Review Article

High-energy Femoral Neck Fractures in Young Patients

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VIDEO 1

ABSTRACT

Femoral neck fractures in physiologically young patients typically occur from high-energy axial loading forces through the thigh with the hip in an abducted position. These fractures have a high rate of associated head, chest, abdominal, and musculoskeletal injuries. High-energy hip fractures differ from traditional geriatric hip fractures regarding incidence, mechanism, management algorithms, and complications. After adequate resuscitation, goals of treatment include anatomic reduction and stable fixation while maintaining vascularity of the femoral head, which can be achieved through a variety of different techniques. Prompt recognition and treatment of these fractures is crucial to achieve a successful outcome because these injuries are often associated with complications such as osteonecrosis, fixation failure, and nonunion.

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High-energy femoral neck fractures in the physiologically young patient can be a devastating injury due to high rates of complications including nonunion, osteonecrosis, chronic pain, disability, and revision surgery.[1,2] Complication rates have been found to be as high as 45% in these highly morbid injuries.[3] Although geriatric femoral neck injuries tend to result from ground level falls and other low energy mechanisms, femoral neck fractures of the younger population are usually the result of high-energy mechanisms such as motor vehicle accidents and falls from height.

The frequency of these injuries is increasing, in part due to improved diagnosis through increased utilization of CT scans and magnetic resonance imaging (MRI) in trauma centers with increased scrutiny of the femoral neck in the setting of an ipsilateral femoral shaft fracture.[4,5]

Although arthroplasty is the preferred surgical treatment option for displaced fractures in elderly patients, most orthopaedic surgeons should strive to preserve the femoral head through anatomic reduction and stable fixation in younger patient populations, given that arthroplasty in young patients carries a high likelihood of eventual revision and higher complication rates.[1]

Anatomy and Biomechanics

Osseous Anatomy

The femoral head diameter ranges from 40 to 60 mm with an average neck shaft angle of 130° ± 7°. The femoral neck is anteverted 10.4° ± 6° relative to the shaft of the femur with little variation between male and female patients. The hip reaches skeletal maturity at age approximately 16 years when the upper femoral epiphysis closes.[2]

The calcar femorale originates at the posteromedial portion of the proximal femoral shaft and fuses with the cortical bone at the posterior femoral neck.[6] The calcar is a critically important structure made up of dense cancellous bone which acts as a strut. It provides support and allows for stress distribution from the head of the femur to the proximal femoral shaft, playing an important role in fracture development in the proximal femur.[6] Because of the posterior overhang of the greater trochanter, the femoral neck lies in the anterior half of the proximal femur, an important consideration when planning internal fixation.[2]

Vascular Anatomy

Understanding the vascular supply to the femoral head and neck is essential in the assessment and treatment of patients with femoral neck fractures.[7] The primary blood supply to this region is the medial circumflex femoral artery (MCFA), which most commonly originates from the profunda femoris artery.[7] The MCFA branches into a descending branch and an ascending/deep branch, which enters the posterior hip capsule and branches into the terminal lateral epiphyseal arterial complex, which supplies most the femoral head (Figure 1).[6,7] Other contributors to the blood supply of the femoral head include the lateral circumflex femoral artery, which supplies aspects of the inferior and anterior femoral head through its terminal inferior metaphyseal arterial branch.[7] The obturator arterial network supplies a small yet variable contribution to the femoral head vascularity through the artery of the ligamentum teres. Recent studies have also described contributions from the inferior gluteal artery because its distal deep branch anastomoses with the MCFA before entering the hip joint.[6,7]

Femoral neck fractures have a substantial effect on these vascular networks, with a direct correlation between degree of fracture displacement and disruption of the lateral epiphyseal arterial network.[2] In addition to direct vascular injury from the fracture, elevated intracapsular pressures from fracture hematoma and nonanatomic fracture reduction during internal fixation

Figure 1

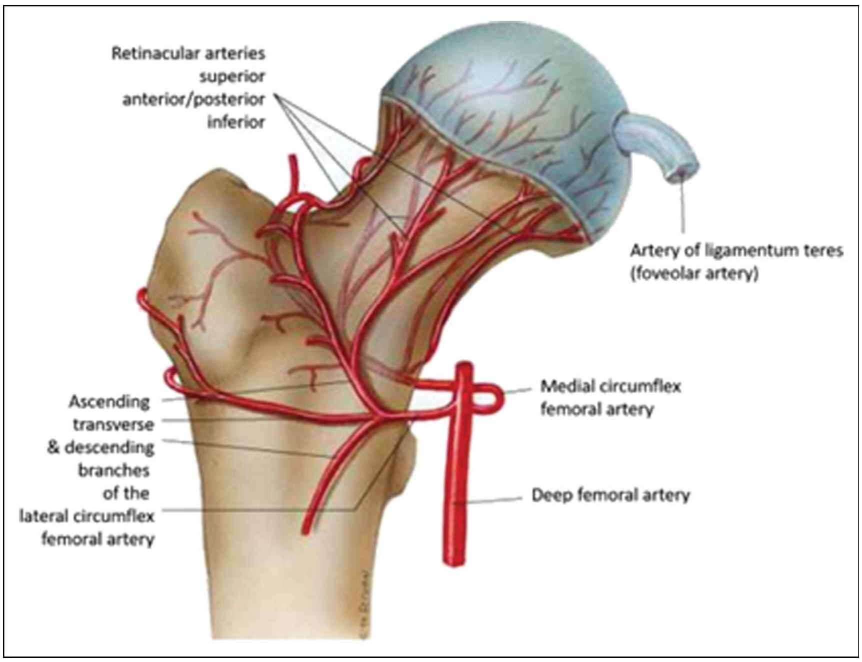


Diagram showing femoral head and neck vascularity. Illustration demonstrating the vascular anatomy of the femoral head and neck. Most the blood supply to the femoral head is through the lateral epiphyseal arterial complex which derives from the ascending branch of the MCFA. Reproduced with permission from ALPF Medical Research. MCFA = medial circumflex femoral artery also contribute to osteonecrosis.[7] High-energy femoral neck fractures often cause a greater degree of fracture displacement and vascular disruption, thus increasing the risk of osteonecrosis.[2,7]

Classification of Femoral Neck Fractures

Many surgeons describe femoral neck fractures based on the location of the fracture within the femoral neck. Subcapital fractures refer to fractures that occur at the junction of the femoral head and neck, transcervical fractures occur in the central aspect of the femoral neck, and basicervical fractures occur at the base of the neck. Basicervical fractures often occur outside the hip joint capsule, and these extraarticular fracture patterns require specific consideration when considering methods of fixation.[2] Elderly femoral neck fractures are often subcapital, but fracture patterns from high-energy mechanisms are quite different. These fractures are often in the basicervical region and more vertically oriented, leading to greater biomechanical instability.[7]

In addition to the descriptive system, several different classification systems exist to describe fractures of the femoral neck. The Garden classification is most widely known and is based on the degree of displacement of the fracture fragments. Nondisplaced fractures are further classified into type 1 (incomplete fracture, valgus-impacted) and type 2 (complete fracture, nondisplaced) and displaced fractures into type 3 (partial displacement) and type 4 (complete displacement). Although commonly used in the geriatric population, this classification system is less useful for high-energy femoral neck fractures.[6]

The Pauwels classification has more utility for hip fractures in physiologically young patients and is based on the Pauwels angle, which is the angle between the femoral neck fracture line and a horizontal axis.[2,6] This fracture classification was designed to be predictive of fracture instability, risk of nonunion, and fixation failure (Figure 2). Type 1 fractures have a Pauwels angle less than 30°, while type 3 fractures have an angle > 50°. Type 2 fractures present with a Pauwels angle between 30° and 50°.[6] In type 1 fractures, compressive forces predominate, but the more vertically oriented nature of Pauwels type 2 and 3 fractures has increased susceptibility to shear forces across the fracture site. Consequently, type 3 fractures are the most difficult category to achieve and maintain a reduction, and they have increased rates of fixation failure, nonunion, and osteonecrosis.[2]

Presentation and Initial Evaluation

Femoral neck fractures in physiologically young patients typically occur after high-energy mechanisms such as motor vehicle accidents or falls from height. They occur from an axial loading mechanism on the thigh with the hip in an abducted position and are commonly seen in dashboard injury mechanisms after vehicular trauma.[2]

Associated injuries are common in young patients with femoral neck fractures. Given the amount of force required to cause these fractures, the reported incidence of associated head, chest, abdominal, and other orthopaedic injuries is 50 to 60%.[2] Common associated injuries include closed head injuries, pneumothorax, cervical and thoracic spine injuries, splenic lacerations, and bowel injuries. Commonly associated musculoskeletal injuries are those also involving an axial loading or dashboard injury mechanism, such as ipsilateral tibial

Figure 2

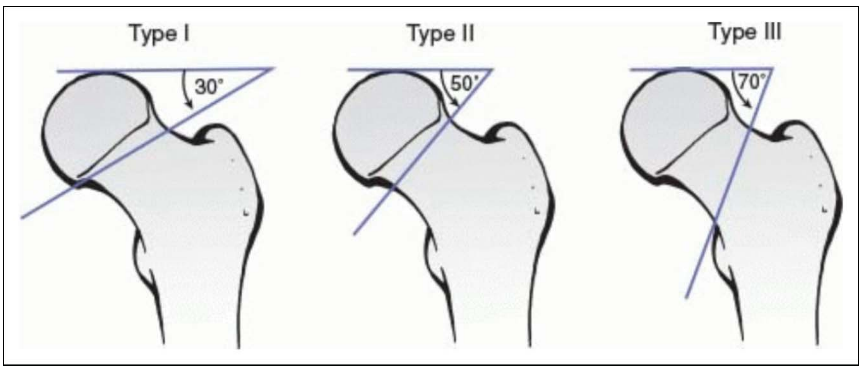


Diagram showing that the Pauwels classification is both descriptive and prognostic of young femoral neck fractures. A type 1 fracture is horizontal and has minimal shear forces. Type 2 is intermediate, and type 3 has a more vertical fracture pattern with the most shear force. Reproduced with permission from Keating JF: Femoral Neck Fractures in Tornetta III and other editors: Rockwood & Green's Fractures in Adults, ed. 9, Philadelphia, PA, Lippincott Williams & Wilkins, 2020.

and femoral shaft fractures, hip dislocations, acetabular fractures, and knee ligamentous injuries.[2]

Initial Evaluation

Because of the high rate of associated injuries, initial evaluation and stabilization of young patients with femoral neck fractures follows the principles of the Advanced Trauma and Life Support protocol.

Imaging Studies

Patients who sustain high-energy traumatic injuries should undergo an initial AP radiograph of the pelvis.[2] The proximal femur should be closely evaluated on this radiograph. When there is suspicion for a femoral neck fracture, a dedicated hip AP and cross-table lateral, when possible, can help clinicians identify and characterize the fracture. Biplanar imaging of the ipsilateral femur should also be obtained, given the relatively high incidence of ipsilateral femoral neck and shaft fractures.[5] Many trauma centers now routinely obtain a CT of the chest, abdomen, and pelvis in patients with trauma, which should be closely reviewed to rule out occult femoral neck fractures when available.[2]

Femoral shaft fractures require scrutiny of the femoral neck. Thin-cut pelvis CT reformats of the initial trauma scans can be used to identify an occult femoral neck fracture or to evaluate fracture characteristics such as the degree of comminution, which can influence surgical planning (Figure 3).[4,5] Given the devastating consequences of a missed femoral neck fracture, many trauma centers now use dedicated fine-cut (2 mm or less) CT scans through the femoral neck in all patients presenting with a femoral shaft fracture after blunt trauma.[4] Ipsilateral femoral neck fractures were previously thought to occur in 1 9% of patients with a femoral shaft fracture.[4] Recent data, however, have shown that the prevalence of ipsilateral femoral neck fracture is closer to 16% when evaluated with rapid sequence MRI (Figure 4).[5] Since fine-cut CT scans are not 100% sensitive for detecting occult femoral neck fractures, some institutions are now using the above-mentioned rapid limited-sequence pelvic MRI for patients with femoral shaft fractures. This two-sequence MRI takes less than 10 minutes and can detect a femoral neck fracture in an additional 8% of patients with a negative fine-cut CT scan.[5] Another recent study demonstrated that diagnosis and treatment of these fine-cut CT-negative femoral neck fractures is greater than the cost of MRI utilization, but this study was done in a national healthcare system and cost analysis may not be generalizable to other types of systems.[8]

Finally, another described method of detecting occult femoral neck fractures involves evaluating thin-cut CT imaging of the femoral neck on soft-tissue window for >1 mm of distention of the anterior hip capsule. This method has been found to be more sensitive than thin-cut CT at detecting occult ipsilateral femoral neck fractures in the setting of femoral shaft fractures.[9]

Management

Nonoperative Management

Nonoperative management plays little to no role in the treatment of high-energy femoral neck fractures in young patients. This treatment is reserved exclusively for those patients for whom surgery carries a substantial mortality risk. Studies have shown that good outcomes can be achieved with fixation of neglected femoral neck fractures, and delayed treatment of these fractures does not necessarily condemn a patient to osteonecrosis.[10] Once a patient is stabilized and appropriate for surgery, then the appropriate surgical treatment strategy should be determined based on the patient's overall status, functional demands, and expected recovery.

Surgical Treatment

In the young patient population, the mainstay of surgical treatment is reduction and internal fixation. This includes nondisplaced fractures in the physiologically young given the grave sequela associated with late displacement. In older populations, arthroplasty is used in treatment of these injuries to allow for earlier weight-bearing and quicker return to preinjury activity levels. Recently, total hip arthroplasty has become an increasingly used treatment option in younger population because of improved implant durability.[1] A recent cost analysis of patients with femoral neck fractures showed that total hip arthroplasty is most cost-effective in patients aged older than 54 years, as well as in patients older than 47 years with mild comorbidities and older than 44 years with severe comorbidities.[11] However, this treatment does carry with it lifelong limitations about the presence of a total hip arthroplasty. In physiologically young and healthy patients, we prefer to have an informed discussion regarding the risks and benefits associated with fixation versus arthroplasty. This patient and surgeon discussion is particularly important with displaced femoral neck fractures because the complication rate can be high with internal fixation.[3] Although we have no strict age cutoff, several factors are considered. As mentioned previously, the

Figure 3

Radiograph showing the nondisplaced femoral neck fracture. **A,** Trauma AP radiograph of the right hip with the nondisplaced fracture line. **B,** The thin cut on CT confirms the presence of a fracture. Occult femoral neck fractures may also be seen on MRI if the CT scan does not elucidate a diagnosis.

overall clinical stability of the patient is of utmost importance to evaluate before proceeding with surgical fixation and is inclusive of activity level, overall health, and in some cases, the ability to survive surgery. In addition, an evaluation of the patient's bone quality should be done starting with the Vitamin D level. Furthermore, the presence of preexisting arthritis, even when asymptomatic, and other comorbidities that would affect bone healing capabilities should be factored into this shared decision. However, to preserve native bone stock and limit the number of subsequent interventions, in high-energy femoral neck fractures in

Figure 4

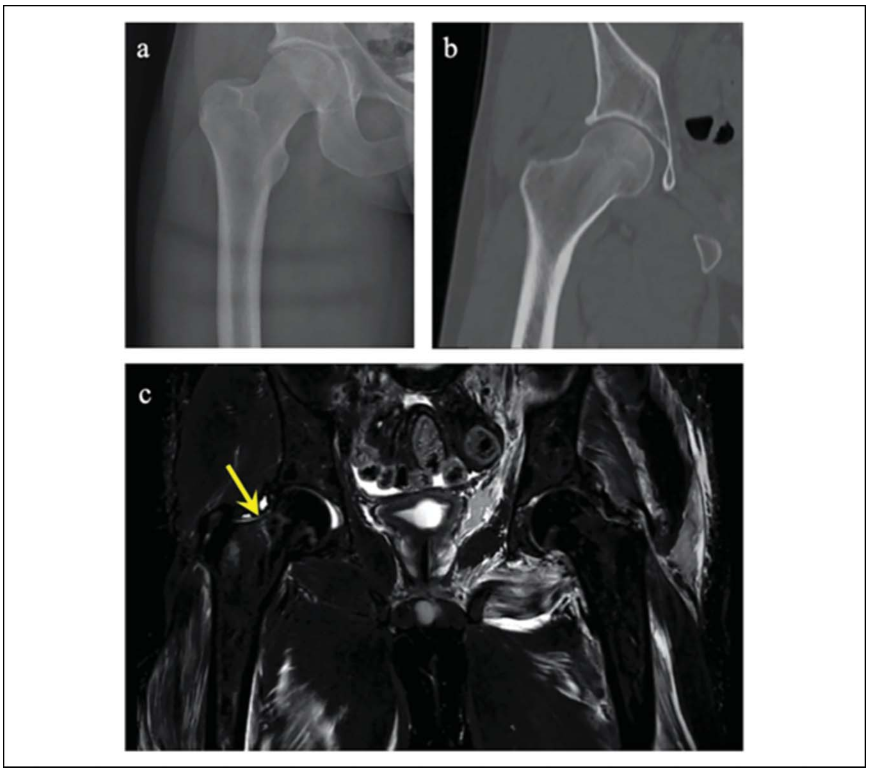


Diagram showing occult femoral neck fracture seen on limited series MRI. **A,** Radiograph and B, thin-cut CT scan without sign of fracture. **C,** Coronal short tau inversion recovery MRI sequence demonstrates femoral neck fracture. Reproduced with permission from NB Rogers, BE Heartline, TS Achor, M Manikavel et al, Improving the Diagnosis of Ipsilateral Femoral Neck and Shaft Fractures – A New Imaging Protocol. *J Bone Joint Surg* 2020;104(2):309-314.

patients aged younger than 54 years, it is our recommendation to proceed with fixation whenever feasible.

Our recommendations are to use a radiolucent flat Jackson table in the supine position with the affected hip bumped with blankets to improve fluoroscopic evaluation. We place the patient's ipsilateral arm across their chest to improve access to the hip and also use intraoperative traction which decreases need for assistants. Some like to use a fracture table; however, this does limit the freedom of the surgeon to manipulate the leg intraoperatively.

Surgical Timing

Previously, surgical treatment of high-energy femoral neck fractures was long thought to be an orthopaedic emergency, due to a belief that delay to fixation compromised blood supply to the femoral head.[7] However, recent literature has been unable to identify surgical delay as a risk factor for osteonecrosis or nonunion and has instead shown that clinical outcomes of these fractures are directly related to quality of reduction.[12,13] While awaiting surgical intervention, traction is recommended against because of increased risk of nonunion.[7] Instead, focus should be placed on patient comfort while awaiting fixation.

Controversy exists over the merits of open versus closed reduction of these high-energy femoral neck fractures with most recommending open reduction to improve quality of reduction. Patterson et al[14] recently found that open reduction was associated with worse outcomes and recommended closed reduction whenever feasible. However, this may be influenced by selection bias because more complex fractures often have a higher probability of needing open reduction. Conversely, Collinge et al[15] published no difference in complication rate after open versus closed reductions,[3] but also recently published data showing a notable difference in outcomes with excellent versus poor reduction quality. In light of above, we recommend attempting closed reduction first, but if unable to achieve a radiographically excellent reduction, then an open reduction should be done.

Approach and Reduction Techniques

The two most commonly used approaches for open reduction of high-energy femoral neck fractures are the modified Smith-Peterson and the Watson-Jones approaches due to low morbidity and excellent fracture visualization. The modified Smith-Peterson approach exploits the interval between the sartorius and tensor fascia lata muscles through the tensor fascia lata fascia. This approach allows for direct visualization of the femoral neck as medial as the acetabulum, and utilization of this trans-TFL fascia approach provides quality tissue flaps for closure after reduction.[16] However, it often necessitates a separate lateral incision for most methods of fixation. Conversely, the Watson-Jones approach uses the interval between the gluteus medius and TFL muscles to access the femoral neck, especially at its base.[16] This allows for placement of fixation implants through the same incision as the capsulotomy for fracture reduction, but it limits medial visualization and manipulation of the femoral neck closer to the head. In a cadaveric study, Lichstein et al[16] noted improved visualization and access to the femoral neck through the modified Smith-Peterson approach over the Watson-Jones approach. This visualization was further improved with a rectus femoris tenotomy particularly on the medial aspect of the femoral neck. However, Patterson et al[17] noted that the quality of reduction is equivalent between these two approaches. Care should be taken with retractors placed within the capsule and particularly the posterior capsule to limit disruption of femoral head blood supply. Shape and orientation of the capsulotomy is controversial but on principal, ensure large enough incision to allow for adequate fracture visualization. The authors typically use a T-shaped capsulotomy with the transverse limb on the side of the acetabulum to theoretically preserve the blood supply to the femoral head (Figure 1).

The importance of anatomic reduction of these fractures has led to multiple descriptions of surgical techniques to achieve the best possible reduction.[18-20] Yu et al[18] described a percutaneous reduction method using Kirschner wires as joysticks and ultrasonography for localization of important structures to prevent injury. This is a relatively limited series, however, with 36 patients and four postoperative complications (one planned total hip, one osteonecrosis, one screw migration, and one screw loosening). Stacey et al[19] described two open reduction techniques, one using a Kirschner wire in the femoral head and a bone hook on the femoral shaft to affect the reduction, and another using a Farabeuf clamp with a screw in the intertrochanteric region and a screw in the femoral head. Halvorson[20] described many reduction techniques, including utilization of pelvic reduction clamps, collinear clamps, and anterior neck plates. Although there is no unanimity on a superior reduction technique, surgeons should have multiple tools at their disposal because of the importance of achieving a

Figure 5

Diagram showing the use of reduction tools. **A,** AP intraoperative radiograph demonstrating Weber clamp and large Schantz "joystick" pin used for reduction of femoral neck fracture. Smaller Kirschner wires provisionally holding fracture reduction. **B,** Lateral radiograph showing Weber clamp and Schantz "joystick" pin in place. **C,** AP radiograph showing final constructs with antirotational screw.

quality reduction (Figures 5 and 6 and Supplemental Video 1, Treatment recommendations for high energy femoral neck fractures in young patients).

Fixation Techniques

Most femoral neck fractures treated with internal fixation use laterally based constructs, such as cannulated screw constructs, sliding hip screws (SHS), a newer generation screw and side plate device with a built-in derotation screw, and/or proximal femoral locking plates. Furthermore, there is no consensus expert opinion regarding the optimal construct, which was illustrated by a survey of active Orthopaedic Trauma Assocation (OTA) members in 2014.[21] Biomechanical studies have sought to determine the optimal position of cancellous screws for vertical femoral neck fractures. Studies have demonstrated that the inverted triangle position of cannulated screws was stronger than linear or triangle positioning of screws.[22] However, other studies have demonstrated that SHS resist shear forces better than

Figure 6

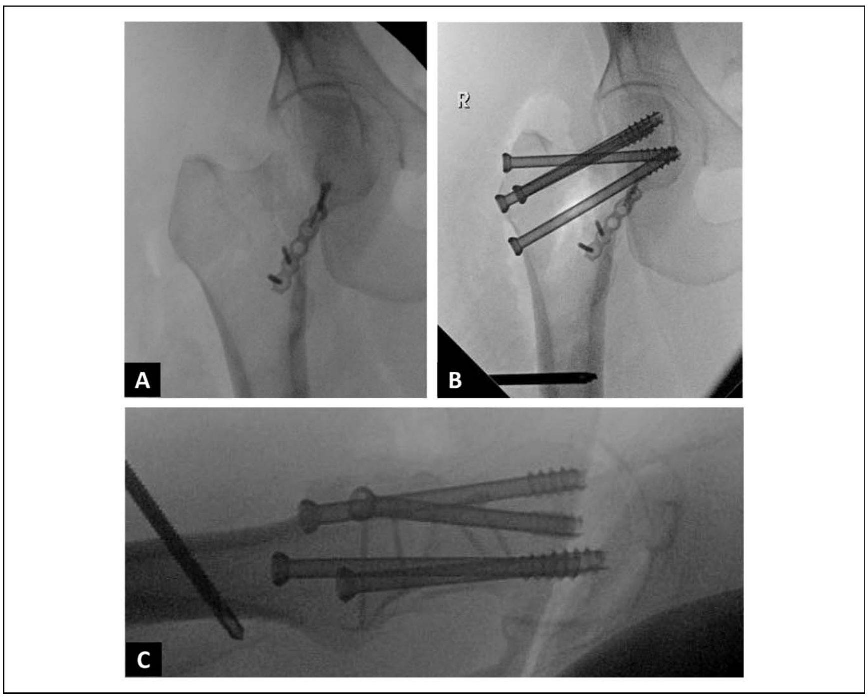


Diagram showing the use of adjunctive miniature fragment plate. A, AP radiograph depicting a miniature plate on the anterior-inferior aspect of the femoral neck. **B** and **C**, AP and lateral radiographs showing a final fixation construct.

cancellous screw constructs in in vitro settings.[23,24] The improved resistance to vertical shear forces with the sliding hip screw is likely due to its fixed angle nature. Some orthopaedic surgeons use a hybrid variation of this first with cannulated screws after the reduction followed by a sliding hip screw. Interestingly, Aminian et al[24] demonstrated that proximal femoral locking plates provide the greatest resistance to shear force. However, these implants are seldom used given their high rate of implant failure and their inability to compress or to allow for controlled collapse. In contrast to Aminian et al, the results of Samsami et al[25] demonstrated that SHS were superior to femoral locking plates regarding limiting interfragmentary motion, which was seen as a risk factor for fixation failure. Both groups, however, agreed on the superiority of both proximal femoral locking plates and SHS over cannulated screws.[24,25]

Clinical evidence supports these biomechanical findings. Liporace et al[26] noted that there was an increased rate of failure associated with cannulated screw fixation as compared with SHS, although in their study this did not reach statistical significance. Findings of O'Toole et al supported this as they demonstrated a markedly lower failure rate with fixed angle constructs as compared with cannulated screws.[27] Other recent studies have noted improved healing rates, patient-reported outcomes, and better biomechanical stability of fixed angle devices (ie, SHS and the newer generation screw and side plate device with a built-in derotation screw) then cannulated screw fixation (Figure 7).[28,29] The fracture fixation in the optimal management of hip fractures (FAITH) two-trial attempted to address this question clinically and was unable to detect a difference in outcomes between fixed angle devices and cannulated screw constructs. However, this study was admittedly underpowered per the authors, and no concrete conclusions should be drawn from these data.[30] Therefore, in light of more recent studies, we recommend using a fixed angle device whenever possible. Given the higher rate of failure of cannulated screw constructs, other studies have sought to determine whether this can be improved through adjunctive methods. Giordano et al[31] performed a biomechanical study demonstrating that the addition of a medial plate to cannulated screw constructs improved biomechanical stability of femoral neck fixation. Clinically, Ye et al[32] demonstrated an 89% rate of union without shortening with medial plating in addition to cannulated screw constructs. Use of cephalomedullary nails (CMNs) in these injuries has begun to emerge with promising preliminary data.[33,34] However, more data are needed before making any strong recommendations on use of CMNs for high-energy femoral neck fractures. Recently, the use of fibular struts to augment cannulated screw constructs has been investigated; however, Kumar et al[35] were unable to show any clinical differences associated with this fibular strut augmentation. Although there is no consensus postoperative protocol for high-energy femoral neck fractures, most surgeons limit weight bearing until there are signs of radiographic union.

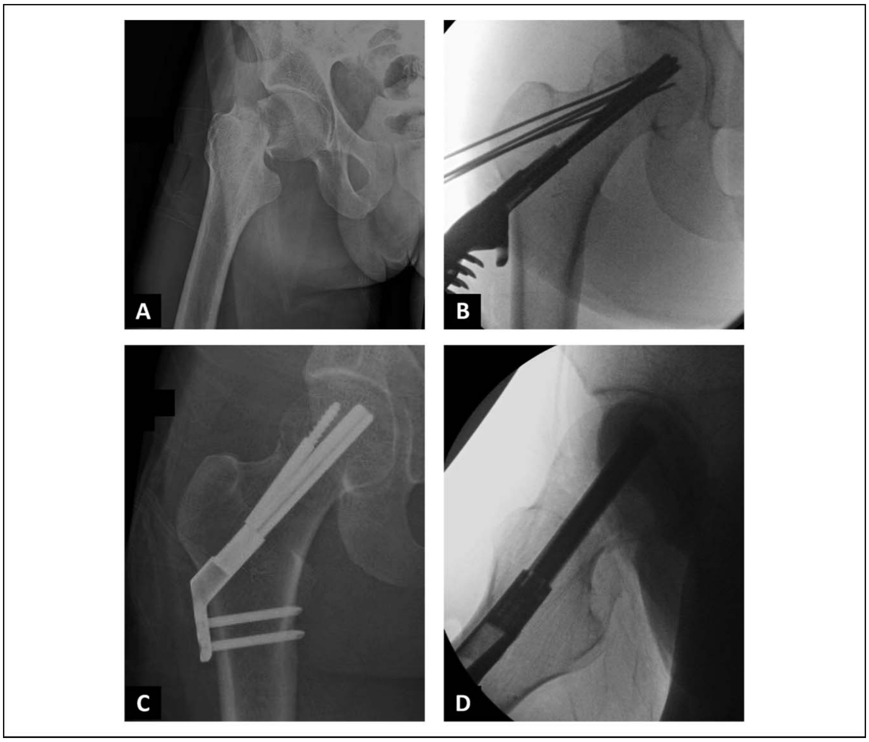
Prognosis and Outcomes

Given the high-energy nature of these fractures, the tenuous vascular supply, and the high shear forces that are exerted across them, the complication rates associated with these fractures are quite high. In fact, Collinge et al noted an overall 45% complication rate.[26] The two most challenging complications of these fractures are nonunion and osteonecrosis of the femoral head. Recent studies have shown improved rates of nonunion and osteonecrosis, likely due to improved diagnosis, implant design, and surgical techniques. Liporace et al[26] demonstrated an osteonecrosis rate of 11% and a nonunion rate of 16%. However, their study has small numbers and has not been reproduced. Heterotopic ossification (HO) has been noted after surgical intervention and is suspected to be related to damage caused by excessive retraction on the rectus femoris and when present, disruption of the iliocapsularis. However, Collinge et al[3] reported a 1.8% HO excision rate which suggests that the presence of HO postoperatively is often asymptomatic and insignificant.

Treatment of Nonunion and Osteonecrosis

Nonunion of high-energy femoral neck fractures is one of the more challenging complications in orthopaedic surgery. Multiple treatment strategies have been suggested, including revision fixation, arthroplasty, vascularized bone grafting, and valgus-producing osteotomy. One of the most reliable methods to treat nonunion is the use of the valgus intertrochanteric osteotomy (VITO).[36] The goal of this procedure is to turn a vertical fracture line with high shear force into a fracture line that more readily allows compression with loading during weight bearing.[36] This is typically done with a blade plate or sliding hip screw (Figure 8). Given the relatively uncommon nature of this complication and the technically demanding nature of the operation, most series are relatively small. Min et al[37] reported on a series of 11 patients with femoral neck nonunions treated with VITO: Nine had excellent

Figure 7



A, AP radiograph of displaced femoral neck fracture. **B,** AP intraoperative radiograph demonstrating provisional Kirschner wire fixation. Closed reduction was done using orthogonal Schanz pins in the femoral shaft, intraoperative sterile traction, and gross manipulation. **C** and **D**, Final AP and lateral radiographs after fixation of the femoral neck with the newer generation screw and sideplate device with a built-in derotation screw.

Figure 8

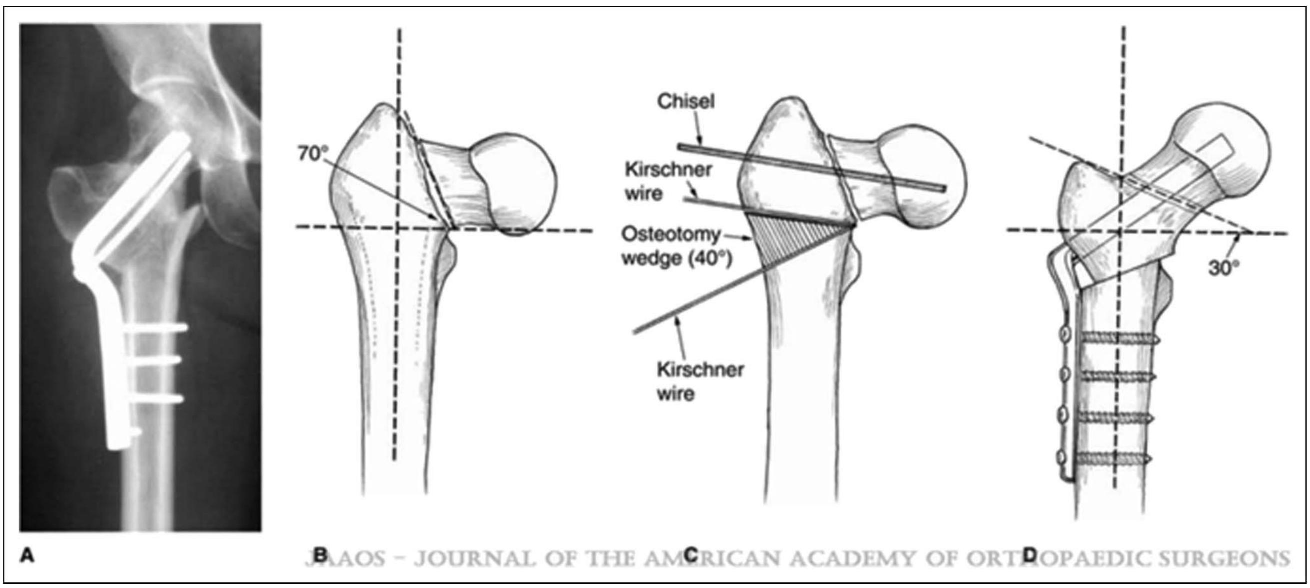


Diagram showing the valgus-producing intertrochanteric osteotomy. **A**, Early AP radiograph after valgus intertrochanteric osteotomy (VITO) performed. **B** and **D**, demonstrate typical varus nonunion with the vertical fracture line, templating and bone cuts, and projected construct of VITO. Reproduced from Haidukewych and Berry, Salvage of Failed Treatment of Hip Fractures, *JAAOS* 2005;13(2):101-9.

outcomes and two went on to total hip arthroplasty. Anglen et al reported on 13 patients, two of whom went on to subsequent arthroplasty, while the remaining 11 had good functional outcomes.[38] Vascularized fibular bone grafting has also shown promising results because LeCroy et al had 20 of 22 patients go on to union.[39] However, VITO alters the native alignment and can make future arthroplasty more challenging.

Osteonecrosis is another challenging problem after fixation of femoral neck fractures with limited treatment options. Vascularized bone grafting and vascularized muscle pedicle grafts, with a goal of improving blood flow to the femoral head, have both been described, but their utilization in the setting of trauma is limited.[40] Often, if the patient is left without a viable femoral articular surface, the only surgical treatment option is total hip arthroplasty. Arthroplasty in this setting is a reliable procedure to relieve pain and return function.

Other Complication

Collinge et al reported a malunion rate of 8% for >15 mm of malalignment and 15% for >10 mm. However, need for revision of malunion is controversial, and intervention is not always needed because patients are often asymptomatic. Painful and prominent implant has also been reported after open treatment, but this is often less of a problem due to frequently generous soft-tissue envelope surrounding the implants. Published rates of implant removal range between 4 and 11%.[3,4]

Conclusion

Femoral neck fractures in young populations are high-energy injuries that carry serious sequelae. Although there is no evidence to suggest that emergent surgical intervention is needed, these fractures should not be treated electively, and timely intervention should take place once the surgeon, patient, and staff are duly prepared.[12,13] Once stable, surgical intervention should be done, and we recommend that internal fixation with a fixed angle device be used whenever possible in physiologically young patients. We pursue a closed reduction first and only use an open reduction if unable to achieve a radiographically excellent closed reduction.[14] Even with anatomic reduction and stable fixation, osteonecrosis and femoral nonunion can occur in this patient population.[26] Early identification of these complications is necessary to provide the widest variety of revision options. In the setting of a high-angle femoral neck fracture that has gone on to nonunion, we recommend the use of VITO or free vascularized fibula grafting in the patient who wishes to avoid hip arthroplasty.[36,39] In patients who prefer the immediate weight bearing afforded by hip arthroplasty, or with symptomatic osteonecrosis precluding a concentric hip joint, arthroplasty is the preferred solution.[1]

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