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Improving Outcomes After Pertrochanteric Hip Fractures

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Abstract

Complex pertrochanteric fractures, such as those with reverse obliquity and subtrochanteric extension, represent a subset of hip fractures that sometimes is difficult to treat. Critical assessment of the available literature and a review of treatment indications, implant recommendations, and technical pitfalls will provide insight to physicians to enable better care of patients with these complex injuries.

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Surgical stabilization of hip fractures in geriatric patients continues to be the standard of care. Surgical repair allows early mobilization, limits the period of recumbency, and allows patients to return more rapidly to functional activity. Nonsurgical management of hip fractures in geriatric patients has been associated with high rates of medical morbidity and mortality and usually is reserved for patients with medical conditions that preclude surgical treatment. Mobilizing elderly patients after fracture fixation aids in preventing the complications of prolonged recumbency, such as decubiti, urinary tract infections, atelectasis and respiratory infections, venous thromboembolism (VTE), and pulmonary embolism (PE).

Nonsurgical treatment is associated with increased rates of mortality at 6 months and 1 year after fracture, and in those who survive, there is a significant loss of functional status and ambulatory ability.[1] Although there is clear evidence that most pertrochanteric hip fractures should be stabilized surgically, the influence of age, sex, medical comorbidities, mental status, and the preinjury level of function on postoperative function, complication rates, and patient mortality remains unclear.

Timing of Surgery

Once surgical treatment is chosen for a geriatric patient with a hip fracture, it should be performed as soon as possible. Many studies have shown an association between a surgical delay of more than 24 to 48 hours and a higher 1-year mortality rate.[2-7] However, there is an important balance between the optimization of medical issues and expeditious surgical management. Table 1 summarizes the existing literature regarding the timing of hip fracture fixation.[2,5-11] In general, hip fracture surgery should be done as soon as possible after the stabilization of all comorbid medical conditions, especially cardiopulmonary problems and fluid and electrolyte imbalances.

Medical Evaluation

Although advanced age itself is not an independent risk factor for complications after surgery, older patients tend to have more coexisting medical conditions that affect surgical risks. Many elderly patients have pulmonary, renal, cardiovascular, or

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Table 1
Summary of Literature Regarding Timing of Hip Fracture Fixation

Study Authors (Year)	Number of Patients	Time to Surgical Repair	Findings
Kenzora et al[8] (1984)	399	96 patients operated on < 24 hours	One-year mortality rate of 34%, which was significantly higher than that reported in patients operated on 2 to 5 days after injury
Zuckerman et al[2] (1995)	367	> 48 hours	Mortality nearly doubles compared with those operated on within 2 hospital days (hazard ratio of 1.76)
Hamlet et al[6] (1997)	168	> 24 hours	Three-year mortality rate of 50%, compared with 20% rate for patients operated on within 24 hours
Doruk et al[9] (2004)	65	> 5 days	Late cohort had longer hospital stay, longer time to functional recovery, lower activities of daily living scores at 6 months postoperatively, and higher mortality at 1 year
Orosz et al[5] (2004)	1,206	> 24 hours	Cohort had significantly less pain, shorter hospital stay, and lower incidence of postoperative complications; no difference in function or 6-month mortality rate
Gdalevich et al[10] (2004)	651	> 48 hours	One-year mortality rate of 25.7%, compared with a rate of 14.1% for patients operated on within 48 hours
McGuire et al[7] (2004)	18,209	> 48 hours	Delayed surgery led to a 17% higher chance of mortality by postoperative day 30
Moran et al[11] (2005)	2,660	> 4 days	Increased risk of mortality at 90 days and 1 year, compared with those operated on within 4 days (hazard ratios of 2.25 and 2.4, respectively)

neurologic disorders concurrent with the normal aging process and may be taking multiple medications for these conditions. Good perioperative care is important. The anesthesiologist frequently assumes care for chronically ill patients who have recently experienced an acute traumatic episode with associated pain, anemia, and hypovolemia. The American Society of Anesthesiologists classification, which is a measure of a patient's acute medical condition at the time of surgery, is predictive of increased mortality risk after hip fracture surgery. American Society of Anesthesiologists class III and class IV patients have a significantly increased risk of death after hip fracture.[12]

Cardiac Conditions

In one study, congestive heart failure, angina, and chronic pulmonary disease were all found to be independent risk factors for mortality at 30 days after injury.[13] Sixty-three percent of inpatient mortalities were attributable to cardiovascular events. The American College of Cardiology and the American Heart Association have developed guidelines for patients undergoing noncardiac surgery, including orthopaedic procedures. Perioperative stress testing is indicated for patients with unstable cardiac conditions and those with either new-onset angina or a change in the anginal pattern. A preoperative echocardiogram is recommended for patients with a history of angina pectoris and any condition in which there is a known decrease in left ventricular function. The more extensive work-up potentially required for older patients with hip fractures and known cardiac disease will provide the anesthesiologist with important physiologic information. Postoperative cardiac complications are the most common medical complications after hip fracture repair.

Pulmonary Conditions

Important factors in determining the risk of postoperative pulmonary complications include a history of smoking, a history of chronic obstructive pulmonary disease, and low oxygen levels on arterial blood gas analysis. The value of routine preoperative pulmonary function testing in pulmonary risk assessment remains controversial. Smetana[14] reviewed the importance of preoperative pulmonary function testing and found that most studies in the medical literature suggested that a forced expiratory volume (FEV_1) or forced vital capacity (FVC) of less than 70% of the predictive value and an FEV_1/FVC ratio of less than 65% are associated with an increased risk of postoperative pulmonary complications.[14] Elderly hip fracture patients are at high risk for postoperative pulmonary complications; efforts to minimize these complications, such as early mobilization, pulmonary toilet, and prevention of VTE, are essential.

Diabetes

Diabetes mellitus is a frequent comorbidity in elderly patients. Oral

Table 2
Summary of Literature Regarding Type of Anesthesia for Hip Fracture Patients

Study Authors (Year)	Number of Patients	Type of Anesthesia	Findings
Koval et al[18] (1998)	631	354 general; 277 regional	No difference in length of hospital stay, recovery of ambulatory ability, or percentage of functional recovery at 3, 6, and 12 months
Gilbert et al[19] (2000)	741	311 general; 430 regional	No difference in mortality rate at 2 years or incidence of postoperative complications; general anesthesia group had slightly better ambulatory function at the 2-year time point
Urwin et al[20] (2000)	Meta-analysis of 15 studies (2,162 patients)	General versus regional	Lower 30-day mortality rate and lower incidence of DVT with regional anesthesia
Parker et al[17] (2004)	Meta-analysis of 22 studies (2,567 patients)	General versus regional	Regional anesthesia associated with lower incidence of DVT and a lower 30-day mortality rate compared with general anesthesia; no difference in mortality rates at 90 days postoperatively

DVT = deep venous thrombosis

hypoglycemic agents usually are stopped the morning of surgery. Serum glucose levels are checked every 4 to 6 hours, and sliding-scale, low-dose regular insulin is given to blunt severe hyperglycemia. Intravenous fluids should not contain glucose. Oral hypoglycemic agents are resumed when the patient is eating well. For patients who require insulin, a general rule is to give one third to one half of the usual dose of long-acting insulin the morning of surgery, with an intravenous drip containing dextrose. A sliding scale of insulin coverage also is required.

Anemia

Elderly patients frequently are anemic because of coexisting medical conditions or bleeding at the fracture site. A reasonable rule is that otherwise healthy elderly people can tolerate a hemoglobin as low as 8.0, whereas those with cardiac or pulmonary disease should maintain a hemoglobin above 9 or 10. Allogeneic blood transfusion should be used judiciously because of the risk of disease transmission. Koval and associates[15] reported a prospective study of 687 community-dwelling, ambulatory, surgically treated geriatric patients with hip fractures. The authors found that allogeneic red blood cell transfusion was associated with an increased incidence of postoperative infection. No studies have defined an acceptable hematocrit level before surgery; the accepted preoperative hemoglobin level should be based on the expected blood loss.[16]

Type of Anesthesia

Although many physicians believe that spinal anesthesia is safer for patients, this has not been proven in the literature. Currently, no consensus exists as to which method of anesthesia is superior in hip fracture surgery[17-20] (Table 2). The choice of anesthesia typically is based on the preference of the anesthesiologist and the patient's medical status and preference. Induction is a crucial time during administration of general anesthesia. Slower circulation may result in overdose, low intravascular volume can lead to hypotension, and cardiac disease can present as ischemic electrocardiogram changes or arrhythmias. Factors especially important in managing geriatric patients with hip fractures undergoing general anesthesia include decreasing the dose of induction agents and having vasopressors on hand in the event of hypotension. Recent evidence suggests that for hip fracture surgery, general anesthesia with controlled hypotension may reduce intraoperative blood loss.[21]

In a Cochrane review of 22 trials involving 2,567 geriatric patients with hip fractures, Parker and associates[17] pooled data from eight trials to compare outcomes after general and regional anesthesia. They found that regional anesthesia was associated with a mild reduction in the incidence of deep venous thrombosis (DVT) and a lower mortality rate at 1 month after surgery; however, there was no significant difference in 3-month mortality rates between the two anesthesia methods. The authors concluded that, based on the available data, there was insufficient evidence to determine the superiority of general or regional anesthesia.

Local anesthesia techniques, such as lateral femoral cutaneous nerve blocks, may have a limited role in the treatment of femoral neck fractures, but there appears to be no role for this modality in pertrochanteric hip fractures.

Table 3
Summary of Literature Regarding VTE Prophylaxis

Study Authors (Year)	Number of Patients	VTE Prophylaxis Agent Studied	Findings
Pulmonary Embolism Prevention Trial Collaborative Group[24] (2000)	13,356	Aspirin versus placebo	Aspirin significantly reduced incidence of symptomatic DVT by 30% and PE by 43%, compared with placebo
Turpie et al[25] (2002)	7,344	Fondaparinux (factor Xa inhibitor) versus enoxaparin (LMWH)	Fondaparinux significantly reduced the incidence of DVT (6.8%), compared with enoxaparin (13.7%), by postoperative day 11
Handoll et al[23] (2002)	Cochrane review of 31 clinical trials	Unfractionated heparin, LMWH, and mechanical prophylaxis	Heparins provided significant protection against DVT; insufficient evidence to confirm protection against PE; mechanical prophylaxis protective, but compliance is problematic
Ennis et al[22] (2003)	1,000	Aspirin versus LMWH (enoxaparin)	Aspirin group had three cases of DVT and one PE, enoxaparin group had two cases of DVT and no PE; slight increase in risk of postoperative bleeding complications with enoxaparin
Eriksson et al[26] (2003)	656	Fondaparinux for 6 to 8 days versus fondaparinux for 1 month postoperatively	Extension of prophylaxis reduced incidence of DVT from 35% to 1.4%

VTE = venous thromboembolism, DVT = deep venous thrombosis, PE = pulmonary embolism, LMWH = low-molecular-weight heparin.

VTE Prophylaxis

Patients with lower extremity fractures, including pertrochanteric hip fractures, are at increased risk for thrombophlebitis. The reported incidence of DVT after hip fracture is 36% to 60%, whereas thrombi involving the proximal venous system have been reported in up to 36%.[22] According to the available literature, the incidence of PE after hip fracture ranges between 4.3% and 24%, while the incidence of fatal PE ranges from 3.6% to 12.9%[22-26] (Table 3). Thrombi limited to the calf veins rarely are associated with PE. Popliteal and more proximal venous thrombi carry a much higher embolic risk; however, most above-knee deep vein thrombi represent extension of thrombi from the calf venous system.

The two basic forms of prophylaxis are chemical and mechanical. In a Cochrane review of different methods of thromboprophylaxis after hip fracture surgery, Handoll and associates[23] compiled data from 31 clinical trials covering 2,958 cases. Based on the pooled data, the authors found that unfractionated and low-molecular-weight heparin protected against the development of lower extremity venous thrombosis, but there was insufficient evidence to confirm a protective effect against the development of PE. Mechanical methods of prophylaxis with foot or calf pumps provide significant protection against the development of DVT and PE and reduce overall mortality, but compliance remains an issue.[23] Although different prophylaxis techniques are effective in preventing thrombotic complications after hip fracture surgery, data are insufficient in the orthopaedic literature to form a consensus protocol with regard to prophylaxis.

Inferior vena cava filters offer the advantage of preventing PE in hip fracture patients when anticoagulation or compression devices are contraindicated or when the patients are at elevated risk despite prophylaxis. Filters may prevent PE when DVT is already present and prevent further emboli in patients who have PE despite anticoagulation therapy. Recently, retrievable filters have been developed to minimize the complications that occur with permanent indwelling inferior vena cava filters.

Pain Issues

Elderly patients, especially cognitively impaired elderly patients, usually receive substantially less pain medication than younger adults.[27] Many elderly patients have medical comorbidities that may influence the choice and dosage of selected analgesics. Drug interactions and potential complications must be considered when choosing an analgesic. In general, elderly patients receive greater peak dosing and have longer duration of action than younger patients because of slower clearance. Elderly patients with hip fractures should be started at lower doses than younger patients and titrated up slowly, based on pain reduction ratings.

Multidisciplinary Approach

The surgical treatment of fractures in elderly patients often is successful; however, the patients are unable to achieve their preinjury level of function. In the mid-1990s, the American Orthopaedic Association developed a task force to serve elderly orthopaedic patients. This task force developed several recommendations, including the use of a collaborative approach.[28]

Collaborative practice, or the multidisciplinary approach, involves the coordination of multiple services within an institution to manage certain nonsurgical patient care issues that can affect outcome. Historically, these programs have begun after surgery, but there is now an initiative to implement these programs as soon as the patient is admitted to the hospital. These programs involve orthopaedic surgeons, geriatricians, physiatrists, therapists, pharmacists, nutritionists, pain specialists, and nurses, with each acting on specific issues to reduce comorbidities and complications in the perioperative period. Reducing potential complications benefits patients, physicians, and hospitals with improved functional outcomes, decreased costs per admission, reduced lengths of hospital stays, and appropriate discharges.

Classification and Fracture Stability

The most commonly used classification systems for intertrochanteric hip fractures are based on fracture stability. The integrity of the posteromedial cortex is a key component for assessing fracture stability in all classifications. Greater involvement of the posteromedial cortex results in a more unstable fracture. The reverse oblique fracture is an inherently unstable pertrochanteric fracture pattern because of the tendency of the adductors to medially displace the femoral shaft. The unstable fracture patterns in the AO/Orthopaedic Trauma Association (OTA) classification (A2.2-A3.3) also are characterized by increasing comminution in the posteromedial cortex and intertrochanteric region (Figure 1). This classification also recognizes the instability of the reverse oblique and transverse intertrochanteric fracture patterns.[29]

Recently, the concept of the lateral femoral wall, defined anatomically as the lateral femoral cortex distal to the vastus ridge, has received more recognition as a factor in determining fracture stability. Gotfried[30] described this concept in a report on 24 patients who required reoperation after failure of fixation of intertrochanteric fractures treated with a sliding hip screw. He concluded that a fracture of the lateral femoral wall resulted in sliding hip screw failures, and that in some patients the fracture occurred during the surgical procedure. Many intraoperative fractures of the lateral wall occur when a large-diameter hole is drilled into the lateral femoral wall for insertion of the sliding hip screw.[31] In a study of 214 patients with intertrochanteric anterior fractures reported by Palm and associates,[32] a lateral wall fracture occurred in one third of AO/OTA type 31-A.2.2 and A2.3 fractures, which are characterized by trochanteric comminution and a thinner lateral cortex, making them more susceptible to lateral wall fractures. The intraoperative fracture of the lateral femoral wall created in these fracture patterns is similar to a reverse oblique or transverse intertrochanteric fracture (AO/OTA A3.1-3.3). The authors concluded that, if the lateral wall or greater trochanter is fractured, a sliding hip screw alone should not be used for fracture fixation.

In the most simplistic terms, intertrochanteric fractures may be classified as stable or unstable based on the integrity of the posteromedial cortex and the lateral wall.[33] The recognition of fracture stability is critical because it directs implant selection. Stable fractures have an intact posteromedial cortex and lateral wall and may be treated with a sliding hip screw, whereas unstable fracture patterns have comminution of the posteromedial cortex, greater trochanteric comminution with loss of the lateral buttress, or reverse and transverse intertrochanteric fracture extension and should not be treated with a sliding hip screw.

Implant Selection and Recommendations

Selection

Compression hip screws have long been considered the gold standard for the treatment of pertrochanteric fractures. The devices currently in use evolved from designs first introduced in the 1950s and have produced reliable results.[34] In stable fracture patterns, the hip screw acts as a lateral tension band; in unstable fractures, it allows the controlled collapse and impaction of the fracture fragments. This collapse shortens the lever arm acting on the implant, which decreases the bending moment, thus decreasing the risk of mechanical failure and screw cutout. Telescoping of a 135° sliding hip screw by 10 and 20 mm improves implant strength by 28% and 80%, respectively, because of the shortened lever arm. This allows the fracture to achieve a position of stability while maintaining a constant neck-shaft angle.[35]

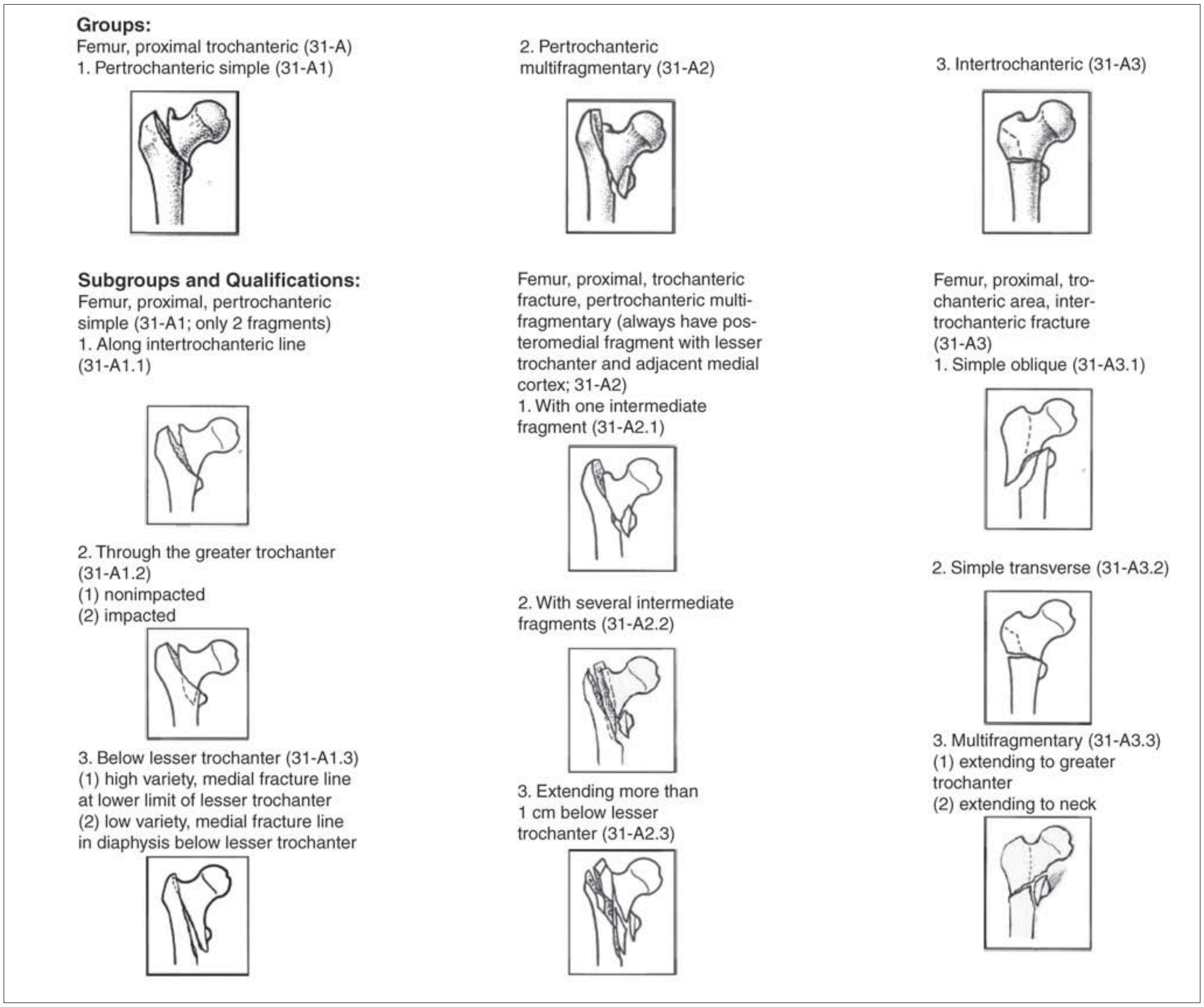

Figure 1 AO/OTA classification of trochanteric fractures. (Adapted with permission from Marsh JL, Slongo TF, Agel JN, et al: Fracture and Dislocation Classification Compendium 2007: Orthopaedic Trauma Association Classification Database and Outcomes Committee. *J Orthop Trauma* 2007;21(suppl 10):S1-S6.)

Reported failure rates of compression hip screws range from 6% to 56%, with screw cutout being the most common mode of failure.[34,36,37] The incidence of screw cutout increases with unstable fracture patterns and has been reported to be as high as 19%.[34] Other reported modes of failure include fatigue failure of the lag screw, implant disassembly, and, rarely, pullout or breakage of the side plate.[30,38] The characteristics of the implant that allow it to maintain implant stability despite loss of reduction because of sliding also contribute to fixation failure. Although sliding of the lag screw increases implant strength, sliding of more than 15 mm increases the rate of fixation failure[35] (Figure 2). Excessive sliding in unstable fractures can result in medialization of the femoral shaft. This can lead to a more stable configuration initially, but medialization of more than one third of the shaft diameter results in a sevenfold increase in fixation failure.[39] Recent studies have shown an association between fracture settling and pain, as well as an association between increased sliding and decreased postoperative mobility.[35,40]

These complications prompted attempts to improve on the compression hip screw, which led to in-

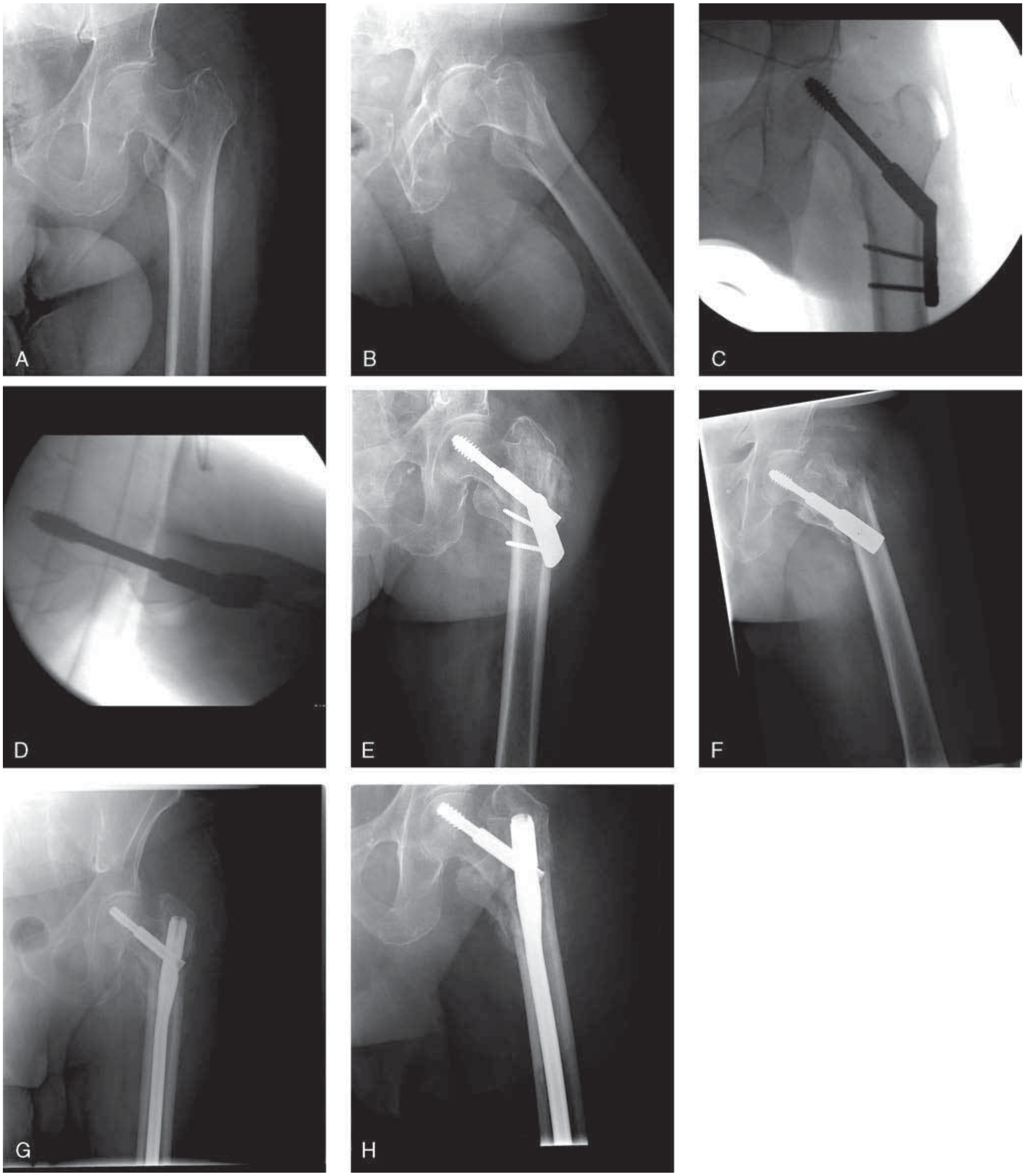

Figure 2 Radiographic views of a pertrochanteric fracture in an 82-year-old man. **A** and **B,** Traction AP and frog-leg lateral preoperative views, respectively, are shown. The fracture was believed to be stable, and the patient was treated with a screw and side-plate device; AP and lateral intraoperative views are shown in **C** and **D,** respectively. The patient reported increasing pain with ambulation, and at 6 weeks presented with implant failure. **E** and **F,** AP and lateral radiographs, respectively, showing implant failure and fracture displacement. The patient had a revision to a long intramedullary implant. **G,** AP view. **H**, Frog-leg lateral view.

creasing use of intramedullary hip screw devices. The intramedullary hip nail is an appealing design because it combines the advantages of intramedullary fixation with those of a sliding hip screw. The most obvious biomechanical advantage of an intramedullary nail over a sliding hip screw is that the nail is a load-sharing device rather than a load-bearing device. Another biomechanical advantage is the location of the nail closer to the hip center than the side plate of the sliding hip screw, which translates to a shorter lever arm with the nail, decreasing tensile strain on the implant.[33,34] This also results in a decreased bending moment on the lag screw, causing a reduction of bending stress and decreasing the rate of implant failure. In fracture patterns where excessive collapse may cause complications, the nail acts as an intramedullary buttress, allowing less collapse to a stable configuration because of the presence of the nail in the medullary canal.[33] None of these biomechanical advantages, however, have translated into clinical advantages.[33,34]

Suggested clinical advantages include shorter surgical time, decreased fluoroscopy time, a smaller incision resulting in decreased soft-tissue trauma, a closed insertion technique resulting in decreased blood loss and decreased transfusion requirements, and decreased intraoperative complications, leading to decreased mortality, improved ambulatory ability, and improved functional outcomes. Only in unstable fractures did Baumgaertner and associates[41] show a decrease in surgical time with intramedullary nails; other studies showed either no significant difference or increased surgical time with intramedullary nails.[33,34]

Some studies comparing intramedullary nails with compression hip screws have shown a higher intraoperative complication rate with nails, but these were based on earlier nail designs that had up to a 20% occurrence of intraoperative and postoperative femoral fractures.[34,41] Problems with early nail designs included long, large-diameter nails and large distal interlocking screws with no or inaccurate targeting; one of the most significant design flaws was a 10° valgus bend in the nail. This resulted in stress shielding of the medial calcar, with load transfer and concentration of the stress at the distal tip of the nail onto the lateral cortex, increasing the risk of femoral fracture at the tip of the nail. Newer nail designs have corrected these problems by decreasing the valgus bend to 4°, decreasing the nail diameter and length, and decreasing the size of the distal interlocking screws while improving the targeting devices.[34,35] Femoral fractures are still reported with the newer intramedullary nail designs, but at a much lower rate.[33] An additional complication of intramedullary nail fixation is cortical hypertrophy distally, which is associated with more frequent thigh pain.[33] However, as with the compression hip screw, the most common cause of failure remains lag screw cutout.[34,41]

Another common but less often reported complication with long intramedullary nails is the result of mismatching of the nail-femur radius of curvature. In general, most nail designs are straighter than the average human femur.[42] Care must be taken when implanting a long intramedullary nail for a pertrochanteric fracture because distal perforation can lead to a stress riser and the potential for peri-implant fracture.

Recommendations

Review of the literature to determine the best implant shows that many studies mix stable and unstable pertrochanteric fractures and use different definitions of unstable. For all fracture patterns, no clinical or functional benefits of the theorized biomechanical advantages of intramedullary nails have been shown.

For stable 31-AO/OTA type A1 pertrochanteric fractures, no studies have shown any improvement in clinical or functional outcomes with intramedullary nails compared with compression hip screws. Studies vary as to which implant is most advantageous regarding operating time, fluoroscopy time, and blood loss and transfusion requirements; however, all show no differences in mortality, ambulatory ability, return to preinjury level of function, need for assistive devices, or overall functional recovery. There are no findings to recommend intramedullary nails over compression hip screws in stable fractures.

The results of treatment of 31-A2 fractures can be difficult to sort out in the literature because they are combined with only A1 fractures in some studies and with A1 or A3 fractures in others. No studies have shown a significant difference in the rates of fixation failure when comparing the sliding hip screw with intramedullary nails in A2 fractures. The frequency and amount of pain are comparable with both implants, but the location of the pain changes, with lateral thigh and groin pain reported with compression hip screws and mid- to distal-thigh pain with intramedullary nails.[43] No significant differences have been proven in rates of functional recovery, return to preinjury level of function, and level of ambulatory independence achieved. Although better mobility scores in the early postoperative period have been reported with intramedullary nails, there was no difference in the total mobility score at 1 year. The ability to ambulate outside was significantly better at 6 and 12 months with intramedullary nails.[33] Hardy and associates[33] also found significant differences in the amount of lag screw sliding in A2 fractures, with compression hip screws showing more sliding than intramedullary nails. This sliding resulted in a significant difference in limb-length discrepancies between the two implants, although the functional significance of this finding was not well defined.[33] Long term, no-compensatory walking strategies have been shown to be used with a limb-length discrepancy of less than 20 mm. A limb-length discrepancy of less than 30 mm has little effect on overall hip biomechanics, so this may not actually contribute notably to mobility differences.[44] Therefore, for 31-A2 fractures, there is no clear indication for choosing intramedullary fixation over a compression hip screw.

Unstable 31-A3 pertrochanteric fractures include fractures with subtrochanteric extension and reverse oblique intertrochanteric fractures. Reverse oblique fractures have not only lost the medial buttress, but the fracture line is parallel to the direction of the lag screw sliding. These fractures represent the only pertrochanteric fracture pattern in which implant choice affects outcomes. Up to 56% loss of fixation has been reported with compression hip screws in the treatment of reverse obliquity fractures.[37] The location of the fracture line distal to the lag screw results in fewer points of fixation in the distal fragment. Sliding of the proximal fragment along the lag screw barrel then results in medialization of the distal fragment. This malalignment can lead to fracture distraction, resulting in nonunion. It also can result in failure of fixation with superior screw cutout.[37] The use of an intramedullary nail in this fracture pattern does not rely on the presence of an intact medial buttress nor does it allow medialization of the distal fragment because the nail itself acts as an intramedullary buttress. This is true not only for reverse oblique intertrochanteric fractures, but also for those with subtrochanteric extension. There is a paucity of literature evaluating treatment of 31-A3 fractures, but improved clinical outcomes are seen in A3 fractures treated with intramedullary nailing compared with compression hip screws.[45] However, no differences in functional outcomes have yet been shown.

No evidence in the literature confirms that using intramedullary devices leads to a decrease in intraoperative or postoperative complications or postoperative mortality, improved mobility, or improved patient and hip function outcomes compared with compression hip screws in A1 and A2 pertrochanteric fractures. It is significant that the primary mode of failure for both types of implants is screw cutout, which is based on screw position rather than the device used and is a function of tip-apex distance. Some authors have concluded that intramedullary nails are the better or preferred implant despite results that do not support this conclusion, and meta-analyses have concluded that the routine use of intramedullary nails for A1 and most A2 fractures is neither indicated nor evidence based.[39,46] In the treatment of A3 fractures, decreased complications and improved clinical outcomes have been reported with intramedullary nails, but there is still no evidence of significant functional differences.

Common Pitfalls

Recognition and avoidance of the common pitfalls associated with the treatment of pertrochanteric hip fractures are the best methods to prevent complications. A failure to recognize complicating underlying conditions, inappropriate decision making regarding implant selection, and failure to obtain an adequate reduction with correct placement of the implants account for most of the common complications associated with pertrochanteric fractures.

Initial evaluation of injury radiographs should focus on the fracture pattern and bone quality. A careful assessment for the presence of metastatic disease is mandatory because metastatic lesions are unlikely to heal and normal union may be compromised. Implant selection for patients with metastatic disease must be based on the ability of the implant to withstand long-term cyclical loading; the implant should splint the entire femur to bridge other potential areas of unrecognized or future metastatic disease. A long intramedullary implant that provides fixation into the femoral head and distal interlocking is best used in these patients. When metastatic disease extends into the femoral neck, internal fixation should be avoided, and hemiarthroplasty should be considered. If metastatic disease is extensive in the area of the medial calcar, a calcar-replacing prosthesis should be considered. In either case, a long-stem prosthesis should be used to splint the femur to the greatest possible extent.

In patients with significant osteoporosis, similar recommendations apply to implant selection. Us-

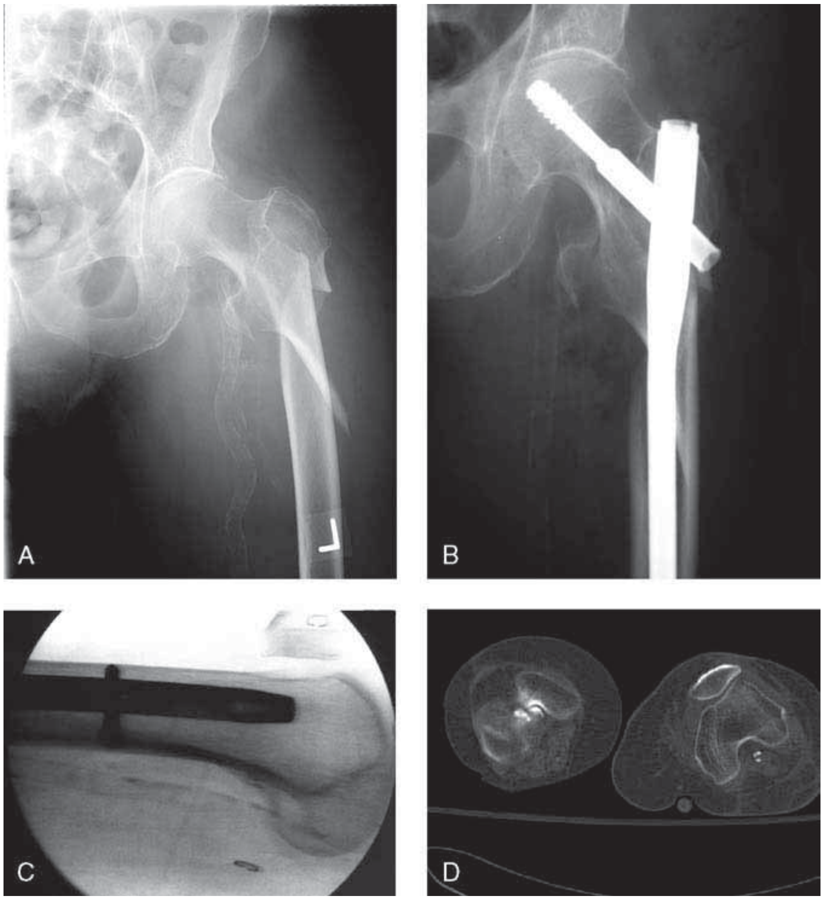

Figure 3 **A,** Preoperative AP radiograph of the proximal femur showing a comminuted intertrochanteric-subtrochanteric femoral fracture in a 90-year-old woman. **B**, Postoperative AP radiograph. **C,** Postoperative lateral radiograph of the distal shaft; a long intramedullary locked nail device is shown. **D,** Malrotation was noted clinically and confirmed with a postoperative CT scanogram.

ing an intramedullary device with a compression hip screw for proximal fixation minimizes the risk of failure at the implant-bone interface distal to the fracture. In contrast, using a cephalomedullary nail-screw device may increase the chance of femoral head cutout because controlled collapse to a stable position is limited by the shaft of the intramedullary device, increasing the deforming varus force at the tip of the screw. Central placement of the screw in the femoral head is paramount to limiting failure. In some patients with significant bone loss from osteoporosis, augmentation of femoral head fixation with bone cement injected into the femoral head may limit cutout. Alternatively, proximal fixation devices focused on increasing implant surface area or minimizing bone loss during insertion have been developed to prevent femoral head cutout, but their effectiveness remains controversial.

Stable fracture patterns can be treated with any implant without undue risk of failure. Unstable fracture patterns are best treated with intramedullary fixation devices that limit fracture collapse and prevent limb-length discrepancy and subsequent abductor weakness. Reverse obliquity intertrochanteric fractures or subtrochanteric femoral fractures should be treated only with intramedullary devices to limit lateral displacement of the proximal fracture fragment that will cause failure of hip screw and side-plate devices. Alternatively, plate fixation with fixed-angle devices (blade plate, dynamic condylar screw, or locking plates) also can be used effectively and can adequately resist lateral displacement of the proximal fragment; however, the extended approach and blood loss with the primary implantation make this a second line option if intramedullary nail fixation is feasible. Regardless of the implant chosen, it is imperative that the proximal fixation be placed in the area of the subchondral bone in the center of the femoral head, as described by Baumgartner and associates.[47] Failure to limit the tip-apex distance to less than 25 mm is a strong predictor of failure at the implant-femoral head interface.

Nonanatomic reduction of pertrochanteric fractures can lead to deformity and delayed union or nonunion. The deforming forces acting at the level of the proximal femur commonly lead to varus, apex-posterior angulation or translation, and rotational malalignment. Although reduction on a fracture table can correct most of these complications, additional careful manipulation can further improve fracture reduction and avoid deformity.[48] Percutaneously placed clamps and ball spike pushers can help reduce posterior sag and translation. Alternatively, external devices can be used to reduce posterior displacement. In fractures with subtrochanteric ex-

Figure 4 **A,** Radiograph of a right pertrochanteric hip fracture sustained by a 50-year-old man in a high-speed motor vehicle collision. **B,** At 6 months, the fracture was not united, and the hardware had failed. **C,** After hardware removal, the nonunion was repaired with a compression blade plate.

tension, care must be taken to avoid malrotation of the femur because reduction keys may be absent (Figure 3). When intramedullary devices are used, eccentric reaming of the lateral femoral cortex also should be avoided to prevent varus deformity.

Salvage After Treatment Failures

Identification of the reason for failure is paramount in selecting the best salvage option to avoid future failure while providing an acceptable functional result (Figure 4). The most common reasons for failed treatment of pertrochanteric femoral fractures are use of the wrong implant, poor implant placement, poor bone quality, limited biologic potential for healing, infection, and patient-related risk factors such as underlying systemic diseases or smoking. Other considerations include the viability of the proximal femoral bone segment, its related healing potential, and the functional demands of the patient. Salvage options consist of either revision of internal fixation or proximal femoral replacement with or without acetabular resurfacing.

Criteria for the revision of internal fixation are viability of the proximal bone segment and the femoral head as shown by bone scans or intraoperative assessment of bleeding potential, reasonable bone quality, no destruction of the femoral head articular surface, and a patient with high or moderate functional demands. For revision of failed internal fixation, the goal is to choose an implant that provides maximal stability and improves the mechanical environment of the fracture, principally with valgus osteotomy.[49] Blade plate fixation allows for planned correction and improvement of the deformity, and valgus osteotomies diminish the varus load at the site of nonunion and convert the tension into compression. Alternatively, locking plates and 95° dynamic condylar screw plates can improve the rigidity of the fixation but provide less correction of deformity or alteration of the mechanical forces at the nonunion site.[50] Bone grafting can be used to improve union when extensive medial soft-tissue stripping is required or for atrophic nonunion. Bone grafting for hypertrophic nonunion is not generally required.

When the criteria for the revision of internal fixation are not met, or when the patient has preexisting arthritis, advanced age, and low functional demands, proximal femoral replacement with or without acetabular resurfacing generally is the best reconstructive option in the absence of infection. When the medial calcar is destroyed or absent, a calcar-replacing prosthesis is required, with tension-band fixation of the greater trochanter to improve hip abductor function (Figure 5). Care must be taken to ensure that cement is not extruded from preexisting sites of internal fixation. Bone wax can be used to seal areas with a cortical defect to prevent cement extrusion. Acetabular resurfacing should be considered in patients with preexisting arthritis or when the articular surface has been destroyed by an extruded implant. In younger, higher-demand patients, recent reports suggest improved function with acetabular resurfacing as opposed to hemiarthroplasty alone.[51,52]

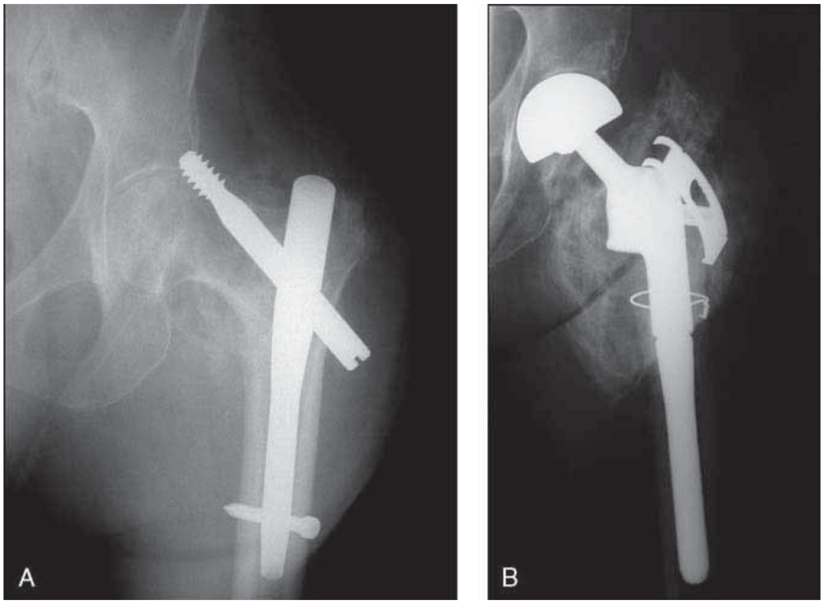

Figure 5 **A,** Radiograph of an unstable intertrochanteric hip fracture treated with a short intramedullary nail device in a 75-year-old woman. At 4 months, there was screw cutout and failure. **B,** Because of the bone quality and functional status of the patient, a calcar-replacing hemiarthroplasty was done.

Infection

Salvage in the presence of infection remains difficult. When analyzing initial treatment failure, infection should remain in the differential diagnosis as a root cause of treatment failure. When considering revision of internal fixation, preoperative laboratory analysis with a white blood cell count, erythrocyte sedimentation rate, and C-reactive protein level should be obtained as baseline tests. Positive values should be further investigated with an indium bone scan or joint aspiration. If salvage with arthroplasty is considered a treatment option, preoperative hip aspiration should be performed, and a staged reconstruction should be considered, with explantation of implanted hardware and culture testing being done first. If cultures are positive, the infection should be eradicated with débridement and antibiotic therapy with antibiotic-impregnated cement before arthroplasty. Revision internal fixation can proceed in the absence of gross purulence, but deep cultures should be obtained at the time of revision surgery. Positive cultures should initiate treatment with organism-specific antibiotics, and implants should be retained as long as they provide stability.

Summary

Improving outcomes in patients with pertrochanteric fractures involves maximizing the perioperative environment and understanding the fracture patterns and classification that ultimately guide treatment and it implant selection. The process begins with the identification of surgical candidates and medical optimization before surgery. It continues with the choice of anesthesia and thromboembolic prophylaxis, and culminates with proper implant selection and the prevention of postoperative complications. Strategies aimed at avoiding pitfalls minimize the potential for complications. Prompt recognition of complications allows salvage and recovery.

References

1. Ooi LH, Wong TH, Toh CL, Wong HP: Hip fractures in nonagenarioans: A study on operative and nonoperative management. *Injury* 2005;36:142-147.
2. Zuckerman JD, Skovron ML, Koval KJ, Aharonoff G, Frankel VH: Postoperative complications and mortality associated with operative delay in older patients who have a fracture of the hip. *J Bone Joint Surg Am* 1995;77:1551-1556.
3. Dorotka R, Schoechtner H, Buchinger W: The influence of immediate surgical treatment of proximal femoral fractures on mortality and quality of life: Operation within six hours of the fracture versus later than six hours. *J Bone Joint Surg Br* 2003;85:1107-1113.
4. Sexson SB, Lehner JT: Factors affecting hip fracture mortality. *J Orthop Trauma* 1987;1:298-305.
5. Orosz GM, Magaziner J, Hannan EL, et al: Association of timing of surgery for hip fracture and patient outcomes. *JAMA* 2004;291:1738-1743.
6. Hamlet WP, Lieberman JR, Freedman EL, Dorey FJ, Fletcher A, Johnson EE: Influence of health status and the timing of surgery on mortality in hip fracture patients. *Am J Orthop* 1997;26:621-627.
7. McGuire KJ, Bernstein J, Polsky D, Silber JH: Delays until surgery after hip fracture increases mortality. *Clin Orthop Relat Res* 2004;428:294-301.
8. Kenzora JE, McCarthy RE, Lowell JD, Sledge CB: Hip fracture mortality: Relation to age, treatment, preoperative illness, time of surgery, and complications. *Clin Orthop Relat Res* 1984;186:45-56.

9. Doruk H, Mas MR, Yildiz C, Sonmez A, Kýrdemir V: The effect of the timing of hip fracture surgery on the activity of daily living and mortality in elderly. *Arch Gerontol Geriatr* 2004;39: 179-185.

10. Gdalevich M, Cohen D, Yosef D, Tauber C: Morbidity and mortality after hip fracture: The impact of operative delay. *Arch Orthop Trauma Surg* 2004;124:334-340.

11. Moran CG, Wenn RT, Sikand M, Taylor AM: Early mortality after hip fracture: Is delay before surgery important? *J Bone Joint Surg Am* 2005;87: 483-489.

12. Richmond J, Aharonoff GB, Zuckerman JD, Koval KJ: Mortality risk after hip fracture. *J Orthop Trauma* 2003;17: 53-56.

13. Nettleman MD, Alsip J, Schrader M, Schulte M: Predictors of mortality after acute hip fracture. *J Gen Intern Med* 1996;11:765-767.

14. Smetana GW: Preoperative pulmonary assessment of the older adult. *Clin Geriatr Med* 2003;19:35-55.

15. Koval KJ, Rosenberg AD, Zuckerman JD, et al: Does blood transfusion increase the risk of infection after hip fracture? *J Orthop Trauma* 1997;11: 260-265.

16. Egol KA, Koval KJ, Zuckerman JD: Functional recovery following hip fracture in the elderly. *J Orthop Trauma* 1997;11:594-599.

17. Parker MJ, Handoll HH, Griffiths R: Anaesthesia for hip fracture surgery in adults. *Cochrane Database Syst Rev* 2004;4:CD000521.

18. Koval KJ, Aharonoff GB, Rosenberg AD, Bernstein RL, Zuckerman JD: Functional outcome after hip fracture: Effect of general versus regional anesthesia. *Clin Orthop Relat Res* 1998;348:37-41.

19. Gilbert TB, Hawkes WG, Hebel JR, et al: Spinal anesthesia versus general anesthesia for hip fracture repair: A longitudinal observation of 741 elderly patients during 2-year follow-up. *Am J Orthop* 2000;29:25-35.

20. Urwin SC, Parker MJ, Griffiths R: General versus regional anaesthesia for hip fracture surgery: A meta-analysis of randomized trials. *Br J Anaesth* 2000;84:450-455.

21. Covert CR, Fox GS: Anaesthesia for hip surgery in the elderly. *Can J Anaesth* 1989;36:311-319.

22. Ennis RS: Postoperative deep vein thrombosis prophylaxis: A retrospective analysis in 1000 consecutive hip fracture patients treated in a community hospital setting. *J South Orthop Assoc* 2003;12:10-17.

23. Handoll HH, Farrar MJ, McBirnie J, Tytherleigh-Strong G, Milne AA, Gillespie WJ: Heparin, low molecular weight heparin and physical methods for preventing deep vein thrombosis and pulmonary embolism following surgery for hip fractures. *Cochrane Database Syst Rev* 2002;4:CD000305.

24. Prevention of pulmonary embolism and deep vein thrombosis with low dose aspirin: Pulmonary Embolism Prevention (PEP) trial. *Lancet* 2000; 355:1295-1302.

25. Turpie AG, Eriksson BI, Lassen MR, Bauer KA: A meta-analysis of fondaparinux versus enoxaparin in the prevention of venous thromboembolism after major orthopaedic surgery. *J South Orthop Assoc* 2002;11:182-188.

26. Eriksson BI: Improvements in the prevention of postoperative venous thromboembolism in hip fracture patients. *Orthopedics* 2003;26(suppl 8): 851-858.

27. Horgas AL, Tsai PF: Analgesic drug prescription and use in cognitively impaired nursing home residents. *Nurs Res* 1998;47:235-242.

28. Koval KJ, Schemitsch E, Liporace F, Strauss E, Zuckerman JD: An AOA critical issue. Geriatric trauma: Young ideas. *J Bone Joint Surg Am* 2003;85: 1380-1388.

29. Browner WS, Pressman AR, Nevitt MC, Cummings SR: Mortality following fractures in older women: The study of osteoporotic fractures. *Arch Intern Med* 1996;156:1521-1525.

30. Gotfried Y: The lateral trochanteric wall: A key element in the reconstruction of unstable pertrochanteric hip fractures. *Clin Orthop Relat Res* 2004;425:82-86.

31. Audige L, Hanson B, Swiontkowski MF: Implant-related complications in the treatment of unstable intertrochanteric fractures: Meta-analysis of dynamic screw-plate versus dynamic screw-intramedullary nail devices. *Int Orthop* 2003;27: 197-203.

32. Palm H, Jacobsen S, Sonne-Holm S, et al: Integrity of the lateral femoral wall in intertrochanteric hip fractures: An important predictor of a reoperation. *J Bone Joint Surg Am* 2007;89: 470-475.

33. Hardy DC, Descamps PY, Krallis P, et al: Use of an intramedullary hip-screw compared with a compression hip-screw with a plate for intertrochanteric femoral fractures: A prospective, randomized study of one hundred patients. *J Bone Joint Surg Am* 1998;80:618-630.

34. Adams CI, Robinson CM, Court-Brown CM, McQueen MM: Prospective randomized controlled trial of an intramedullary nail versus dynamic screw and plate for intertrochanteric fractures of the femur. *J Orthop Trauma* 2001;15:394-400.

35. Lorich DG, Geller DS, Nielson JH: Osteoporotic pertrochanteric hip fractures: Management and current controversies. *Instr Course Lect* 2004; 53:441-454.

36. Butt MS, Krikler SJ, Nafie S, Ali MS: Comparison of dynamic hip screw and gamma nail: A prospective, randomized, controlled trial. *Injury* 1995; 26:615-618.

37. Haidukewych GJ, Israel TA, Berry DJ: Reverse obliquity fractures of the intertrochanteric region of the femur. *J Bone Joint Surg Am* 2001;83: 643-650.

38. Bolhofner BR, Russo PR, Carmen B: Results of intertrochanteric femur fractures treated with a 135-degree sliding screw with a two-hole side plate. *J Orthop Trauma* 1999;13:5-8.

39. Parker MJ, Gillespie LD, Gillespie WJ: Hip protectors for preventing hip fractures in the elderly. *Cochrane Database Syst Rev* 2004;3:CD001255.

40. Bendo JA, Weiner LS, Strauss E, Yang E: Collapse of intertrochanteric hip fractures fixed with sliding screws. *Orthop Rev* 1994;23(suppl): 30-37.

41. Baumgaertner MR, Curtin SL, Lindskog DM: Intramedullary versus extramedullary fixation for the treatment of intertrochanteric hip fractures. *Clin Orthop Relat Res* 1998;348 :87-94.

42. Egol KA, Chang EY, Cvitkovic J, Kummer FJ, Koval KJ: Mismatch of current intramedullary nails with the anterior bow of the femur. *J Orthop Trauma* 2004;18:410-415.

43. Saudan M, Lubbeke A, Sadowski C, Riand N, Stern R, Hoffmeyer P: Pertrochanteric fractures: Is there an advantage to an intramedullary nail? A randomized, prospective study of 206 patients comparing the dynamic hip screw and proximal femoral nail. *J Orthop Trauma* 2002;16:386-393.

44. Olsson O, Ceder L, Hauggaard A: Femoral shortening in intertrochanteric fractures: A comparison between the Medoff sliding plate and the compression hip screw. *J Bone Joint Surg Br* 2001;83:572-578.

45. Kregor PJ, Obremskey WT, Kreder HJ, Swiontkowski MF: Evidence-Based Orthopaedic Trauma Working Group: Unstable pertrochanteric femoral fractures. *J Orthop Trauma* 2005;19:63-66.

46. Parker MJ, Pryor GA: Gamma versus DHS nailing for extracapsular femoral fractures: Meta-analysis of ten randomised trials. *Int Orthop* 1996;20: 163-168.

47. Baumgaertner MR, Curtin SL, Lindskog DM, Keggi JM: The value of the tip-apex distance in predicting failure of fixation of peritrochanteric fractures of the hip. *J Bone Joint Surg Am* 1995;77:1058-1064.

48. Vaidya SV, Dholakia DB, Chatterjee A: The use of a dynamic condylar screw and biological reduction techniques for subtrochanteric femur fracture. *Injury* 2003;34:123-128.

49. Haidukewych GJ, Berry DJ: Hip arthroplasty for salvage of failed treatment of intertrochanteric hip fractures. *J Bone Joint Surg Am* 2003;85: 899-904.

50. Marti RK, Schuller HM, Raaymakers EL: Intertrochanteric osteotomy for non-union of the femoral neck. *J Bone Joint Surg Br* 1989;71:782-787.

51. Macaulay W, Nellans KW, Garvin KL, Iorio R, Healy WL, Rosenwasser MP; other members of the DFACTO Consortium: Prospective randomized clinical trial comparing hemiarthroplasty to total hip arthroplasty in the treatment of displaced femoral neck fractures: Winner of the Dorr Award. *J Arthroplasty* 2008;23(6, suppl 1):2-8.

52. Keating JF, Grant A, Masson M, Scott NW, Forbes JF: Randomized comparison of reduction and fixation, bipolar hemiarthroplasty, and total hip arthroplasty: Treatment of displaced intracapsular hip fractures in healthy older patients. *J Bone Joint Surg Am* 2006;88:249-260.