**Periprosthetic Femoral Fractures Associated With Hip Arthroplasty**

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**educational objectives**

As a result of reading this article, physicians should be able to:

1. Discuss the Vancouver classification of periprosthetic fractures.
2. Explain the principal treatment for periprosthetic fractures according to the Vancouver classification.
3. Recall the indication for open reduction and internal fixation or revision joint arthroplasty in the presence of an acute periprosthetic fracture.

Total hip arthroplasty (THA) is an extremely effective procedure with a high likelihood of excellent long-term results and a relatively low risk of complications. A rare major complication of THA is postoperative periprosthetic femoral fracture. With the increasing number of hip replacements in service, and with the aging population, the number of periprosthetic femoral fractures has been proportionally increasing worldwide. The overall incidence of periprosthetic femoral fractures has been reported to range between 0.1% and 7.8% of all THAs. Management of these fractures often requires different techniques from those used to treat routine femur fractures. The surgeon may need to simultaneously address implant loosening, bone loss, and fracture. An understanding of the unique characteristics of the different fracture types, and their underlying causes, combined with a familiarity of the various fixation devices, bone grafts, and prosthetic implants is critical.

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Epidemiology and Etiology

The prevalence of periprosthetic femoral fracture ranges from 0.1% to 7.8% depending on the series reviewed. Berry reported the incidence of postoperative periprosthetic femoral fractures is <1% (238 of 23,980) of primary THA and up to 7.8% (497 of 6349) of revision THA. The Mayo clinic reports an accumulated incidence of 0.6% in primarily cemented THA and 0.4% in primarily uncemented THA. The Swedish National Hip Registry reports an accumulated incidence of 0.4% following primary THA and 2.1% following revision THA. Löwenhielm et al reported a study of 1442 primary cemented THAs with a maximum accumulated risk rate of 2.5% for periprosthetic femoral fracture and an annual incidence ranging between 0% and 1.2%.

The incidence of periprosthetic femoral fractures seems to be increasing because of several factors: the increasing prevalence of patients with femoral prostheses; the broadening indications for THA; the increasing number of elderly patients at risk for osteoporosis; the increasing numbers of young patients with THA at risk for high-energy trauma events; and the increasing numbers of revision procedures.

Periprosthetic femoral fractures also are often associated with other physiologic conditions such as osteoporosis, osteolysis, and occasionally infection. As a result, periprosthetic femoral fractures usually result from low-energy trauma and frequently occur after falls or spontaneously during activities of daily living. Adolphson et al reported low-energy trauma as the cause of approximately 88% of periprosthetic femoral fractures (28 of 32). Cooke and Newman reported major trauma accounts for approximately 8% (6 of 75) in their series. Similarly, Lindahl et al reported only 7% of periprosthetic femoral fractures are the result of major trauma, whereas 75% occurred from a fall at the same level (sitting or standing), and 18% occurred spontaneously. Beals and Tower reported 66% of their fractures occurred from a fall at home, 8% occurred spontaneously, and 25% of the patients (22 of 93) had loose femoral components before fracture. The majority of these fractures results from relatively low-energy trauma and is associated with underlying physiological condition.

Vancouver Classification

An effective classification system should be prognostic of outcome and guide the surgeon to the most appropriate treatment. Most authors agree that treatment decisions for periprosthetic femoral fracture depend on the fracture location, stability of the implant, and quality of the surrounding bone stock. Various radiographic classification systems have been proposed including those of Tower and Beals, Johansson et al, Bethea et al, and Cooke and Newman. None of these classifications addresses all 3 factors critical to treatment decisions. Currently, the most commonly used system is the Vancouver classification (Table 1). It is more comprehensive, taking into account fracture location, implant stability, and quality of the surrounding bone stock. This system has been shown to be reproducible, reliable, and valid.

The Vancouver classification divides periprosthetic femoral fractures into A, B, and C categories based on the location of the fracture: A, trochanteric region; B, around or just below implant; C, well below the stem tip. Type A fractures are divided into those involving the greater trochanter (AG) or those involving the lesser trochanter (AL). Type B fractures then are divided into B1 (prosthesis stable) and B2 or B3 (prosthesis loose) depending on the stability of the implant and degree of bone loss. An implant is defined as stable if there is an absence of radiolucent lines around the femoral stem or progressive implant migration or subsidence on serial radiographs. B1 and B2 fractures are separated based on available bone stock. In B3 fractures, the surrounding bone stock is adequate, and in B1 fractures, the bone stock loss is of the magnitude that it no longer is capable of supporting a standard revision stem.

TREATMENT

The goals of treatment of periprosthetic femoral fractures include a united fracture in acceptable alignment, a stable prosthesis, and an early mobilization, with a rapid return to prefraction function. Options for treatment have included nonoperative methods such as protected weight bearing, traction, casts, and braces. Surgical methods include internal fixation with plates or cable plate systems and revision arthroplasty with or without allograft. The Vancouver clas-
sification suggests an algorithm for treatment, but requires correct interpretation. Lindahl et al\textsuperscript{16} suggests that the high rate of B\textsubscript{1} group treatment failure may be attributed to the misinterpretation of stem stability on preoperative radiographs and errant classification of type B\textsubscript{1} fractures as type B\textsubscript{2}.

Treatment of Type A Fractures

Type AG: the greater trochanter fracture. These fractures are usually stable and can be treated nonoperatively with protected weight bearing and avoidance of active abduction for 6 to 12 weeks, when there is convincing clinical and radiographic evidence of union (Figure 1). Pritchett\textsuperscript{17} reported that trochanteric fractures with migration \(<2\text{ cm}\) can be treated nonoperatively. Internal fixation and autografting should be considered when migration is \(>2.5\text{ cm}\) or trochanteric nonunion results in pain, instability, or weakness in abduction.

Type AL: the lesser trochanter fracture. Type AL fractures are rare and are usually due to low-energy mechanisms. Their presence suggests osteolysis and loosening of the stem. This fracture pattern often involves a large portion of the femoral calcar, and is not readily apparent on plain radiographs (Figure 2). Subsequent stem revision is more complex because of the loss of the medial buttress. Truly isolated type AL fractures without infection or osteolysis can be treated nonoperatively.

Treatment of Type B Fractures

Type B\textsubscript{1}: fractures around the stable stem. In patients with B\textsubscript{1} fractures, the femoral stem can be retained. These fractures should be treated with open reduction and internal fixation with or without cortical strut allograft (Figure 3). The options available for promoting osteosynthesis include conventional plates, dynamic compression plates, paraskeletal clamp-on plates (Mennen, Devon, United Kingdom), cable plate systems, and locking compression plates. The modern Less Invasive Stabilization System (LISS) plates (Synthes, Paoli, Pennsylvania) appear to be superior to the original osteosynthesis plates with bi-cortical screws and may negate the need for allograft struts or multiple plates.

Type B\textsubscript{2}: fractures around the loose stem. The most commonly recommended fixation for type B\textsubscript{2} fractures is revision with a longer femoral stem, effectively bypassing the fracture by a minimal distance of at least 2 femoral diameters\textsuperscript{18} (Figure 4). In cases of unstable transverse fractures, revision intramedullary fixation with an extramedullary allograft cortical strut and cerclage wires or cables may be necessary to enhance the rotational stability of the femur. For oblique or spiral fractures that can be stabilized with cerclage fixation, onlay cortical struts may not be necessary. The use of cemented components has more complications including loosening, nonunion, and refracture than cementless components, because the femoral fragments are separated by the cement.\textsuperscript{8} In general, a cementless revision stem is preferable and cemented stems are rarely indicated except in cases of severe osteoporosis or osteomalacia.\textsuperscript{19}

Type B\textsubscript{3}: fractures around the loose stem with substantial bone loss. In the B\textsubscript{3} fracture type, it is particularly challenging to simultaneously achieve implant and fracture stability. Surgical options include proximal femoral replacement with either an allograft-prosthetic composite (Figure 5) or a megaprosthesis\textsuperscript{20} (Figure 6). Elderly patients (older than 80 years), are best treated with a tumor prosthesis due to the relatively short operative time and immediate stability of the construct.\textsuperscript{21}

Treatment of Type C Fractures

Type C: fractures well below the implant. Patients with Type C fractures are treated with open reduction and internal fixation (Figure 7). Fractures close to the tip of the femoral stem require a plate that
spans the tip of the stem proximally and avoids a stress riser between the 2 implants. For very distal fractures, short intramedullary nail systems can be considered because of the relatively large distance between the fracture and the prosthesis.

TECHNIQUES

Nonoperative treatments of periprosthetic femoral fractures were popular in the past, but have become obsolete for most fractures. Adolphson et al emphasized the high rate of complications including malalignment or malunion. Somers et al recommended operative management after reviewing 34 periprosthetic femoral fractures treated nonsurgically. In addition, the longer immobilization period of the limb increases the risk of thrombosis, embolism, pneumonia, pressure ulceration and knee joint contractures. Presently, nonoperative treatment is reserved only for stable fractures of the trochanters. Operative options include open reduction and internal fixation and revision arthroplasty. The choice of internal fixation largely supposes that the existing femoral implant has not been loosened by the fracture.

Cable Plate Systems

Numerous cable plate systems are available including Ogden plate, Dall-Miles plate, cable-ready plate (Zimmer, Warsaw, Indiana) and peri-fix plate (Merete, Berlin, Germany). These systems allow attachment of cables, wires, and screws, providing the surgeon with many options for securing the plate to the fractured femur without interfering with the intramedullary device or the cement mantle. The Ogden plate was one of the first designs to include cables or screws for use with a plate, but restricted the location of screw and cable attachments. The more recent designs allow cables and screws to be alternated along the plate as the fracture requires. Zenni et al reported 80% satisfactory results in 19 periprosthetic femoral fractures treated with a cable plate system. Kaminemi et al successfully stabilized 13 of 15 periprosthetic femoral fractures and advocated at least 3 proximal cables and 4 distal cortical screws.

However, Tsiridis et al reported 10 of 16 periprosthetic femoral fractures around cemented femoral components were successfully treated with cable-plate systems. They analyzed the reason for failure in 6 cases and revealed the inherent weaknesses of this plate system, subsequently recommending the combination of Dall-Miles plates with the additional measures of long-stem revision or strut allografting. Venu et al described their experience with the Dall-Miles plate in 12 periprosthetic femoral fractures. Five were augmented by cancellous bone graft, and in 3 cases a strut allograft was also used. All but 3 periprosthetic femoral fracture patients had successful union at a mean of 4.4 months and returned to their pre-injury level of mobility. Tandross et al also reported 7 periprosthetic femoral fractures treated with Dall-Miles plates: 3 achieved union and satisfactory results, 2 failed to unite, and another 2 developed an unacceptable varus malunion. The high rate of failure in this series may suggest that additional fixation such as cancellous bone graft or onlay cortical struts should be used with cable plate systems.

Locking Plate Fixation

The application of locking plates in periprosthetic femoral fracture around THA is a relatively new concept. Locking plate systems provide angular stability and strong fixation in bone of poor quality. Locking plates may have a lower incidence of hardware failure, and may not interfere with the periosteal blood supply. In view of these mechanical and biological advantages, it seems that locking plates are a reasonable choice in the treatment of periprosthetic femoral fracture.
Several reports exist regarding the use of locking plates for the treatment of periprosthetic femoral fractures. Schütze et al\textsuperscript{29} reported 14 periprosthetic femoral fractures, close to a hip prosthesis, treated by LISS plating using minimally invasive techniques, with only 1 failure of fixation. O’Toole et al\textsuperscript{30} reported the results of use of LISS plates in the treatment of periprosthetic femoral fracture around total hip and total knee replacements. Eighteen of the 19 fractures in their series healed uneventfully with a complication rate of 5.2%. Berlusconi et al\textsuperscript{31} reported the application of locked compression plating (LCP) with minimally invasive techniques in 14 periprosthetic femoral fractures, all of which had a stable femoral component. All the fractures in the series united, at an average of 6 months. Immediate partial weight bearing was initiated postoperatively and all returned to their preinjury mobility status.

Erhardt et al\textsuperscript{32} reported the results of treatment of periprosthetic femoral fractures with the non-contact bridge plating that combines conventional and locking plate techniques. The union rate was 90% with a malunion rate of 5% and a reoperation rate of 15%. Buttaro et al\textsuperscript{33} recently reported 14 type B\textsubscript{1} fracture patients treated with LCP, resulting in 3 nonunions with plate breakage and 3 cases of screw pullout. All but 1 of these failures occurred in cases treated initially without cortical onlay allograft. The authors conclude that locking plate fixation should also be used in conjunction with bone graft for success. Ebraheim et al\textsuperscript{34} also reported 13 consecutive patients with type B\textsubscript{1} periprosthetic femoral fractures who were stabilized with a reversed distal femoral locking plate. All fractures healed at an average of 14 weeks after fixation. Bryant et al\textsuperscript{35} reported 10 type B\textsubscript{1} periprosthetic femoral fractures treated with LCP that were followed for a mean of 27 weeks. Only patients who had fracture fixation with a locked plate, without supplemental allograft struts, cerclage cables, or wires, were included in their study. All achieved fracture union at a mean of 17 weeks.

We believe that open reduction and internal fixation using a lateral locked plate is a successful treatment method, especially for Vancouver type B\textsubscript{1} fractures. Important techniques to consider are indirect reduction techniques, with bridge technique, bicortical fixation in the proximal femur, and allograft bone struts.

**Bone Grafting**

Bone grafting is an important technique for the treatment of periprosthetic femoral fractures. There are several bone graft styles including cortical strut allograft, cortical onlay allograft, segmental allograft, and impaction bone grafting. The use of cortical strut allografts first was reported by Chandler and Penenberg\textsuperscript{36} in 1989. A series of 19 periprosthetic femoral fractures was treated with massive cortical onlay graft. Sixteen of 19 patients achieved union at a mean of 4.5 months. There was 1 malunion and 2 nonunions in the series. In 1998 Chandler and Tigges\textsuperscript{37} described the successful use of a metal plate with allograft strut, and confirmed union of the allograft with host bone in 21 of 22 patients. Head et al\textsuperscript{38} also described the basic science and demonstrated good clinical results with strut allografting. Haddad et al\textsuperscript{39} reported a union in 39 of 40 fractures treated with cortical onlay allografts with or without a plate, but encountered 4 malunions and 1 deep infection. Maury et al\textsuperscript{40} retrospectively assessed the results and complications of the use of a proximal femoral allograft to treat 25 Vancouver type B\textsubscript{1} periprosthetic femoral fractures in 24 patients. Twenty-one of the 24 patients reported no or mild pain and 23 patients were able to walk. Although excellent union rates have been shown with allograft struts alone, the authors suggest allograft struts should be used in conjunction with plates where possible. The struts fatigue more rapidly than metallic implants and if fracture union is delayed beyond 4 to 6 months, the structural integrity of the construct may be compromised prior to fracture union.\textsuperscript{41}

Segmental allograft also can be used to reconstruct bone deficiency at the time of revision THA for Type B\textsubscript{1} fractures. Wong and Gross\textsuperscript{42} described the use of proximal structural allograft in 19 patients with severe bone loss presenting with periprosthetic femoral fracture. Fifteen patients were available for review with a mean follow-up of 5 years. Thirteen patients had a good result. Two patients required additional surgery; 1 patient required plating for nonunion, and another patient required a revision to a similar construct.

Periprosthetic femoral fractures around THA are often associated with osteolysis. Impaction grafting was originally introduced as a means to restore acetabular and femoral deficits during revision THA. Sloop et al\textsuperscript{43} recommended a minimum of 270 mL of corticocancellous allograft chips of the size and shape for femoral impaction grafting. The bone graft was fresh-frozen irradiated allograft croutons measuring 4 mm in diameter and rinsed in normal saline before implantation. Tsiridis et al\textsuperscript{44} reported on a series of 106 patients with periprosthetic femoral fractures treated with femoral component revision with impaction bone grafting. Periprosthetic femoral fractures treated by impaction grafting and a long stem were greater than 5 times more likely to unite than those treated by impaction grafting and a short stem. Furthermore, those with impaction grafting and a long stem were significantly more likely to unite than those with a long stem without impaction grafting. There was also a trend towards a higher rate of union in those treated by impaction grafting than in those without. Lee et al\textsuperscript{45} recently reported that in 7 patients with femoral fractures treated with long stem femoral component revision using the impaction grafting bone technique, 6 patients experienced a good or an excellent result.

**Revision THA**

A revision THA is indicated in periprosthetic femoral fracture when the prosthesis is loose (Vancouver types B\textsubscript{2} and B\textsubscript{3} fractures). The femoral prosthesis should bypass the fracture by at least 2 femoral diameters.\textsuperscript{2,3,18} A cemented or cementless
... prosthesis can be used, but cementless prostheses are more commonly used. Frequently when a cemented prosthesis is used, the cement is forced into the fracture site and impedes union. Beals and Tower reported that 31% of patients revised with cemented stems developed pseudoarthroses, another 15% sustained new fractures, and 15% developed permanent bone defects. In contrast, only 7% of patients with cementless implants sustained new fractures. Because of difficulties in attaining fracture union, the authors reserve cemented stems for the treatment of elderly, osteoporotic patients who have large femoral canal diameters that cannot be readily treated with cementless stems. When using cemented stems in the treatment of such patients, a careful cement technique, avoiding extrusion of the cement at the fracture site is prudent. Sandhu et al. reported that 31% of patients revised with cemented stems developed pseudoarthroses, another 15% sustained new fractures, and 15% developed permanent bone defects. In contrast, only 7% of patients with cementless implants sustained new fractures. Because of difficulties in attaining fracture union, the authors reserve cemented stems for the treatment of elderly, osteoporotic patients who have large femoral canal diameters that cannot be readily treated with cementless stems. When using cemented stems in the treatment of such patients, a careful cement technique, avoiding extrusion of the cement at the fracture site is prudent. Sandhu et al. described a unique technique that avoids cement extrusion into the fracture site in a series of 5 patients. A split 60-mL syringe is used as a sleeve around the fractured femur, preventing cement extrusion.

Popularized as a method of bypassing proximal bone deficiency in revision THA, there has been an increased interest in using distally fixed porous-coated stems as intramedullary fixation for complex periprosthetic femoral fracture. Mont and Maar reported 80% satisfactory results of types B2 and B3 periprosthetic femoral fractures that were treated with long-stem revision arthroplasty. Tower and Beals reported the use of a modular prosthesis with proximal ingrowth and a fluted long stem for torsional control produced better results than revisions in which cement is used. They suggested that an extensively coated diaphyseal stem also would give such torsional control. This can be used in conjunction with cortical onlay allograft or plate and cerclage cables to provide maximal stability and fracture control. MacDonald et al. reported on 14 cases of postoperative fracture treated with extensively-coated cementless stems. All 14 fractures healed with no deformity. One stem, however, developed fibrous ingrowth but has not been revised. Springer et al. demonstrated a prosthetic survival of 90% at 5 years and 79.2% at 10 years for 118 hips treated by long-stem revision arthroplasty for type B periprosthetic femoral fracture.

Recent results reported by Fawzy et al. are encouraging with 95% fracture union, 95% 5-year implant survival and a low complication rate (12.5%). They treated and analyzed 40 periprosthetic femoral fractures with revision hip surgery using the Oxford trimodular femoral stem with an average follow-up of 7.9 years.

An alternative option in elderly patients is the use of a tumor prosthesis, allowing a shortened rehabilitation and permitting immediate weight bearing (Figure 6). Proximal femoral replacements have been shown to be effective in this demanding patient population, but the durability of these reconstructions is limited. One series reported only 64% prosthesis survivorship at 12 years.

**Physiological Classification**

The Vancouver classification has limitations as it is a purely anatomically based system and does not account for the underlying physiologic causes of the periprosthetic femoral fracture. In our experience, the classification is most helpful in low-energy, or spontaneous, fractures in elderly persons with osteoporosis or osteolysis. Lindahl et al. reported that 7% of the patients in their series sustained high-energy trauma. In our experience, the Vancouver classification is less helpful in this uncommon population. We propose a physiological description of periprosthetic fractures, dividing fractures between high-energy and low-energy mechanisms (Table 2).

The rare patients sustaining high-energy fractures frequently have associated soft tissue injuries that may change operative treatment significantly. These fractures may be open or impending open. A timely, aggressive debridement of all devitalized soft tissue and early soft tissue coverage seems to be critical to treatment success. Open wound management in these open fractures may be contraindicated as the exposed prosthesis rapidly becomes colonized with bacteria. If early coverage cannot be obtained, then removal of the prosthesis may be considered. Operative treatment of high-energy closed periprosthetic fractures should be delayed until healing of the adjacent soft tissues. The role of temporary spanning external fixation in these rare patients is unknown.

Low-energy periprosthetic fracture is occasionally the presenting symptom of a subclinical, periprosthetic infection. If a revision THA is considered, the possibility of infection should be investigated preoperatively. The bone loss and implant loosening frequently identified in the presence of an infection can be mistaken as osteolysis and the operative treatment of...
the fracture, as directed by the Vancouver classification may then be complicated by nonunion, recurrent prosthetic loosening, or clinically apparent surgical site infection. Unfortunately, the diagnosis of subclinical infection, in the presence of an acute fracture is difficult. The physical examination is blurred by the pain related to the fracture. Serology, such as erythrocyte sedimentation rate and C-reactive protein may be spuriously elevated by the recent trauma. A history of pain in the joint prior to the fracture may be the most important symptom, but is not discriminatory between osteolysis and infection. Aspiration results may be diluted by the fracture hematoma. Intraoperative frozen section analysis of the periprosthetic membrane and synovial tissues is a useful test for infection; however, the utility of this test, in the presence of an acute fracture has not been studied. Multiple intraoperative cultures should be obtained whenever the prosthesis or periprosthetic tissues are exposed to guide postoperative treatment. Unfortunately, intraoperative gram stain lacks sufficient sensitivity to direct intraoperative management. If an underlying infection is considered likely, the patient should be treated with a two-stage revision using a spacer that allows for healing of the fracture. Osteolysis also is a common complication in THA and cause of periprosthetic fracture. Osteolytic lesions are seen on plain radiographs as progressive linear radiolucencies around the stem, indicating stem loosening. Excessive wear debris production contributes to the osteolysis. Revision of the bearing surfaces or correction of components generating unintended wear debris should be performed.

CONCLUSION
The incidence of periprosthetic femoral fractures is increasing as a result of changes in population demographics and the increase in the number of total hip replacement performed. The surgical intervention is a challenge to the surgeon as he/she not only has to treat the fracture but also may have to revise the prosthesis as well. The Vancouver classification system is presently the best system that allows the surgeon to determine the most appropriate treatment method. We propose a supplemental physiological classification as a useful adjunct. Future treatment changes are expected as internal fixation, revision prostheses, and biological treatment options improve.

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