Periprosthetic Fracture after Total Hip Arthroplasty
Frank A. Difazio, MD* and Stephen J. Incavo, MD†

Periprosthetic fractures after total hip arthroplasty can present a difficult challenge to the reconstructive surgeons. Femoral fractures are addressed by the Vancouver classification system. Periprosthetic acetabular fracture treatment is based on adequate bone support to provide component stability.

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Periprosthetic fracture is a complication that is encountered with increasing frequency after total hip arthroplasty (THA). This trend relates to several factors, including the greater number of THA procedures being performed each year, the extension of this surgery to patients of younger age, the increased use of cementless implants, and, with the aging of the population, the rise in rates of revision THA with associated osteolysis and/or component loosening. Finally, the recent popularity of minimally invasive approaches to THA may also lead to an increase in periprosthetic fracture, particularly during the learning curve for these procedures.

The management of these fractures is technically challenging and the treatment outcome can have a significant impact on the long-term success of the arthroplasty. This chapter outlines the incidence and cause of periprosthetic fracture after THA and reviews the surgical treatment approaches and results.

Incidence

Periprosthetic fractures may occur intraoperatively or postoperatively and more commonly involve the femur. In a review of the Mayo Clinic Joint Registry, Berry1 reported a 1% rate of intraoperative periprosthetic femur fracture in primary THA and a 7.8% rate in revision THA. This series and others2-6 have found an increased prevalence of fracture with cementless femoral stems (3-5.4%) compared with cemented stems (0.3-1.2%). A similar trend has been reported in revision THA series with a fracture rate of 21% in cementless femoral revision versus 3.6% in femoral revision procedures using cement.1

The reported incidence of postoperative periprosthetic femur fracture ranges from 0.1 to 2.1%.1,5,7-11 In the largest series to date, Berry1 identified periprosthetic femur fracture after 1% of primary THA and after 4% of revision THA. Beals and Tower12 estimated that the incidence of this complication over the lifetime of a prosthesis is less than 1%.

Few reports in the literature describe the incidence of periprosthetic fracture of the acetabulum. In 1972, Miller13 described 9 cases of ischiopubic fractures after THA. McElfresh and Coventry14 reported 1 acetabular fracture in a series of 5400 cemented THA. Peterson and Lewallen15 reported on 11 patients who had a periprosthetic fracture of the acetabulum after THA between 1985 and 1991 at the Mayo Clinic. In a multicenter series of THA using noncemented acetabular components, Sharkey and coworkers16 identified 13 intraoperative acetabular fractures. A press-fit technique with underreaming of the acetabulum by 1 to 3 mm was performed in all patients in their series.

Etiologic Factors

A major factor that predisposes to periprosthetic fracture is the quality and mechanical strength of the host bone. This may be affected by underlying disease processes such as osteoporosis, rheumatoid arthritis, or Paget’s disease. Cortical stress risers may lead to fracture and can occur at the tip of the femoral stem or at screw holes, perforations, windows, or osteotomy sites.

Careful preoperative planning and surgical technique are paramount in prevention of intraoperative fractures. These fractures commonly occur during canal and acetabular preparation and component insertion in both primary and revision procedures. Underreaming of the acetabulum by more than 2 mm should be avoided and line-to-line reaming with component screw fixation has been suggested for revision cases or in patients with osteopenic bone.17,18 Prophylactic cerclage fixation should be considered if a risk of femur fracture is perceived.19 Femoral cortical defects, when anticipated or recognized at surgery, should be bypassed by at least 5 cm or twice the outer

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diameter of the diaphysis with a long stem implant. Augmentation with an allograft strut can also be considered.

Osteolysis associated with aseptic loosening of the implant is the single most common risk factor for postoperative periprosthetic fracture. The majority of these fractures occur with a minor episode of trauma. Lewallen and Berry²⁰ reported that nearly 50% of their patients experienced insidious pain and fracture without a history of antecedent fall or trauma. Routine radiographic surveillance of THA patients can identify osteolytic defects and component loosening and allow for proactive surgical intervention.

**Periprosthetic Femoral Fractures**

**Classification**

Several different classification systems for periprosthetic fractures of the femur have been described.⁸,¹²,²¹-²³ Of these, the Vancouver classification²⁴ is the only one that has proven reliability and validity.²⁵,²⁶ This classification system is based on the location of the fracture, the stability of the femoral component, and the quality of the surrounding bone stock (Table 1). Type A fractures involve the trochanteric region and are subdivided as Type AG, which involve the greater trochanter, and Type AL, which involve the lesser trochanter. Type B fractures occur around the femoral stem or just distal to it and are subdivided on the basis of implant stability and quality of the femoral bone stock. In Type B1 fractures the femoral component is well fixed, in Type B2 fractures the stem is loose, and in Type B3 the stem is loose and the there is deficient femoral bone stock around the implant due to osteolysis, osteopenia, and/or fracture comminution. Type C fractures are situated well below the tip of the femoral stem.

**Treatment**

Nonoperative treatment of periprosthetic femur fractures is largely historical. Early reports in the literature favored nonsurgical treatment methods including traction, casts, or braces.¹⁴,²⁷ Such regimens often involved a prolonged period of recumbency with its attendant medical risks, especially for elderly patients. In addition, nonoperative treatment has been associated with a high incidence of subsequent revision for femoral component loosening as well as a high rate of fracture nonunion and malunion.⁸,¹²,²¹ Such treatment is reserved for stable fractures, primarily nondisplaced Type A trochanteric fractures, and for patients whose general medical condition precludes surgery.

The goals of treatment of periprosthetic femur fractures are anatomic alignment, fracture union, and preservation or enhancement of the function of the arthroplasty. The Vancouver classification provides an algorithm that can assist the reconstructive surgeon in developing an appropriate treatment strategy (Fig. 1).

<table>
<thead>
<tr>
<th>Type and Subtype</th>
<th>Location and Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td></td>
</tr>
<tr>
<td>AG</td>
<td>Greater trochanter</td>
</tr>
<tr>
<td>AL</td>
<td>Lesser trochanter</td>
</tr>
<tr>
<td>Type B</td>
<td></td>
</tr>
<tr>
<td>B1</td>
<td>Around stem or stem hip; stem well fixed</td>
</tr>
<tr>
<td>B2</td>
<td>Around stem or stem tip; stem loose</td>
</tr>
<tr>
<td>B3</td>
<td>Around stem; stem loose, poor proximal bone stock</td>
</tr>
<tr>
<td>Type C</td>
<td>Distal to stem</td>
</tr>
</tbody>
</table>

Type A Fractures

The majority of Type A fractures are stable and may be treated nonsurgically. Internal fixation should be considered for fractures of the greater trochanter with greater than 2.5 cm of displacement or for symptomatic trochanteric nonunion (Fig. 1). Those fractures associated with osteolysis require fixation with bone grafting and polyethylene exchange or acetabular revision. Although most Type A1 fractures are minor and inconsequential, large fragments that disrupt the medial buttress of the proximal femur will necessitate surgical stabilization. The possibility of pathologic fracture of the lesser trochanter secondary to metastatic disease must also be considered.

Type B1 Fractures

Type B1 periprosthetic fractures occur around well-fixed femoral stems and are amenable to open reduction and internal fixation techniques (Fig. 2). Although successful results have been reported with standard AO plates and screws, proximal screw fixation can violate an existing cement mantle or can be limited by the presence of a cementless implant. To avoid these potential risks, alternative fixation options have been developed. In 1978, Mennen designed a paraskeletal clamp for fixation of unstable shaft fractures. While early reports of periprosthetic femur fractures treated with the Mennen plate were encouraging, a number of more recent studies have found a high percentage of nonunion and mechanical failure of this plate device.

Ogden and Rendall were the first to describe the use of a plate for periprosthetic femur fractures that combined proximal cerclage fixation with distal screw fixation. The success of this method has led to the introduction of plates that are secured with metal cables that employ specialized tensioning devices and locking mechanisms. Tadross and coworkers reported their results of the Dall–Miles plate and cable system in seven Type B1 periprosthetic fractures. Three of these fractures healed uneventfully and four fractures went on to failure. All of the failed cases occurred in patients whose femoral stem was in a varus position. Venu and associates reviewed six Type B1 fractures treated using this system. Their one case of fixation failure similarly occurred in a patient with a prefracture varus-positioned femoral component. Tsiridis and coworkers reported two plate failures in three patients in whom Type B1 fractures were stabilized with the Dall–Miles device and concluded that the Dall–Miles plates and cable system alone was insufficient for treatment of periprosthetic femoral fractures.

In 1989, Chandler and Penenberg first described the use of cortical strut allografts to fix periprosthetic femur fractures. Strut allografts can act as biological plates conferring mechanical stability as well as enhancing fracture healing and increasing bone stock. In a series of 19 patients with periprosthetic femur fractures, Chandler and coworkers reported that 16 of the 19 patients achieved fracture union at a mean of 4.5 months and were able return to their preinjury level of function. A
malunion occurred in 1 patient in whom a tibial strut allograft had been used. The 2 patients who developed a non-union had had a previous surgical procedure that involved periosteal stripping of the femoral shaft.

Chandler and Danylchuk subsequently described the combined use of a metal plate on one cortex and a cortical strut allograft on the other to treat periprosthetic fractures. Anatomical union occurred in 21 of 22 patients (95%). Hadaad and coworkers reported on this technique in 4 patients with Type B1 periprosthetic fractures. The clinical outcome was excellent in all 4 patients, although 1 patient developed a 20° malunion.

In a more recent multicenter study, Haddad and associates reviewed the results of 40 Type B1 periprosthetic femur fractures managed with cortical onlay allograft alone or with a plate and one or two cortical struts. Union was achieved in 98% and all but 1 patient returned to their preoperative level of function within 1 year. These authors recommend that cortical strut allograft be used routinely in the treatment of these fractures.

The concept of dual fixation of periprosthetic fracture around a well-fixed femoral stem consisting of either a lateral plate and anterior or medial allograft strut or two allograft struts has been further supported by biomechanical studies. These experimental results suggest that a minimum of three fixation points above and below the fracture will enhance the mechanical stability of the construct. Plates should be secured with bicortical screws distally and cables, rather than smooth wires, proximally. Strut grafts should not make contact with each other during tensioning of the cerclage device as this will result in compression of the struts to one another rather than to the host bone.

**Type B2 Fractures**

Type B2 fractures are associated with a loose or failed femoral component and require stem revision in addition to fracture fixation (Fig. 3). Although earlier reports concerned cemented long-stem revision for these fractures, high rates of failure and the potential for cement to interfere with fracture union has led to the more widespread use of cementless stems in this situation. Currently, cemented long-stemmed implants are reserved for selected older patients with simple fracture patterns that can be reduced anatomically to preclude cement extrusion.

Several studies have demonstrated successful treatment of Type B2 fractures using cementless, long-stemmed, extensively porous-coated femoral implants. These prostheses allow initial stability in the intact diaphysis and offer the added advantage of providing intramedullary fixation. The distal extent of the femoral shaft fracture should be bypassed by at least two cortical diameters. Fixation can be supplemented with cerclage cables, plates, and/or cortical strut allografts. Despite satisfactory short- to medium-term results, concerns remain about proximal stress shielding and loss of bone stock. Proximally coated uncemented stems, by contrast, have been associated with poor outcomes primarily
related to aseptic loosening of the revision femoral component.\textsuperscript{20,52}

An alternative approach to the management of periprosthetic femoral fracture around a loose stem has been suggested by Tsiridis and coworkers.\textsuperscript{53} In a recent retrospective review, these authors evaluated the results of 106 Type B2 and B3 fractures treated by impaction allografting and showed a rate of union of 88\% within a mean of 7.44 months. In this technique fresh frozen cancellous allograft bone chips are impacted into the femoral canal to provide a so-called neoendosteum for components inserted with cement. The impacted allograft reconstructs the femur from inside out and prevents extrusion of cement and its interposition between fracture fragments. Tsiridis and coworkers\textsuperscript{53} recommend that, when the impaction allografting

\begin{figure}[h]
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\includegraphics[width=\textwidth]{figure4.png}
\caption{This patient with metastatic breast cancer sustained this Vancouver B3 fracture after radiation therapy to the proximal femur (A). Revision to a long tapered cementless stem was performed which allowed full weightbearing postoperatively. Additional cerclage wire fixation of the allograft strut was not performed because of the difficulty encountered passing wires around the irradiated tumor mass.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure5.png}
\caption{Vancouver C Fracture. This multiply revised patient sustained a nondisplaced fracture that was successfully treated with a hip spica cast.}
\end{figure}
technique is used for periprosthetic fracture, it should always be supported by a long-stem femoral component and augmented by an extramedullary fixation device, preferably cortical strut grafts.

**Type B3 Fractures**
Type B3 periprosthetic femur fractures are defined by the presence of a loose or unstable stem and deficient proximal femoral bone stock (Fig. 4). These are complex and challenging cases with significant potential for complications. Type B3 fractures often necessitate replacement of the proximal femur with a structural allograft–prosthesis composite or a tumor prosthesis.24 Proximal femoral replacement prostheses are used in elderly patients in whom immediate postoperative weightbearing is desirable.

Allograft–prosthetic composites are used in younger patients and allow reattachment of remnants of the proximal femur around the allograft, which improves the stability and function of the construct. Wong and Gross54 reported on the use of segmental allograft in 19 patients who presented with severe proximal femoral bone loss and periprosthetic fracture. At a mean follow-up of 5 years, 13 of 15 available patients had a good result.

**Type C Fractures**
These fractures occur distal to the femoral component and their management is independent of the presence of the arthroplasty (Figs. 5, 6). Standard plates and/or cerclage cables are the most common methods of fixation, but a revision to a long stem component can be considered in selective cases. A technical caveat is to avoid creating a stress riser between the fixation device and the distal end of the femoral stem.55

**Periprosthetic Acetabular Fractures**

**Classification**
Periprosthetic fractures of the acetabulum are broadly classified as intraoperative or postoperative. Those that occur intraoperatively are distinguished by whether there is involvement of the acetabular wall or one or both of the acetabular columns (Fig. 7).56 Peterson and Lewallen15 classified postoperative peripro-

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**Figure 6** A Vancouver type C fracture (A) with significant osteolysis surrounding the femoral component was treated with a fully HA coated long revision prosthesis and supplemental allograft strut fixation (B, C).
thetic acetabular fractures into two types. In Type I fractures the acetabular component is clinically and radiographically stable and in Type II fractures the component is unstable.

**Treatment**

When a fracture of the acetabulum is encountered at the time of surgery, adequate exposure is undertaken to assess the extent and stability of the fracture. A stable fracture of the acetabular wall can be managed by supplemental screw fixation of the acetabular component alone. An unstable wall fracture should be secured with cancellous bone screws and the fracture site should be augmented with autograft from the femoral head. The acetabular component is then stabilized with an adequate number of fixation screws. If the posterior or anterior column is involved, a buttress plate is utilized with additional lag screw fixation of the opposite column, if possible, with bone grafting.17,56

Type I postoperative periprosthetic acetabular fractures are typically treated nonoperatively with 6 to 8 weeks of toe-touch weight-bearing. Peterson and Lewallen15 found that four of six patients with radiographically stable acetabular components eventually required revision surgery, despite healing of the fracture. Therefore, appropriate radiographic follow-up and patient counseling is essential in these cases.

Type II fractures are associated with acetabular component looseness and require surgical intervention.17,56 This necessitates restoration of the bony support of the acetabulum and subsequent revision of the acetabular prosthesis. A fracture that involves the medial wall with intact anterior and posterior walls and columns can be treated with morselized allograft packed medially and a large cementless acetabular cup fixed with screws.

Patients with Type II periprosthetic acetabular fractures that are transverse or involve the posterior column can be managed with reconstructive plates, morselized bone graft, and a cementless acetabular component secured with screws. In cases of pelvic discontinuity, at least one column (typically the posterior column) is stabilized with plating and structural bulk allograft, if necessary. An uncemented cup is inserted and is fixed with cancellous screws. An alternative approach for elderly patients with osteopenia or patients with massive bone loss secondary to osteolysis is to use an antiprotrusio cage to secure the superior hemipelvis to the ischium. An all-polyethylene acetabular component is cemented into the cage.

**Summary**

Periprosthetic fractures after total hip arthroplasty are being encountered with increasing frequency. These fractures are often complex in nature and present a difficult challenge to the reconstructive surgeon. The Vancouver classification of periprosthetic femur fractures is based on the location of the fracture, the stability of the femoral component, and the quality of the surrounding bone. This classification system provides an excellent basis for treatment decisions. In general, a fracture around a stable implant should be treated with open reduction and internal fixation using a combination of a cable plate and strut allograft or dual-strut grafts secured with cables. When the fracture occurs around a loose stem, component revision as well as fracture fixation is necessary. The choice of revision prosthesis is determined by the condition of the host bone.

The management of periprosthetic acetabular fractures is determined by the fracture pattern and the condition of the supporting bone as well as the stability the acetabular component. Fractures associated with unstable acetabular implants require fixation using reconstruction plates and/or lag screws, bone grafting, and reinsertion of a cementless component augmented with cancellous screws. Bulk structural allograft and antiprotrusio cages may be needed in select cases.