Periprosthetic Fractures of the Femur After Hip Arthroplasty: An Analysis of 99 Patients

Keith Holley, MD · Jonathan Zelken, BA · Douglas Padgett, MD ·
George Chimento, MD · Andrew Yun, MD · Robert Buly, MD

Published online: 25 April 2007
© Hospital for Special Surgery 2007

Abstract The medical records and radiographs of 99 patients treated for a periprosthetic femur fracture after total hip arthroplasty over a 17-year period at a single institution were prospectively reviewed. Fractures were classified according to the Vancouver system and stratified as to treatment method. Sixty-six patients had complete records available and a minimum of 12 months follow-up. Overall, 86% of the patients achieved fracture union. The success rate of cemented revision in the B2 and B3 groups was 84%, whereas cement-less revision was 86% successful. The complication rate of surgical treatment was 29%. Fracture union with a stable implant was possible in the majority of cases. Our results support the use of the Vancouver classification as a treatment algorithm.

Key words periprosthetic fracture · THA · revision THA · ORIF · Vancouver classification

Introduction

Periprosthetic fractures of the femur after total hip arthroplasty (THA) represent a difficult treatment challenge. The results of management of periprosthetic fractures have varied greatly due to factors such as bone quality, fracture pattern and method of treatment including nonoperative measures, reduction-fixation, or revision surgery. These treatments have historically been fraught with a high incidence of complications, treatment failures, and compromised outcomes [1–13]. Despite these problems, surgical treatment has become the standard in treating the majority of periprosthetic femur fracture [14].

The true incidence of periprosthetic fractures is uncertain, with estimates ranging from 0.1 to 2.1% [6, 14, 15]. In data from the Mayo Clinic Joint Registry, the incidence of periprosthetic fracture after primary THA was 1.1%, and it was 4.0% after revision THA [14, 16]. In one series, periprosthetic fracture after THA was the second leading cause of revision, after aseptic loosening [14]. With the increasing prevalence of THA and revision THA in the USA, along with an aging population, the absolute number of periprosthetic fractures can be expected to increase as well.

Currently, the treatment of periprosthetic fractures has included nonoperative measures, open reduction internal fixation (ORIF) as well as revision. Due to the number of confounding variables regarding treatment, Duncan and Masri developed a system of classification of periprosthetic fractures according to location, implant stability, and degree of bone loss (Vancouver Classification [17]) and advocated an algorithm towards treatment. The purpose of this investigation was to examine our experience with the

No institutional or private financial support was available for this study. The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Navy, the Department of Defense, or the United States Government.

K. Holley, MD
Naval Medical Center San Diego Department of Orthopaedic Surgery,
San Diego, CA, USA

J. Zelken, BA · D. Padgett, MD · R. Buly, MD (✉)
Hospital for Special Surgery,
Cornell University Medical Center,
535 E 70th St, New York, NY 10021, USA
e-mail: bulyr@hss.edu

G. Chimento, MD
Ochsner Clinic Foundation,
1514 Jefferson Highway, New Orleans, LA 70121, USA

A. Yun, MD
The Arthritis Institute, John F. Kennedy Hospital,
Dr Carreon Blvd, Indio, CA 92201, USA

treatment of periprosthetic fractures of the hip over a 17-year period and to corroborate the recommendations of the Vancouver group.

Materials and methods

A retrospective review of all periprosthetic femur fractures after THA treated at our institution from 1984 to 2001 was performed. All surgical procedures were performed at a single institution, but these were performed by a total of 12 different surgeons. The medical records of all patients were reviewed for such factors as patient age, sex, type of treatment, operative findings, number and type of complications associated with the fracture and its treatment, and condition of the patient before and after surgery. Radiographs were reviewed to ascertain fracture type, type of prosthesis (cemented or noncemented), the presence of preexisting osteopenia, evidence of healing, and condition of the prosthesis at latest follow-up.

Fractures were classified according to the Vancouver classification of Duncan and Masri [17, 18]. This classification system, described in previous publications, is now widely accepted in the classification and treatment of periprosthetic fractures of the femur. Type A fractures are fractures of the greater or lesser trochanters. Type B fractures involve the femoral diaphysis and/or metaphysis around the femoral stem and are subdivided into three types. In type B1 fractures, the stem is stable, B2 fractures are associated with a loose stem, and B3 fractures are associated with a loose stem and significant bone loss. Type C fractures are well distal to the tip of the femoral stem.

The treatment was classified as (1) nonoperative; (2) reduction and fixation employing interfragmentary or cerclage fixation, plate fixation (including flat plates, plate-clamp devices, and plates with fixed-angle devices), or plate fixation with use of cortical strut grafts; or (3) revision surgery using either uncemented in-growth stem or cemented stem revision. In cases of femoral stem revision, cables were commonly used for fixation, but supplemental plates were not used. The use and type of bone graft material was also recorded.

The stability of the femoral prosthesis was judged from the radiographs at final follow-up. Criteria for judging the stability of cement-less stems were those described by Engh et al. [19] and include the presence of spots welds, lack of radiolucent lines, absence of pedestal formation, absence of calcar remodeling, and no evidence of migration. For cemented femoral components, the criteria of Harris et al. [20] were utilized. Stems that had migrated on serial radiographs were considered as definitely loose, stems with a continuous radiolucent zone at the bone–cement interface on either anteroposterior or lateral radiographs were considered as probably loose, and stems with a radiolucent zone occupying between 50 and 100% of the bone–cement interface were considered as possibly loose.

Patients who had not been recently evaluated were asked to make an office visit for routine clinical evaluation

and radiographs. Patients who declined to return for follow-up did so for a variety of reasons, which commonly included remote geographic location, advanced age, and difficulty with travel. Patients who could not come to the hospital for follow-up were interviewed over the telephone. The study had the approval of the Institutional Review Board. Patients who had less than 12 months of follow-up and could not be contacted or had died were excluded.

In this study, the main outcome measure was either fracture union or implant survival. Treatment within each fracture type was stratified and chi-square analysis was performed to determine the level of statistical significance in regards to treatment outcome at the 95% confidence level.

Results

There were 99 periprosthetic femur fractures after THA treated during this time period. These consisted of 32 males and 67 females with an average age of 68.1 years. Demographic data are listed in Table 1.

Twenty-five patients had died with less than 12 months of follow-up. These by and large tended to be elderly patients, frequently with multiple medical comorbidities. An additional eight patients with less than 12 months of follow-up could not be contacted. All of these eight patients were two or more years postsurgery at the time of this review and were lost to follow-up despite all attempts to locate and contact them. These 33 patients were therefore excluded from the outcome analysis. The study

Table 1. Patient demographics

Characteristic	Value
Sex	
Male	32
Female	67
Average age	68.1
Side	
Right	56
Left	43
Diagnoses	
OA	57
RA/JRA	22
Posttraumatic	13
Osteonecrosis	5
Other	2
Implant	
Primary THA	53
Revision THA	37
Hemiarthroplasty	9
Time to fracture (months)	112
Fracture type	
A	4
B1	31
B2	32
B3	13
C	19

OA=osteoarthritis

group for analysis of treatment outcomes and complications therefore comprised 66 patients with a minimum of 12 months of follow-up. There were 21 males and 45 females. The average age was 64.0 years, with a range of 17 to 96 years. The right hip was involved in 39 patients and the left hip in 27 patients. The diagnoses leading to hip arthroplasty were osteoarthritis in 36 patients, rheumatoid arthritis (RA) or juvenile rheumatoid arthritis (JRA) in 16 patients, posttraumatic arthrosis in eight patients, osteonecrosis in five patients, and developmental dysplasia of the hip in one patient. The periprosthetic fracture involved a primary THA in 33 cases, a revision THA in 29 cases, and a primary hemiarthroplasty in four cases. The Vancouver classification of this group of fractures was 2 type A, 25 type B1, 20 type B2, 9 type B3, and 10 type C.

The patients had an average of 2.2 previous surgeries on the involved hip prior to the periprosthetic fracture. The average time period between the original hip replacement procedure and the periprosthetic fracture was 109 months. The period of follow-up from the time of the periprosthetic fracture ranged from 12 to 180 months, with an average of 62 months.

Type A fractures (trochanteric fracture)

There were two patients with type A fractures of the greater trochanter. Both of these patients underwent operative treatment consisting of ORIF utilizing a plate/clamp device with implant retention. The fracture united in both cases (100% union). One patient sustained a dislocation 8 months

Table 2. Type B1 fractures

Patient	Sex	Age	Primary or Revision	Femoral Stem	Prior Surgeries	Cause of Fracture	Operative Treatment	Complications	F/U Time (months)	Fracture Outcome	Implant Stability
1	Female	91	Primary	Cemented	1	Low energy	ORIF plate/alloy strut	None	117	Union	Stable
2	Male	83	Revision	Uncemented	3	Iatrogenic	ORIF plate	Hematoma	19	Union	Loose
3	Male	31	Primary	Cemented	1	Low energy	ORIF plate	None	180	Union after reoperation	Stable
4	Female	62	Primary	Cemented	1	Low energy	ORIF plate	None	43	Union after reoperation	Stable
5	Female	33	Revision	Cemented	4	Spontaneous	Nonoperative	None	57	Nonunion	Loose
6	Male	40	Primary	Uncemented	1	Iatrogenic	ORIF cerclage	None	13	Union	Stable
7	Male	84	Primary	Cemented	1	Low energy	ORIF plate/alloy strut	None	37	Union	Stable
8	Male	44	Revision	Uncemented	4	Low energy	ORIF plate/alloy strut	PE, infection, dislocation	33	Union	Stable
9	Male	64	Primary	Cemented	3	Low energy	ORIF plate	None	25	Union	Stable
10	Female	43	Revision	Cemented	3	Low energy	ORIF plate/alloy strut	None	131	Union	Stable
11	Male	63	Primary	Uncemented	1	Iatrogenic	ORIF plate	None	42	Union after reoperation	Stable
12	Female	73	Revision	Cemented	2	Low energy	ORIF plate	Dislocations	90	Union	Stable
13	Female	83	Primary	Cemented	1	Low energy	ORIF plate	None	28	Union after reoperation	Stable
14	Female	39	Primary	Cemented	8	Spontaneous	ORIF cerclage	Infection	108	Union	Stable
15	Female	96	Primary	Cemented	1	Low energy	ORIF plate	None	43	Nonunion	Stable
16	Female	65	Revision	Cemented	1	High energy	Nonoperative	None	62	Union	Stable
17	Female	33	Revision	Cemented	3	Iatrogenic	ORIF plate/alloy strut	None	48	Union	Stable
18	Male	61	Revision	Uncemented	2	Low energy	ORIF plate/alloy strut	None	12	Union	Stable
19	Female	82	Revision	Cemented	2	Low energy	ORIF plate/alloy strut	None	25	Nonunion	Stable
20	Female	75	Primary	Cemented	2	Low energy	Nonoperative	Infection	18	Nonunion	Loose
21	Female	53	Revision	Uncemented	2	Low energy	Uncemented revision	None	66	Union	Stable
22	Male	62	Revision	Cemented	4	High energy	ORIF plate	None	24	Union	Stable
23	Female	63	Primary	Uncemented	1	Iatrogenic	ORIF cerclage	None	123	Union after reoperation	Stable
24	Female	77	Primary	Cemented	1	Low energy	ORIF plate/alloy strut	None	13	Union	Stable
25	Female	62	Primary	Cemented	1	Low energy	Nonoperative	None	39	Union	Stable

F/U=follow-up

after the fracture surgery, which was treated with closed reduction. The second patient underwent elective hardware removal at 1 year postoperatively for lateral trochanteric pain but had no other complications.

Type B1 fractures (fracture with stable implant)

The type B1 subgroup consisted of 25 patients with 7 uncemented and 18 cemented stems. Data for this group are listed in Table 2. Of these, four were treated nonoperatively and 20 were treated with ORIF: three with cerclage wiring, nine ORIF with a plate device, eight ORIF with a plate device plus strut allograft, and one underwent revision with an uncemented femoral stem. At latest follow-up, 18 patients (72%) achieved union of their fracture after the initial treatment, three patients (12%) required one or more further procedures to achieve union, and four patients (16%) had an established nonunion. Three patients who sustained a second periprosthetic fracture of the same femur had union or early healing at latest follow-up. Overall, 22 (88%) patients had a stable implant at final follow-up and three patients had implants that were considered to be loose.

There were four treatment failures: two in the nonoperative group (two of four), one with ORIF with plate alone (one of nine), and one ORIF with plate and allograft strut (one of eight). Two of the four patients initially treated nonoperatively subsequently failed to heal the fracture and were considered treatment failures. Both of these patients had an established nonunion at latest follow-up despite subsequent revision of the femoral component. At final follow-up, 18 of 20 patients treated with ORIF achieved union (90%). Of the nine patients treated with ORIF and a plate device, six achieved fracture union after the primary treatment, two required reoperation for delayed union, and one fracture was a nonunion. Two of these six patients sustained a second periprosthetic fracture between 1 and 3 years later, both of which were healing at latest follow-up after repeat surgical treatment. Of eight patients who had ORIF with a plate device plus a strut allograft, seven had primary fracture union and one went on to an established nonunion. One patient with a B1 fracture around an S-ROM (Depuy Orthopaedics, Warsaw, IN, USA) stem underwent revision to a longer S-ROM stem with retention of the ingrown sleeve component, as well as stabilization with a strut allograft and cables. This patient healed successfully without complications and had a stable component at latest follow-up. Union rates by treatment type were as follows: nonoperative treatment 2/4 (50%) and ORIF treatment 18/20 (90%).

There were nine complications associated with treatment in five patients. These included one nonfatal pulmonary embolism (PE), three soft-tissue infections, one deep joint-space infection, two hematomas requiring surgical drainage, and two patients with one or more subsequent dislocations. All three soft tissue infections were treated successfully with surgical irrigation and debridement plus antibiotics, and all three subsequently had successful union of their fractures. The deep joint space infection was associated with nonunion

of the fracture and was treated with long-term antibiotic suppression due to a compromised medical condition and limited global function.

Type B2 fractures (fracture associated with loose implant)

This subgroup consisted of 20 patients with 2 uncemented and 18 cemented stems. Two patients underwent ORIF of the fracture with a plate, 13 underwent treatment with cemented revision of the femoral stem, and 5 underwent uncemented revision of the femoral stem. Data are listed in Table 3. Overall, 17 patients achieved union after the primary treatment (85%), two patients' fractures united after a second procedure, and one patient had an established nonunion at latest follow-up, for a 95% success rate. Three patients in this group sustained a second periprosthetic fracture and required further surgical treatment. All three of these patients had demonstrated union of the second fracture at latest follow-up. Seventeen patients (85%) had a stable implant at latest follow-up. Three patients had a loose femoral stem, one of which was associated with an established nonunion, one of which was awaiting revision, and one in which the patient had died.

Both of the patients treated by ORIF with a plate and morcelized bone graft (100% union) subsequently healed despite the presence of a loose femoral stem. One of these patients had no further surgery and still had a loose implant at latest follow-up. The other sustained a second periprosthetic fracture 4 years later, which was treated with a cemented femoral revision. This patient had a healed fracture and a stable implant at latest follow-up. Of the 13 patients who had a cemented femoral revision, 11 healed without another procedure (85%), one healed after placement of additional internal fracture fixation, and one had an established nonunion despite having undergone a second revision procedure to an uncemented femoral component with placement of a plate and allograft struts. Of the five patients treated with an uncemented femoral revision, four achieved primary fracture union (80%) and one required a repeat revision of the femoral component before healing. There was no difference in union rates between the ORIF group, the cemented revision group, or the uncemented revision groups ($p=0.53$).

There were a total of seven complications associated with treatment, which occurred in six patients. They were one postoperative cardiac arrhythmia, one nonfatal PE, one superficial wound infection requiring irrigation and debridement, one septic joint requiring two-stage implant exchange, two dislocations treated nonoperatively, and one postoperative hematoma requiring surgical drainage.

Type B3 fractures (fracture, loose stem, and bone loss)

There were nine patients with type B3 fractures around one uncemented and eight cemented stems. Data are listed in Table 4. Six patients were treated with cemented femoral revision, two patients with uncemented femoral revision, and one patient with ORIF. Seven patients achieved fracture union after the primary treatment (78%), one

Table 3. Type B2 fractures

Patient	Sex	Age	Primary or Revision	Femoral Stem	Prior Surgeries	Cause of Fracture	Operative Treatment	Complications	F/U Time (months)	Fracture Outcome	Implant Stability
1	Female	71	Primary	Cemented	4	Low energy	ORIF plate	None	82	Union	Loose
2	Female	82	Primary	Cemented	1	Low energy	Cemented revision	None	41	Union	Loose
3	Male	37	Revision	Cemented	2	Low energy	Cemented revision/plate/strut	None	139	Union	Stable
4	Female	78	Revision	Cemented	2	Low energy	Uncemented revision/plate/strut	Arrhythmia	40	Union	Stable
5	Male	51	Revision	Cemented	2	Spontaneous	Cemented revision	Infection, refracture	14	Union after reoperation	Stable
6	Male	80	Revision	Cemented	2	Low energy	Uncemented revision	None	40	Union	Stable
7	Female	72	Revision	Cement-less	3	Spontaneous	Cemented revision/plate/strut	None	26	Union after reoperation	Stable
8	Female	62	Revision	Cemented	2	Low energy	Cemented revision/strut	None	108	Union	Stable
9	Female	68	Revision	Cement-less	2	Spontaneous	Cemented revision/strut	None	56	Union	Stable
10	Female	42	Revision	Cemented	5	Low energy	Cemented revision/strut	None	111	Union	Stable
11	Female	75	Revision	Cemented	2	Low energy	Cemented revision	None	12	Union	Stable
12	Male	46	Primary	Cemented	2	Low energy	Cemented revision/strut	Hardware failure, dislocation	83	Nonunion	Loose
13	Female	38	Primary	Cemented	1	Low energy	Cemented revision	Refracture	14	Union after reoperation	Stable
14	Female	71	Revision	Cemented	2	Spontaneous	Cemented revision/strut	Dislocation, infection	24	Union	Stable
15	Female	86	Primary	Cemented	1	Low energy	Cemented revision	None	35	Union	Stable
16	Male	57	Revision	Cemented	2	Low energy	Uncemented revision	None	100	Union after reoperation	Stable
17	Male	44	Primary	Cemented	2	Spontaneous	Cemented revision	None	16	Union	Stable
18	Male	82	Primary	Cemented	1	Low energy	Uncemented revision/strut	PE, hematoma	33	Union	Stable
19	Male	69	Primary	Cemented	2	Spontaneous	Uncemented revision/strut	None	46	Union	Stable
20	Female	76	Revision	Cemented	2	Low energy	ORIF plate	Refracture	57	Union after reoperation	Stable

F/U=follow-up

patient's fracture united after further surgery, and one patient's fracture never healed despite multiple surgeries. All patients in this group were considered to have stable implants at latest follow-up.

Five of six patients who were treated with a cemented femoral revision (three with strut allografting, two without) went on to fracture union (83%). One patient with RA who was initially treated with a cemented femoral revision had multiple subsequent surgeries for infection, refracture, and nonunion was ultimately converted to a total femur replacement. Two patients treated with uncemented revision subsequently achieved union without further fracture treatment. One woman with JRA and severe bone loss was initially treated by ORIF with a plate, cables, and morcelized allograft. She developed a deep space infection

and delayed union of the fracture. After hardware removal and treatment of the infection, she was successfully treated with an uncemented femoral revision. The results demonstrated higher union rates in the revision group vs. the ORIF group ($p=0.047$)

Only three patients in this group did not have a postoperative complication associated with the fracture treatment. Of the other six patients, four had one or more dislocations, and three had deep infections requiring implant removal and further revision procedures.

Type C fractures (fracture below implant)

Data for type C fractures are listed in Table 5. There were ten patients in this subgroup with two uncemented and

Table 4. Type B3 fractures

Patient	Sex	Age	Primary or Revision	Femoral Stem	Prior Surgeries	Cause of Fracture	Operative Treatment	Complications	F/U Time (months)	Fracture Outcome	Implant Stability
1	Female	78	Primary	Cemented	2	Low energy	Uncemented revision/strut	Dislocations	54	Union	Stable
2	Male	75	Revision	Cemented	3	Spontaneous	Cemented revision/strut	Dislocation, infection	62	Union	Stable
3	Female	73	Primary	Uncemented	4	Iatrogenic	Cemented revision/plate/strut	Refraction, recurrent infections	169	Nonunion, total femur	Stable
4	Female	72	Primary	Cemented	2	Low energy	Cemented revision	None	117	Union	Stable
5	Female	70	Primary	Cemented	1	Low energy	Cemented revision/strut	Dislocation	63	Union	Stable
6	Female	70	Revision	Cemented	2	Iatrogenic	Uncemented revision/strut	None	96	Union	Stable
7	Female	32	Revision	Cemented	2	Low energy	ORIF plate	Infection, refracture	37	Union after reoperation	Stable
8	Female	81	Primary	Cemented	2	Low energy	Cemented revision	Dislocation	69	Union	Stable
9	Male	77	Primary	Cemented	1	Spontaneous	Cemented revision/strut	None	54	Union	Stable

F/U=follow-up

eight cemented stems. Two patients were treated initially with nonoperative treatment, six were treated by ORIF with a plate device, and two were treated by ORIF with a plate plus strut allograft. Of the two patients that were initially treated with traction followed by a cast or brace, one went on to heal without complications (50%) but the other patient developed a nonunion, which was subsequently treated with ORIF plus bone grafting. This surgery was complicated by hematoma formation and recurrent infection, and the patient ultimately required a transfemoral

amputation. Eight patients underwent ORIF with or without strut grafting. Of these, four achieved primary fracture union (50%) and two required repeat ORIF but were united at latest follow-up. The other two patients went on to a nonunion. One patient who required multiple surgical procedures for recurrent joint sepsis, osteomyelitis, and nonunion was finally treated with a total femur replacement. The other patient had an established nonunion despite a second ORIF and a subsequent revision to a long-stem S-ROM. Eight out of the ten (80%) had a stable femoral implant at the latest follow-up.

Table 5. Type C fractures

Patient	Sex	Age	Primary or Revision	Femoral Stem	Prior Surgeries	Cause of Fracture	Operative Treatment	Complications	F/U Time (months)	Fracture Outcome	Implant Stability
1	Female	69	Primary	Cemented	1	Low energy	ORIF plate	None	59	Union	Stable
2	Female	90	Revision	Cemented	3	Low energy	ORIF plate	Refracture	60	Union after reoperation	Stable
3	Female	92	Primary	Cemented	1	Low energy	ORIF plate	None	25	Union	Stable
4	Male	62	Revision	Cemented	4	Spontaneous	ORIF plate/strut	Recurrent infections, hematomas	53	Nonunion, total femur	Stable
5	Male	17	Primary	Uncemented	1	Low energy	ORIF plate	Refracture	80	Nonunion	Stable
6	Female	57	Primary	Cemented	1	Low energy	Nonoperative	None	62	Union	Stable
7	Female	79	Revision	Cemented	4	Low energy	ORIF plate	None	44	Union	Stable
8	Female	44	Primary	Cemented	2	Low energy	Nonoperative	Hematoma, infection, amputation	139	Nonunion	Loose
9	Female	59	Primary	Uncemented	1	Low energy	ORIF plate	None	16	Union	Stable
10	Female	86	Primary	Cemented	3	Low energy	ORIF plate/strut	None	18	Union after reoperation	Stable

F/U=follow-up

Complications associated with treatment in this group consisted of the two patients with recurrent infections mentioned above. There was no statistical difference between groups regarding union whether nonoperative or ORIF was the treatment of choice ($p=0.49$).

Discussion

Although the overall rate of periprosthetic femur fractures associated with THA is unknown, it appears to be increasing [21, 22]. Estimates in the literature range from 0.1 to 2.1% for postoperative fractures and from 0.3 to 5.4% for intraoperative fractures [14]. Postoperative fracture rates are generally higher for revision THA compared to primary THA, whereas intraoperative rates are generally higher for uncemented THA compared to cemented THA.

The treatment of periprosthetic femur fractures after THA has historically been associated with a high rate of treatment failures, complications, and unsatisfactory outcomes. Difficulty arises in comparison of various results in the literature due to differences in length of patient follow-up, patient demographics, types of implants used, the number of revision arthroplasties, the types of operative techniques employed, and variable outcome measures utilized. To date, no prospective randomized trial studying treatment interventions has been performed. It has been the work of Duncan and Masri [17] that has clearly aided in the classification and recommendation for treatment of these complex fractures. According to these authors, treatment is guided by the classification system, with type A fractures generally being treated nonoperatively or with cerclage fixation. Type B1 fractures can be treated by ORIF with plate devices and or the use of cortical strut grafts. Type B2 fractures usually require revision to a long-stem femoral component, with or without additional extramedullary fracture fixation. Type B3 fractures, in addition to revision of the femoral stem, generally require the use of significant allograft in an attempt to reestablish bone stock. Type C fractures can usually be treated by ORIF with standard plate systems or fixed angle plate devices. While these recommendations occurred after the onset of our study, our results appear to be consistent with what these authors have found.

The results of this series are similar to those from previous reports and reflect the difficulty in treating periprosthetic fractures of the femur after THA. In this study, 74% of patients achieved fracture union after the primary treatment, whereas another 12% united the fracture after undergoing further surgical treatment, for a final fracture union rate of 86%. Complications relating to surgical treatment occurred in 19 patients, for a rate of 29% confirming the complicated nature of this type of surgery including several patients with multiple complications. There are several limitations inherent to this type of review including different biases towards treatment over the study time period and the limited number of study patients within some groups. However, clearly some trends are worth noting.

While not statistically significant, among the type B1 fractures, those treated with ORIF and the use of a plate plus a cortical strut graft had a higher healing rate (seven of eight, 88%) than those treated with a plate device alone (six of nine, 67%), although the numbers are small in this subgroup. There has been support in the recent literature for use of onlay allograft cortical struts [4, 23], as well as animal studies investigating the use of osteogenic proteins to enhance strut allograft healing [24].

In the B2 group the success rate with cemented revision (11 of 13, 85%) was equivalent to that of uncemented revision (four of five, 80%). Not surprisingly, our type B3 fractures were associated with the highest complication rates (66%) in our series, as might be expected given the difficulty of surgical reconstruction of many of these fractures. Cemented femoral revision was surprisingly successful in this subgroup, with five of six patients (83%) healing and having a stable femoral component at latest follow-up. Of note, while both patients in whom ORIF was performed gained union, the implants were still both loose at follow-up, making the patients potentially at risk for fracture. Currently, we would recommend revision of the implant.

In the C group of patients, it was interesting to note that union was difficult to obtain regardless of treatment (50%). Clearly, patient factors such as osteopenia and the effect of stress shielding may play a role in getting these fractures to unite. Consideration of adjuvant bone grafting as well as potential use of bone enhancing agents should be given at the time of surgery.

A clear trend was that patients with RA or JRA fared much worse than the overall group. In addition to having compromised immune systems due to the effects of various disease-modifying agents, these patients also frequently had poor bone stock. Of 16 patients, only eight successfully healed after initial treatment. Six fractures ultimately went on to become nonunions, with two patients being converted to total femur replacement due to recurrent infection, nonhealing, and bone loss. Total femur replacement following periprosthetic fractures in RA patients has also been previously reported in the literature [25]. Three patients sustained a refracture and 6 of the 16 (38%) had one or more infections. These high complication rates highlight the risk to RA and JRA patients whose underlying disease can compromise treatment outcomes.

Recently, authors at the Mayo clinic reported the results of revision arthroplasty for 118 hips with Vancouver type-B fractures [11]. The femoral implants used in this series included cemented stems, proximally porous coated uncemented stems, extensively coated stems, and allograft-prosthetic composites. Overall, Kaplan–Meier analysis showed a 5-year survival rate of 90% and a 10-year rate of 79.2%. They concluded that the best results were seen when an uncemented and extensively porous coated stem was used. There have also been recent reports demonstrating good results with the use of Wagner-type fluted tapered stems for the treatment of Vancouver type-B fractures [12, 13]. The patient numbers were small in these two studies, however.

Beals and Tower [1] reported the results of 93 periprosthetic fractures treated at numerous facilities by multiple surgeons. Overall, outcomes were considered excellent in 32% of cases, good in 16%, and poor in 52%. Most fractures except trochanteric fractures had a poor result with nonoperative treatment. They also found that the results of ingrowth revision were superior to those for cemented revision for all fracture types. The complication rates were 41% relating to the fracture and 33% relating to the arthroplasty.

Sledge and Abiri [2] reported on seven patients with Vancouver B2 fractures treated in a standardized manner with removal of the implant, cerclage wiring of the fracture with allograft struts, and implantation of a long, uncemented stem. A modular, proximally loading implant was used in three cases, and a curved, fully porous-coated stem was used in four cases. At 33 months average follow-up, they reported no failures, no refractures, and an average Harris hip score of 83. All patients except one returned to their preoperative ambulatory status. They did not comment on complications.

Enthusiasm for operative treatment of complex periprosthetic fracture gained popularity based upon the work of Mont and Maar [26], whose meta-analysis of 26 published reports looked at periprosthetic fractures in 487 patients. While comparisons are difficult due to a lack of uniformity in fracture classification and reporting of outcomes, they found the most satisfactory outcomes for type 2, 3, and 4 fractures (around the tip of the stem) with cerclage fixation or long-stem revision. Screw/plate fixation and nonoperative treatment with traction generally lead to unsatisfactory outcomes. Highly comminuted type 5 fractures appeared to be best treated with long-stem revision.

Our results demonstrate good success rates in treating the majority of periprosthetic femur fractures. However, surgeons should be alerted to the high rate of complications in this group. When presented with a periprosthetic fracture, we feel that the Vancouver classification system provides excellent stratification and uniform terminology. In addition, our data support the treatment algorithm recommended by the Vancouver group. While one of the limitations of this study includes small numbers of subjects, especially in the nonoperative treatment groups, we believe that depth of analysis of the surgical group provides ample support for our conclusions. Future studies employing prospective randomized trials should be conducted in an attempt to confirm classification systems and outcome measures. However, based upon our data, we recommend the use of the Vancouver classification system and treatment algorithm for these difficult fractures.

References

1. Beals RK, Tower SS (1996) Periprosthetic fractures of the femur. An analysis of 93 fractures. *Clin Orthop* 327:238–246
2. Sledge JB, Abiri A (2002) An algorithm for the treatment of Vancouver type B2 periprosthetic proximal femoral fractures. *J Arthroplasty* 17:887–892
3. Ahuja S, Chatterji S (2002) The Mennen femoral plate for fixation of periprosthetic femoral fractures following hip arthroplasty. *Injury* 33(1):47–50
4. Brady OH, Garbuz DS, Masri BA, Duncan CP (1999) The treatment of periprosthetic fractures of the femur using cortical onlay allograft struts. *Orthop Clin North Am* 30(2):249–257
5. Eingartner C, Volkmann R, Putz M, Weller S (1997) Uncemented revision stem for biological osteosynthesis in periprosthetic femoral fractures. *Int Orthop* 21(1):25–29
6. Lewallen DG, Berry DJ (1998) Periprosthetic fracture of the femur after total hip arthroplasty: treatment and results to date. *Instr Course Lect* 47:243–249
7. Tadross TS, Nanu AM, Buchanan MJ, Checketts RG (2000) Dall-Miles plating for periprosthetic B1 fractures of the femur. *J Arthroplasty* 15(1):47–51
8. Venu KM, Koka R, Garikipati R, Shenava Y, Madhu TS (2001) Dall-Miles cable and plate fixation for the treatment of periprosthetic femoral fractures—analysis of results in 13 cases. *Injury* 32(5):395–400
9. Schmidt AH, Kyle RF (2002) Periprosthetic fractures of the femur. *Orthop Clin North Am* 33(1):143–152
10. Nelson CL (2002) Periprosthetic fractures of the femur following hip arthroplasty. *Am J Orthop* 31(4):221–223
11. Springer BD, Berry DJ, Lewallen DG (2003) Treatment of periprosthetic femoral fractures following total hip arthroplasty with femoral component revision. *J Bone Joint Surg Am* 85-A(11):2156–2162
12. Ko PS, Lam JJ, Tio MK, Lee OB, Ip FK (2003) Distal fixation with Wagner revision stem in treating Vancouver type B2 periprosthetic femur fractures in geriatric patients. *J Arthroplasty* 18(4):446–452
13. Berry DJ (2003) Treatment of Vancouver B3 periprosthetic femur fractures with a fluted tapered stem. *Clin Orthop* 417:224–231
14. Berry DJ (2002) Management of periprosthetic fractures: the hip. *J Arthroplasty* 17(4 Suppl 1):11–13
15. Clift B (2000) Periprosthetic fracture of the femur. *J Bone Joint Surg Am* 82(3):446–447
16. Berry DJ (1999) Epidemiology: hip and knee. *Orthop Clin North Am* 30(2):183–190
17. Duncan CP, Masri BA (1995) Fractures of the femur after hip replacement. *Instr Course Lect* 44:293–304
18. Brady OH, Garbuz DS, Masri BA, Duncan CP (1999) Classification of the hip. *Orthop Clin North Am* 30(2):215–220
19. Engh CA, Massin P, Suthers KE (1990) Roentgenographic assessment of the biologic fixation of porous-surfaced femoral components. *Clin Orthop* 257:107–128
20. Harris WH, McCarthy JC, O'Neill DA (1982) Femoral component loosening using contemporary techniques of femoral cement fixation. *J Bone Joint Surg Am* 64(7):1063–1067
21. Abendschein W (2003) Periprosthetic femur fractures—a growing epidemic. *Am J Orthop* 32(9):34–36
22. Berry DJ (2003) Periprosthetic fractures associated with osteolysis: a problem on the rise. *J Arthroplasty* 18(3 Suppl 1):107–111
23. Wang JW, Wang CJ (2000) Periprosthetic fracture of the femur after hip arthroplasty: the clinical outcome using cortical strut allografts. *J Orthop Surg (Hong Kong)* 8(1):27–31
24. Cook SD, Barrack RL, Santman M, Patron LP, Salkeld SL, Whitecloud TS 3rd (2000) The Otto Aufranc Award. Strut allograft healing to the femur with recombinant human osteogenic protein-1. *Clin Orthop* 381:47–57
25. Porsch M, Galm R, Hovy L, Starker M, Kerschbaumer F (1996) Total femur replacement following multiple periprosthetic fractures between ipsilateral hip and knee replacement in chronic rheumatoid arthritis. Case report of 2 patients. *Z Orthop Ihre Grenzgeb* 134(1):16–20
26. Mont MA, Maar DC (1994) Fractures of the ipsilateral femur after hip arthroplasty. A statistical analysis of outcome based on 487 patients. *J Arthroplasty* 9(5):511–519