Specific mechanism of the knee joint preventing tumor invasion

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Tumor extension from the anterior aspect of the distal femur into the knee joint was examined histologically and with MRI in 10 patients with primary malignancy of bone. Histologically, 1 tumor had invaded the joint with destruction of the transitional area between the articular cartilage and bone. In another case, the transitional area had been destroyed by mechanical traction of the periosteum by the tumor without invasion. The fatty connective tissue and superficial synovial layer were detached from the femoral cortex and elevated upwards by tumor growth without destruction in 7 tumors but were unchanged in 3 tumors. Tl-weighted MRI clearly revealed high signal intensity of the connective tissue and synovium in the 7 tumors with elevation. The average elevation of this detachment of the fatty connective tissue and synovium from the femoral cortex calculated from MR images was 12 mm. Destruction of the transitional area between the articular cartilage and bone was detected in 2 tumors on Tl-weighted MR images. Our results indicate that fatty connective tissue and the superficial synovial layer are easily detached and elevated by tumors. This mechanism probably prevents tumor extension into the joint space.

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When primary malignant bone tumors of the distal femur destroy the anterior cortex and periosteum, only a weak structure consisting of fatty connective tissue and the superficial synovial cell layer remains separating the joint space from tumor tissue. Because we believe that this structure represents an insufficient tissue barrier to tumor invasion into the joint space, it is our policy in such cases to operate without opening the joint space, just as in cases with joint invasion. However, we have encountered very few cases in which the tumor had actually invaded the joint space. To understand the mechanisms preventing tumor invasion into the joint space, we examined the anterior part of the distal femur and femoral part of the joint capsule histologically and with MRI.

Material and methods

We selected 10 of the patients with primary malignant bone tumors of the distal femur who were operated on at our hospital during the last 5 years according to the two criteria: (1) Radiography had disclosed bony changes in the anterior part of the distal femur facing the joint capsule of the knee; (2) Pathological specimens of the anterior part of the distal femur and knee joint which included bone, fatty connective tissue, and the superficial synovial layer of at least the sagittal plane were available (Table 1). There were 9 osteosarcomas and 1 chondrosarcoma. Amputation was performed in 3 patients (Disarticulation Group); the tumor and the extensor mechanism of the knee, includ-

Table 1. Observations in 10 patients with primary malignant bone tumor of the distal femur

A	B	C	D	E	F	G	H	I	J	K
1	26	m	E	–	+	+	2	+	+	10
2	18	f	E	–	–	–	1	–	?	–
3	57	f	E	–	+	–	2	–	–	5
4	61	m	I	–	–	–	1	–	–	–
5	18	f	I	–	–	–	1	–	–	–
6	34	m	I	+	+	–	2	–	–	7
7	15	f	I	+	+	–	2	–	–	–
8	17	m	D	+	+	–	2	–	–	10
9	18	m	D	+	+	+	3	+	+	17
10	12	f	D	+	+	–	2	–	–	20

A Case
B Age
C Sex
D Type of operation
E extracapsular
I intracapsular
D disarticulation
E Metastases
Pathology
F Elevation of soft tissue
G Disruption at transitional area
H Extent of tumor
1 cortical
2 subperiosteal
3 intraarticular
MRI examination
I Interruption of soft tissue HSI
J Disruption at transitional area
K Soft tissue elevation, mm

ing the patella, patellar ligament, and joint capsule, were resected without opening the knee joint in 3 (Extra-capsular Group); in the remaining 4, the knee joint was opened by the medial parapatellar approach, and the extensor mechanism was preserved with reconstruction by a method similar to that in total knee replacement (Intra-capsular Group). In the extra-capsular operation, only the skin, superficial layers of the retinaculum, neurovascular bundle, and posterior hamstring muscles were preserved after wide resection of the tumor tissue, followed by reconstruction with an artificial distal femur and knee joint supported by a knee brace, such as the Kotz modular type.

The average follow-up period after operation was 20 months. There was no local recurrence in any of the 10 patients, but all 3 patients in the Disarticulation Group and 1 in the Intra-capsul Group died of metastatic diseas Specimens from the knee joir were examined pathologically f elevation of fatty connective tiss and synovium, cortical and periosteal destruction, tumor invasion into the connective tissue, the superficial synovial layer and the joint space and site of tumor invasion into the joint. In addition, MR images—mostly sagittal—of these 10 knee joints were examined to determine whether the signal intensity of the fatty connective tissue and superficial synovial layer varied with the continuity of disruption by tumor invasion.

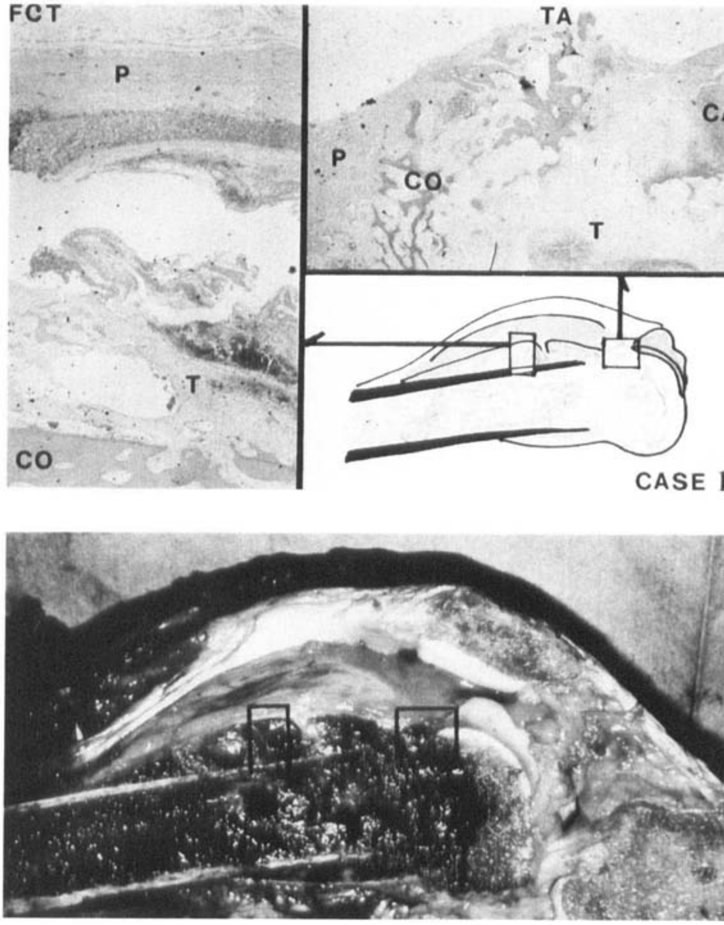

Figure 1. The transitional area between the articular cartilage (CA) and bone (CO) is thought to be the weakest part of the distal femur. The traction of the periosteum (P) induced by tumor (T) growth can easily destroy this area, allowing tumor extension into the joint (TA). FCT Fatty connective tissue.

Results

In Cases 1 and 9 the transitional area between the articular cartilage and the periosteum was destroyed; the tumor had reached the joint through the region of the transitional area, while in Case 1 no tumor cells were found in the destroyed transitional area, suggesting that the destruction was due to mechanical traction of the periosteum induced by the tumor (Figure 1). The fatty connective tissue and the superficial synovial layer were elevated by tumor growth in 7 joints and unchanged in 3. Tumor extension into the joint was detected in only 1 of the 7 joints with elevation (Table 1). T1-weighted MR images of 1 knee joint clearly revealed the high signal intensity of the fatty connective tissue and superficial synovium and the low signal intensity of the transitional area between the articular cartilage and periosteum (Figure 2). MRI revealed elevation of the connective tissue and synovium by the tumor growth from below in 6 joints; the average height of this elevation from the surface of the femoral cortex to the base of the connective tissue was 12 mm. Destruction of the transitional area between the articular cartilage and periosteum was detected in 2 joints, and interruption of the high signal intensity of the connective tissue and superficial synovium was clearly demonstrated in 2 joints (Table 1).

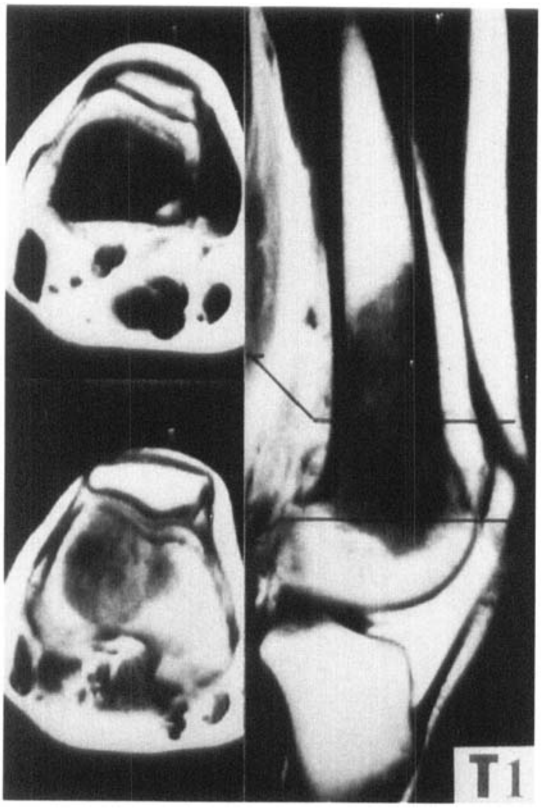

Figure 2. Tl-weighted MR image of a knee joint clearly showing fatty, connective tissue and superficial synovium with high signal intensity and transitional area between the articular cartilage and periosteum with low signal intensity.

Discussion

The knee joint cavity is separated from the femur by a thin synovial layer, lipomatous connective tissue and periosteum. If a tumor destroys the anterior cortex and attached periosteum, the joint presumably would be infiltrated by tumor cells, as there is no longer any connective tissue and synovium barrier. However, in almost all our cases, the tumor had not invaded the joint. We concluded that the fatty connective tissue and superficial synovial layer are easily detached from the periosteum and elevated by tumor after destruction of the femoral cortex and periosteum. This mechanism appears to prevent tumor extension into the joint space. In advanced cases, the tumor growth is so vigorous that it elevates the connective tissue and synovium, and this traction destroys the transitional area between the articular cartilage and the periosteum. This transitional area is probably the weakest part of the distal femur with regard to resistance to tumor extension from the marrow. The fatty connective tissue and superficial synovial layer are clearly depicted as high signal-intensity areas on Tl-weighted MR images because of their fat content, while the transitional area appears as a low signal-intensity area on Tl- and T2-weighted images. These structures are easily distinguished from tumor tissue, which shows relatively low signal intensity on Tl-weighted images and high signal intensity on T2-weighted images (Sundaram et al. 1987a,b, Redmond et al. 1989). If the connective tissue and synovial layer display continuous high signal intensity on Tl-weighted images and the transitional area appears intact, the probability of tumor invasion into the knee joint is low, and intra-capsular operation preserving the extensor mechanism of the knee can be selected, resulting in very good function after limb-sparing operation. On the other hand, if the disruption of the high signal-intensity area on Tl-weighted image reflecting connective tissue and synovium or if low signal intensity indicating destruction of the transitional area is observed, the probability of tumor invasion into the knee joint is great enough to warrant selection of extra-capsular resection.

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