IMAGING OF INTRAMEDULLARY TUMOUR SPREAD IN OSTEOSARCOMA

A COMPARISON OF TECHNIQUES

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The level of bone resection for osteosarcoma depends on the pre-operative evaluation of the extent of intramedullary tumour. We compared the accuracy of magnetic resonance imaging (MRI), computerised tomography (CT), and isotope bone scanning with the actual extent of the tumour in the resected specimens from 34 patients with primary osteosarcoma of a long bone.

The extent of medullary tumour was defined accurately in 23 of 24 MRI scans (96%) and 24 of 32 CT scans (75%). A flexion contracture of a joint close to the tumour was an important cause for inaccurate measurements from both MRI and CT scans. Isotope bone scanning was inaccurate: its role is now confined to detecting skeletal metastases and skip lesions.

Amputation was the traditional definitive treatment for osteosarcoma, but recent advances in chemotherapy, imaging and reconstructive surgery have made limb salvage a valid alternative for most patients (Simon et al 1986). The level of bone resection in such cases is based on a pre-operative assessment of extent of intramedullary tumour. Accurate measurement is crucial, since marginal or intralesional resection of the tumour will give a high incidence of local recurrence (Simon et al 1986). Until recently these measurements were made from radio-isotope scans and computerised tomography (Lane et al 1986), but they have now been supplemented by magnetic resonance imaging (MRI).

Early reports of the value of MRI in patients with primary bone tumours were promising (Aisen et al 1986). The ability to obtain images in any plane, and the high level of soft-tissue contrast are important advantages

Table I. Sites of 34 osteosarcomas

	Number
Proximal femur	1
Distal femur	17
Proximal tibia	12
Distal tibia	1
Proximal fibula	1
Proximal humerus	1
Distal humerus	1

especially in the assessment of bone marrow involvement (Volger and Murphy 1988).

We have evaluated the accuracy of MRI and other imaging methods in determining the extent of intramedullary tumour in patients with osteosarcoma.

PATIENTS AND METHODS

We treated 39 patients for osteosarcoma from October 1985 to March 1989. Imaging studies and resected specimens were available for comparison in 34 patients, all with primary tumours of long bones (Fig. 1a), 29 of which were around the knee (Table I). There were 21 males and 13 females; their ages ranged from six to 49 years (mean 16.8).

Imaging methods. All patients had standard isotope bone scans using ^{99m}Tc , and CT scans of both limbs using a Somatom DR2 (Siemens, Dublin, Ireland). Contiguous

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0301-620X/91/6246 \$2.00
J Bone Joint Surg [Br] 1991; 73-B: 998-1001.

transaxial 5 mm sections were made from a level of at least 5 cm distal to the tumour to 10 cm proximal to the furthest extent of marrow infiltration by tumour. Twenty-five of the patients also had MRI examinations.

We used a Magnetom 1.5 superconducting magnet system operating at 63 MHz (Siemens AG, Erlangen, Germany) performing T1- and T2-weighted spin echo (SE) pulse sequences. The T1-weighted images were obtained with an echo time (TE) of 17 ms, repetition time (TR) of 400 to 600 ms, 5 mm slice thickness and two excitations. The T2-weighted and spin-density images were obtained with dual echo TE 30 and 90 ms, TR of 2000 ms and one excitation. Multiplaner images were obtained to correlate the level of tumour involvement.

adjacent joint line (Fig. 1d). Curette specimens were taken at the upper and lower limits of the tumour and examined to determine the histological extent of the tumour.

We regarded imaging measurements as accurate if they were within 1 cm of the specimen measurement.

RESULTS

The detailed results are given in Table II. Of the 25 patients assessed by MRI, one was excluded because only straight sagittal views were possible; fixed flexion of the knee prevented other views being taken. MRI accurately predicted tumour extent in 23 of 24 cases (96%).

Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1d

Osteosarcoma of the distal femur. Figure 1a – Radiograph showing typical radiological features. Figure 1b – On MRI, the coronal T1-weighted image clearly demonstrates the extent of the marrow infiltration. Distally the tumour is bounded by the epiphysis. Proximally there is an abrupt signal change at the interface between normal marrow and tumour. Figure 1c – The coronal T2-weighted image also shows the extent of the tumour. Marrow infiltration is not well shown, but the soft-tissue ossification and necrosis are better defined. Figure 1d – Section of the resected specimen showing the histologically proven extent of medullary tumour (arrow).

Intramedullary extent was determined for each method of imaging in each patient, measurements being taken from the joint margin of the involved bone to the furthest point of contiguous tumour infiltration. Tumour infiltration of the marrow on the CT scans was detected by comparing tissue attenuation between equivalent sections of both limbs. In the MRI scans we compared signal intensity profiles (Figs 1b,c). The MRI and CT scans were performed on the same day and all imaging was completed in the week before the operation.

After operation, the precise intramedullary extent of the tumour was determined from examination of the pathological specimen of either an en bloc resection, or an amputation where limb salvage was not possible. Each specimen was sectioned longitudinally and the extent of intramedullary tumour was measured from the

Of the 34 patients assessed by CT scans two were excluded, because adequate sections above and below the tumour were not taken. CT scans gave accurate predictions in 24 of 32 cases (75%).

The CT scans and MRI studies which had given inaccurate measurements were reviewed by a radiologist with no knowledge of the pathological findings. The only inaccurate MRI scan was of a patient with a flexed joint below the tumour: this had led to an underestimation of the extent of medullary infiltration.

Of the eight CT scans which were inaccurate, four underestimated and four overestimated the extent of tumour. Underestimation had occurred in two patients with a flexed joint immediately below the tumour and in two with large soft-tissue components immediately anterior to the bone at the level of marrow involvement.

Fig. 2a

Fig. 2b

Osteosarcoma of the distal femur. Figure 2a – Sagittal T1-weighted image. The marrow involvement and extent are well defined. The knee is not involved, but the soft-tissue component and the relationship to the neurovascular structures are not well defined. Figure 2b – In the axial T2-weighted image the soft tissue is well defined. The tumour is clearly margined except where there is direct muscle invasion, and the relationship to the neurovascular structures is well defined (arrow). As expected, the marrow component is poorly defined.

Although the soft-tissue spread was accurately defined, measurement of the marrow level was inaccurate due to a lack of tissue contrast.

Of the four CT scans with overestimation, three were inaccurate due to the lack of tissue contrast. The original estimate of tumour extent had erred on the side of caution. In the other patient, the CT scan had detected sclerosis of the cortical bone extending 26 cm proximal to the knee. The true intramedullary extension had been correctly measured at 18 cm on the MRI scan, but this did not detect the sclerosis seen on CT. The pathological findings were that the sclerotic area was free of tumour.

Tumour extent can only be determined from ^{99m}Tc -MDP scanning where the entire limb is displayed on a single film. Eleven scans taken early in the series fulfilled this criterion and, of these, seven were accurate. Later in the series, CT and MRI had clearly replaced isotope scans as a method of determining local extent, so no measurements were taken from subsequent isotope scans. However, other skeletal metastases were detected in four of the patients by this method, indicating stage III disease.

DISCUSSION

The improved survival of patients with osteosarcoma in the last decade can be attributed mainly to the advances in neo-adjuvantive and adjuvantive chemotherapy (Link et al 1986). With the further advances in imaging and in reconstructive surgery, limb salvage is now the definitive treatment for carefully selected patients.

Accurate localisation of the intramedullary extent

of the tumour is therefore increasingly important. Jaffe (1958) demonstrated that the limit of longitudinal advance of an osteosarcoma was generally demarcated by a dome-shaped plug within the medullary cavity. Modern imaging modalities can be used to determine the exact extent of this medullary plug, and thus to confidently define the level of bone resection required.

It is reported that ^{99m}Tc -MDP scanning tends to overestimate the extent of local tumour because it cannot differentiate hyperaemic osteoporosis from tumour (Bloem et al 1987). This was not a problem in our series,

Fig. 3

Osteosarcoma of the distal right femur; CT scans of the mid-shaft region of both legs. There is an area of altered attenuation in the marrow on the right at the proximal extent of the tumour (arrow). Gross muscle wasting is shown, particularly of the hamstrings.

Table II. Accuracy of MRI, CT and ^{99m}Tc -MDP scans in assessing the intramedullary extent of long-bone osteosarcomas

	Tumours imaged	Scans measured	Accurate		Estimate	
			Number	Per cent	Over	Under
MRI	25	24	23	96	0	1
CT	34	32	24	75	4	4
MDP scan	34	11	7	64	1	3

but localisation was not very accurate: in one case, tumour extent was significantly underestimated. Its main role is confined to the detection of skeletal metastases and of skip lesions within the bone.

MRI provides the best evaluation of bone marrow and was extremely accurate in determining the level of termination of the tumour plug. The T1-weighted sequence was best for determining marrow involvement and clearly indicating the tumour-marrow interface (see Fig. 1b). For soft-tissue extension, the T2-weighted sequence provided the high level of contrast needed between tumour and normal adjacent structures (Fig. 2). In one patient, however, MRI underestimated the extent of the tumour because fixed flexion of the joint below the tumour made it impossible to image along the axis; both coronal and axial sections were subject to volume averaging.

CT depicted tumour tissue as an area of altered attenuation (Fig. 3), but it was less sensitive than MRI in distinguishing normal tissue from tumour tissue with errors due to this in five cases. In both CT and MRI a flexed joint appeared to be a cause for the underestimation of tumour extent, and this may be important in leading to inadequate bone resection.

The patient with sclerosis of femoral bone proximal to the medullary tumour presented difficulties. Histological examination of the resected specimen, showed that the CT scan had accurately demonstrated the sclerosis,

confirming the superiority of CT over MRI in demonstrating cortical abnormalities (Boyko et al 1987). The sclerotic area was found to be tumour free, which meant that 8 cm of femoral shaft had been resected unnecessarily. However, we feel that it would have been unwise to have decided the resection level on the findings of MRI alone. The presence of tumour-free sclerosis proximal to an osteosarcoma has not previously been reported.

Conclusions. We believe that, in patients with osteosarcomas, soft-tissue extension and bone marrow involvement are best demonstrated by MRI. Measurements may be inaccurate in patients who cannot straighten the affected limb, or who are unable to remain still during the scan. However, MRI techniques will continue to improve, resulting in thinner sections, improved resolution and faster scan times. The tumour-tissue interface will be even more accurately depicted. When MRI is available it should be used in preference to CT scanning.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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