Implant-Related Fractures of the Femur Following Hip Fracture Surgery

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Background: Most hip fractures are treated surgically, with use of either internal fixation or prosthetic replacement of the femoral head. The presence of these implants increases the risk of a later femoral fracture in susceptible osteoporotic patients. The purpose of this study was to analyze the incidence of and risk factors for implant-related fractures of the femur after previous hip fracture surgery.

Methods: Over a ten-year period from January 1988 to December 1997, 6230 patients (median age, eighty-two years; male:female ratio, 1247:4983) who sustained a total of 6696 hip fractures were admitted to the Edinburgh Orthopaedic Trauma Unit. Demographic information on the patients and details of the original treatment of the hip fracture were prospectively coded and entered into a trauma database. All subsequent readmissions due to a femoral fracture related to the implant were prospectively audited and extracted for the purposes of this study.

Results: One hundred and forty-one patients sustained an ipsilateral fracture of the femur at a median of twenty-four weeks following the original hip fracture surgery. Survivorship analysis of the hip fracture population revealed an overall rate of subsequent femoral fracture of 2.9% at five years, which increased to 5.1% at ten years. The median age and gender distribution of the patients who sustained a subsequent femoral fracture were similar to those of the hip fracture population as a whole. Two-thirds of the fractures propagated from the tip of the implant.

Analysis of the subsequent fractures according to the type of implant used to treat the original fracture revealed considerable differences in incidence. The incidence was relatively high in the patients initially treated with a Gamma nail (18.74 fractures per 1000 person-years) or a cementless hemiarthroplasty (11.72 per 1000 person-years) and was relatively low in those treated with a compression hip screw (4.46 per 1000 person-years), cannulated screws (4.50 per 1000 person-years), or a primary arthroplasty with cement (6.2 per 1000 person-years). The highest incidence of fracture was seen in the patients who had required an arthroplasty with cement as a revision procedure following failure of a primary implant (22.39 per 1000 person-years).

Conclusions: Implant-related fractures following hip fracture surgery are more common than has previously been appreciated. The risk of later ipsilateral femoral fracture is increased by the use of a Gamma nail or a cementless hemiarthroplasty to treat the original hip fracture.

Although a fracture of the femur has been reported to occur in 1% to 3% of patients following hip replacement surgery for the treatment of arthritis[1-3], the occurrence of this complication following surgical treatment of hip fractures has been poorly documented. The ever increasing numbers of hip fractures encountered in most developed countries are now usually treated surgically, often with implants similar to those used for the surgical treatment of arthritis. Patients with a hip fracture are usually older, are more likely to have osteoporosis, and have a greater susceptibility to recurrent falls and reinjury and thus are theoretically at greater risk for a subsequent fracture of the femur after hip surgery[4,5]. Furthermore these patients tend to be medically unfit and have a poor prognosis if complications develop and require a reoperation[6].

It is therefore of considerable medical and economic importance to define the epidemiology of these fractures, to identify risk factors for their occurrence, and to adopt preventative strategies. In this study, we analyzed the incidence of and risk factors for ipsilateral femoral fracture in a prospective cohort of patients who had previously had surgical treatment of a hip fracture.

Materials and Methods

Over the ten-year period from January 1988 to December 1997, 6230 patients (median age, eighty-two years;

male:female ratio, 1247:4983) who sustained a total of 6696 hip fractures were admitted to the Orthopaedic Trauma Unit of The Royal Infirmary of Edinburgh. The injuries were prospectively coded and entered into the Edinburgh Orthopaedic Trauma Database. All hip fractures in a well-defined adult catchment population of 602,897 are treated at the Unit. Only permanent Edinburgh residents undergoing surgical treatment for an intracapsular or extracapsular hip fracture (basicervical and all intertrochanteric subtypes) were included in the study. Patients with a subtrochanteric fracture, pathological fracture, or isolated fracture of the greater or lesser trochanter were excluded, as were 132 patients who died preoperatively and thirty-five medically unfit patients who were treated nonoperatively.

The recorded information on individual patients included age, sex, hip fracture classification[7,8], medical comorbidity, prefracture mobility and level of residence[9], any radiographic evidence of hip arthritis[10], and type of implant used to treat the hip fracture. Since only plain radiographs were available for review, it was not possible to analyze the role of osteoporosis.

All injury events were verified with use of other sources of prospectively collected data, including the Scottish Trauma Audit Group and the Scottish Hip Fracture Audit, which provided a 98% cross-validation of individual cases. The type of fracture was verified by reclassification of all initial radiographs by an observer who was blinded with regard to outcome. Mortality data on all patients were collected from the General Register Office for Scotland.

Between February 1994 and June 1995, a randomized, controlled trial that included 400 extracapsular fractures was carried out in our unit. During this time, all patients with such a fracture were randomized to receive internal fixation with either a compression hip screw (Smith and Nephew, Cambridge, United Kingdom) or a short standard Gamma nail (Stryker-Howmedica Osteonics, Berkshire, United Kingdom). At all other times within the study period, the choice of using either a compression hip screw or a Gamma nail to treat an extracapsular fracture was determined entirely by the preference of the attending surgeon. All Gamma nails were locked with a single locking screw placed through the more proximal of the two available distal locking-screw holes. No long Gamma nails were used in the primary treatment of extracapsular fractures during the ten-year study period.

Undisplaced intracapsular fractures were all treated with internal fixation with either three parallel cannulated cancellous 6.5-mm screws or a compression hip screw (Table I), depending on the preference of the attending surgeon. Displaced intracapsular fractures in physiologically frail, elderly patients were all treated with a cementless Austin Moore hemiarthroplasty (Stryker-Howmedica Osteonics, Berkshire, United Kingdom). Younger, more active individuals were treated either with primary reduction and internal fixation or with bipolar or total hip arthroplasty, again depending on the preference of the attending surgeon (Table I). Revision to a bipolar or total hip arthroplasty with cement was required in 210 patients because of complications or failure of primary treatment with internal fixation or cementless hemiarthroplasty; this group was considered separately from the group treated with primary arthroplasty with cement in subsequent analysis.

All femoral fractures were coded and entered into the same database; readmissions due to an ipsilateral or a contralateral fracture of the femur after previous hip fracture surgery were recoded and linked to the previous fracture event. Intraoperative fractures were not included in the analysis as they were treated primarily at the time of the original surgery.

Femoral fractures were classified as proximal (around or above the implant and proximal to its tip), tip (centered at the level of the tip of the implant or propagating distally from it), or distal (involving the distal part of the femur but not the area occupied by the implant)[11]. In addition, the operative records and the radiographs of all patients with an implant-related fracture were examined to determine possible predisposing factors for that fracture.

Statistical Analysis

The incidence of fracture of the femur was measured in age and sex cohorts in the general population and in the hip fracture population with use of the person-years at-risk method. The incidence of ipsilateral fracture of the femur following hip fracture surgery was compared with the incidence of femoral fracture in the general Edinburgh population to provide an estimate of the relative risk of ipsilateral femoral fracture following hip fracture surgery. Patients who have had a hip fracture are more likely to sustain another low-energy fracture than is the population as a whole. We therefore calculated the risk of a femoral fracture occurring on the same side as the previous hip fracture by comparing the incidences of ipsilateral and contralateral fractures of the femur in the hip fracture population.

Survivorship analysis with ipsilateral fracture of the femur following hip fracture surgery as the end point was carried out with use of life-tables, with censorship at death or at the completion of follow-up. In addition, patient survival following ipsilateral fracture of the femur was compared with survival in the hip fracture population as a whole, with censorship at the completion of follow-up. Differences in survival between subgroups were examined with use of the log-rank method.

Candidate risk factors for femoral fracture following hip fracture surgery, including age, sex, fracture type, implant used to treat the original fracture, implant malalignment, medical comorbidity, prefracture residence, prefracture use of walking aids, and severity of osteoarthritis, were independently examined with use of univariate logistic regression analysis[12]. All variables were included in a multiple regression model to determine independently significant predictors of fracture. For all statistical analyses, a p value of ≤ 0.05 for a Type-1 error was considered significant.

Results

Of the original cohort of 6696 fractures, 141 (2.1%) in 141 patients were followed by a subsequent ipsilateral fracture of the femur by the end of 1998. The median age of these

patients was identical to that of the hip fracture population (eighty-two years; interquartile range, seventy-five to eighty-six years), and the male:female ratio was 17:124 (Table I). The fractures occurred either after another simple fall (124 patients) or after sudden onset of thigh pain while the person was walking or transferring (seventeen patients).

The incidence of ipsilateral fracture of the femur increased with age and mirrored the incidence of hip fractures in the general population, in that the incidence of implant-related fracture was consistently higher in post-menopausal women than it was in men. The risk of fracture of the femur in the patients who had sustained a previous hip fracture was increased by a factor of 40 compared with the risk in the general population (relative risk = 40.06, 95% confidence interval = 33.69 to 47.25, p = 0.0001). The femoral fracture was four times more likely to occur on the same side as the previous hip fracture than it was to occur on the contralateral side (relative risk = 4.23, 95% confidence interval = 2.86 to 6.25, p = 0.005), although the risk of ipsilateral femoral fracture was less than a third of the risk of a fracture of the contralateral hip (relative risk = 0.30, 95% confidence interval = 0.22 to 0.41, p < 0.0046).

Comparison of the incidence of implant-related fracture of the femur following hip fracture surgery with the incidence of femoral fracture in the general population by age cohort revealed that the relative risk of fracture decreased incrementally from 42.00 (95% confidence interval = 8.75 to 44.92) in individuals younger than sixty-five years of age to 2.76 (95% confidence interval = 1.58 to 4.47) in those older than ninety. In contrast, when the analysis was confined to the patients who had had previous hip fracture surgery, the relative risk of an implant-related fracture in the same femur compared with that in the contralateral femur increased incrementally with age from 2.27 (95% confidence interval = 0.58 to 8.82) in patients younger than sixty-five years of age to 7.27 (95% confidence interval = 1.67 to 31.68) in those older than ninety.

Analysis of implant-related femoral fractures by the type of implant used to treat the original fracture revealed considerable differences in both incidence and configuration of the fracture. The incidence of implant-related fracture was relatively high in patients treated with a Gamma nail or a primary cementless hemiarthroplasty and was relatively low in patients treated with a compression hip screw, cannulated screws, or a primary hemiarthroplasty with cement (Table I). The highest incidence of fracture was seen in the 210 patients who required revision of the primary implant to an arthroplasty with cement. Analysis of the relative risk of ipsilateral versus contralateral implant-related fracture in the hip fracture population revealed a similar distribution of risk (Fig. 1).

Of the implant-related fractures in this series, 66.7% propagated from the tip of the implant, and the relative risk of an ipsilateral versus a contralateral fracture of the femur was independently greater for fractures occurring in this area (relative risk = 5.20, 95% confidence interval = 3.10 to 8.72, p = 0.001). The relative risk was also greater for fractures occurring far from the implant, in the distal metaphysis (relative risk = 2.33, 95% confidence interval = 1.25 to 4.33, p = 0.005). This pattern of injury was seen especially in patients in whom the original fracture had been treated with a compression hip screw: 47% of all fractures that occurred following the primary use of this implant propagated from the tip of the implant (Table I). Fractures proximal to the implant occurred almost exclusively in patients treated with cementless arthroplasty (Table I).

The majority of the implant-related fractures occurred within the first year after the hip fracture surgery (median time until fracture, twenty-four weeks; interquartile range, four to 100 weeks) (Table I), with the exception of the fractures that occurred after the use of a compression hip screw or after arthroplasty with cement (median time until fracture,

TABLE I Demographics of the Hip Fracture and Implant-Related Fracture Populations According to the Type of Implant Used to Treat the Hip Fracture Primarily

	Hip Fracture Population		No. of Original Fractures			
Type of Implant	Male:Female Ratio	Median Age (Interquartile Range) *(yr)*	Total	Undisplaced Intracapsular	Displaced Intracapsular	Extracapsular
Compression hip screw	585:2149	83 (76-88)	2734	47	102	2585
Gamma nail	50:204	84 (77-89)	254	0	2	252
Cannulated screws	206:733	77 (67-84)	939	563	369	7
Cementless hemiarthroplasty	324:1629	84 (78-88)	1953	0	1944	9
Primary arthroplasty with cement	113:487	78 (71-83)	600	0	596	4
Revision to arthroplasty with cement	39:171	77 (70-83)	210	35	133	42
Other	4:2	56 (47-66)	6	0	3	3
Total	1321:5375	82 (75-87)	6696	645	3149	2902

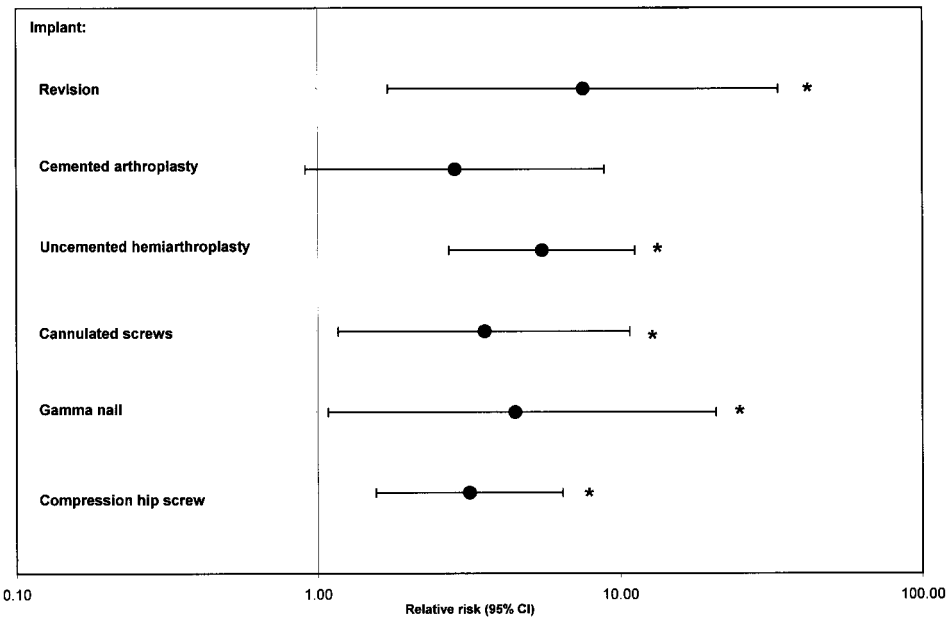

Fig. 1

Relative risk of ipsilateral femoral fracture versus contralateral femoral fracture according to the type of implant. An asterisk indicates a significantly increased risk of ipsilateral fracture ($p < 0.05$).

seventy-eight and eighty-four weeks, respectively). The trend toward early fracture was most apparent following insertion of parallel screws, with fractures occurring at a median of four weeks after such treatment. Analysis of this subgroup revealed that all thirteen fractures in the diaphysis propagated distally from the site of the distalmost parallel screw, which had been placed distal to the level of the lesser trochanter in nine of the thirteen patients. At surgery, multiple perforations of the lateral cortex of the femur, resulting from failed attempts to position guide-wires appropriately in the femoral head, were apparent in ten of the thirteen patients.

Survivorship analysis revealed the overall rate of ipsilateral femoral fracture following previous hip fracture surgery to be 2.9% (95% confidence interval = 1.84 to 3.76) at five years, which increased to 5.1% (95% confidence interval = 3.91 to 8.54) at ten years. Survivorship analysis confirmed the significantly increased rate of fracture within the first five years after hip surgery in patients treated with a Gamma nail (five-year survival rate = 93.22, 95% confidence interval = 92.5 to 95.39) compared with those treated with a compression hip screw (five-year survival rate = 98.09, 95% confidence interval = 97.40 to 98.98, p = 0.001 [log-rank test]). The incidence of ipsilateral fracture following cannulated screw fixation was low (five-year survival rate = 98.24, 95% confidence interval = 97.36 to 99.12). The incidence following cementless arthroplasty (five-year survival rate = 96.10, 95% confidence interval = 94.90 to 97.30) was higher than that following arthroplasty with cement (five-year survival rate = 97.31, 95%

TABLE I *(continued)*

Implant-Related Fracture Population		No. of Implant-Related Fractures				Incidence of Implant-Related Fractures in Hip Fracture Population *(Per 1000 Person-Yr)*	Median Time to Implant-Related Fracture (Interquartile Range) *(wk)*
Median Age (Interquartile Range) *(yr)*	Male:Female Ratio	Total	Proximal to Tip of Implant	At or Around Tip of Implant	Distal to Tip of Implant		
82.00 (77.00-85.00)	3:31	34	1 (3%)	17 (50%)	16 (47%)	4.46	78.00 (32.00-124.00)
82.50 (80.00-88.00)	2:8	10	0	8 (80%)	2 (20%)	18.74	30.00 (3.00-82.00)
81.00 (73.00-86.00)	1:14	15	0	13 (87%)	2 (13%)	4.50	4.00 (3.00-16.00)
82.00 (77.00-87.00)	6:48	54	10 (18.5%)	34 (63%)	10 (18.5%)	11.72	9.00 (4.00-46.00)
79.50 (74.00-86.50)	2:10	12	0	9 (75%)	3 (25%)	6.2	84.00 (38.50-124.00)
72.00 (66.25-80.75)	3:13	16	0	13 (81%)	3 (19%)	22.39	9.00 (6.25-94.74)
N/A	N/A	0	0	0	0	0	—
82.00 (74.75-86.00)	17:124	141	11 (7.8%)	94 (66.7%)	36 (25.5%)	7.51	24.00 (4.00-100.00)

confidence interval = 95.55 to 99.07), but this increase was not significant. The risk of ipsilateral femoral fracture in the patients who had undergone revision arthroplasty after failure of the primary treatment (five-year survival rate = 89.28, 95% confidence interval = 83.73 to 94.83) was significantly greater than that in those who had undergone primary arthroplasty with cement (log-rank test, $p = 0.001$).

On univariate logistic regression analysis, factors that were significantly predictive of later ipsilateral fracture of the femur included the type of implant used to fix the original hip fracture (Gamma nail or revision arthroplasty with cement), prefracture residence (in a nursing home or long-stay hospital), and female gender ($p < 0.05$). On multiple logistic regression analysis that included all variables, only implant type remained a significant independent predictor of later femoral fracture. The use of a Gamma nail to treat an extracapsular fracture increased the risk of implant-related fracture almost threefold (odds ratio = 2.98, 95% confidence interval = 1.45 to 6.12, $p = 0.003$), and revision to an arthroplasty with cement following failed primary treatment of an intracapsular fracture increased the risk fourfold (odds ratio = 4.00, 95% confidence interval = 2.24 to 7.15, $p = 0.0001$).

Discussion

Late femoral fracture is a well-recognized sequel to total hip arthroplasty performed for the treatment of arthritis, and the epidemiology of this complication has previously been studied in large cohorts of patients with use of data from joint replacement registries[1-3]. However, such studies are difficult to carry out among patients with a hip fracture, as often such patients are not followed over the long term and this complication has not been reported in many of the larger series[13-17]. In addition, because of the high mortality rate during the first year after surgery many patients may not survive long enough to sustain this complication[18,19]. During the present prospective study, treatment for hip and femoral fractures in a well-defined catchment population was provided in a single unit.

It is apparent from this study that ipsilateral fractures of the femur following hip fracture surgery differ from those following hip replacement in patients with arthritis. They occur earlier and are seen in a frailer, more elderly population with clearly recognizable risk factors for fracture.

The incidence of both femoral fractures in the general population and implant-related femoral fractures following previous hip fracture surgery increased with age, although the magnitude of increase in the former group was greater than that in the latter. This explains our apparently paradoxical finding that the relative risk of an implant-related fracture compared with the risk of fracture in the general population decreases with increasing age. When the analysis was confined to the hip fracture population, in which the incidence of femoral fracture on the side of the previous hip fracture surgery was greater than the incidence on the contralateral side, the magnitude of the increased relative risk of an ipsilateral versus a contralateral fracture in the hip fracture population increased with age. This is probably due to the fact that elderly patients who have had a hip fracture have an increased risk of reinjury because of their more advanced osteoporosis and greater susceptibility to falls.

The risk of fracture varied considerably according to the type of implant that had been used. The differences in incidence may largely be explained by the patients' physiological status, which determined their primary treatment; the configuration of the implant that was used; and whether the implant was inserted in either a primary or a revision procedure. In general, the use of implants with an intramedullary stress riser (the Gamma nail and the primary uncemented and revision cemented prostheses) increased the risk of later fracture. However, this was not the case for the patients treated with a primary cemented prosthesis, probably because this technique was reserved for younger, physically active individuals, who were likely to be at lower risk for a subsequent implant-related fracture. Implants without an intramedullary stress riser (compression hip screws and cannulated screws) were associated with a low incidence of implant-related fracture.

The majority of fractures occurred early in the postoperative period and were related to the tip of the implant. However, a number of fractures occurred well distal to the tip of the implant, which apparently was not involved in the fracture. Interestingly, the risk of fracture occurring either in relation to the tip of the implant or well distally was higher than the risk of fracture in the corresponding region of the contralateral, uninjured femur. Several factors are probably responsible for this finding. First, the previous hip fracture surgery makes the patient more susceptible to additional falls and reinjury on the side of the previous fracture. Second, the previous fracture exacerbates osteoporosis in the femur and the presence of an implant alters its biomechanical properties, increasing the femur's susceptibility to a fracture throughout its length[20-24].

It has been well recognized that use of a standard Gamma nail for the treatment of an extracapsular fracture is associated with a higher incidence of later fracture of the femur[25,26]. However, it is interesting to note that the incidence of femoral fracture following the use of the Gamma nail was similar to that following cementless hemiarthroplasty and lower than that following revision arthroplasty after a failed primary procedure. The presence of an intramedullary stress riser in the proximal part of the femur, whether from a Gamma nail or from the stem of an uncemented hemiprosthesis, probably increases the risk of a later femoral fracture to the same degree.

Fractures following the use of parallel screws occurred early in the postoperative period, and most propagated distally from the site of insertion of the inferior screw. This early complication of the technique and its association with distal screw placement and the presence of multiple drill-holes in the lateral femoral cortex have been recognized before[27,28]. The incidence of this complication may be reduced by the use of a trial guidewire laid over the front of the femoral neck to determine the

correct entry point in the lateral cortex under image-intensifier control before drilling the bone.

The incidence of implant-related femoral fracture was greater in patients who had received a primary uncemented prosthesis than it was in those who had received a primary cemented prosthesis. However, there was considerable selection bias in our choice of implant, and the difference could be explained by our policy of using a cementless arthroplasty to treat frail, demented, or medically unfit patients, who might be expected to have more severe osteoporosis and a greater risk of reinjury. It is unclear from our study whether the use of a cemented implant in these patients would have reduced the incidence of implant-related fracture. The issue of implant choice is difficult, as it is often determined by multiple factors. For example, although the use of cementless arthroplasty to treat a displaced intracapsular hip fracture increases the risk of later femoral fracture, the technique is likely to remain popular for the treatment of frail, elderly patients because the risk of reoperation due to union-related complications is lower than that with internal fixation techniques[29,30].

The need for revision to an arthroplasty with cement following failure of the primary treatment also increased the risk of later femoral fracture significantly. This increased incidence of femoral fracture has been well recognized in association with revision procedures following surgery for the treatment of hip arthritis[3,31]. However, the increase following hip fracture surgery is somewhat surprising as the patients undergoing revision procedures were younger (median age, seventy-two years) and initially were deemed good candidates for internal fixation of the fracture.

Although our study identified some of the risk factors for implant-related femoral fracture following hip fracture surgery, we were unable to assess the extent to which other intrinsic patient factors, such as the severity of osteoporosis, frequency of falls, and mental status, contributed to this increased risk. In the future, more detailed prospective evaluation of these factors at the time of the original hip fracture may allow us to predict with greater sensitivity which individuals are at higher risk for a later fracture of the femur. However, even if it were possible to identify, at the time of the original hip fracture, patients at high risk for an implant-related fracture, it is currently unknown whether such fractures could be avoided through preventative measures. ■

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