Comparative analysis of risk factors for pathological fracture with femoral metastases

RESULTS BASED ON A RANDOMISED TRIAL OF RADIOTHERAPY

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A number of risk factors based upon mostly retrospective surgical data, have been formulated in order to identify impending pathological fractures of the femur from low-risk metastases. We have followed up patients taking part in a randomised trial of radiotherapy, prospectively, in order to determine if these factors were effective in predicting fractures. In 102 patients with 110 femoral lesions, 14 fractures occurred during follow-up. The risk factors studied were increasing pain, the size of the lesion, radiographic appearance, localisation, transverse/axial/circumferential involvement of the cortex and the scoring system of Mirels. Only axial cortical involvement >30 mm (p = 0.01), and circumferential cortical involvement >50% (p = 0.03) were predictive of fracture. Mirels' scoring system was insufficiently specific to predict a fracture (p = 0.36). Our results indicate that most conventional risk factors overestimate the actual occurrence of pathological fractures of the femur. The risk factor of axial cortical involvement provides a simple, objective tool in order to decide which treatment is appropriate.

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A pathological fracture in a metastatic lesion in the femur can be most distressing and cause considerable morbidity. Metastatic lesions with a high risk of fracture require surgical stabilisation using prophylactic osteosynthesis. Painful, low-risk lesions can be treated conservatively using external beam radiotherapy, chemotherapy, hormonal therapy or regular infusions with bisphosphonates. However, it is difficult to differentiate between low- and high-risk lesions on their radiographic appearance. Attempts have been made to formulate objective risk factors for impending fracture, mostly using surgical and retrospective data, in order to decide which lesions need prophylactic osteosynthesis and which can be treated conservatively. Factors mentioned include the size of a lesion (>25 mm),[1-3] a radiographic osteolytic appearance,[1-9] the percentage of circumferential cortical involvement (>50%),[3,7,8,10-14] and increasing local pain.[1-4,7-10,14-17] In 1989, Mirels[7] proposed a scoring system for the prediction of fracture in which several radiographic and clinical factors were combined into a single score. However, the majority of the patients in these studies had presented with a fracture or had undergone prophylactic osteosynthesis. Little is known about the natural behaviour of similar lesions without surgical fixation. It is possible that strict application of these risk factors leads to surgical overtreatment in patients who only have a limited life expectancy.

We therefore studied the prognostic value of conventional risk factors and the scoring system of Mirels in 102 patients with femoral metastases treated conservatively. They received external beam radiotherapy as part of a large, prospective, randomised multicentre trial[18] which was designed to assess the palliative effect on pain of a single fraction of 8 Gy as opposed to six fractions of 4 Gy in bone metastases. A total of 1157 patients were randomised with a median follow-up of 21 months. There were no major differences between the two radiation schedules with regard to pain, overall survival, the quality of life, consumption of analgesics or side-effects of treatment. Although the patients with a femoral lesion were considered by the treating physician to have a low risk of pathological fracture, 14 fractures occurred during follow-up. We have reviewed all the patients with femoral metastases in the trial in order to evaluate the risk of pathological fracture of the femur.

Patients and Methods

Patient selection and follow-up. Between March 1996 and September 1998, 1157 patients with painful bone metastases from solid tumours were randomised to treatment with either a single fraction of 8 Gy (n = 579) or six frac-

Table I. Conventional risk factors for the impending fracture of femoral metastases: review of the literature

	Number of femoral lesions	Actual fractures	Increasing pain (with or without radiotherapy)	Lesion size	Radiographic osteolytic appearance	Proximal lesion	Ratio width metastasis/ bone	Transverse cortical destruction	Axial cortical involvement	Circumferential cortical involvement	Primary tumour	Remarks
Snell and Beals[1]	19	19	+	>25mm	+			+	+	+		At risk: any lesion > 25 mm invading cortex
Parrish and Murray[10]	103	99	+							>50%		Advancing cortical destruction
Beals et al[2]	34	3	+	>25mm	+			+				Five lesions pinned prophylactically
Fidler[11]	18	18	-							>50%		95% of fractured lesions had cortical involvement >50%
Zickel and Mouradian[4]	46	34	+		+			+	+	+	+	Even small involvement of cortex, at risk: lung carcinoma
Cheng et al[27]	75	4		-		+				-		At risk: diffusely mottled lesions; six lesions fractured before radiotherapy
Fidler[12]	87	32								>50%		Cortical involvement estimated or measured by using a rolled paper tube
Miller and Whitehill[5]	136	14		>20mm	+	+				+		Mentions increased bodyweight and activity as risk factors
Bunting et al[6]	?	1			+							Number of femoral lesions studied not noted
Keene et al[25]	516	26	-	-	-				+			57% unmeasurable permeative lesions. Axial cortical involvement in proximal lesions larger in 11 fractured lesions ($p < 0.01$)
Menck et al[13]	69	69					>0.6		>30mm	>50%		If lesion is in the femoral neck, >13 mm axial cortical involvement
Mirels[7]	78	27	+		+	+				>66%		Scoring system, including upper limb lesions. Number not mentioned
Yazawa et al[8]	68	41	+		+					>50%		All patients treated surgically: impending and actual fractures
Dijkstra et al[16]	54	24	+				>0.9		>38mm			Accurate measurements in 50% of the lesions studied

+ = significant

- = insignificant

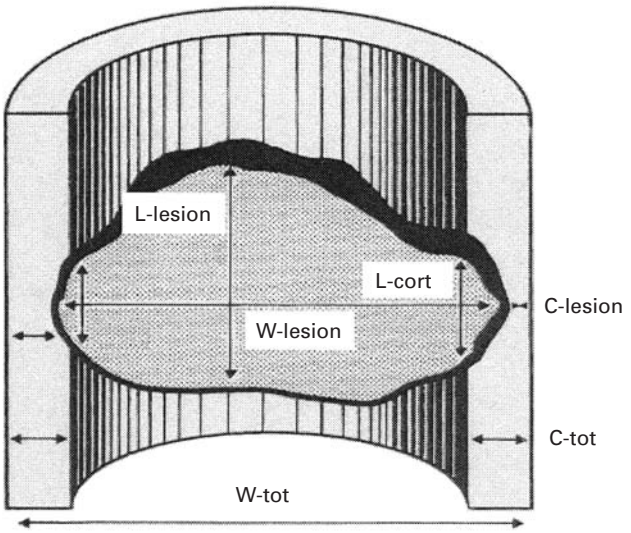

Fig. 1

Measurements of metastatic lesions in the femur (mm): largest axial length of the entire lesion *(L-lesion),* largest transverse extension of the lesion *(W-lesion),* largest axial cortical involvement *(L-cort).* Measurement of the femur (mm): largest transverse width of the bone *(W-tot),* maximal thickness of cortex without lesional involvement *(C-tot)* and minimal thickness of cortex with lesional involvement *(C-lesion).*

tions of 4 Gy (n = 578).[18] The purpose of the study was to establish the efficacy of single or multiple fractions. The end-point was the response to pain. The patients had a minimum pain score of 2 on an 11-point scale of 0 (no pain) to 10 (worst imaginable pain).[19] The radiotherapeutic dose schedules were chosen for the treatment of pain. The prevention of fracture was not an end-point. Consequently, patients with suspected impending or actual fracture through the metastases were excluded from the study at the discretion of the treating physician, but there were no established guidelines for such a decision. The Medical Ethics Committees of all the participating institutions approved the trial and all patients gave informed consent. After randomisation, intensive follow-up with 13 weekly, and afterwards, monthly questionnaires concerning pain, side-effects of treatment, quality of life and analgesic consumption were completed until a maximum of two years or death. Data managers in the participating hospitals collected information concerning death and the occurrence of a fracture. The final follow-up was in December 1998 after which the trial was closed. All 102 patients with a femoral metastasis were selected for this study.

Risk factors. A search of the literature was carried out in order to list conventional risk factors for the impending fracture of femoral metastases (Table I). The following were studied: 1) increasing pain; 2) lesion size >25 mm; 3) radiographic osteolytic appearance; 4) a proximal lesion; 5) the ratio of the width metastasis/width bone >0.6; 6) transverse cortical involvement; 7) axial cortical involvement >30 mm, and 8) circumferential cortical involvement >50%.

In order to evaluate increasing pain after radiotherapy as a sign of an impending fracture, we analysed the individual pain scores which were reported by the patients in their follow-up questionnaires in the first year. The concomitant use of analgesics or systemic treatment was also studied.

All radiographic imaging material obtained before treatment was reviewed and scored by three experienced observers (a radiologist, an orthopaedic surgeon and a radiation oncologist) who, separately, analysed all the femoral lesions. If there was more than one lesion within the field for radiation treatment, only the lesion which was considered to be at risk of fracture was analysed. In patients with more than one lesion which was at risk, lesions were analysed separately only if they were a minimum of 50 mm apart. The appearance (predominantly osteolytic or predominantly osteoblastic), and axial localisation (proximal femur, shaft, distal femur) were assessed. If there was discrepancy in scoring, the observers re-examined the radiographs and reached a consensus.

The lesions were measured (in mm) on conventional radiographs only (Fig. 1) to determine the largest axial length of the entire lesion *(L-lesion)*, the maximum transverse extension of the lesion *(W-lesion)* and the largest axial cortical involvement *(L-cort)*. The largest transverse width of the bone *(W-tot)*, the maximal thickness of the cortex without lesional involvement *(C-tot)* and the minimum thickness of the cortex with lesional involvement *(C-lesion)* were also measured. The measurements were summarised and a mean score for the three observers was calculated.

In the absence of CT scans for all lesions and an accurate tool for measuring the circumferential cortical involvement on conventional radiographs, the observers estimated the percentage of circumferential cortical involvement using a two (≤50%, >50%) and a three-tiered approach (≤33%, 33% < x ≤ 66% >66%). The separate scores of the observers were then combined. In the case of scoring discrepancies, the majority opinion was taken as to the final outcome.

In 1989, Mirels described a scoring system for the impending fracture of long bones.[7] We modified this in order to apply it to our study population (Table II):

(i) The site was converted from upper limb, lower limb and peritrochanteric to shaft/distal femur and proximal femur.

(ii) Pain was converted from mild, moderate and severe to pain scores of 2 to 4, 5 to 7 and 8 to 10.

For the analysis, the separate scores of the observers were combined. As proposed by Mirels, a cut-off point for an impending fracture of between 8 and 9 points was chosen in order to differentiate between high- and low-risk lesions.

Statistical analysis. The database was analysed using SPSS 10.0 for Windows (SPSS Inc., Chicago, Illinois). Spearman's rank correlation tests were used in order to analyse interobserver variability and the scoring system of Mirels.[7]

Table II. The modified scoring system of Mirels[7] for the diagnosis of impending pathological fractures

	Score*		
	1	2	3
Site	-	Shaft/distal femur	Proximal femur
Pain†	2 to 4	5 to 7	8 to 10
Lesion	Blastic	Mixed	Lytic
Size	<1/3	≥1/3, ≤2/3	>2/3

* each lesion is assessed on four variables (site, pain, lesion and size). The minimum score is 5 points and the maximum score is 12 points
† the pain score modified from 1 (mild), 2 (moderate), 3 (severe) into the 11-point pain score used in the randomised trial. Scores range from 0 (no pain) to 10 (worst imaginable pain). At randomisation, patients had a minimum pain score of 2

Table III. Radiographic features and measurements of femoral lesions in patients treated within the randomised trial

	Pathological fracture absent (n = 96)	Pathological fracture present (n = 14)	p value	UV*	
				HR	(95% CI)
Appearance†					
Osteoblastic	12%	0%	0.44	1	
Osteolytic	88%	100%		29	(0.0 to >100)
Vertical localisation†					
Proximal	64%	86%	0.18	1	
Shaft	33%	7%		0.1	(0.0 to 1.5)
Distal	3%	7%		2.4	(0.3 to 18.9)
Median length (range) in mm					
L-lesion	48 (14 to 251)	58 (31 to 229)	0.13		
L-cort	29 (0 to 120)	42 (27 to 155)	0.001		
L-cort >30 mm	42%	86%	0.01	7	(1.6 to 31.4)
Median width (range) in mm					
W-tot	39 (22 to 81)	40 (26 to 74)	0.53		
W-lesion	23 (7 to 59)	31 (15 to 52)	0.22		
Median cortical measurements (range) in mm					
C-tot	6 (1 to 11)	6 (2 to 18)	0.11		
C-lesion	2 (0 to 9)	1 (0 to 6)	0.29		
Median ratio (range)					
W-lesion/W-tot	0.65 (0.26 to 0.99)	0.75 (0.41 to 0.85)	0.15		

* UV = univariate analysis, HR = hazard ratio, calculated with Cox proportional hazards model, 95% CI = 95% confidence intervals
† radiographic features were scored for 110 identified lesions using conventional radiographs, CT scans, MRI scans and/or bone scintigrams. Conventional radiographic measurements were only performed for 100 lesions as ten lesions were invisible on conventional radiographs

For baseline characteristics, Fisher's Exact tests were used to compare proportions and Mann-Whitney tests were used to compare quantitative and ordered variables. Sensitivity (SE), specificity (SP), positive predictive values (PPV) and negative predictive values (NPV) of conventional risk factors for an impending fracture were calculated, as well as the Mirels' scores. The log rank test was used for survival analysis with the end-point being either the final follow-up or death. A Cox proportional hazards model was used for univariate (UV) and multivariate (MV) analyses. All reported p values are based on two-sided tests with $p < 0.05$ considered to be significant.

Results

Patient characteristics. The baseline characteristics of the 102 femoral patients have been discussed elsewhere.[20] In summary, no major differences were found in age, sex, Karnofsky Performance Scale,[21] initial pain score, or primary tumour between the 14 patients who fractured and the 88 who did not. All fractures occurred within a median of 8.5 weeks (2 to 36) of randomisation; 90% within six months. Patients who suffered a pathological fracture survived no longer than those who did not. The median overall survival for all patients was 38 weeks (95% CI 29 to 47). During follow-up, no prophylactic internal fixation was required for increasing pain or to prevent a pathological fracture. In total, 110 lesions were identified on either conventional radiographs (51% anteroposterior radiographs, 49% multidirectional radiographs), CT, MRI and/or bone scintigrams. Ten lesions were unmeasurable because they were invisible on conventional radiographs. Ultimately, 100 lesions were measured and 110 were scored radiographically.

Conventional risk factors

Increasing pain. Increase in pain during the weeks preceding a fracture was not seen in all 14 patients who fractured. Many patients experienced increasing pain but without the development of a pathological fracture. Figure 2 shows the pain scores of eight individual patients, illustrating patterns of pain during follow-up. At the time of randomisation,

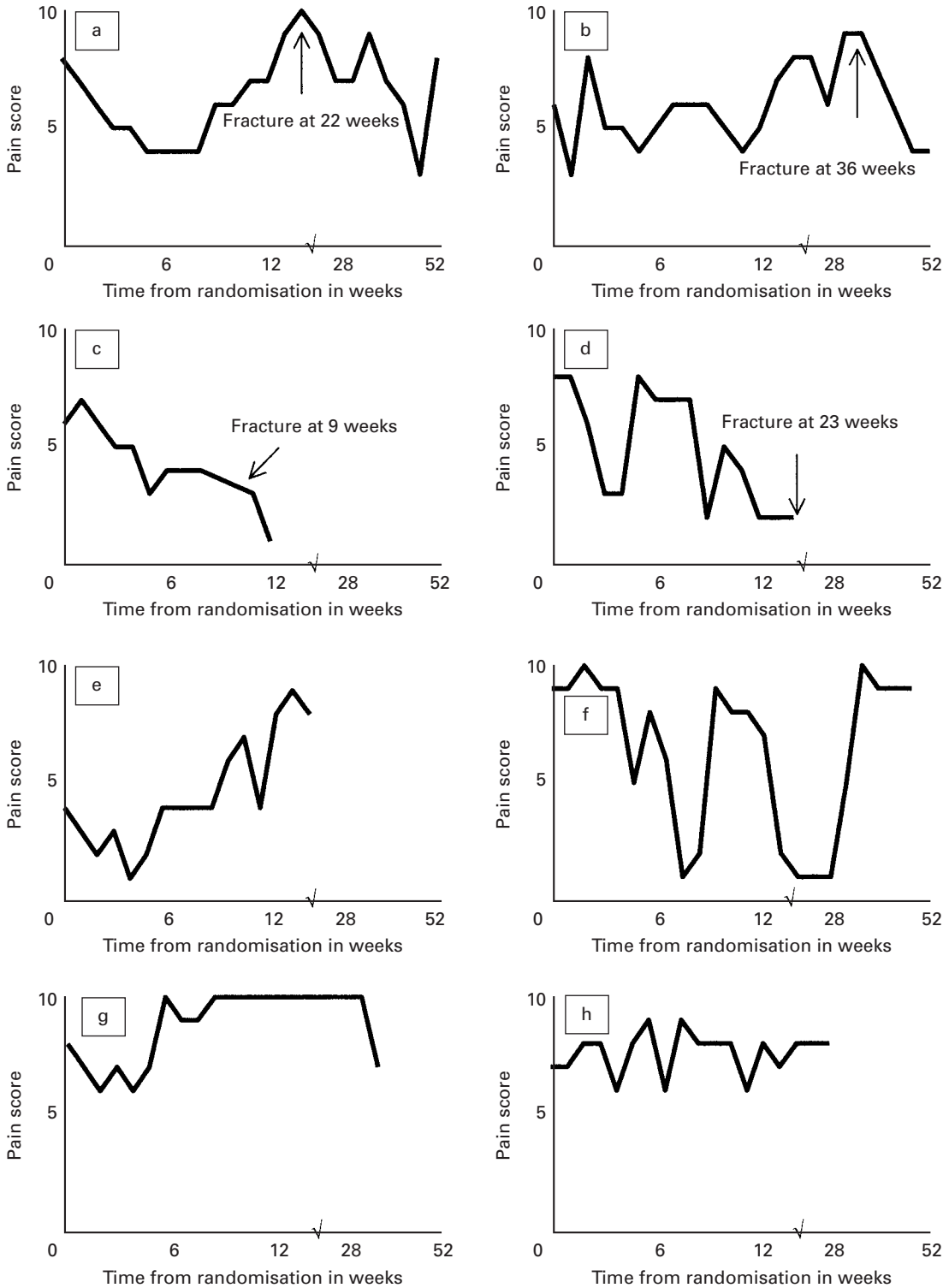

Fig. 2

Individual pain scores for the first year after randomisation for patients with a femoral metastasis. Pain scores were reported on an 11-point pain scale ranging from 0 (no pain) to 10 (worst imaginable pain). On the X-axis the follow-up shifts after 12-weekly pain scores to monthly pain scores. Figures 2a and 2b – pain score increases in weeks before fracture. Figures 2c and 2d – pain scores show no obvious increase in the weeks before fracture. Figures 2e to 2h – increasing or high pain scores without pathological fracture.

Table IV. Sensitivity, specificity and predictive values of risk factors for an impending fracture in femoral metastases

	Pathological fracture absent (n = 96)	Pathological fracture present (n = 14)	p value*	SE† (%)	SP† (%)	PPV‡ (%)	NPV‡ (%)
Axial cortical involvement							
≤30 mm	56	2	*0.01*	*86*	*58*	*23*	*97*
>30 mm	40	12					
Circumferential cortical involvement							
≤50%	79	8	*0.03*	*43*	*82*	*26*	*91*
>50%	17	6					
Scoring system of Mirels§							
Score 6 to 8	12	0	*0.36*	*100*	*13*	*14*	*100*
Score 9 to 12	84	14					

* UV = univariate analysis, using a Cox proportional hazards model
† SE = sensitivity, SP = specificity
‡ PPV = positive predictive value, NPV = negative predictive value
§ To differentiate between high-risk and low-risk lesions a cut-off point between 8 and 9 was chosen, as proposed by Mirels[7]

93% and 82% of patients with or without a fracture respectively, were using analgesics (p = 0.46). When looking at strong opioids only, 43% of patients who developed a fracture used these as opposed to 31% of patients who did not fracture (p = 0.54). Concurrent systemic treatment was given in 57% and 59% of patients with or without a fracture respectively (p = 1.0).

Lesional measurements and radiographic characteristics (Table III). There was adequate interobserver agreement on lesional measurement to justify the calculation of mean values (Spearman's rank correlation coefficients; 0.64 to 0.70 for *L-lesion*; 0.52 to 0.57 for *L-cort*; 0.65 to 0.74 for *W-lesion*; 0.71 to 0.75 for *W-tot*; 0.46 to 0.65 for *C-tot*; 0.58 to 0.80 for *C-lesion*).

The conventional risk factors of a lesion size >25 mm, are osteolytic appearance on the radiographs, a proximal lesion, a ratio of width metastasis/width bone >0.6, and transverse cortical involvement were not significantly predictive of a fracture (Table III). Metastases which did not lead to fracture had a median *L-lesion* of 48 mm as opposed to 58 mm in those with a fracture (p = 0.13). All lesions which fractured, and 88% of those which did not, had a radiographic osteolytic appearance (p = 0.44). Most metastases, whether involved with fractures or not, were located proximally in the femur (86% and 64% respectively (p = 0.18). The median ratio *W-lesion/W-bone* was 0.65 in lesions without fracture and 0.75 in those with (p = 0.15). The amount of transverse cortical destruction was similar for both circumstances (median *C-lesion* 1 mm and 2 mm respectively) (p = 0.29). Axial cortical involvement was the only risk factor that was significantly predictive of a fracture in the univariate analysis (p = 0.001). *L-cort*, with a cut-off point of 30 mm, significantly predicted a fracture (p = 0.01); HR 7; 95% CI 1.6 to 31.4). When we corrected for the radiotherapy treatment schedule, *L-cort* >30 mm remained predictive of a fracture in the multivariate analysis (p = 0.02); HR 6; 95% CI 1.3 to 27). Table IV lists the number of lesions with *L-cort* ≤30 mm or >30 mm. Ten lesions that were only visible on CT, MRI and/or bone scintigrams were considered to have *L-cort* ≤30 mm. In 56 lesions without fracture the *L-cort* was ≤30 mm. Twelve of 14 sites of fracture had an *L-cort* >30 mm (sensitivity 86%) but 40 of 96 without fracture also had an *L-cort* >30 mm. The specificity and PPV of *L-cort* were therefore limited to 58% and 23% respectively. However, the NPV of *L-cort* was high (97%), demonstrating that axial cortical involvement correctly identified high-risk lesions.

Circumferential cortical involvement. Table IV lists the circumferential cortical involvement using the two-tiered approach (≤50%, >50%). Of the 14 lesions which eventually fractured six were considered to have circumferential cortical involvement >50% as opposed to only 17 of the 96 without fracture (UV, p = 0.03, HR 3.1, 95% CI 1.1 to 9.1). The sensitivity was low (43%). If the circumferential cortical involvement had been used as a guideline in order to identify lesions suitable for prophylactic surgery, eight which eventually fractured would have been missed. However, the circumferential cortical involvement correctly depicted 79 of the 96 lesions which did not fracture as at low-risk (specificity 82%; PPV 26%; NPV 91%). Figure 3 shows the circumferential cortical involvement using a three-tiered approach (≤33%, >33% but ≤66%, >66%). The observers considered more lesions to have a high risk of fracture when using a three-tiered approach. Eight with fractures and 24 without were estimated to have a circumferential cortical involvement >66%. With the three-tiered approach the sensitivity increased to 57% but the specificity lowered to 75%.

The scoring system of Mirels. Table IV lists the combined scoring for the 110 lesions according to Mirels.[7] The interobserver variation between the three observers was acceptable (Spearman's rank correlation coefficients 0.70 to 0.75; p < 0.001), justifying the combination of separate scores. With a cut-off point at between 8 and 9 for an impending fracture, all lesions with fractures were considered to be at high-risk (SE 100%, NPV 100%). However, 84 lesions without fracture also had a score ≥9. Consequently, the scoring system did not significantly predict a fracture (UV, p = 0.36). The specificity was only 13% and the PPV was 14%. If the scoring system had been used as a guideline in order to differentiate lesions for treatment, 84 which did not fracture would have had prophylactic osteosynthesis.

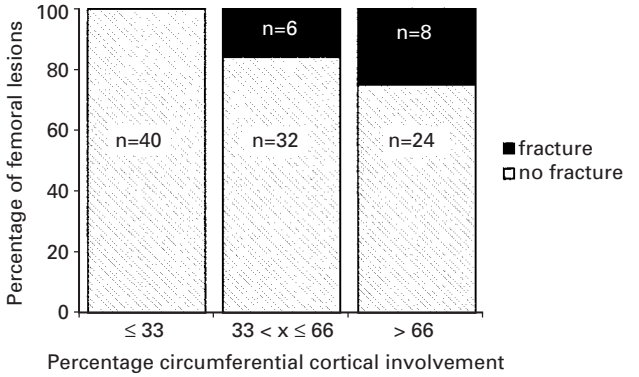

Fig. 3

Likelihood of fracture based upon the circumferential cortical involvement in 110 femoral metastases.

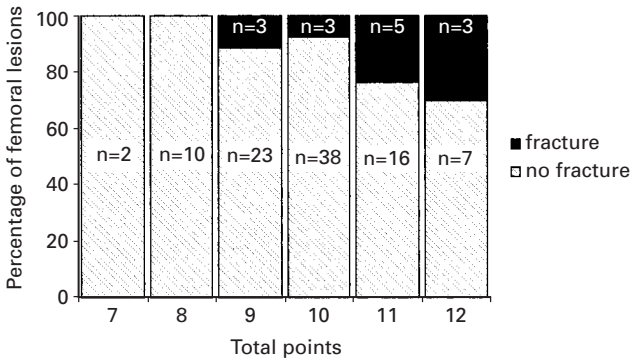

Fig. 4

Likelihood of fracture based upon the scoring system of Mirels[7] in 110 femoral metastases.

In Figure 4, Mirels' scoring for all 110 lesions is shown graphically. The median score for lesions with fractures was 11 (9 to 12) as opposed to 10 for those without (7 to 12). Shifting the cut-off point did not improve the outcome. With a cut-off point between 9 and 10, 61 lesions without fracture scored as high-risk although the specificity increased to 36%. However, three fractures would have been missed, lowering the sensitivity to 79%.

Discussion

We studied the predictive values of frequently-cited risk factors for a pathological fracture of the femur in a population of 102 patients, treated within a prospectively randomised trial. We demonstrated that none of these risk factors were accurate enough to adequately predict which lesions would fracture during follow-up and which would not. We were able to point out that most conventional risk factors overestimate the actual occurrence of a pathological fracture. As a consequence, if these were to be used in deciding which treatment to apply, a large proportion of patients with a limited life expectancy would undergo unnecessary prophylactic operations.

Because fracture is considered to be a multifactorial process, influenced by many interacting properties of both the lesion and the patient, adequate prediction of a fracture of the femur due to metastatic involvement is difficult. A pragmatic approach could be to prophylactically fix all patients with expected high-risk lesions. The quality of life of a patient with a limited life expectancy is best when remaining ambulant, without the stress and pain of a pathological fracture. Furthermore, prophylactic surgery is of lesser magnitude when compared with an emergency operation for a pathological fracture.[3,14,22-24] However, the post-operative morbidity and mortality in patients with metastatic disease can be considerable.

There is a need for the assessment of relatively simple and objective risk factors in order to predict an impending fracture. In our study the only one meeting these criteria was the axial cortical involvement *L-cort* with a cut-off point at 30 mm. All other conventional observations were not predictive of fracture because the majority of lesions which did not fracture also complied with these criteria. Menck et al[13] have already reported the importance of axial cortical involvement in their retrospective study of 69 fractures. They observed an *L-cort* >30 mm in 90% of 53 lesions with fractures located in the trochanteric, subtrochanteric and diaphyseal regions. In another study by Keene et al[25] a significant increase in axial cortical involvement was noted from 50% in 68 proximal lesions without fracture to 75% in 11 with ($p < 0.01$). However, in their discussion the authors questioned the outcome of their study because the ranges of involvement overlapped considerably. Dijkstra et al[16] found an *L-cort* >38 mm in nine actual and nine impending subtrochanteric fractures.

Increasing pain did not adequately predict the occurrence of a fracture. We found no fixed pattern when analysing the individual courses of pain during follow-up. Several authors have already questioned the relevance of increasing pain as a risk factor for an impending fracture because of its subjectivity.[11,17,25] Hoskin[26] noted in his paper on the clinical aspects of radiotherapy in the treatment of bone metastases that large lesions may give little pain and small, single lesions can cause severe pain.

Although the circumferential cortical involvement has been mentioned by most studies as a risk factor, it is difficult to measure objectively on plain radiographs. Valid, objective measurement probably requires CT scans, as Hipp et al[17] proposed in their study on metastatic bone defects. However, the routine use of CT scans for every bone metastasis is difficult to implement in everyday practice. Most authors did not specifically state how they measured circumferential cortical involvement.[4,5,10,11,27] In the absence of CT scans for most of the patients in our study, we estimated the circumferential cortical involvement on plain radiographs, using a two- and three-tiered approach. With the three-tiered approach, surprisingly, more lesions

were considered to have a circumferential cortical involvement >50% irrespective of fracture, underlining the subjectivity of this method.

Two other studies which addressed the use of risk factors for the prediction of pathological fractures in long bones were by Cheng et al[27] and Mirels.[7] The former reviewed 75 femoral metastases, of which six had already fractured before radiation treatment. Of the remaining femoral lesions, 94% did not fracture during a median follow-up of 11 months. Forty-one femoral lesions were considered to be at high-risk because they were painful, osteolytic, larger than 25 mm, or had a circumferential involvement >50%. Only four fractured. They concluded that radiotherapy was usually effective and prophylactic surgery not warranted in most cases. Unfortunately, Cheng et al[27] were not able to refine the existing risk factors. Mirels retrospectively studied 78 irradiated femoral lesions with a minimum follow-up of six months after irradiation or until the bone fractured.[7] No information was given about the total doses of irradiation. During follow-up, 35% of the lesions fractured. Mirels used a scoring system in which the site and size of the lesion, the amount of pain and the radiographic appearance were combined into a single score. With a total score of 8 points the risk of fracture was 15%. A score of 9 indicated a 33% chance of a fracture. Mirels therefore concluded that a score of ≥9 was predictive of a fracture. When we applied his scoring system to our patients we came to the opposite conclusion. Although all 14 fractured lesions in our study had a score ≥9, almost all lesions which did not fracture were also considered to be at high-risk.

Only 13% of lesions without fracture were low-risk according to the Mirels score. A possible explanation for the different outcomes between Mirels' observations and our own could be that he studied a relatively large percentage of high-risk lesions when compared with our patients. Consequently, in our patients, the application of the Mirels' scoring system instead of the axial cortical involvement as a guideline for treatment would have increased the number of unnecessary operations for fixation from 40 to 84.

We could find no definite risk factors to adequately predict the occurrence of a pathological fracture of a femoral metastasis. The application of risk factors should be undertaken with care in order to avoid overtreatment. If only conventional radiographs are available, we advocate the use of axial cortical involvement as a simple and practical tool in deciding which treatment to apply. If axial cortical involvement is less than 30 mm, a non-invasive treatment such as radiotherapy should be the treatment of choice. If axial cortical involvement exceeds 30 mm then prophylactic osteosynthesis should be considered, depending upon the general condition of the patient. Although the use of axial cortical involvement still leads to surgical overtreatment, its use instead of the scoring system of Mirels or other conventional risk factors reduces the number of patients referred for unnecessary prophylactic osteosynthesis.

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