Curr Rev Musculoskelet Med (2012) 5:214–221
DOI 10.1007/s12178-012-9127-x

TRAUMA (MJ GARDNER, SECTION EDITOR)

Contemporary management of femoral neck fractures: the young and the old

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Published online: 25 May 2012

Abstract The optimal management strategy for femoral neck fractures remains highly debated. The femoral neck is intracapsular and the vascular supply is fragile. Furthermore, the curvature of the proximal femur results in high mechanical stresses through the femoral neck. Poor outcomes of nonunion and avascular necrosis (AVN) are common. This chapter reviews the current evidence with respect to the treatment principles of femoral neck fractures in two distinct patient populations: "young" and "old." Contemporary controversies including surgical timing, choice of implant, arthroplasty options, nonoperative management, capsulotomy, and associated complications will be discussed.

Keywords Femoral neck fractures · Physiologically young hip fracture · Old hip fracture · Contemporary hip fracture treatment · Trauma

Introduction

Patients that present with femoral neck fractures fall into one of two evidence-based age categories: "young" and "old." These categories are based on the patient's physiological age, not chronological age. "Young" patients are those with good bone stock (that can maintain internal fixation) in whom arthroplasty is a poor choice, and in whom the goal of treatment is joint preservation. "Old" or "elderly" patients are those with fewer functional demands, with poor bone quality, and in whom primary arthroplasty is a good treatment option. "Young" patients typically sustain the injury as a result of a high energy mechanism, may have associated traumatic injuries, but typically have high physiological reserves without medical comorbidities. "Old" patients typically sustain femoral neck fractures as a result of low energy trauma, present with isolated fractures, and have multiple comorbidities that must be considered when deciding on surgical timing and tactic [1].

The first step in the management is assigning the patient to one of these categories. When young patients sustain femoral neck fractures, all treatment decisions focus on preservation of the native femoral neck and head. Contemporary management controversies in these patients revolve around decreasing the rates of nonunion and avascular necrosis (AVN) of the femoral head , and include surgical timing, open versus closed reduction, and implant choices. In the elderly or "old" patients, controversy exists regarding fixation versus arthroplasty, and then total hemi-arthroplasty (THA) versus hemi-arthroplasty (HA). In these patients, surgical timing is considered in trying to decrease the rates of medical complications and mortality. The aim of this chapter is to review the evidence with respect to the treatment principles of femoral neck fractures in these two distinct patient populations.

Management principles: physiologically young

The primary goal in the young patient with a femoral neck fracture is joint preservation. These fractures usually fall into a completely different treatment algorithm when compared to elderly patients. Young patients are healthier and

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have higher functional demands. The femoral neck fracture in this patient population has a historically dismal outcome profile. AVN rates of 85 % and nonunion rates as high as 60 % have been reported [2]. Multiple studies demonstrate that the prediction of femoral neck fracture failure is multi-factorial. Injury factors including initial displacement, fracture pattern (as described by Pauwels [3]) and posterior neck comminution have been strongly correlated with poor outcomes by all authors who have evaluated these factors. It is thought that the presence of posterior comminution precludes the maintenance of an anatomically stable reduction and has been associated with a higher incidence of failure and displacement [1, 4, 5]. Technical factors, those that can be controlled by the surgeon, have been less consistently predictive. Surgeon-controlled factors have been evaluated, including 1.) open (capsulotomy) versus closed reduction, 2.) time to surgery, 3.) implant choice, and 4.) quality of reduction.

Indication for capsulotomy

The role for decompression of intracapsular hematoma and its relation to the development of avascular necrosis has been debated. The increased intracapsular pressures and resultant tamponading effect to the femoral neck vasculature has been well cited [6–11]. Open reduction techniques decompress the intracapsular hematoma by definition, but in the case of a successful closed reduction, one could argue the role of percutaneous capsulotomy to relieve the pressure. There have been clinical studies that show a reduction in intracapsular pressure with capsulotomy and a resulting improvement in blood flow to the femoral head [10–14]; however, there are no clinical data correlating capsulotomy to improved outcomes.

Upadhyay found no difference in the rates of AVN and nonunion after prospectively randomizing patients to open reduction/capsulotomy versus closed reduction [15••]. Maruenda et al [9] measured preoperative intracapsular pressure in 34 patients and followed them for seven years. Five of the six patients that developed AVN had preoperative intracapsular pressures less than the diastolic blood pressure. Maruenda et al concluded that AVN may result from damage at the time of injury and not from vascular tamponade. There has not been one consistent variable predictive of AVN, although there have been many hypotheses, including initial displacement, quality of reduction, postoperative time to weight bearing, loss of reduction, nonunion, and associated femoral shaft fracture [2, 16–18, 19•, 20–29].

Surgical timing

Early reduction and fixation of femoral neck fractures is directed at the idea that the tenuous blood supply to the femoral head may be stretched or kinked by the injury, and that rapid reduction allows restoration of the blood flow. In 1984 Swiontkowski and colleagues [16] reported low rates of AVN (20 %) and no symptomatic nonunion in 27 patients aged 15–50, and attributed this success to the application of an institutional protocol of "immediate reduction" (within eight hours of diagnosis) and internal fixation with compression. This work labeled femoral neck fractures as "orthopaedic emergencies" in our literature.

Since this publication, several studies have been published supporting the correlation between time interval to surgery and the outcomes of nonunion and AVN. Retrospective observational studies by Gerber et al [30] and Robinson et al [31] demonstrated similarly low rates of AVN and nonunion in patients treated early, corroborating Swiontkowski's work. Jain et al [22] prospectively compared two non-randomized cohorts and found that 16 % of those patients treated more than12 hours after injury developed AVN versus no patients that were treated within 12 hours. Of note, no patients developed nonunion in either group. All of these authors report that their data support emergent treatment of young patients with femoral neck fractures.

Most contemporary studies do not identify an association between time to surgery and development of AVN or nonunion. Haideukewych et al [19•] retrospectively compared 73 patients between ages 15–50 treated for femoral neck fractures. Those patients treated within 24 hours of injury demonstrated AVN 23 % of the time, and 7 % developed nonunions. Those treated after 24 hours developed AVN 20 % of the time and 10 % developed nonunion. Similarly, Upadhyay [15••] evaluated 92 patients less than 50 years old with femoral neck fractures and overall rate of AVN of 16 % with no difference in treatment before or after 48 hours. 547 fractures were retrospectively reviewed in a meta-analysis of 18 studies looking at femoral neck fractures in the physiologically young [32]. Of the seven studies that looked at correlation between timing to surgery (within 12 hours or after 12 hours), no difference in rate of osteonecrosis was found. Finally, three case series have been published reporting on cohorts of patients treated after "inadvertent" delays of 6 days to two years, with rates of AVN and nonunion similar to those series in which patients were treated emergently (0 to 25 %) [33–35].

The importance of surgical timing on the outcomes of AVN and nonunion in femoral neck fractures remains controversial. The current best evidence suggests a lack of an association, but is limited to retrospective observational cohorts that are far underpowered to reach meaningful conclusions.

Implant choice

Implant options generally fall into two categories. There are those that afford dynamic interfragmentary compression by

allowing sliding of the fragments along the implant - this is evident in the sliding hip screw and compression screw fixation. "Length-stable devices" are another option for stabilization, and include fully threaded screws, dynamic condylar screws, blade plates, and proximal femoral locking plates.

To date, there have not been many studies comparing implants and functional outcomes in the younger population. In order to understand which implants would best be utilized, it is crucial to have a thorough understanding of the fracture pattern. The Pauwels classification is most applicable to young femoral neck fractures because it can guide implant choice and dictates which patterns are more likely to be unstable. With increasingly vertically oriented fracture lines (Pauwels type II/III-50°/70° from horizontal respectively), it becomes more challenging to place implants perpendicular to the fracture, and shear forces predominate.

The most commonly reported implant choice for these fractures remains three parallel compression screws. Typically, three cancellous lag screws oriented along the femoral neck axis and parallel to each other are placed in an inverted triangle. This configuration is biomechanically superior to any other orientation and decreases the risk of subtrochanteric fracture [36–43]. As demonstrated by Lindequist et al [44••] and other previous authors, the first screw should be placed within 3 mm of the cortical calcar femorale to allow a three-point buttressing effect (with fixation in the dense subcortical femoral head, the calcar, and the lateral femoral cortex of entry) [45]. A second screw should be placed within 3 mm along the posterior superior neck, and a third screw then on the superior-anterior (tensile) surface. The screws allow buttressing and reconstitution of the femoral neck cortices. In higher angle fractures, however, it is very difficult to get these screws perpendicular to the fracture line and a 4th "Pauwels" lag screw, directed from lateral to medial and perpendicular to the fracture line is recommended [46]. This screw fixation construct has been shown to have superior biomechanical stability when compared to other contemporary fixation methods [47].

Due to the difficulty in achieving perpendicular fixation in highly vertical fractures, fixed implant devices may be more appropriate. Liporace et al [48•] reviewed 62 patients aged 19–64 years and showed a 19 % nonunion rate in 37 patients treated with compression screws for Pauwel type III fractures. 25 patients were treated with a fixed-angle implant (dynamic condylar screw versus sliding hip screw versus cephalomedullary device) with an 8 % nonunion rate. Again, while higher powered studies are necessary to extrapolate generalized conclusions of significance, this cohort highlights the advantage of fixed angle implants and the difficulty treating vertical shear fractures.

Pauwels Type III and basicervical neck fractures with comminution remain a challenge. Blair et al [41] recommended sliding hip screw fixation following a biomechanical cadaveric study that reviewed three different fixation constructs for treatment of a basicervical neck fracture. Baitner et al [37] showed a greater load to failure and less displacement with use of a sliding hip screw compared to cannulated screws. Bonnaire and Weber [39] compared sliding hip screw fixation with or without a derotational screw with cancellous screws and a fixed angle blade plate in a cadaveric study to evaluate fixation in Pauwels Type III fractures. They demonstrated biomechanical superiority of the sliding hip screw with the derotational screw and recommend its use for high angle femoral neck fractures.

The role for proximal femoral locking plates has yet to be clearly defined and we feel that it should be avoided in all fractures except those that are circumferentially comminuted along the femoral neck and have no areas to allow cortical contact (truly length unstable patterns). Aminian et al [49] showed that the locking plate was the stronger and most stable construct when compared to three 7.3 mm cannulated screws, the sliding hip screw, and the dynamic condylar screw for fixation of Pauwels Type III fractures. The dynamic condylar screw was next in strength and stability, followed by the sliding hip screw and the cannulated screws. Because the proximal femoral locking plate does not allow for compression about the fracture, anatomic reduction and preloaded compression prior to placement of the implant is of paramount importance.

Reduction quality

The only technical factor that has been consistently and robustly associated with outcomes is the quality of the achieved surgical reduction. Regardless of implant, fracture malreduction has consistently been associated with nonunion, particularly varus malreduction. Varus malreduction is a harbinger of nonunion, and increases the shear forces through the femoral neck, threatening even securely placed implants and decreasing the likelihood of bone formation. Several authors have reported nonunion rates upwards of 80 % in patients with poor reductions [19•, 48•]. Poor reduction quality in the presence of posterior neck comminution leads to an extremely unsound mechanical situation, and this combination of variables was highly associated with nonunion in Upadhyay's trial [15••].

Management principles: physiologically old

With the projected growth of the elderly population, the incidence of hip fracture will most certainly have more of an impact on the health care system. The age-adjusted incidence of femoral neck fracture in the United States has been noted to be 63.3 per 100,000 person-years for women

and 27.7 per 100,000 person-years for men [50]. It has been suggested that 77 million Americans and 25 % of Canadians will be over age 65 by 2041 and that their respective health care systems will see the brunt of the socioeconomic effects of the projected increase in proximal femur fractures [51, 52]. An estimated 1.66 million hip fractures occurred in 1990, and of these, 0.28 million occurred in the United States. According to epidemiologic projections, this worldwide annual number will rise to 6.26 million by 2050 [53, 54]. Many of these patients present with multiple medical comorbidities, which has continued to spark debate regarding the optimal treatment algorithm for this population. These patients will present with more medical comorbidities and perioperative issues. As seen in the young patient population, there is also considerable controversy regarding management of the physiologically old femoral neck fracture patient. These include, but are not limited to surgical timing, type of fixation, and partial hip arthroplasty versus total hip arthroplasty. Early mobilization and decreasing the risks associated with prolonged bed rest (pneumonia, decubiti, UTI, DVT, etc) are the primary goals for the physiologically older patient.

Implant choice

For nondisplaced femoral neck fractures, the surgeon must decide if surgery is indicated or if nonsurgical management is preferred. Due to the high rate of subsequent displacement and the adverse outcomes associated with non-ambulatory status, the recommended treatment is surgical. While there is occasionally a role for nonoperative management for the nondisplaced fracture, this is reserved for nonambulatory patients deemed high risk surgical candidates. The associated medical complications of nonoperative treatment with prolonged bedrest include pneumonia, decubitus ulcers, urinary tract infection, and thromboembolic events [55–57]. Discretion should be used when considering conservative management in the cognitively impaired as even higher mortality and complication rates have been shown in this cohort [8, 58].

Most of the controversy in the management of “old” patients with femoral neck fractures lies in the treatment of displaced fractures. These are considered operative and are unstable injuries. The majority of the investigations done to date have examined the role of internal fixation versus arthroplasty, and favor arthroplasty. The osteoporosis that is coincident with these fractures correlates with high rates of fixation failures and nonunion following internal fixation [59], and there has been a subsequent shift in surgical treatment towards varying arthroplasty options.

Ongoing studies are currently being conducted to determine which implant is best suited for internal fixation of femoral neck fractures when that is the chosen treatment. Compression screw fixation (not unlike that described for the young patients except without the open reduction) is the most commonly used fixation strategy. Bhandari’s meta-analysis showed a higher risk of revision surgery with screw fixation versus a sliding hip screw construct [60••]. Other studies comparing the two constructs have shown no difference in union rates or complications [61]. Until there is more clinical evidence comparing fixation of these fractures, there will be considerable debate regarding which implant is most appropriate.

Internal fixation has been associated with high rates of failure in osteoporotic bone, as well as poor functional outcomes due to femoral neck shortening and malunion leading to abductor dysfunction. Zlowodzki et al evaluated 127 fractures treated with internal fixation after closed reductions of the femoral neck, 64 % of which were nondisplaced, and showed that 66 % shortened by the time of union and 39 % healed with varus collapse. These malunions translated into lower functional outcome scores and were prognostic of subsequent ambulation assistive devices [62, 63•]. Similar results were demonstrated by Ravikumar and Marsh [44••] when they showed declining function and pain control 13 years following internal fixation. Patients also had a 33 % revision rate compared to 6.75 % revision rate for those patients treated with arthroplasty. Thus, even when considered “successful” in terms of union, internal fixation has correlated with poor functional outcomes.

Arthroplasty has emerged as a favorable alternative to internal fixation for displaced femoral neck fractures in the elderly. Iorio and colleagues [40] compared 120 patients with displaced neck fractures treated with internal fixation to 66 patients treated with arthroplasty (total arthroplasty versus hemiarthroplasty). They demonstrated no difference in reoperation rate or mortality, however arthroplasty was associated with more independent living and was more cost effective than internal fixation. Several meta-analyses have compared surgical treatment available for displaced femoral neck fractures. When treated with internal fixation, 67 % of displaced fractures achieve union within two years with 35 % requiring secondary procedures for repeat fixation, hardware removal, or conversion to arthroplasty. 70 % of these patients were shown to achieve pain free union during the first two years, however nonunion rates were reported to occur in upwards of 30 % with similar rates of osteonecrosis [60••, 64]. Pooling from over 1900 patients, Bhandari found statistically insignificant higher rates of infection, blood loss, and a trend towards a higher four month mortality in those treated with arthroplasty; those treated with internal fixation had a four fold higher risk of subsequent surgery and conversion to hip replacement [60••]. A meta-analysis of 2289 patients by Rogmark et al [38] reviewed 14 studies and showed that primary arthroplasty leads to significantly fewer major method-related hip complications (deep infection, early redisplacement, nonunion, avascular necrosis) and reoperations, compared to internal fixation. In all

studies comparing methods of internal fixation, regardless of the type of fixation, the failure rate was 21–57 % and reoperations were performed in 14–53 % of all the cases. In the nine studies using THA, the failure rate was 4–11 % and the reoperation rate was 2–8 %. The corresponding numbers for hemiarthroplasty were 3–23 % and 0–24 %. Most of the studies found better function and less pain after primary arthroplasty.

The current best evidence supports arthroplasty over internal fixation for displaced femoral neck fractures in elderly patients. Current investigations question the best arthroplasty to perform: total hip arthroplasty versus hemiarthroplasty. Common surgical issues with hemiarthroplasty include concerns with wear of the native acetabulum, while surgeons fear the dislocation risks associated with total hip arthroplasty. These two options have been studied in several comparative series. Ravikumar and colleagues concluded that total hip arthroplasty was superior to hemiarthroplasty when prospectively looking at 271 elderly patients comparing internal fixation, hemiarthroplasty, and total arthroplasty. 27 % of the hemiarthroplasty patients complained of hip pain at one year followup compared to none of the total hip arthroplasty patients. Extended followup of 13 years showed 45 % versus 6 % of patients (hemi versus total) reported pain. The hemiarthroplasty patients also had a higher rate of reoperation (24 % vs 7 %) and lower Harris Hip Scores (55 versus 80) [65]. Blomfeldt et al [66••] performed a prospective randomized study comparing total hip arthroplasty to hemiarthroplasty in 120 patients and showed no differences in overall complications or mortality, but did report statistically significant improvements in Harris Hip Scores at four and twelve months in favor of total hip arthroplasty. Keating reported similar results with two year followup [67]. Although the data favors total hip arthroplasty, the series are relatively small and larger, prospectively randomized studies are required to help with this decision.

To date, there is not consistent evidence supporting unipolar over bipolar hemiarthroplasty. Both are reasonable options for the low demand elderly patient with a femoral neck fracture. Wathne et al [68] prospectively observed 140 patients with displaced fractures treated by cemented modular unipolar hemiarthroplasty (48) or cemented bipolar hemiarthroplasty (92). There were no significant differences at one year followup in functional ability, need for revision surgery, or incidence of hip pain. They concluded that there is no advantage to use of bipolar endoprosthesis for treatment of femoral neck fracture in the elderly. The lower cost of modular unipolar prostheses provides further support for their use. In theory, bipolar hemiarthroplasty may provide an advantage for patients with neuromuscular disease, dementia, or Parkinson's disease who may be predisposed to instability. Developed to increase joint mobility, reduce acetabular cartilage deterioration, and allow easy conversion to total hip arthroplasty, bipolar endoprostheses can be a successful option in select patients. Meta-analysis by Lu-Yao et al [64] reported 85 % of patients with no or mild pain, and 85 % of patients were able to walk without aids or with only one cane 2 years after bipolar hemiarthroplasty. In a prospective randomized study, Raia et al [69] reviewed 115 elderly patients, comparing unipolar and bipolar hemiarthroplasty, and found no advantage between the two with regard to blood loss, transfusion, hospital stay, return to community ambulation, and functional outcomes. The decision for use of unipolar vs. bipolar endoprostheses is surgeon dependent. Both have been shown to be viable options for the elderly patient with a femoral neck fracture.

Surgical timing

The increased mortality rates associated with elderly hip fractures have been well documented, with international surveys showing average rates of 30 % [70]. Numerous studies have reported the correlation between time to surgery and increased mortality [57, 71••, 72–76]. Shiga and colleagues' meta-analysis of 16 observational studies demonstrated increased mortality rates at 30 days and one year of 41 % and 32 % respectively when surgery was delayed more than 48 hours [73]. Other studies suggest similar mortality rates. Radcliff et al [76] prospectively observed 5,683 elderly patients with hip fractures and showed that delays greater than four days were associated with increased mortality within the first 30 days. Preinjury risk factors of older age, higher ASA, increased functional dependence, and cognitive impairment were also elucidated.

Based on current evidence, minimal delay to surgical fixation is recommended; however, medical comorbidities must be taken into account and optimized. Observing 2,660 patients, Moran et al [71••] compared mortality rates at one month, three months, and one year in patients deemed fit for surgery or who required management of medical comorbidities preoperatively. At one month, the fit patients that had delays of more than four days had a mortality rate of 10.7 %. This number was increased at 90 days and one year. Patients admitted with medical problems requiring optimization preoperatively had a 30 day mortality nearly 2.5 times greater (17 %) than fit patients. Mortality rates were unchanged in the patients who required medical treatment regardless of surgical timing. Bottle [75] also highlighted the importance of controlling comorbidities in a retrospective review of 129,522 patients and found that surgical delays greater than 24 hours were associated with increased in-hospital mortality. However, when comorbidities were controlled, mortality odds ratio was lower (1.27 compared to 1.39).

The correlation between surgical timing, medical comorbidities, and mortality has been thoroughly highlighted in the current body of orthopaedic evidence. Given the high

mortality rates associated with uncontrolled comorbidities, the current recommendation for patients admitted with active medical issues is optimization prior to surgery despite potential delays.

Conclusion

While there still remains considerable controversy regarding certain aspects in the management of femoral neck fractures, the basic principles have remained the same. In the young patient, the goal is to preserve the native femoral head and avoid avascular necrosis as well as nonunion. Anatomic reduction and stable fixation are of paramount importance. In the elderly, once the distinction is made regarding the patient's physiologic age ,the primary goals are optimization of medical comorbidities and surgical fixation with minimal delay to allow early mobilization. Existing debates regarding issues such as timing of surgery, implant of choice, and perioperative management will continue to be elucidated as higher powered prospective randomized trials are conducted.

Disclosure No potential conflicts of interest relevant to this article were reported.

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- •• Of major importance

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