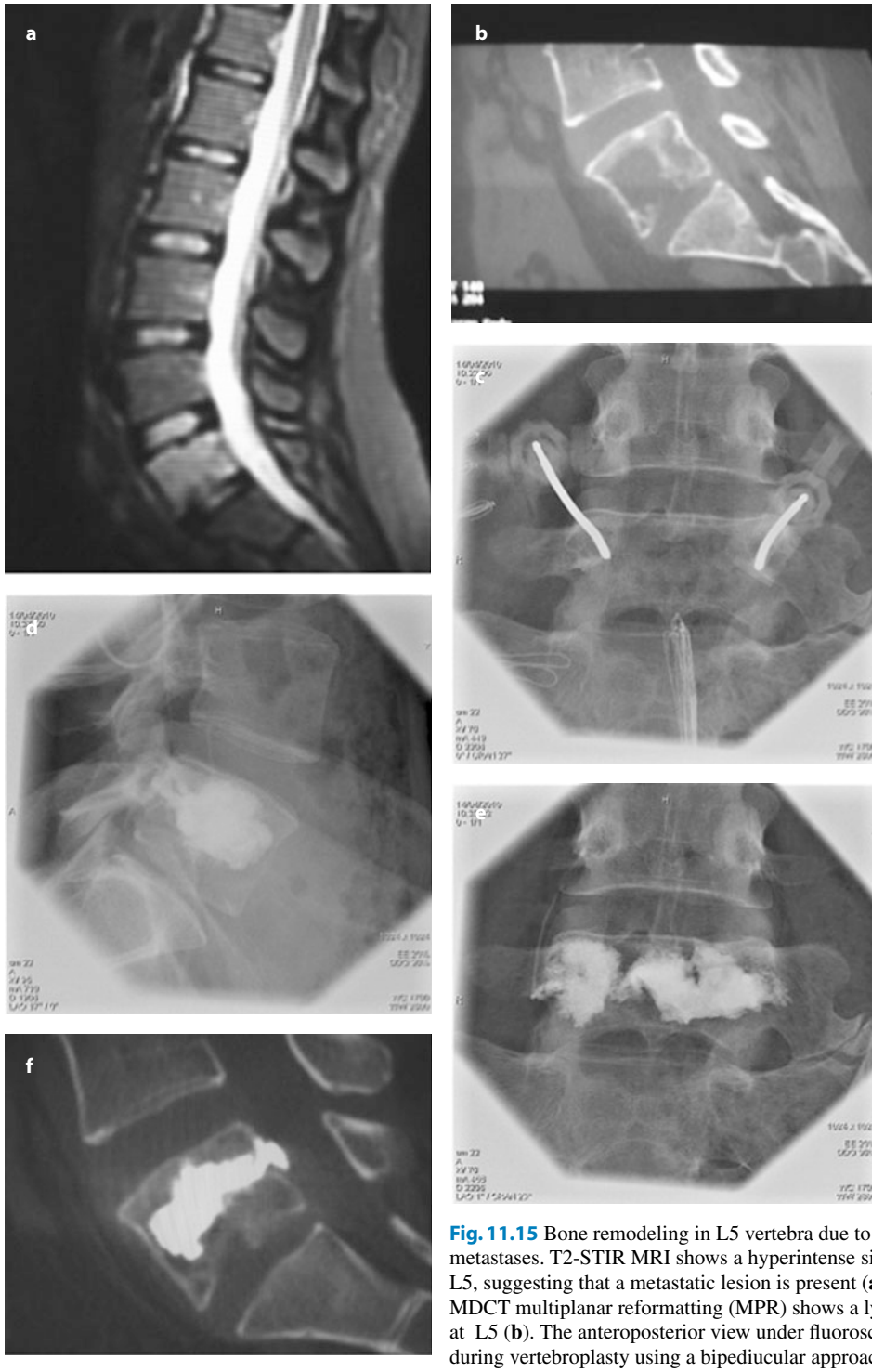


Fig. 11.15 Bone remodeling in L5 vertebra due to breast cancer metastases. T2-STIR MRI shows a hyperintense signal at L5, suggesting that a metastatic lesion is present (**a**). Sagittal MDCT multiplanar reformatting (MPR) shows a lytic lesion at L5 (**b**). The anteroposterior view under fluoroscopic control during vertebroplasty using a bipediucular approach shows good positioning of the needles (**c**). Left lateral and anteroposterior views under fluoroscopic control post-vertebroplasty show PMMA remodeling of the lesion without cement leakage (**d** and **e**). Sagittal MDCT MPR shows the remodeling effect due to PMMA (**f**)

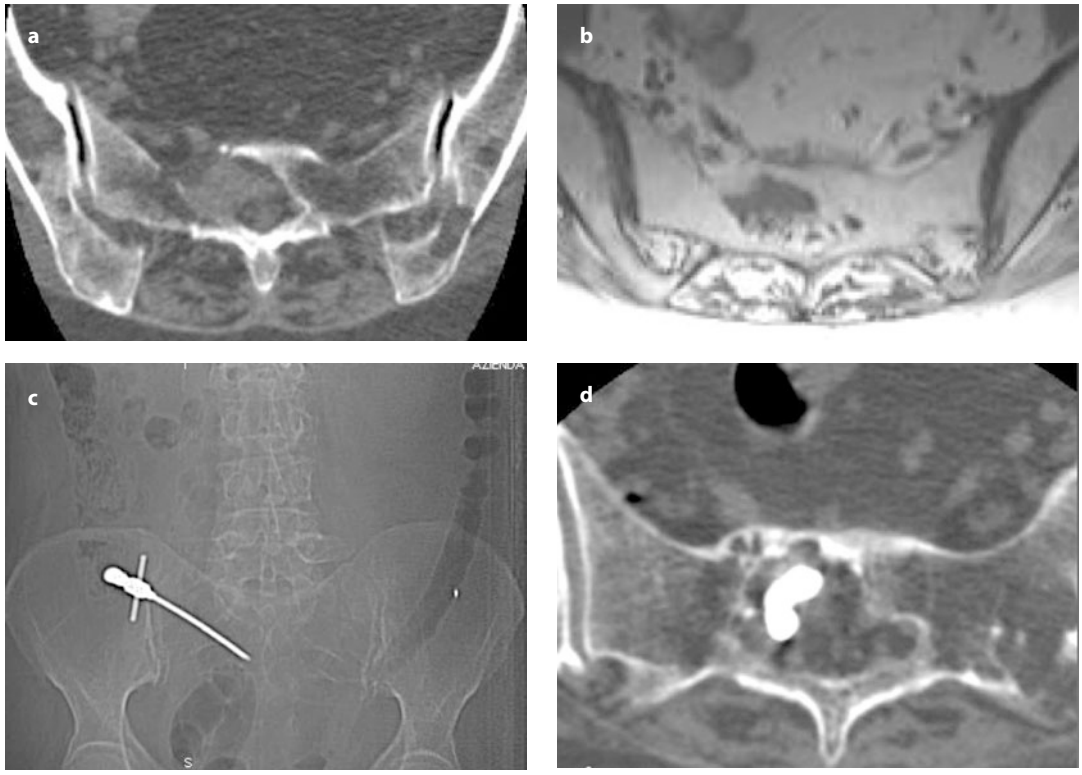


Fig. 11.16 Small sacral lesion and targeted PMMA injection in a patient with multiple myeloma. On CT (**a**) and T1-weighted MRI (**b**), a small lesion can be observed at the body-to-wing line of the sacrum. A 11-G needle is placed carefully into the lesion *via* a CT-guided transalar approach (**c**) and the lesion filled with PMMA, resulting in pain resolution (**d**)

11.8 Vertebroplasty and the Neoplastic Sacrum

Neoplastic involvement of the sacrum can be part of secondary disease. It can be responsible for severe local pain, preventing the patient from sitting or standing up. Pain control is based on radiotherapy and/or drug use. More recently, percutaneous interstitial laser photocoagulation (ILP) of vertebral bone tumors such as osteoid osteomas under CT or MRI guidance has been used to obtain thermal destruction of the nidus tumor with low-power laser energy. ILP is a minimally invasive method that can be an alternative to conventional surgical treatment (i.e., percutaneous laser photocoagulation of spinal osteoid osteomas under CT or MRI guidance [51–54]. Sacroplasty using intra-tumor injection of cement is a powerful tool for pain relief, even for very small sacral lesions (Fig. 11.16). From a technical viewpoint, if C-arm fluoroscopy is adopted to introduce a needle, the overlapping bony pelvis usually obscures sacral visualization to a considerable extent. This complicates assessment of whether the injected cement is contained within the sacrum or has leaked outside the sacral boundaries (i.e., into the sacral foramina) [55]. Garant et al. [56] attempted to overcome this problem by placing several 15 cm-long, 20-G Chiba needles in the sacral foramina to identify their location during PMMA injection. However, lateral-view C-arm fluoroscopy is frequently insufficient for safe depiction of the sacral foramina and sacral boundaries.

CT guidance during sacroplasty and adoption of manual PMMA micro-injection with small syringes (i.e., 1.5–2.0 cm^3 by time) appears to be the best choice to reduce the risk of extrasacral leakage

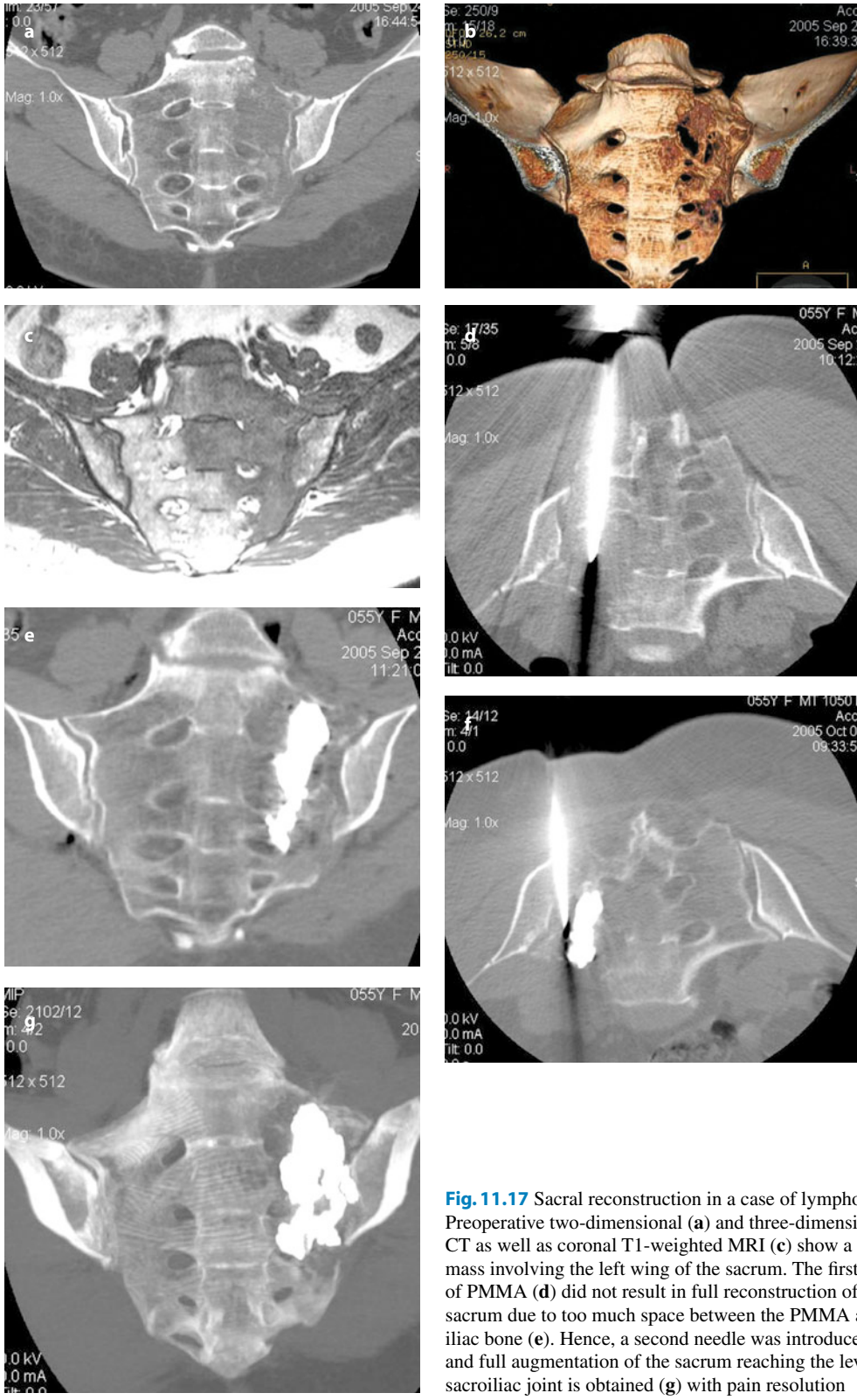


Fig. 11.17 Sacral reconstruction in a case of lymphoma. Preoperative two-dimensional (**a**) and three-dimensional (**b**) CT as well as coronal T1-weighted MRI (**c**) show a large mass involving the left wing of the sacrum. The first injection of PMMA (**d**) did not result in full reconstruction of the sacrum due to too much space between the PMMA and the iliac bone (**e**). Hence, a second needle was introduced (**f**) and full augmentation of the sacrum reaching the level of the sacroiliac joint is obtained (**g**) with pain resolution

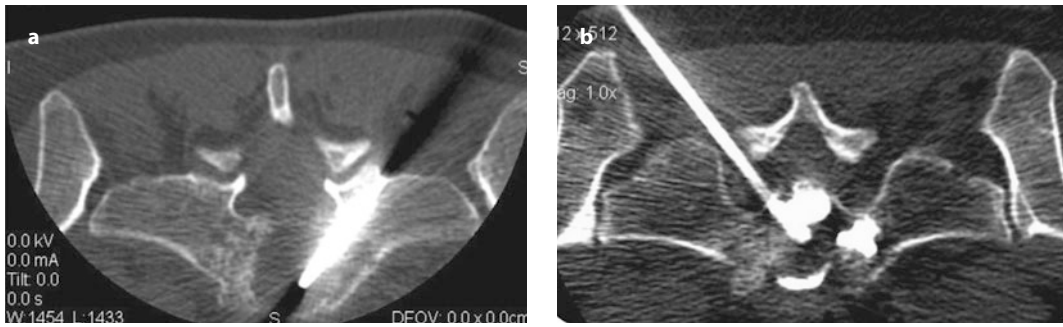


Fig. 11.18 A different approach to carrying out a sacroplasty. The Jamshidi needle can be introduced through the sacral wing (**a**) or directly into the sacral body *via* the posterior sacral foramina (**b**), paying sparing attention to sparing the sacral nerve

for two main reasons. First, one can immediately appreciate the initial intraforaminal leakage. The procedure can be stopped and the needle moved away from the foramen to prevent intraforaminal extravasations (Fig. 11.17). Second, the best orientation of the needle can be chosen easily. The vertebroplasty needle should be oriented to cover the entire extension of the sacral fracture according to the shape of the sacrum and the distribution of the sacral tumor osteolysis. New access routes different to the traditional transpedicular approach (e.g., parapedicular route, transdiskal access) have been adopted by several authors [57] to reach the VB. One of the advantages of a combination of a C-arm-assisted procedure and CT-guided procedure [58] is the abilty to choose the best route to reach the target because markers (i.e., pedicles) are not needed. In general, the transalar and transforaminal approaches can be adopted to minimize the risk of complications (Fig. 11.18). Moreover, in patients with anarchic osteolysis related to malignancies, the chance to see the true PMMA distribution inside the sacrum permits consolidation of all the area occupied by the disease. This allows sacral remodeling to be undertaken in the case of extensive osteolytic disease (Fig. 11.19). Finally, as demonstrated by several authors, CT-guided spinal interventional methods significantly reduce radiation exposure to the patient and the operator. Recently, Perisinakis et al. demonstrated that fluoroscopic-guided vertebroplasty and kyphoplasty exposed patients to significant radiation doses: 10 min of fluoroscopic exposure equated to a mean value of 173 mGy for vertebroplasty and 233 mGy for kyphoplasty. Histological analyses of skin specimens of patients who underwent 10 min of kyphoplasty demonstrated cellular injuries [59, 60].

11.9 Aneurysmal Bone Cysts (ABCs)

ABCs are expansive osteolytic lesions with thin walls containing blood-filled cystic cavities. Although benign, ABCs can be aggressive and can cause extensive weakening of the bony structure and impinge on surrounding tissues. Malignant transformation is extremely rare [61]. ABCs predominantly affect individuals aged <20 years, with a female preponderance [62–64]. The cause of ABCs is not known [65]. The tibia and femur are affected in 24.7% and 17.3% of all cases, respectively, followed by the upper extremities (10%) and pelvis (9%). About 14% of all ABCs are encountered in the spine, with those in the cervical spine making up only 2% [66]. The expansive nature of the lesions can cause pain, swelling, deformity, disruption of growth plates, neurological symptoms (depending on their location), and pathologic fractures [66–67]. ABCs can be asymptomatic, but usually produce pain that is resistant to medication. Occasionally, ABCs can be found incidentally or cause acute onset with spinal cord syndrome.

The treatment of spinal ABCs is controversial. For vertebral lesions, the choice of treatment must

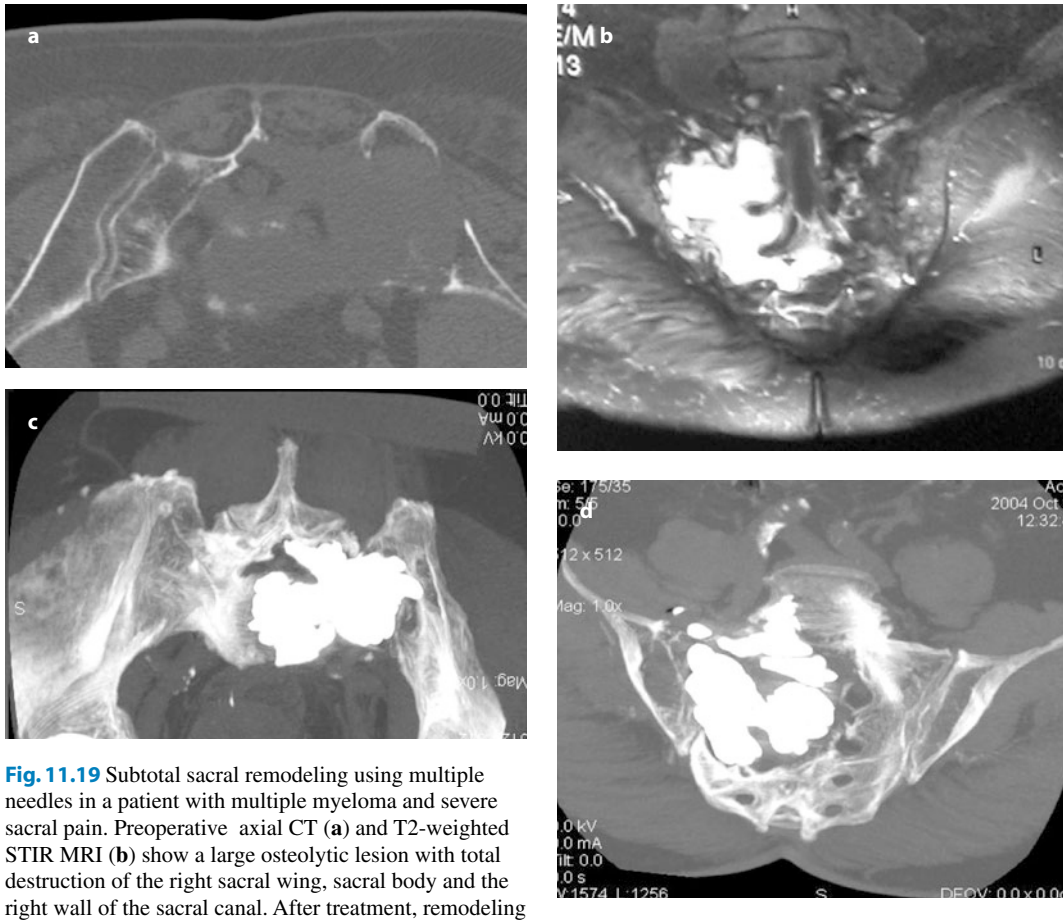


Fig. 11.19 Subtotal sacral remodeling using multiple needles in a patient with multiple myeloma and severe sacral pain. Preoperative axial CT (**a**) and T2-weighted STIR MRI (**b**) show a large osteolytic lesion with total destruction of the right sacral wing, sacral body and the right wall of the sacral canal. After treatment, remodeling of the sacral wing and posterior wall of the sacral canal can be observed, with remodeling the right first and second sacral foramina and with no leakage into the sacral canal (**c** and **d**)

take into consideration the risk of neurological and vascular lesions as well as preserving the stability (and, if possible, mobility) of the spine [65].

Surgery is the first-line treatment for these lesions, and includes resection, curettage and spinal fixation. These procedures carry the risk of significant blood loss, postoperative spinal deformity, axial deformity, and postoperative hemorrhage [68]. Some authors have proposed a simple intra-lesion excision with bone grafting. Other authors have proposed "*en-bloc*" resection of the involved vertebra as the only treatment free from the risk of local recurrence [65], but this treatment is frequently complicated by kyphoscoliosis and compression of the spinal cord and nerve roots. Deformity is frequently worsened by the surgical procedures often needed for control of these lesions, which can involve more than one level [69]. Hemorrhage and pulmonary embolism can occur during or after surgery [67, 70–72].

Other strategies include radiotherapy, sclerotherapy and endovascular treatment [73–74]. In general, radiotherapy is contraindicated because of the risk of inducing neoplasm formations (sarcomas), gonadal damage, and disruption of growth plates. Nevertheless, low-dose radiotherapy is used occasionally to treat lesions that cannot be treated by surgery [73]. Another option is selective arterial embolization, which

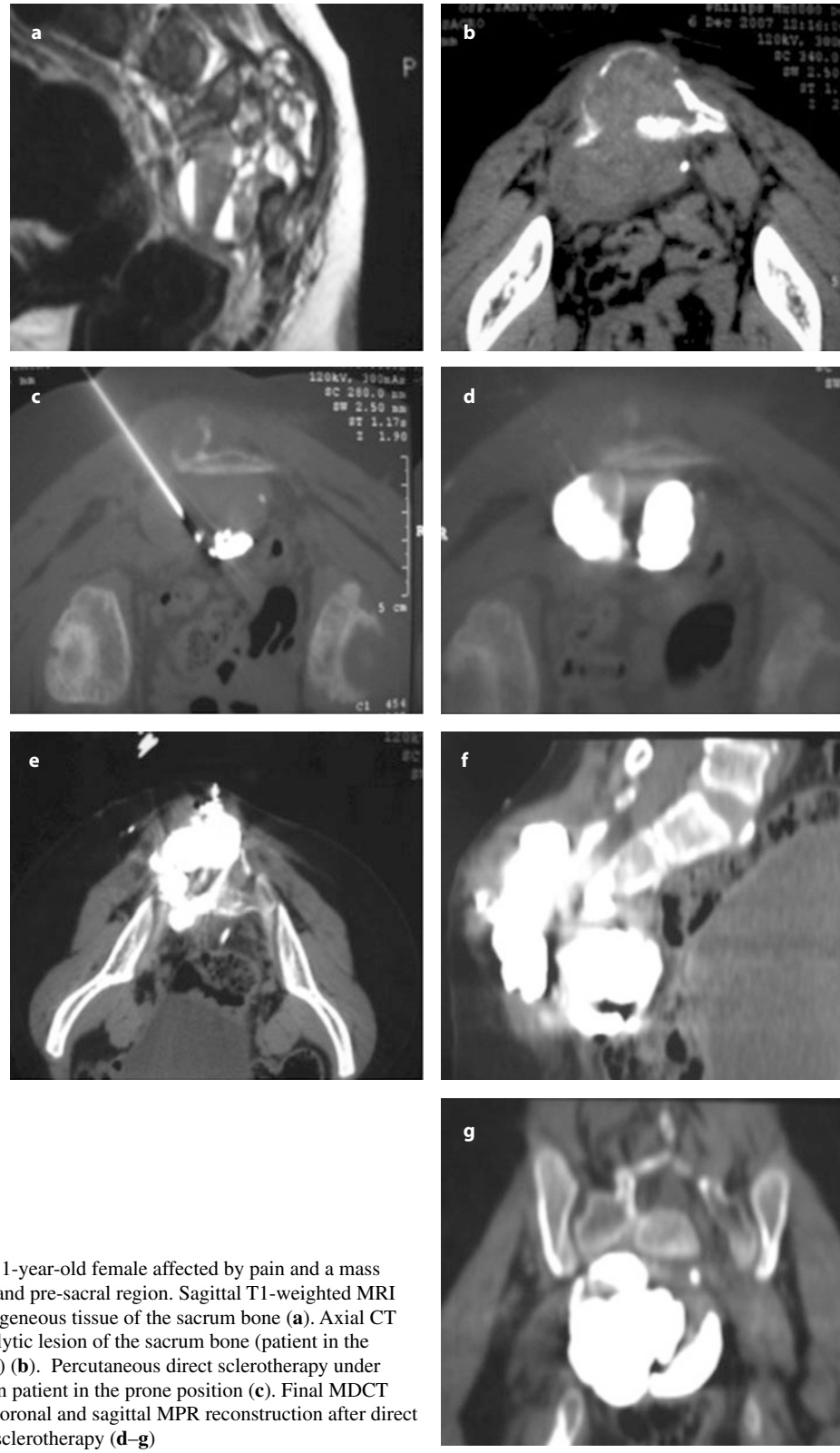


Fig. 11.20 A 11-year-old female affected by pain and a mass in the lumbar and pre-sacral region. Sagittal T1-weighted MRI shows inhomogeneous tissue of the sacrum bone (**a**). Axial CT shows a large lytic lesion of the sacrum bone (patient in the prone position) (**b**). Percutaneous direct sclerotherapy under CT guidance in patient in the prone position (**c**). Final MDCT control with coronal and sagittal MPR reconstruction after direct percutaneous sclerotherapy (**d**–**g**)

has a recurrence rate that is not significantly different from that observed after intra-lesion excision. However, it is associated with the risk of spinal-cord ischemia (especially if the ABC is at the thoracic level). Some authors have proposed preoperative arterial embolization followed by surgical excision with bone grafting, whereas de Kleuver et al. considered arterial embolization to be insufficient treatment [75]. de Cristofaro et al. reported a recurrence rate of 10.5% after super-selective embolization [76].

Percutaneous intra-lesion injections represent a relatively new minimally invasive therapeutic option for ABCs. They can be combined with surgical or endovascular treatments (especially for large and resistant lesions) [75–77]. The procedure comprises percutaneous injection of glue directly into the lesion to obtain obstruction at the venous side of the multiple parietal arteriolar afferents of the ABC by direct damage to the endothelial lining. This triggers a coagulation cascade and thrombotic occlusion of blood vessels [78], thereby avoiding the potential functional disabilities produced by surgery or radiotherapy (Fig. 11.20).

Several sclerotic agents have been developed. Polidocanol, Ethibloc® or Glubran® can be combined with super-selective embolization by Onyx®. The *rationale* of using these agents is to elicit arterial embolization of the feeders or venous embolization by direct injection of the cystic lesion.

Polidocanol (3% hydroxypolyaethoxydodecan) is used for the treatment of varicose veins as well as venous malformations of the head and neck. Rastogi et al. reported good outcomes with a mean clinical response of 84.5% with low recurrence rate (2%), with the avoidance of complications such as hypopigmentation, injection-site necrosis, pulmonary embolism, osteomyelitis, and allergic reactions [78].

Ethibloc is a fibrosing and sclerotic agent containing a hydroalcoholic radiopaque solution of zein, a contrast agent, oleum papaverin and propylene glycol. Falappa et al. and Adamsbaum et al. reported good outcomes in long-term follow-up in subjects treated by direct percutaneous injection of Ethibloc, demonstrating it to be a safe and efficient minimally invasive method [79–81].

Glubran is a cyanoacrylate-based synthetic glue that becomes radiopaque upon addition of Lipiodol® (which is also the diluent). Glubran polymerizes in contact with blood to elicit a sclerotic effect. The speed of polymerization is dependent upon its dilution with Lipiodol. The amount injected is dependent upon the extension of the lesion and vascular structures. However, injection requires in-depth study of the lesion, its circulation and the collateral circulation to avoid severe complications due to inappropriate use.

Onyx is a biocompatible liquid polymer that precipitates and solidifies in contact with blood, thus forming a soft and spongy embolus. The injected material is sufficiently thick to fill vessels but does not adhere to the catheter. Three concentrations are available to permit a range of precipitation rates. One drawback of Onyx is the angiotoxicity of dimethylsulfoxide. It is injected under fluoroscopic guidance if combined with direct percutaneous treatment. The procedure is employed under general anesthesia or local anesthesia (depending on patient cooperation) and under fluoroscopic guidance. In general, and especially for vertebral sites, the needle used is the same as for percutaneous injection (16 G). It can be positioned directly into the lesion followed by a slow injection of the agent for better control of flow. Very careful and considered patient selection with good understanding of vascular anatomy is recommended for correct use of this procedure [82].

11.10 Osteoid Osteoma (OO)

OO is a small, benign (but painful) reactive bone lesion that, in general, occurs in males aged 10–20 years. The tumor is characterized by a nidus of diameter <1.5 cm and comprised well-organized trabecular bone with vascular fibrous connective stroma surrounded by reactive cortical bone. Most lesions are found in the long bones of the lower extremities (particularly the metadiaphyseal regions of the femur and tibia). Intramedullary and subperiosteal lesions are less common, are usually intra- or juxta-articular, and usually demonstrate less osteosclerosis (which may ap-

pear at some distance from the nidus) [83].

Spinal OO accounts for 10–25% of all cases of OO and 1% of spinal tumors (59% in the lumbar, 27% in the cervical, 12% in the dorsal, and 2% in the sacral region). It involves the posterior elements in 70–100% of cases and the VB in 7% of cases [83]. Spinal OO typically begins with an insidious onset of pain over the affected region that may radiate distally. Scoliosis can occur at the side of the lesion due to asymmetric muscle spasm. This causes asymmetric inhibition of the growth of the vertebral epiphysis and leads to a rotaional deformity. In general, most of these lesions are asymptomatic but management can become complex if they become symptomatic. Spontaneous regression due to unknown mechanisms has been documented.

The treatment options are:

- medical therapy with aspirin;
- *en-bloc* resection;
- minimally invasive percutaneous treatment with radiofrequency ablation (RFA).

Minimally invasive percutaneous treatment with RFA was described by Rosenthal et al. in 1989 and 1992, and was undertaken with CT guidance under local anesthesia [84]. The procedure involves placement, using a bone biopsy needle, of a radiofrequency probe into the nidus. At this point, RFA is carried out by inducing thermal necrosis of the lesion**.** Two cycles of ablation at 90°C for 2 min are needed for lesions of diameter <1 cm whereas for lesions of diameter >1 cm, a further two 2-min cycles in a different position are required. The duration of the procedure is about 90 min, but the duration of post-procedural hospitalization for observation is 3–24 h [84–85]. All daily activities can be resumed immediately without external supportive help.

The principle of RFA is use of an alternating current of high-frequency radio waves (>10 kHz) that pass from an electrode tip in body tissue and which dissipates its energy as heat. A radiofrequency generator forms an electric current that flows from the generator, through the electrode, into the patient and out through a ground electrode back to the generator. The resistance of biological structures causes local ions to vibrate. This "ionic agitation" results in friction around the electrode tip as ions change direction due to the alternating current and create heat to the point of dessication [86].

Vanderschueren et al. [87] reported a success rate of 79% on 28 RFAs without complications. Cioni et al. [88] observed good outcome in 30/38 patients. Rosenthal et al. demonstrated a success rate of >85% [86]. The recurrence rate is 5–10% and skin burns are reported quite often [83–90].

The relative contraindications for RFA are:

- a lesion on the hand in the spine (<1 cm from vital structures such as nerves);
- pregnancy;
- cellulitis;
- sepsis;
- coagulopathy.

Lesions with a nidus >1 cm usually require multiple applications of the electrode in various positions. Percutaneous RFA ablation induces necrosis in the lesion. It is a minimally invasive alternative to surgical treatment of OOs.

11.11 Vertebral Hemangiomas (VHs)

VHs are benign tumors with a rich vasculature. They represent 2–3% of all spinal tumors, and are identified in 10–12% of all vertebral autopsies [91–93]. They are usually asymptomatic and are diagnosed as accessory findings during radiographic or MRI examinations undertaken for other purposes. They tend to remain stable over time. Only 0.9–1.2% of VHs are symptomatic [94–95]. Symptoms vary from vertebral pain (54% of cases)–sometimes resistant to conservative medical treatment–to progressive neurological deficits (45% of cases) due to a vertebral fracture or medullary compression related to extension of the lesion to the VB/vertebral arch [95–96].

The histological pattern is characterized by anomalous vascular proliferation with regular venous and capillary structures (more frequently in the vertebral soma). A cavernous and capillary pattern of VH can be distinguished. The most common type that occurs in VBs is the cavernous variety, which is characterized by large sinusoidal spaces of venous engorgement and a single stratified epithelium [93, 97, 98].

VHs become symptomatic with the onset of critical neurological deficits as: the lesion grows in the VB or vertebral arch; when they determines the compression of the dural sac or of the nerve root due to presence of epidural tissue; or due intra-lesion bleeding. Venous types of congestion impair the trabecular architecture of the vertebral bone, thereby leading to fractures [97].

The physiological changes that occur during pregnancy tend to stress the growing tendency of VHs (especially during the first trimester of gestation). In fact, venous occlusion, increased intra-abdominal pressure, and the vascular redistribution of flow in the vertebral venous plexus due to uterine enlargement predispose to VH growth and to the related onset of compression fractures [99].

The management of VHs is complex. Surgery or radiotherapy have been first-line treatments for several years, but are worsened by intraoperative and postoperative hemorrhagic complications related to the rich vascularization that characterizes this type of lesion [92–93].

Recently, vertebroplasty (with or without MRI) has been introduced as an alternative to traditional surgical and radiotherapy of symptomatic VHs . The principle of vertebroplasty is to completely fill the vertebral lesion with cement (PMMA) to achieve irreversible sclerosis of the hemangiomatous venous pool, thus obtaining an antalgic effect. Moreover, in the case of vertebral fracture due to compression from tumor growth, the cement stabilizes the movements of the trabecular microfractures of the spongious bone which is responsible for the pain, and it also makes the VB more compact and resistant [100].

The main characteristics that make vertebroplasty the first-line treatment for VHs are a minimally invasive approach, early antalgic effect, and the low prevalence of complications. The low level of invasiveness is related to the use of a 11–15 G needle (depending on the location of the VH) with a length of 10–15 cm through the vertebral pedicle. Traumatic cutaneous and muscular incisions are not required. This type of procedure reduces the duration of hospitalization and offers a faster and less painful postoperative recovery.

The procedure is the same as that used for the treatment of porotic or primary/secondary vertebral tumors. However, a bipedicular approach is recommended to guarantee complete filling of the VB with an antalgic effect. The amount of cement used is dependent upon the size of the VH. In general, filling up the VH is the most important feature to obtain complete venous embolization. During treatment of expansive cavernous VHs, the perivertebral component of the lesion can become thrombosed even if it is not directly involved in the cement injection because the thrombolization is secondary to cementification of the main vascular bed, as described by Manfrè et al. [101].

Deramond et al. [102] described the successful outcome of vertebroplasty for the treatment of symptomatic and/or VHs with neurological deficits in >80% of patients, even if the lesions showed aggressive features upon imaging. Brunot et al. [103], in the short-term and long-term follow-up of treatment with vertebroplasty of symptomatic VHs observed efficacious treatment in 90% of cases and, in the long term, 3 patients preemptively treated for aggressive VHs remained asymptomatic. None of the treated patients showed a worsening of symptoms during the follow-up. Our research team has also observed complete remission of vertebral pain within 24–72 h of treatment without major or minor complications in all patients [100].

The selection criteria for cervical VHs are very strict. Patients with persistent pain with signs of atypical VH upon MRI should undergo vertebroplasty. Treatment can be combined with laminectomy. Feydy et al. [104] described 2 cases of symptomatic and non-aggressive VHs at the C4 level treated with vertebroplasty with a good antalgic effect and good vertebral stabilization as well as prompt regression of pain. Dousset et al. [105] reported a case of non-symptomatic but collapsed VHs treated with vertebroplasty for spinal stabilization.

Some authors have described the association of PMMA injection with direct intra-lesion injection of ethanol (<15 mL). Ethanol emphasizes the sclerotizing effect of the cement, thereby producing thrombosis of vascular angiomatous lesions. Nenertheless, injection of too large much ethanol in one dose can produce vertebral collapse [106–108].

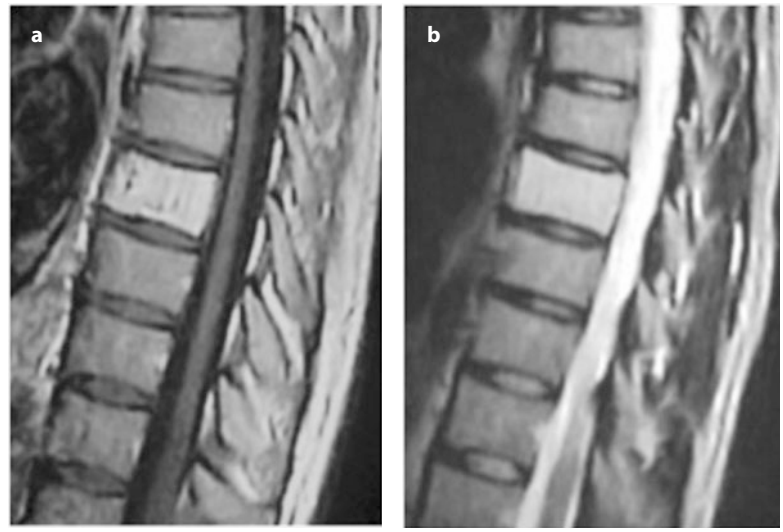


Fig. 11.21 Typical vertebral hemangioma at the dorsal level. Sagittal T1-weighted and T2-weighted MRI show the typical hyperintense signal (**a** and **b**) without epidural tissue or cortical erosion. The patient was asymptomatic

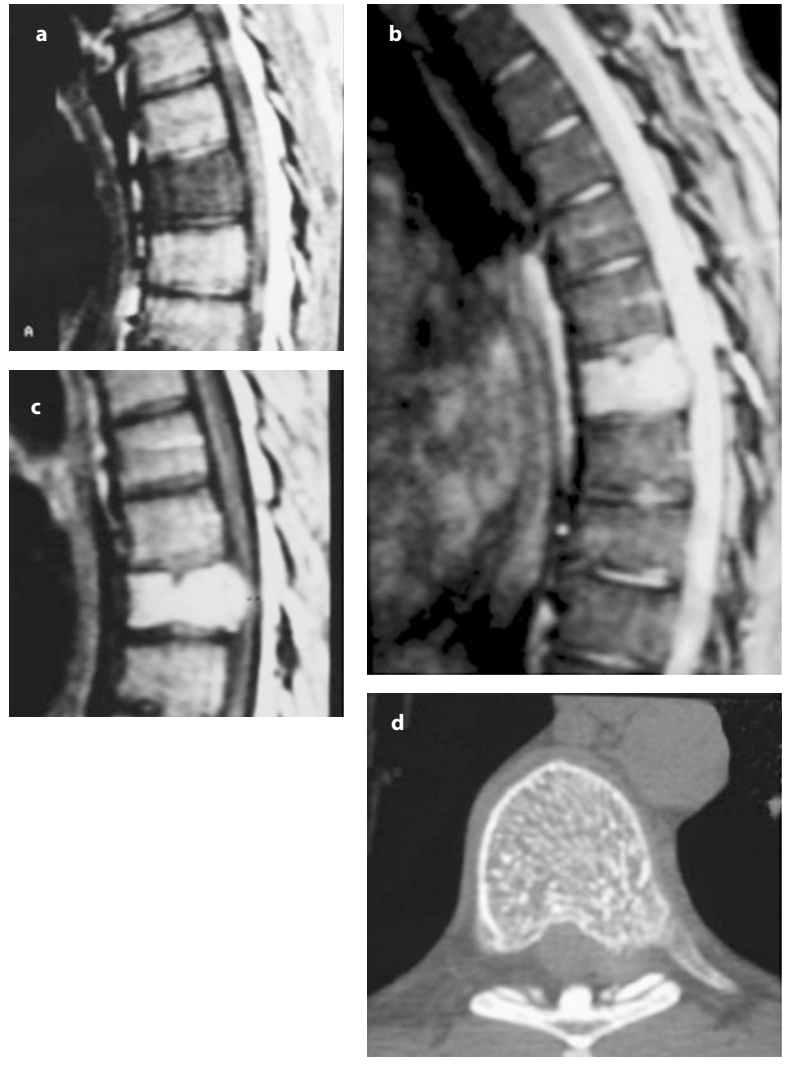


Fig. 11.22 Atypical vertebral hemangioma at the dorsal level with a hypointense signal on sagittal T1-weighted MRI (**a**) and a hyperintense signal on T2-weighted MRI (**b**) as well as homogeneous contrast enhancement on T1-weighted MRI on mild soft epidural tissue (**c**). Axial MDCT confirms the hemangioma of the vertebra at the dorsal level (**d**)

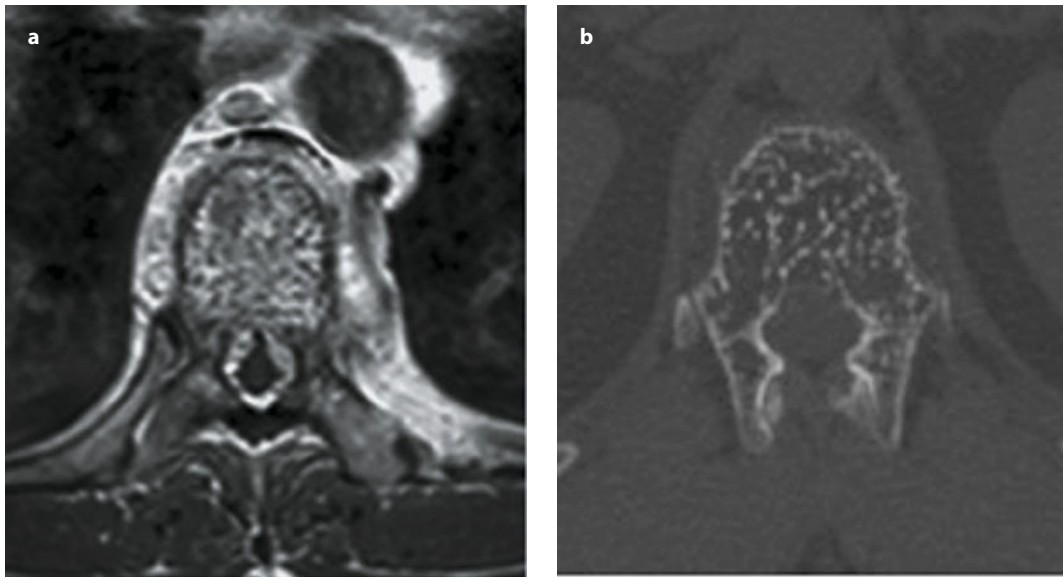


Fig. 11.23 An aggressive vertebral haemangioma with epidural tissue

The risk of complications for VHs (as well as for all vertebroplastic treatment) is related to cement leakage during extravertebral intra-canal injection, as well as in the prevertebral and paravertebral venous plexus with the risk of spinal-cord compression or pulmonary embolism [100]. In the treatment of the VHs, this risk is increased doing arterial access due to anarchic intravertebral vascularization, aggressive lesions, high-flow ectasisia (due to expansive angiomas) or the formation of intravertebral and paravertebral venous neoanastomoses related to the tumor extension. The risk is reduced by carrying out venous embolization with vertebroplasty.

To reduce the risk of complications during the vertebroplasty of VHs, restricted selection criteria are recommended. The population affected by VHs can be divided into four categories on the basis of clinical manifestations:

- asymptomatic patient with no sign of an aggressive VH (Fig. 11.21);
- symptomatic patient with no sign of an aggressive VH;
- asymptomatic patient with signs of an aggressive VH;
- symptomatic patient with signs of an aggressive VH.

The final group can be subdivided further based on the presence or absence of an epidural vascular component. Hypo-intensity on T1-weighted MRIs and hyperintensity on T2-weighted and T2 short TI inversion recovery (STIR) sequences with enhancement after contrast injection, the presence of epidural tissue, or evidence of cortical erosion are radiological features of aggressiveness (Fig. 11.22 and 11.23). Vertebroplasty is not indicated for patients in the first group. For patients in the second group, there could be an indication for vertebroplasty related to the presence of low back pain even in the absence of radiological evidence of aggressiveness. The patients in the third group must be evaluated carefully; management comprises annual MRI to check disease evolution. In fact, this treatment must be reserved only for VHs that are symptomatic and resistant to common conservative treatments, with radiological evidence of aggressiveness and/or epidural extension. All patients in the fourth group must undergo vertebroplasty [109] (Fig. 11.24).

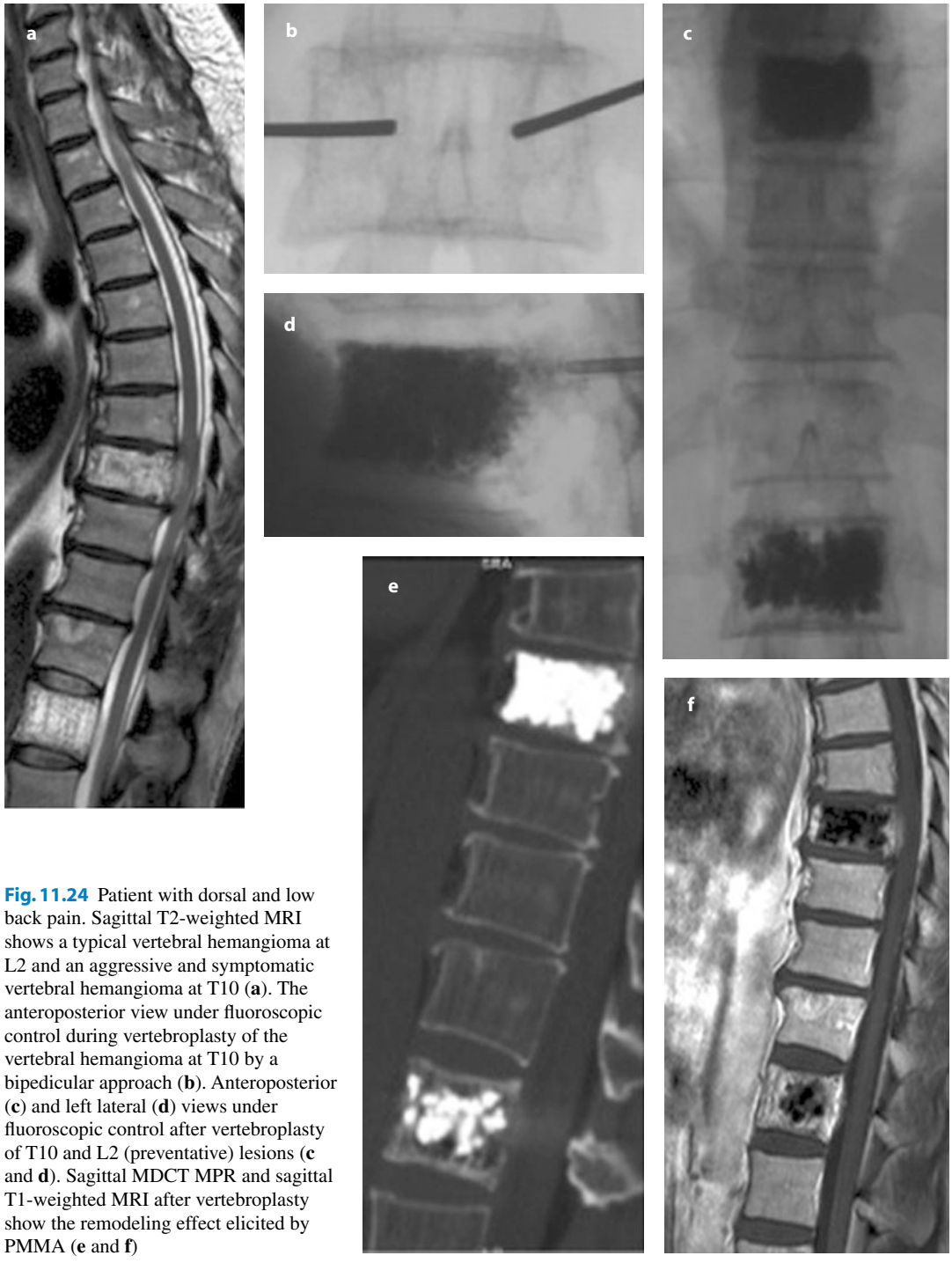


Fig. 11.24 Patient with dorsal and low back pain. Sagittal T2-weighted MRI shows a typical vertebral hemangioma at L2 and an aggressive and symptomatic vertebral hemangioma at T10 (**a**). The anteroposterior view under fluoroscopic control during vertebroplasty of the vertebral hemangioma at T10 by a bipedicular approach (**b**). Anteroposterior (**c**) and left lateral (**d**) views under fluoroscopic control after vertebroplasty of T10 and L2 (preventative) lesions (**c** and **d**). Sagittal MDCT MPR and sagittal T1-weighted MRI after vertebroplasty show the remodeling effect elicited by PMMA (**e** and **f**)

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