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Gaps and opportunities in the management of the young femoral neck fracture

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ABSTRACT

Femoral neck fractures in young adults are difficult to treat. There are substantial gaps in our knowledge regarding treatment and prevention of young adult femoral neck fractures. Avoiding malunion or nonunion of these fractures after fixation remains a challenge. Currently available fixation techniques may allow for healing to occur, but in a shortened position, with negative consequences on gait mechanics and physical function. Osteonecrosis remains a problem, affecting up to half of patients who sustain femoral neck fractures. Achieving reliable healing may require a reconsideration of fracture fixation implants as well as biological methods to address metabolic, endocrine, and/or genetic abnormalities that may be present in the young adult femoral neck fracture patient. Also, prevention of low-energy femoral neck fractures (e.g. stress fracture) remains an area ripe for investigation.

Introduction

Young adults with femoral neck fractures face numerous challenges. Displaced femoral neck fractures in elderly patients are often treated with joint arthroplasty. However, this is not necessarily a good option for a younger (<60 years of age) patient with a femoral neck fracture, as the arthroplasty may not last for as long as it would in an elderly, lower-demand patient. As the authors of other articles in this supplement have indicated, the challenges for treating the young adult femoral neck fracture patient are substantially different from that in the elderly patient, as native joint preservation is the main goal. There are many gaps in our knowledge, which represent opportunities for improvement in algorithms of treatment for these young hip fracture patients.

There are at least five considerations in young patients with femoral neck fractures, all of which merit further study. First, how do we obtain and then (crucially) maintain a reduction of a femoral neck fracture? Second, how can we prevent shortening of a comminuted femoral neck fracture? Successful healing of a femoral neck fracture with substantial shortening may not be acceptable to the patient. Third, how can we reduce rates of femoral head osteonecrosis after displaced femoral neck fracture? Fourth, are there other factors associated with difficulty healing femoral neck fractures, which are metabolic in nature? Fifth, although investigating methods of treatment are important, what about investigating femoral neck fracture prevention in young adults? This manuscript intends to review these considerations in light of current gaps in our knowledge.

Achieving and maintaining reduction of femoral neck fractures

Femoral neck fractures in young patients are often the result of high-energy injury mechanisms, such as motor vehicle crashes or falls from a substantial height [1]. The density of bone in the hip of a healthy young individual is high, and therefore substantial force would be expected in order to create a non-pathological fracture. Traditional methods of fixation of femoral neck fractures include treatment with multiple independent screws or with a fixed-angle device, such as a compression hip screw. However, these methods of treatment are variable in their ability to maintain a reduction, once one is obtained.

Reduction methods for femoral neck fractures vary. Closed reduction techniques, utilizing traction with manipulation of the extremity, are variably successful. What would be deemed an "anatomical" reduction, however, may not be perfect; the method of assessment utilizes radiography, and imperfect reductions may appear acceptable on radiographs [2]. Are these imperfect reductions more likely to displace? Complication rates are higher with radiographically imperfect reductions of femoral neck

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fractures [3,4]. Open reductions of femoral neck fractures are often successful at achieving good reductions [5]. However, extensive comminution of the fracture may preclude the ability to achieve a perfect reduction, and surgeons' judgments are necessary in those cases. How can reduction be acceptably maintained?

The independent screw concept of femoral neck fracture fixation is one, in elderly patients, which relies upon a third point of contact with solid bone. The points of contact of independent screws include the lateral femoral cortex and the subchondral bone of the femoral head. A third point of contact is provided by the intact inferior and posterior aspects of the femoral neck (in continuity with the shaft of the femur). This is important to resist translation of the fracture fragments in the setting of a patient with poor bone quality in the femoral neck [6]. The bone quality of a younger patient is better, and therefore this technical consideration of screw insertion may not be necessary. However, in the patient with comminution of the femoral neck fracture site, an effective "fracture gap" exists, which can be thought of as a surrogate for poor femoral neck bone density. Fixed-angle implants may be able to avoid this problem of displacement.

Compression hip screws have been utilized successfully in the treatment of femoral neck fractures [7]. However, they have a tendency to shorten (more on this later). Some other fixed-angle devices used for femoral neck fracture fixation (for example, an angled blade plate, a locking proximal femoral plate, or a 95° condylar screw construct), on the other hand, may predispose to fracture nonunion due to their inherent resistance to shortening. How can maintenance of reduction without shortening, while achieving reliable healing, be accomplished? Recently, a technique of intraoperative compression of femoral neck fractures, followed by placement of length-stable fixation constructs, has been published to be successful [8]. It is possible that improving mechanics of the fracture, by creating valgus alignment, may also improve the likelihood of healing. However, the effects of such intentional malreduction may be unacceptable to the patient.

Preventing shortening of femoral neck fractures during healing

Malunion of femoral neck fractures takes various forms. Varus malunion of a femoral neck fracture can lead to hip impingement, with concomitant loss of hip motion and the possibility of increasing the rate of arthrosis progression due to resultant articular cartilage and/or labral pathology. Shortening of a femoral neck fracture during healing can also be problematic. Although impingement may not be a problem, loss of abductor tension can have an adverse effect upon gait [9]. Also, fracture fixation implants become more prominent when femoral neck fractures shorten during healing; this can lead to implant-associated irritation of the hip, with resultant pain and an inability to lay on the affected side when in bed.

Surgeons' opinions vary with regard to methods of preventing shortening of femoral neck fractures during healing. In one survey, 89% of surgeons felt that shortening had an adverse effect on hip abductor function, and 69% felt that it adversely affected patients' physical function [10]. Non-parallel length-stable implants which lock into a side plate after being placed in lag fashion were postulated to be a potential solution. A study of 56 patients with femoral neck fractures treated with multiple cancellous screws revealed that patients in whom shortening occurred had a substantial negative effect on physical function [11]. In a multicentre cohort study, shortening of a femoral neck fracture during healing resulted in lower SF-36 physical function and EuroQol 5D scores [12]. Clearly, methods of preventing shortening of femoral neck fractures during healing would be beneficial.

Use of length-stable constructs for femoral neck fracture fixation has been examined by multiple authors. Use of intraoperative compression, followed by placement of length-stable implants (fully threaded cancellous screws), resulted in reliable femoral neck fracture healing without substantial shortening [8]. Although locked plating constructs have been proposed as a potential solution to prevent femoral neck fracture shortening [10], clinical results of locked plate fixation for femoral neck fractures have been suboptimal [13,14]. A recent report documented successful treatment of femoral neck fractures with a locked plating construct; however, this construct still allowed for femoral neck fracture shortening through use of telescoping fixation screws [15].

Young patients' femoral neck fractures are often characterized by comminution at the fracture site. This can prevent a stable reduction without shortening during the healing process. The presence of a non-comminuted posterior femoral neck cortical fracture line has been associated with improved healing in a length-stable position after fixation [16]. Cortical substitution in the setting of comminuted femoral neck fractures may be an area for further exploration. Fibular strut allografts have been successful in the management of comminuted proximal humerus fractures. They may also be of benefit in femoral neck fracture treatment. At 2 years post-surgery, 20 of 36 (56%) of young patients with femoral neck fractures treated with cancellous screw fixation and fibular strut graft augmentation had good-to-excellent Harris Hip Score results in one study [17]. In another clinical study, neglected femoral neck fractures (average of 14 weeks from fracture) were treated with valgus osteotomy and fibular strut grafting. Union was achieved in 95% of patients and good-to-excellent functional outcomes were achieved in 85% [18]. Augmentation of comminuted femoral neck fractures with synthetic bone void fillers has also been examined biomechanically. In a comminuted femoral neck fracture gap model, augmentation with hydroxyapatite was noted to prevent shortening during biomechanical testing after fixation, as compared to non-augmented fixation constructs [19].

Prevention of osteonecrosis after femoral neck fracture

Young adults with displaced femoral neck fractures are at risk of osteonecrosis. Currently accepted osteonecrosis rates after displaced femoral neck fractures are estimated to be as high as 45% [20]. Risk of osteonecrosis was demonstrated to be higher in older patients (53.5 years of age or older) in an under-65 aged population of femoral neck fracture patients [21]. No other factors were associated with increased risk.

Theories about the aetiology of osteonecrosis include frank disruption of the vascular supply to the femoral head via fracture displacement, as well as tamponade by a surrounding capsular haematoma. The former theory does not describe why 20% (9/46) of undisplaced femoral neck fracture patients develop osteonecrosis [22]. The latter theory does not explain why femoral neck capsulotomy is only variably successful in the prevention of osteonecrosis [23], although increased intracapsular pressures $>$30 mmHg were associated with osteonecrosis after femoral neck fracture in a recent clinical series [24]. Clearly, our understanding of the aetiology and prevention of osteonecrosis is limited.

Early reduction of femoral neck fractures and decompression of capsular hematomas may be of benefit for reducing the initial vascular insult and for optimizing revascularization in the setting of interrupted blood supply. Biological mechanisms for improving revascularization may also be of benefit; these are poorly understood and are likely not considered in the treatment of femoral neck fractures. Osteonecrosis of the femoral head has been associated with certain genetic abnormalities. Children with Perthes' disease were shown to have low circulating levels of insulin-like growth factor I (IGF-1) in one clinical series [25]. A recent series of adult Chinese patients with osteonecrosis of the