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Computed tomography analysis of bone tumors: patterns of cortical destruction and soft tissue extension*

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Abstract. Computed tomography was used to identify three different ways in which primary bone tumors may transgress a bony cortex. Analysis of the pattern of cortical transgression was used in conjunction with the presence or absence of matrix mineralization to classify correctly the lesion into one of four different diagnostic categories in 84% of 72 cases. These data demonstrate that certain types of behavior characterize the lesions under discussion and that this information may be helpful in diagnosis.

The superb density discrimination of computed tomography (CT) has been exploited in every organ system of the body. In the musculoskeletal system, CT has been used to accurately demonstrate the location, extent, and surrounding relationships of primary osseous neoplasms [3, 6]. With the possible exception of magnetic resonance imaging (MRI), it is the single most useful imaging modality in delineating associated soft tissue masses, and has also proven to be helpful in evaluating "skip metastases" and other metastatic lesions to bone [1, 7]. The appraisal of intramedullary extension of disease can not be made by any other conventional imaging technique [2], although magnetic resonance imaging shows considerable promise.

Despite the unchallenged usefulness of CT for these purposes, many authors consider it to be of little value in arriving at a histologic diagnosis [3, 6]. The present study was undertaken to determine whether this perception is justified. Since the basic criteria for diagnosis of bone lesions by conventional radiography are well-established [4], and since radiographs are usually obtained prior to CT, it appeared possible that important diagnostic information in the CT scan was being overlooked.

The cross-sectional display format of CT is particularly well suited to evaluate the way in which osseous neoplasms penetrate the bony cortex. Several discrete patterns can be observed. We have studied the relationship of these patterns to the diagnosis and to the tumor grade where appropriate, and have investigated our ability to use this information in determining the diagnosis from the CT scans alone, without knowledge of the findings of conventional radiography.

Material and methods

Eighty-five consecutive cases were collected in each of four diagnostic categories: (1) giant cell tumor (GCT), (2) chondrosarcoma, (3) osteogenic sarcoma (OGS), and (4) round cell tumors (Ewing sarcoma, lymphoma). Thirteen cases were excluded because of incomplete or technically unsatisfactory studies. The 72 remaining cases included 23 giant cell tumors, 15 chondrosarcomas, 22 osteogenic sarcomas, and 12 round cell lesions. There were 31 males and 42 females ranging in age from 6–80 years.

Radiographs and CT scans were separated from each other by one of the authors (DIR) and numerically coded. The coded CT scans were then reviewed by the two authors who were unaware of the diagnoses and of the plain film findings. The location of the lesion, its size and pattern of cortical transgression were noted. The pattern of cortical transgression was classified into one of three morphologic categories (Fig. 1). Type 1 lesions were those in which the cortex was remodelled around an expanding lesion by means of periosteal new bone formation giving the appearance of being pushed or expanded. Focal defects in mineralization were allowed if they appeared to be part of the generalized process of cortical attenuation. Type 2 lesions revealed a clear localized cortical discontinuity, with tumor ex-

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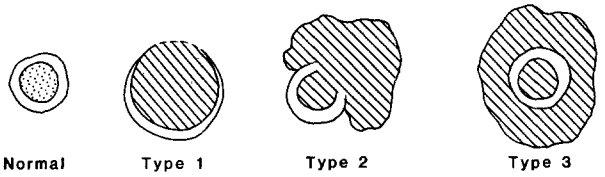

Fig. 1. Three morphologic types of cortical transgression; Type 1, expanded or "pushed" cortex; type 2, "buttonhole" pattern with a focal cortical defect and asymmetric soft tissue mass; and type 3, "permeative pattern" with symmetric soft tissue mass and the appearance of an intact cortex

tending through the defect into the soft tissues while the majority of the cortex was intact. This resulted in an eccentrically placed soft tissue component of the lesion. Type 3 lesions demonstrated tumor within the soft tissues despite the appearance of a grossly intact cortex. These lesions generally exhibited symmetrical tumor around the bone.

Using this information, plus the location of the lesion and the presence of recognizable tumor matrix, a diagnosis was reached, based upon CT findings alone. The scans were then matched with the coded radiographs, and any alteration in findings or diagnosis was recorded. This result was compared with the proven pathologic diagnosis. In addition, in the case of chondrosarcomas, the histologic grade (when available) was compared to the radiologic findings.

Results

Twenty of 23 giant cell tumors (Fig. 2) were classified as type 1 lesions by CT. The other three were placed within type 2. No type 3 lesions were seen among the giant cell tumors (Table 1). All of these lesions were correctly diagnosed on the basis of the CT alone, and only one other lesion (a low grade chondrosarcoma) was incorrectly classified among the giant cell tumors.

Chondrosarcomas were distributed relatively evenly among the three types of cortical transgression patterns (Table 1). There were four type 1, five type 2 (Fig. 3), and six type 3 lesions. There was a strong correlation between the histologic grade and the pattern of cortical permeation (Table 2). Tumors arising in pre-existing lesions tended to be assigned a more aggressive CT margin than was warranted by the histologic grade. Twelve of 15 chondrosarcomas were correctly diagnosed on the basis of the CT appearance alone. Of the three misdiagnoses, two in retrospect were seen to be errors of interpretation, one being due to artifact from orthopedic hardware. The third misdiagnosis was a dedifferentiated chondrosarcoma which was misdiagnosed as a round cell lesion.

Twenty of 22 osteogenic sarcomas demonstrated type 3 patterns of cortical breakthrough (Fig. 4). The other two exhibited "buttonhole" (type 2) and "expanded" (type 1) patterns respectively (Table 1), and were both incorrectly diagnosed as chondrosarcomas. Of the 20 OGS within type 3, 19 were correctly diagnosed by CT alone, the remaining case was thought to represent a round cell lesion. Eleven of 12 round cell tumors displayed type 3 margins (Fig. 4). Ten of these were correctly diagnosed from CT. It was not possible to distinguish Ewing tumor from lymphoma on CT morphology alone. There was close agreement between the type of CT pattern and the plain film bone/tumor margin when classified according to the system of Lodwick et al. [5] (Table 3).

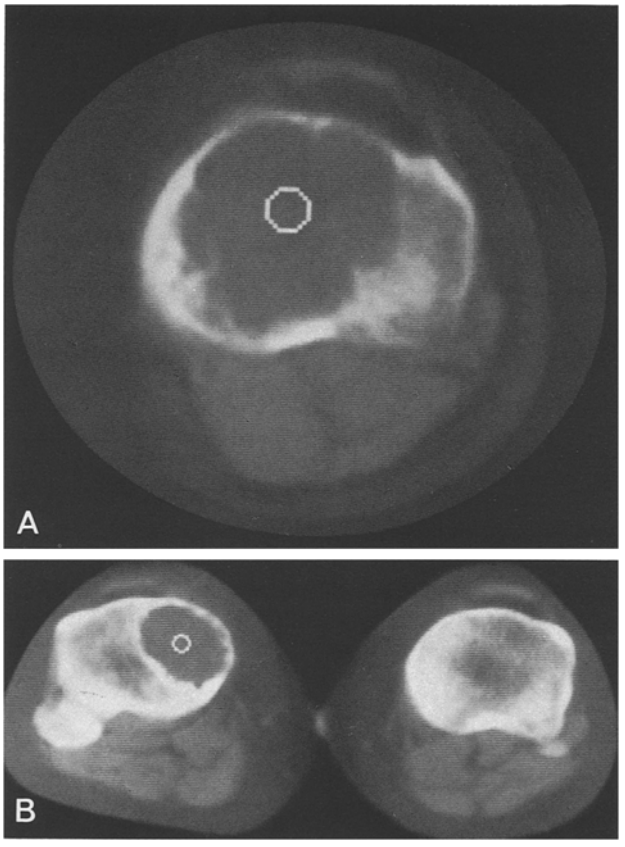

Fig. 2. Two representative giant cell tumors exhibiting type 1 pattern of cortical transgression, **A** occurring in proximal tibia of 50-year-old female, **B** another proximal tibial lesion in a 30-year-old female

Table 1. Patterns of cortical transgression

Diagnosis	Type 1	Type 2	Type 3
GCT	20	3	0
Chondrosarcoma	4	5	6
OGS	1	1	20
Round cell	1	0	11

Distribution of patterns of cortical transgression relative to diagnostic category

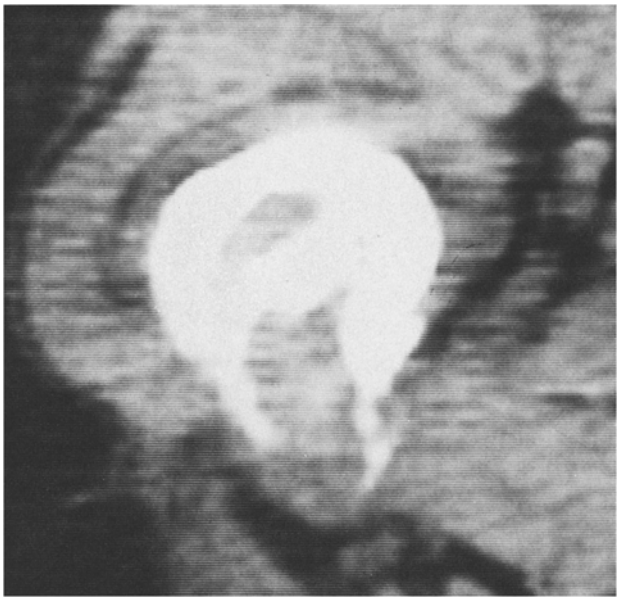

Fig. 3. Typical type 2 pattern of cortical transgression exhibited by a low grade chondrosarcoma in a 44-year-old female. Note the focal cortical defect

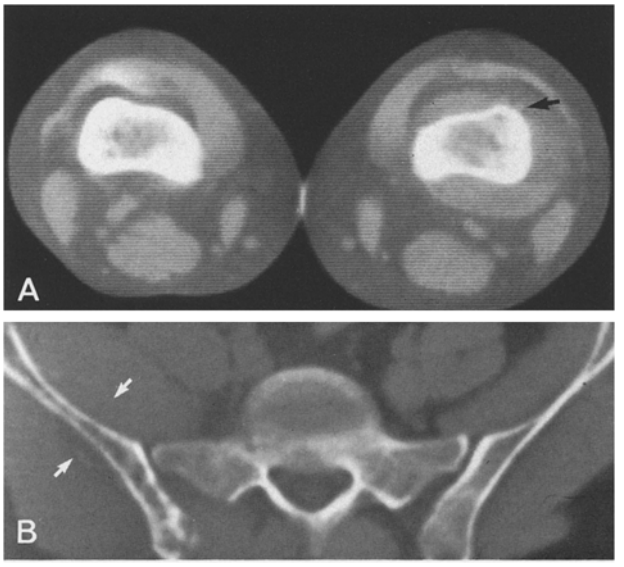

Fig. 4. Two examples of the type 3 pattern of cortical transgression. **A** An osteogenic sarcoma in the distal femur of a 14-year-old female. Soft tissue mineralization is faintly visible (*arrow*). **B** A Ewing sarcoma in a 19-year-old male. Tumor is visible both posteriorly and anteriorly (*arrows*) despite grossly intact cortex

Table 2. Chondrosarcomas

	Type 1	Type 2	Type 3
Grade I	3	1	1
Grade II	0	3	0
Grade ≥ III	0	1	3

Chondrosarcomas as classified according to pattern of cortical transgression and histologic grade; a strong correlation is evident

Table 3. Plain film margin

CT Pattern	IA	IB	IC	II	III
Type 1	2	18	4	0	2
Type 2	1	3	5	0	1
Type 3	0	1	1	7	29

The CT pattern of cortical transgression appears to be of predictive value in assessing tumor aggressiveness, as reflected by the correlation with the plain film bone/tumor margin

Table 4. Actual diagnosis

CT Diagnosis	Ewings/ Lymphoma	GCT	Chondro- sarcoma	OGS
Ewings/Lymphoma	10	0	1	1
GCT	0	23	1	0
Chondrosarcoma	0	0	12	2
OGS	1	0	1	19

Overall accuracy indistinguishing between the four diagnostic categories examined was 84%

Discussion

Contrary to several opinions expressed in the literature, it is our experience that computed tomography is useful for the diagnosis of bone lesions. Our overall accuracy was 84% (64/72) in distinguishing among these four entities (Table 4). In only three instances did addition of conventional radiographs alter the diagnostic impression reached by review of the CT alone.

The pattern of cortical transgression is an extremely useful piece of information available on the CT scan. Lodwick et al. [5] and others [8] have shown that analysis of the tumor/bone margin on plain films is the single most important piece of information in determining the rate of growth and hence the histologic grade of lesions from the radiographs. Our present findings confirm this impression. Both types of margin analysis appear to predict the degree of invasiveness of the lesion.

The diagnosis made by computed tomography was inferred from the pattern of cortical transgression plus the presence or absence of mineral content. From CT alone, it was frequently impossible to identify the mineralization as being cartilaginous or osseous in type. Type 1 lesions without mineralization characterize giant cell tumors (Fig. 2). Type 1 or type 2 lesions with mineralization were generally chondrosarcomas (Fig. 3). Type 3 lesions with mineralization were classified

as osteogenic sarcomas and type 3 lesions without mineralization were called round cell lesions (Fig. 4). When the plain films improved the diagnostic accuracy, it was generally because of the improved recognition of a pathologic fracture which was not apparent on the CT scan or by identification of a characteristic periosteal response. We had considerable difficulty in accurately categorizing periosteal response on CT.

It is clear that the ability to classify a lesion into one of four diagnostic categories as demonstrated here is an artificial situation. For the truly unknown lesion, a much broader range of diagnostic possibilities must be entertained, and consequently diagnostic accuracy is likely to be reduced. However, within the context of this trial the diagnostic utility of computed tomography is considerable. We also believe that the CT scan provides useful information regarding the patterns of growth which distinguish these four lesions.

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