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Prediction of pathological subtrochanteric fractures due to metastatic lesions

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Abstract We report a radiographic review of 54 consecutive patients with 24 impending and 30 actual pathological fractures due to metastatic bone lesions in the subtrochanteric femoral region. In an attempt to develop criteria for metastatic lesions at risk of fracturing, the following variables based on anteroposterior and lateral X-rays were considered: appearance of the lesion, width of the lesion, ratio between width of the lesion and bone width, length of the lesion, length of cortex involvement, proportion of transverse cortical bone destroyed and local pain. Nearly all (99%) of the lesions were radiographically classified as lytic. In 27 cases (50%) they were radiographically unmeasurable. Maximal longitudinal cortical destruction showed a difference between patients with an actual or impending fracture. Prophylactic internal fixation of pathological subtrochanteric fractures due to metastatic lesions has to be considered in cases of increasing pain. If the conventional X-ray can not be evaluated, a computed tomography (CT) scan has to be considered.

Introduction

Malignant metastatic tumour is the most common bone tumour. The incidence of skeletal metastasis to the femur is high (30–50%) [1, 2] and rising due to prolonged patient survival as a result of more effective treatment of visceral metastases [3]. About 10% of patients with disseminated breast cancer develop a pathological fracture of the proximal femur [4]. One-third of impending and actual femoral fractures is located in the subtrochanteric region [5–7].

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Pathological fractures can greatly affect the quality of life. Prophylactic fixation of impending fractures is generally preferred over treatment of actual fractures. Quick relief of pain, earlier mobility, decreased hospital stay and reduction of operative complications are reported as significant advantages [8–10]. As a result, prophylactic fixation is being increasingly performed. There are three main accepted principles in assessing femoral fracture risk [9]: (1) a lytic lesion 25 mm or larger involving the femur; (2) lytic circumferential cortical destruction of 50% or more; (3) persistent pain with weight-bearing, despite local therapy. At present, these criteria pervade clinical practice, despite the fact that several authors have concluded that pain is not a reliable sign in diagnosing impending fractures [6, 10, 11]. Furthermore, one-half of the standard radiographs is not evaluable, i.e. measurements of radiographic appearance or pathology cannot be evaluated adequately [6, 11–14].

Therefore, there is a need for better criteria for lesions at risk of fracturing. In an attempt to develop such criteria for a metastatic lesion, we retrospectively analysed patients with impending and actual fractures due to metastatic bone lesions in the subtrochanteric femoral region, paying special attention to the size of the metastases, involvement of the cortex and bone pain at the site of the lesion.

Materials and methods

Data were collected by reviewing all of the files and radiographs of 54 consecutive patients with 30 impending and 24 actual pathological fractures in the subrochanteric femoral region treated from 1978 to 1990. The criteria of an impending pathological fracture were: a lytic lesion of 25 mm or more, circumferential destruction of 50% of more and persistent pain. There were 43 women and 11 men, with a median age of 58 years (range 24–85 years). The primary tumours were breast in 35 patients, multiple myeloma in 5, bronchus in 4, kidney in 4, prostate in 2, sarcoma in 2, and other sites in 2. The median period between the diagnosis of the primary tumour and actual or impending pathological fracture was 31 months (range 0–193 months). In 28 patients the bone lesion was located only in the subtrochanteric region. The intertrochanteric region was also involved in 12 patients and the proximal diaphyseal region, in another 14 patients.

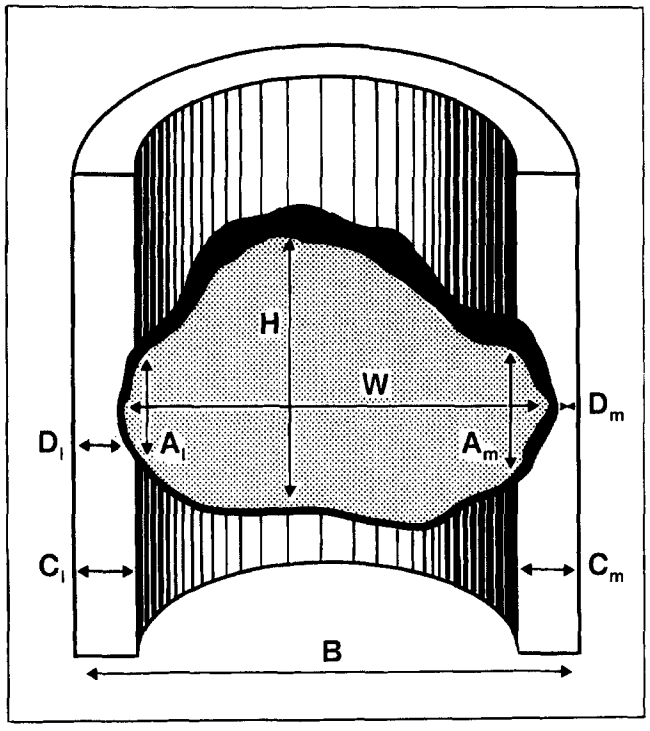

Fig. 1 Measurements of size of the metastases of actual and impending pathological subtrochanteric fractures; *W* width of metastases, *B* width of bone, *H* length of metastases, C_m and C_l width of cortex, D_m and D_l width of cortical destruction, and A_m and A_l axial cortical destruction

The anteroposterior (AP) and lateral radiographs were examined in the following manner by one observer. First, the bone lesions were classified as lytic, blastic or mixed (lytic and blastic). Then the appearance of the lesion as circumscript solitary, circumscript with multiple foci, or diffuse was recorded. Third, the following measurements of the metastasis were made (Fig. 1) [6]: largest width of the metastasis *(W)*, largest width of bone *(B)* at *W*, largest intramedullary length of the metastasis *(H)*, longitudinal length of cortex involvement *(A)*, the remaining cortex on the level of the largest involvement of the cortex (D_{medial}, $D_{lateral}$, $D_{anterior}$, $D_{posterior}$) and the uninvolved cortex below or above the bone lesion (C_{medial}, $C_{lateral}$, $C_{anterior}$, $C_{posterior}$). Calculations were made of percentage of cortex destruction [$P = (1 - (D_m + D_l + D_a + D_p)/(C_m + C_l + C_a + C_p))*100$] and largest ratio between width of the metastasis and width of the bone *(W/B)*. The measurements of the radiograph were corrected for the magnification at the rate of 1.2

The Spearman rho test was used for correlation analyses, the Mann-Whitney test for non-paired analyses of two groups, and the Fisher exact test for one case in different groups.

Results

Nearly all lesions were radiographically classified as lytic; in two patients lytic and blastic (mixed) lesions were recorded. The radiographic aspect of the lesions was recorded in 16 patients as solitary, in 23 patients as multiple foci, and in 15 patients as diffuse. However, in 5 cases no measurements could be made of the AP radiograph and in 22 cases of the lateral radiograph, due to unidentifiable margins of the bone involved. In 27 patients (50%) accurate measurements were made.

In the AP view 8 metastases were medial (30%) [$(1 - D_m/C_m) - (1 - D_l/C_l) > 1/4$], and 11 metastases were centrally located [$(1 - D_m/C_m) - (1 - D_l/C_l) < 1/4$). In the lateral view 11 metastases (40%) were located anterior and 7 metastases, posterior. No relationship was found between the size of the metastases and the histology of the lesion. There is a significant difference in maximal destruction of the longitudinal cortex *(A)* among patients with an actual or impending fracture ($P < 0.05$). The other three assessments *(W, B, H)* showed no significant difference between the two groups (Table 1).

In the search for lesions at risk we found a 'cut-off point' in several measurements between actual and impending treated patients: maximal longitudinal cortex destruction *(A)* was equal to or greater than 38 mm, intramedullary bone lesion width *(W)* was equal to or greater than 30 mm, ratio metastasis width: bone width (W/B) exceeded 0.9 (Table 2).

At first presentation local pain had occurred in 41 patients (78%) 14 weeks (median) before fracturing, with a

Table 1 Radiographic measurements of actual ($n = 9$) and impending ($n = 18$) fractures are given in median values (range) (A, B, H, W are visualized in Fig. 1) (*$P < 0.05$)

Measurements of bone lesion	Actual ($n = 9$)		Impending ($n = 18$)		Total ($n = 27$)	
Width metastases *(W)*	33	(21–48)	28	(17–50)	30	(17–50)
Length *(H)*	100	(42–200)	65	(25–150)	75	(25–200)
Ratio: W/width of bone *(B)*	0.88	(0.5–1)	0.79	(0.2–1)	0.83	(0.2–1)
Maximal longitudinal cortical destruction *(A)**	54	(38–100)	38	(7–125)	42	(7–125)
Transverse cortical destruction	0.37	(0.0–0.71)	0.50	(0.07–0.94)	0.44	(0.0–0.94)

Table 2 Prevalence of radiographic risk factors in actual ($n = 9$) and impending ($n = 18$) fractures. The 95% confidential limits are given in *parentheses* (*$P < 0.005$, **$P < 0.05$)

Risk factors	Actual ($n = 9$)	Impending ($n = 18$)
Maximal longitudinal cortical destruction ≥ 38 mm*	9 (58–83)	9 (24–59)
Ratio width metastases/width bone ≥ 0.9**	7 (0.45–0.94)	5 (0.13–0.51)
Maximal width bone lesion > 30 mm**	8 (48–82)	8 (21–55)

Table 3 Literature review of femoral bone lesions at risk of fracturing

References	Total bone lesions (actual fractures)	Pain	Radiographic lytic aspect	Transverse cortical bone destruction	Circumferential bone destruction	Size of well-defined lesion	Longitudinal cortical destruction	Ratio width metastases/bone
Parrish and Marray [17]	109 (103)	+ Increasing			+ > 50%			
Beals et al. [1]	27 (22)	+	+	+		+ ≥ 25 mm		
Fidler [10]	19 (19)	–			+ > 50%			
Zickel and Mouradian [5]	46 (35)	+ Increasing	+[c]	+				
Fidler [19]	87 (32)				+ > 50%			
Harrington [9]	– (–)	+[a]	+		+ > 50%	+ ≥ 25 mm		
Miller and Whitehill [18]	136 (15)		+	+	+ > 25%	+ ≥ 20 mm		
Keene et al. [11]	516 (26)	–	–		–	–	+ > ?	
Menck et al. [6]	69 (69)	–			+ > 50%		+ ≥ 30 mm	+ ≥ 0.60
Mirels [13]	78 (27)[b]	+ Increasing	+		+ > 67%			
Yazawa [7]	120 (71)	+			+ > 50%			
Dijkstra (this shely)	54 (19)	+ Increasing	+				+ ≥ 38 mm	+ > 0.9

[a] Despite radiotherapy
[b] Including pathological humerus fractures
[c] Occult lesion

range of between 1 and 220 weeks. In this study approximately one-third of patients with an impending (11/30) or actual (9/24) fracture complained of initial pain within 3 months before surgery. However, 6 patients complained of aggravating pain, of which 5 developed an actual fracture within 2 months (95% confidence 1 units = 57%–100%; $P < 0.05$). Pain was not related to tumour histology nor to radiographic measurements.

Discussion

In this selected series nearly all (99%) osseous lesions were lytic. In contrast, Keene et al. [11] found in non-selected data no difference in fracture rate among lytic, blastic or mixed lesions. Most studies, however, report a higher fracture risk for lytic osseous lesions [5, 13, 15]. Several investigators have considered the difficulty of accurate measurements of these bone lesions. These data show that 46%–60% are evaluable [7, 11]. In the remaining group the margins of bone involvement were not well enough defined or actual fracture had distorted the geometry of the bone lesions. In our study there was difficulty in identifying the involvement of the cortex in 50% (27 cases) due to unidentifiable margins of bone involvement. Controversially, Menck et al. [6] reported no problems in radiographic evaluation in 69 patients with pathological femoral fractures. Patient selection and differences in measurement methods probably explain these contradictory results. If the conventional AP or lateral radiograph is not evaluable, computed tomography (CT) has been suggested as a diagnostic option [12, 13].

The indications for prophylactic internal fixation, first described by Griesmann and Schüttemeyer [16], concern the size and extent of the cortical destruction by metastases and have been controversial since their were proposed (Table 3). Several combinations of criteria have been suggested: pain, lytic aspect, occult lesion, amount of cortical destruction, size of well-defined lesion, longitudinal cortical destruction and ratio: width metastsis/width bone. The assessment of the percentage of the circumferential cortical destruction to intact bone is generally regarded as essential [6, 7, 9, 10, 17–19].

However, there are some arguments to emphasize. Often it is difficult to radiograph these painful and dysfunctioning limbs, and without radiographic standardization in two directions, assessment of the circumferential cortical destruction seems rather questionable. Furthermore, for therapy purposes alone often only AP radiographs are taken.

In this study we used a modified formula [$P = (1 - ((D_m + D_l + D_a + D_p)/(C_m + C_l + C_a + C_p))*100$] suggested by Hipp et al. [12] to calculate the percentage of destroyed cortical wall thickness to intact cortical wall thickness from radiographs in two directions. Hipp et al. [12] considered a 50% reduction in bone strength in an experimental study of endosteal shaft lesions in dog femora when 35% cortical destruction had occurred. Zickel and Mouradian [5] described in a clinical study of 46 impending and actual pathological subtrochanteric fractures the concept of a 'high-risk femur' as a lesion with (any) involvement of the cortex (Table 3). Keene et al. [11] and Bremner and Jelliffe [20], on the other hand, concluded in a clinical study that there is no relationship between the involvement of the cortex and bone fracture.

Metastatic lesions tend to follow a path of least resistance and therefore commonly occur along the endosteal surface of long bones without completely penetrating the cortical wall. Beals et al. [1] described in a small series of 27 cases that a size of more than 25 mm in a well-defined metastatic lesion has predictive value for bone fracture. Accurate measurements of 69 actual pathological femur fractures by Menck et al. [6] indicated that longitudinal cortical destruction of more than 30 mm has a reliable predictive value for bone fracture. This is compatible with our results (38 mm or more). Similarly, in an experimen-

tal study Frankel and Burstein [21] found that a single saw-cut of one-fifth of the length of the tibia decreased torsional energy absorption by 70%, while increasing the width and maintaining the same length did not further weaken the torsional strength. This reduction is mainly due to a redistribution of shear stress in the cross-sectional bone. In contrast, Clark et al. [22] and McBroom et al. [23] reported no significant strength reduction by longitudinal cortical destruction.

Although the bone width versus width of the metastases varied greatly in the peritrochanteric region, an intramedullary lesion width of 30 mm or more has predictive value. The introduction of the relative width of bone metastases in this region seems to be important. According to the findings by Menck et al., the relative width of the metastases (W/B) has a predictive value for bone fracture (0.9 or more; Table 3).

Many authors mention (increasing) pain as a sign of impending fracture and as a criterion for prophylactic surgery (Table 3) [1, 2, 5, 7, 13, 17]. Pre-fracture pain is reported to occur in 11%–84%, and it seems to be a questionable criterion for prophylactic surgery [6, 11, 19]. According to our results, pain at first presentation occurred in a very large time window prior to fracturing. Also, no differences were found between impending and actual fractures. No pain was observed in 11 patients (18%). Therefore, in this series, pain at onset prior to fracture was not considered a predictive sign. However, if increasing pain was recorded, an actual fracture followed within 2 months in 5 of the 6 cases. We regard increasing local pain as an indication for a lesion at risk.

The indications for prophylactic fixation of impending fractures in the long bones have not been defined clearly, and the availabele information comes from retrospective studies. Prospective studies should be performed but are unfeasible since there are not enough patients. This suggests a role for in vitro experiments.

The risk of pathological fractures is a constant concern in the management of metastatic disease in long bones. To prevent an actual pathological fracture, an aggressive approach to impending fractures is imperative. The high-risk criteria of impending fractures in metastatic bone lesions still have to be defined.

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