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ARTICLE

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Spinal osteoblastoma: CT and MR imaging with pathological correlation

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Abstract *Objectives.* To illustrate the CT and MRI features of spinal osteoblastomas and correlate the imaging with histological findings.
Design. In a retrospective review the CT and MRI features of spinal osteoblastomas with respect to mineralisation, signal intensity (SI), adjacent reactive changes, enhancement following gadolinium-DTPA (5 cases) and adjacent soft tissue masses were compared and correlated with the histological findings including the degree of osteoid formation and matrix mineralisation, vascularity and surrounding reactive changes in bone and soft tissue.
Patients. Eleven patients (7 males and 4 females; age range 8–43 years, mean age 19.5 years) with 12 osteoblastomas (1 patient suffered a recurrence) were studied.
Results. All lesions showed classical features on CT with varying degrees of matrix mineralisation, whereas MRI identified mineralisation in only eight of 12 cases. MRI showed low signal intensity of the lesion on both T1- and T2-weighted sequences in several cases in the absence of heavy mineralisation. In these cases, histological examination revealed diffuse osteoid production by the tumour. All patients given gadolinium showed enhancement within the tumour on MRI. Reactive bone marrow changes were identified on MRI in 10 cases, and in five of these the changes were at multiple levels. An adjacent soft tissue mass was demonstrated in five cases, but extraosseous tumour was present histologically in only two of these.
Conclusions. The MRI appearances of spinal osteoblastomas are varied and show no characteristic features. MRI may also overestimate the extent of the lesion due to extensive reactive changes and adjacent soft tissue masses. CT should continue to be the investigation of choice for the characterisation and local staging of suspected spinal osteoblastomas.

Key words Osteoblastoma · Spine · Radiography · CT · MRI · Pathology

Introduction

Osteoblastoma is a rare benign bone tumour accounting for less than 1% of all bone tumours and approximately 3.5% of benign bone tumours [1]. Between 32% and 46% of all osteoblastomas involve the spinal column, including the sacrum [2,3]. Although the plain radiographic and computed tomographic (CT) features of the lesion are well documented [4,5], there are few reports of the magnetic resonance imaging (MRI) features of vertebral lesions [5–13]. The purpose of this study was to illustrate the CT and MRI features in 11 patients with 12 spinal osteoblastomas and to correlate these with the histological findings.

Table 1 Clinical and CT features of 12 cases of osteoblastoma

Case no	Age (years)	Sex	Site of lesion	CT appearances
1	22	M	R. T3 body/pedicle/ transverse process	Mainly lytic with little calcification. Mild adjacent reactive sclerosis
2	13	F	L. T10 pedicle	Lytic with moderate calcification. Sclerosis in adjacent pedicle
2a	17	F	L. T10 pedicle	Lytic with little calcification
3	22	M	R. T8 body	Lytic with little calcification. Moderate sclerosis in body
4	14	M	R. L4 lamina	Lytic with little calcification. Cortical destruction. Sclerosis in adjacent pedicle extending into body
5	8	F	L. C4 lateral mass	Heavily calcified. Dense sclerosis in adjacent lamina
6	16	M	R. L2 lamina	Conventional tomography. Heavily calcified
7	43	M	L. L3 superior articular process	Lytic with little calcification. Mild sclerosis in pedicle and body
8	11	F	L. L2 transverse process	Lytic with moderate calcification. Dense sclerosis in pedicle and body
9	11	M	L. L4 lamina	Lytic with moderate calcification. Sclerosis of neural arch and L. L5 pedicle
10	20	F	L. lateral mass C4	Heavily calcified
11	15	M	R. T12 pedicle	Lytic with moderate calcification

Materials and methods

Between 1990 and 1997, 11 patients were identified from the records of the Department of Morbid Anatomy with a histologically confirmed diagnosis of spinal osteoblastoma. One patient suffered a local recurrence 4 years 6 months after excision of the original tumour. There were therefore 12 tumours for which MRI studies were available. A diameter of greater than 1 cm was used to differentiate osteoblastoma from osteoid osteoma, in accordance with Lucas et al. [2].

All patients had been imaged with MRI and plain radiographs, six had isotope bone scans and 10 had CT. One patient had conventional tomography. The CT appearances of the tumour were noted, particularly with reference to the degree of matrix mineralisation and adjacent bone reaction.

The MRI studies were performed at a variety of field strengths ranging from 0.2 T to 1.5 T. Combinations of T1-weighted spin echo (SE) and T2-weighted SE sequences were obtained in sagittal and axial planes. In five cases, T1-weighted SE sequences were repeated following intravenous injection of gadopentetate-dimeglumine (Gd-DTPA; Magnevist, Schering, Berlin, Germany). In two cases, gradient echo sequences were employed. MRI studies were assessed for the following features:

1. T1 and T2 signal intensity (SI) of the tumour;
2. presence of signal void within the tumour consistent with matrix mineralisation;
3. presence of enhancement within the tumour following Gd-DTPA injection;
4. SI changes in adjacent bone;
5. presence and characteristics of adjacent soft tissue masses.

In two cases, repeat MRI of the spine was available 12 and 15 months after successful surgical excision of the lesion.

Histology of the tumour was available for review in all cases. An attempt was made to grade various aspects of the lesion subjectively as being minor, moderate or major features. These included tumour osteoid formation, matrix mineralisation and tumour vascularity. The former two were also defined as being either focal or diffuse. In addition, tissue was available for histological examination from areas of altered SI in bone marrow (12 cases) and soft tissue (8 cases) adjacent to the tumour.

Results

There were seven males and four females with a mean age of 19.5 years and age range of 8–43 years. All patients presented with focal back pain lasting between 7 and 36 months. The plain radiographic (Figs. 2A, 3A, 4A), scintigraphic (Fig. 1A) and CT features (Figs. 1E, 2B) were considered typical of osteoblastoma in all cases. The tumours ranged from 12 to 30 mm in size. Table 1 documents the relevant clinical and CT features.

The MRI features are documented in Table 2. The SI of the lesion was variable on T1- and T2-weighted sequences (Figs. 1B–D, 2C, 3B, 4B,C). The presence of low SI of the tumour did not always correlate with a heavily mineralised lesion (Fig. 1B–D). Tumour mineralisation appeared as focal punctate areas of signal void (Fig. 3B) except in one case where it appeared hyperintense on T1-weighted images. In four cases MRI did not identify matrix mineralisation (Figs. 1B–D, 4B,C).

Table 2 MRI features of 12 osteoblastomas [*LowT1* low signal intenstiy (SI) on T1-weighted images, *HighT2* high SI on T2-weighted images]

Case no	Tumour SI		Calcification identified	Tumour enhancement	Adjacent bone marrow changes	Adjacent soft tissue mass
	T1	T2				
1	Intermediate	High	No	N/A	LowT1+HighT2 T1–T4 vertebrae	R. anterior mass. High SI on T2
2	High	High	Yes	N/A	LowT1+LowT2 adjacent pedicle	Nil
2a	Intermediate	High	Yes	Uniform	LowT1+HighT2 T10–T11 vertebrae enhancement	Enhancing extradural and paravertebral mass
3	Low	Low	No	Patchy	LowT1+HighT2 T7–T9 Vertebrae enhancement	R. anterolateral mass from T5-T10
4	Intermediate	Low	No	Uniform	LowT1+HighT2 in adjacent vertebra with enhancement	Enhancing R. L4/5 foraminal mass
5	Intermediate	Low	Yes	N/A	Nil	L. C4/5 foraminal mass
6	Intermediate	Intermediate	Yes	N/A	Nil	Nil
7	Low	Mixed	Yes	Patchy	LowT1+HighT2 in vertebra	Nil
8	Intermediate	Intermediate	Yes	N/A	LowT1+HighT2 in vertebra	Nil
9	Intermediate	Intermediate	Yes	N/A	LowT1+HighT2 in L4 and L5 neural arch	Nil
10	N/A	Low	Yes	N/A	High SI in C3, C4 and C5 vertebrae	Nil
11	Intermediate	High	No	Uniform	LowT1+HighT2 with enhancement	Nil

Abnormal signal intensity was seen in the adjacent vertebral body or neural arch marrow in 10 cases, and in five of these, changes were seen at levels other than the vertebral level of the tumour (Fig. 1B,C). Paravertebral or extradural soft tissue masses were present in five cases (Figs. 1B–D, 2C). In the two cases re-imaged following successful tumour excision, the reactive bone marrow and soft tissue changes had resolved (Fig. 1F).

The histological findings are documented in Table 3. All lesions showed varying degrees of matrix mineralisation, in keeping with the CT findings. Those lesions showing diffuse osteoid production (Fig. 1G) all had intermediate to low SI on T2-weighted sequences. Six lesions showed focal osteoid production (Fig. 4D). Four of these had high SI on T2-weighted sequences (Fig. 4C) while the other two cases had intermediate SI on T2-weighted sequences but diffuse mineralisation. All tumours showed a varying degree of vascularity. This was manifest on MRI by tumour enhancement in all the cases for which Gd-DTPA was given (Figs. 1B, 2C, 4B).

Histological findings in areas of altered marrow and soft tissue SI consisted of either reactive new bone formation or inflammation manifest as vascularised fibrous tissue with a perivascular infiltrate of lymphocytes and plasma cells.

Discussion

The first MRI report of a vertebral osteoblastoma was published in 1987 [6]. Since that time we have found only 11 other cases of spinal osteoblastoma, excluding sacral tumours, for which the MRI features have been reported [5, 7–13]. As with most tumours, the lesion is usually described as being hypointense on T1-weighted sequences and hyperintense on T2-weighted sequences [6, 9, 11, 13]. These tumours tended to be mainly lytic on CT with little evidence of matrix mineralisation. Depending on the degree of tumour matrix mineralisation, T2-weighted sequences may show areas of mixed low and high SI or may be mainly of low SI [5, 8]. Nguyen et al. [10] described an interesting case in which the tumour had homogeneous low SI on both T1- and T2-weighted SE MRI and CT demonstrated a homogeneously dense tumor. The his-

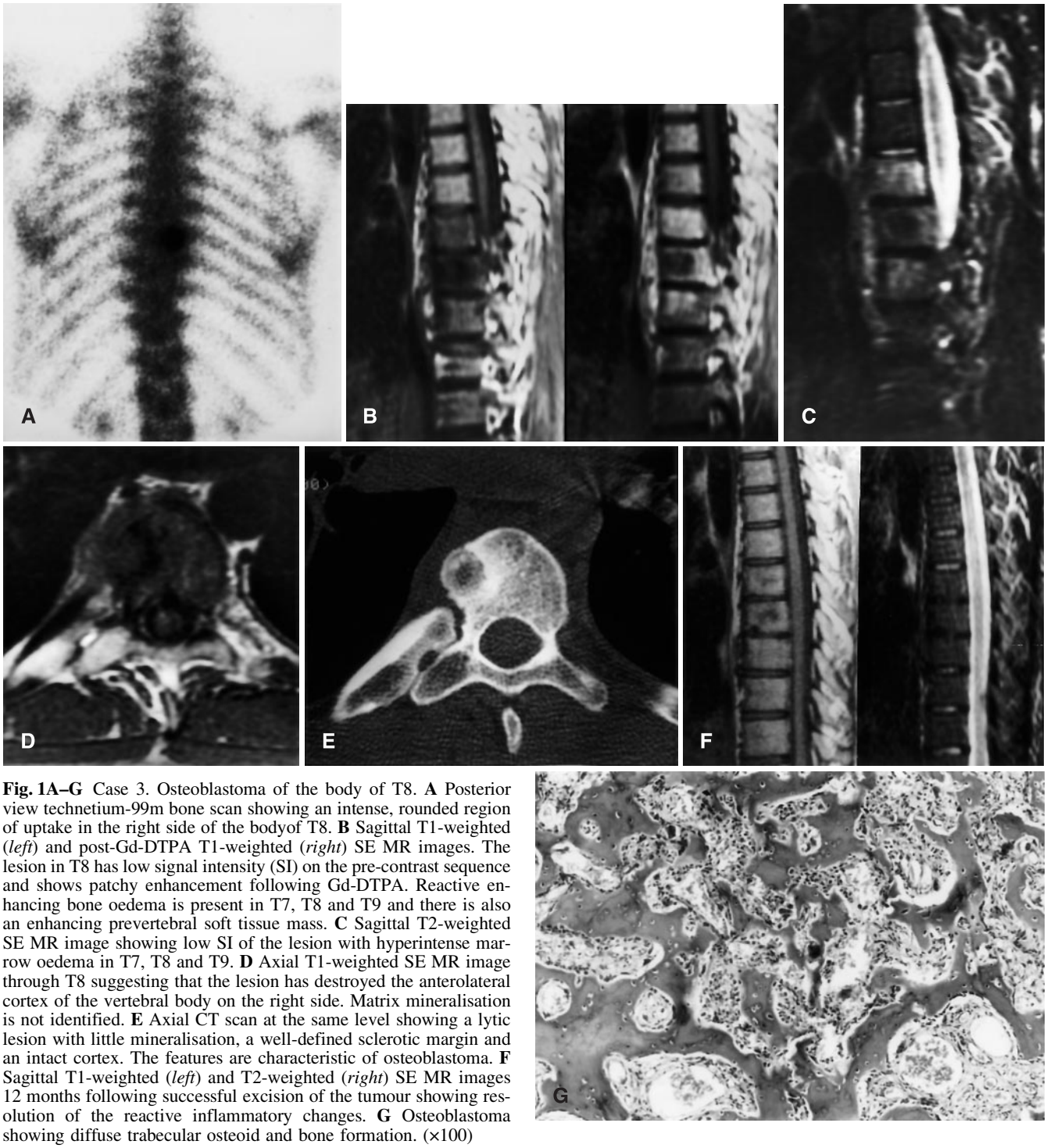
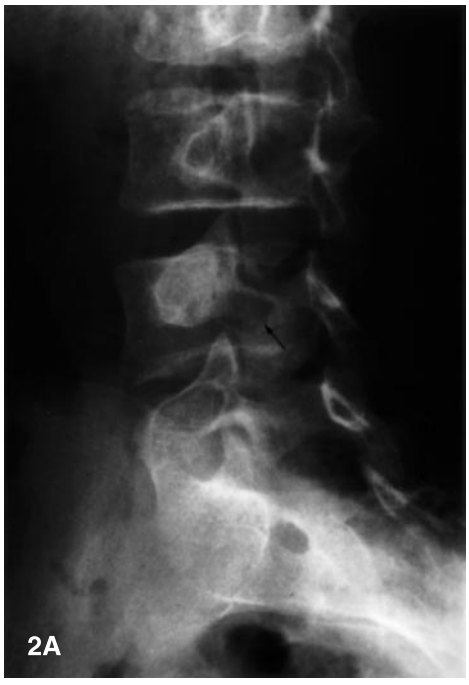
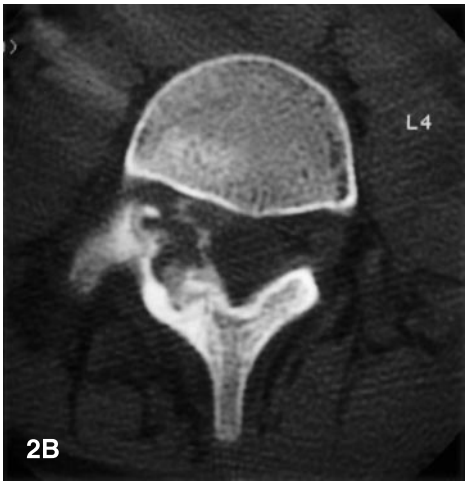


Fig. 1A–G Case 3. Osteoblastoma of the body of T8. **A** Posterior view technetium-99m bone scan showing an intense, rounded region of uptake in the right side of the bodyof T8. **B** Sagittal T1-weighted (*left*) and post-Gd-DTPA T1-weighted (*right*) SE MR images. The lesion in T8 has low signal intensity (SI) on the pre-contrast sequence and shows patchy enhancement following Gd-DTPA. Reactive enhancing bone oedema is present in T7, T8 and T9 and there is also an enhancing prevertebral soft tissue mass. **C** Sagittal T2-weighted SE MR image showing low SI of the lesion with hyperintense marrow oedema in T7, T8 and T9. **D** Axial T1-weighted SE MR image through T8 suggesting that the lesion has destroyed the anterolateral cortex of the vertebral body on the right side. Matrix mineralisation is not identified. **E** Axial CT scan at the same level showing a lytic lesion with little mineralisation, a well-defined sclerotic margin and an intact cortex. The features are characteristic of osteoblastoma. **F** Sagittal T1-weighted (*left*) and T2-weighted (*right*) SE MR images 12 months following successful excision of the tumour showing resolution of the reactive inflammatory changes. **G** Osteoblastoma showing diffuse trabecular osteoid and bone formation. (×100)

tological features were felt to be consistent with a mature osteoblastoma. Enhancement of the tumour following intravenous Gd-DTPA has also been documented, in keeping with the vascular nature of the lesion [11, 12].

The MRI features in the present study are somewhat different from those published previously. Four of the tumours (cases 1, 3, 4 and 7) were mainly lytic with only little matrix mineralisation. However, two of these still had low SI on T2-weighted SE sequences. Three other cases had intermediate SI on T2-weighted sequences. All lesions showing little to moderate matrix mineralisation but still having intermediate to low SI





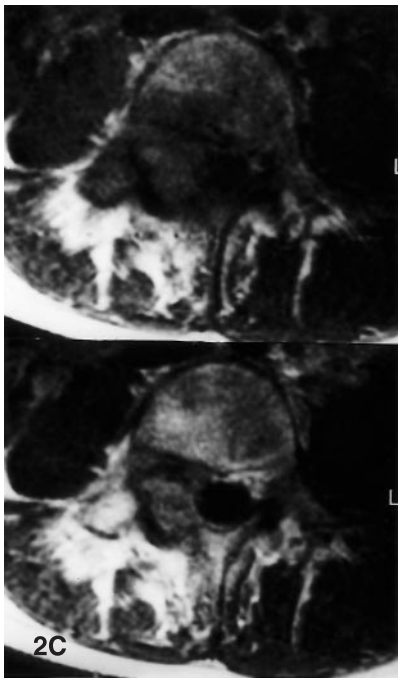
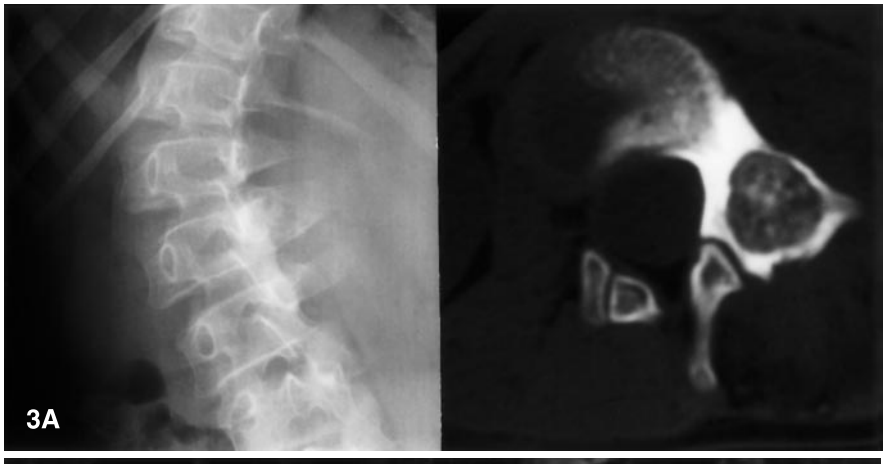


Fig. 2A–C Case 4. Osteoblastoma of the right lamina of L4. **A** Lateral oblique radiograph demonstrates the predominantly lytic lesion in the lamina (*arrow*) with reactive sclerosis and enlargement of the adjacent pedicle. **B** Axial CT scan through L4 showing the minimally mineralised lesion in the right L4 lamina. There is extension through the anterior cortex of the lamina and an extraosseous tumour mass in the right L4/5 lateral recess and neural foramen. **C** Axial T1-weighted (*top*) and post-Gd-DTPA T1-weighted (*bottom*) SE MR images at the same level. The tumour has intermediate SI on T1-weighted sequences and shows patchy enhancement following Gd-DTPA. The break through the cortex is demonstrated but the matrix mineralisation is not identified. Marrow changes are present in the posterolateral aspect of the vertebral body on the right



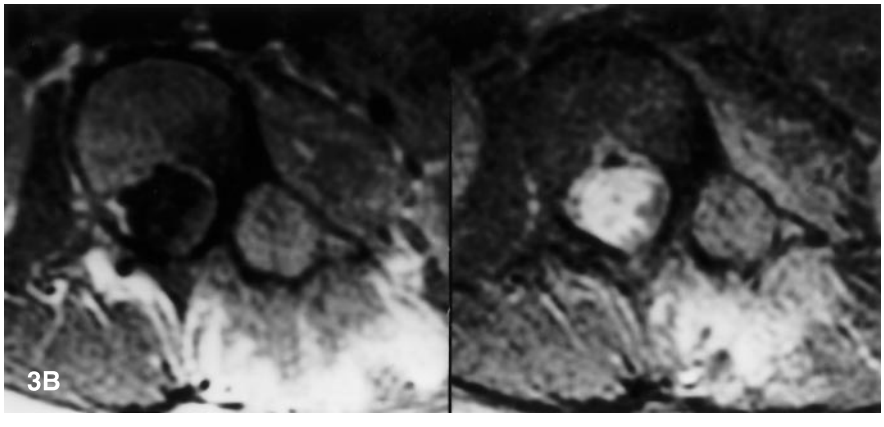


Fig. 3A, B Case 8. Osteoblastoma of the left transverse process of L2. **A** Anteroposterior radiograph (*left*) and CT scan (*right*) show the moderately mineralised lesion within the expanded left transverse process of L2. **B** Axial T1-weighted (*left*) and T2-weighted (*right*) SE MR images through L2. The lesion is of intermediate SI on both sequences and the mineralisation appears as multiple areas of signal void. Sclerosis in the left pedicle of T10 appears as low SI on both T1-weighted and T2-weighted sequences

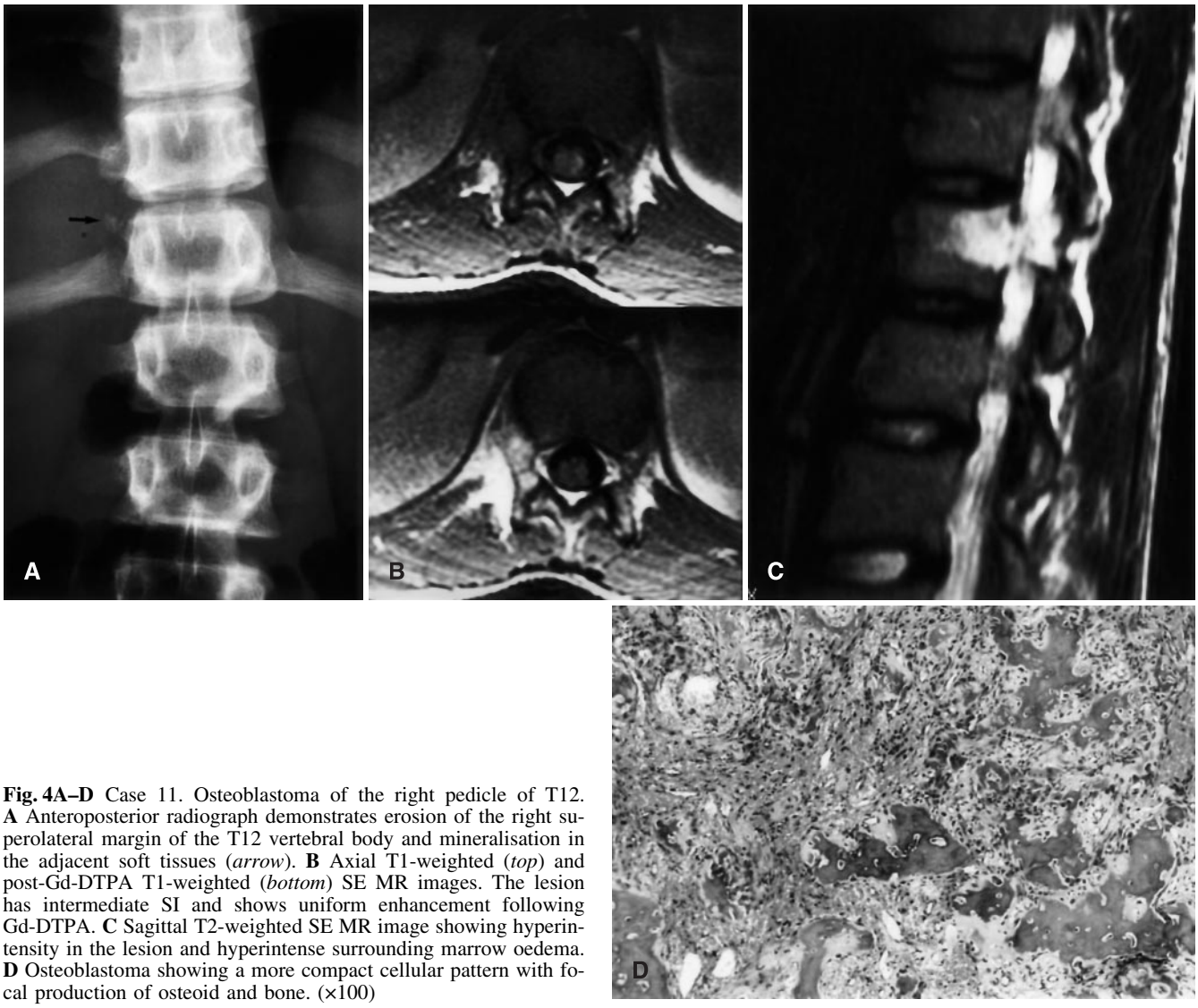


Fig. 4A–D Case 11. Osteoblastoma of the right pedicle of T12. **A** Anteroposterior radiograph demonstrates erosion of the right superolateral margin of the T12 vertebral body and mineralisation in the adjacent soft tissues (*arrow*). **B** Axial T1-weighted (*top*) and post-Gd-DTPA T1-weighted (*bottom*) SE MR images. The lesion has intermediate SI and shows uniform enhancement following Gd-DTPA. **C** Sagittal T2-weighted SE MR image showing hyperintensity in the lesion and hyperintense surrounding marrow oedema. **D** Osteoblastoma showing a more compact cellular pattern with focal production of osteoid and bone. (×100)

on T2-weighted sequences showed evidence of diffuse osteoid production histologically. Unmineralised osteoid would be expected to show signal characteristics similar to fibrosis due to the lack of mobile protons. All the tumours showing heavy matrix mineralisation (cases 5, 6 and 10) had predominantly low SI on T1- and T2-weighted SE sequences or showed extensive areas of signal void. However, one case was unusual in that the mineralisation was relatively hyperintense on the T1-weighted SE sequences, which may be due to medullary spaces being formed within dense tumour bone formation (J.A.S. Pringle, personal observation), but this was not confirmed on histological examinationy. High SI calcification on T1-weighted SE sequences has also been reported in the intervertebral discs of patients with degenerative disc disease [14], which could be another explanation for the observed signal change. This is thought to be related to the structure of the calcium crystal, with those crystals having a relatively large surface area being associated with shortening of the T1 relaxation time.

In case 2 the tumour matrix was relatively hyperintense on both T1- and T2-weighted GE sequences, which may be related to the low field strength (0.2 T) and the gradient echo sequences performed. Water-containing tissues, such as the intervertebral disc, can be relatively hyperintense on low field strength gradient echo images. This patient suffered a local recurrence, and on re-imaging at 0.5 T with spin echo sequences, the more typical intermediate signal intensity on T1-weighted sequences and hyperintensity on T2-weighted sequences was demonstrated. All tumours enhanced following the administration of Gd-DTPA, as would be expected from the vascular nature of the lesion.

Table 3 Histological features of spinal ostoeblastomas (+/–=minor, +=moderate, ++=major , *F* focal, *D* diffuse)

Case no	Osteoid formation	Matrix mineralisation	Vascularity	Bone reaction	Soft tissue reaction
1	F+	D++	++	+	++
2	F+	D++	++	++	+
2a	F+	F++	+	+	Nil
3	D+	F+	++	++	++
4	D+	F++	++	+	+/–
5	D+/–	D++	+	++	++
6	F+/–	D+	+	+	+
7	D++	D+	+/–	+	Nil
8	F+	D++	+	+	Nil
9	D+/–	D+	+	++	Nil
10	D+	D++	+/–	++	++
11	F+	F+	+	+	+

Reactive sclerosis on plain radiographs is a common feature adjacent to the lesion [2]. MRI may demonstrate low SI on both T1- and T2-weighted sequences in bone marrow consistent with sclerosis, but low SI on T1-weighted sequences and high SI on T2-weighted sequences due to bone marrow oedema has also been described [7], which may involve adjacent vertebrae and soft tissues. Biopsy of the soft tissues performed in this case [7] revealed only non-specific inflammatory changes and, in this case, the tumour was only identified on CT. These authors [7] warned of the misleading appearances that may occur with MRI, due to adjacent inflammatory changes. The present study indicates that reactive changes in the vertebral body adjacent to an osteoblastoma were seen in 10 of 12 cases; this was commonly marrow oedema, which often showed enhancement following Gd-DTPA. Histological changes included increased fibrovascular tissue within the marrow and a perivascular infiltrate of lymphocytes and plasma cells. The MRI changes are non-specific, however, having been described with a wide variety of both benign and malignant lesions [15], and are thought to be due to prostaglandin production by the tumour cells [16]. In the two cases where repeat MRI was available following successful surgical resection of the tumour, reactive marrow changes were no longer identified. Although it is true that these changes are not evident on CT, this cannot be seen as representing an advantage of MRI over CT since it may reduce the clarity with which the tumour margins are identified, resulting in a greater than necessary resection of bone.

It was also not uncommon to find reactive changes at more than one vertebral level. Multilevel reactive sclerosis on radiography and CT has been reported in relation to spinal osteoid osteomas [17] and osteoblastomas [18], and the multilevel changes seen on MRI in the present cases represent a similar phenomenon.

A paravertebral soft tissue mass was identified in five cases. Reactive soft tissue masses have been described with osteoid osteomas [19] but, because of the different growth behaviour of osteoblastoma, adjacent soft tissue masses cannot be assumed to be reactive or inflammatory in nature, as the extraosseous soft tissue proved to be tumour at surgical exploration in two of our cases. CT proved valuable by showing clear cortical destruction, whereas in those patients with soft tissue masses that were shown to be inflammatory, the tumour had not broken through the cortex on CT. The demonstration of cortical destruction is clearer on CT compared with MRI, as is the identification of matrix mineralisation [20]. Therefore, we suggest that CT is superior to MRI, both in the characterisation of the tumour and in the accuracy of local staging.

However, MRI is the investigation of choice in patients with low back and radicular pain or with signs of cord compression – both situations that can occur with spinal osteoblastoma. It is important, therefore, to be aware of the variety of MRI features associated with this tumour.

In summary, the MRI features of 11 patients with spinal osteoblastoma are described. The variability of appearance of the tumour and adjacent reactive bone and soft tissue changes would suggest that MRI is of limited value in the characterisation and local staging of this lesion.

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