Femoral head fractures

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Abstract Femoral head fractures may present in various patterns with or without associated fractures around the hip. As a result, the treating orthopaedic surgeon must understand not only the fracture pattern, but also patient-related fractures and the relevant operative exposures and reconstructive options to achieve the best functional outcome while minimizing complications. Treatment options range from non-operative treatment to fracture fragment excision or fracture fixation using various surgical exposures and implants. This article reviews the current literature on the treatment options for femoral head fractures and presents modern operative techniques that have improved exposure of the fracture while minimizing associated risks such as avascular necrosis, heterotopic ossification, and neurovascular compromise. A sound understanding of the anatomy and these newer techniques can enable the surgeon to provide improved expectations and clinical outcomes.

Keywords Femoral head fracture · Hip · Surgical dislocation · Hip dislocation · Trauma

Introduction

Femoral head fractures are relatively uncommon injuries; however, appropriate treatment of these fractures is of prime

importance to help prevent the development of post-traumatic osteoarthritis. Approximately six to 16 % of posterior hip dislocations have been noted to be associated with a femoral head fracture [1–3]. Since the first description of a femoral head fracture [4], several case series have been published; however, no firm conclusions have been reached regarding optimal treatment. Historically, these fracture patterns have been associated with poor functional outcomes [5].

Reduction of a dislocated hip is a true emergency given the relationship between delayed reduction and the development of osteonecrosis [1]. The goals of definitive treatment for acute femoral head fractures are to achieve an anatomic reduction, restore or maintain stability, and remove interposed bony fragments when necessary. Rarely are these goals accomplished with nonoperative treatment. Management of these rare, complex fractures requires not only a sound knowledge of the anatomy of the hip, but also current treatment options and potential complications.

Clinical evaluation

The vast majority of patients that present with a fracture-dislocation of the hip have been involved in high-energy trauma. A thorough history and physical examination is thus crucial not only to diagnose the hip injury but also to identify any associated injuries. It is imperative that concomitant injuries, such as head, intra-abdominal, and chest injuries are identified and treated appropriately. Long bone fractures must also be identified and stabilized. Should the patient present unconscious or obtunded, discussion with emergency medical personnel at the scene may provide details with

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regard to the accident and/or medical information that was gathered from the patient prior to their arrival at the hospital.

Examination of the injured hip often reveals a shortened lower extremity secondary to muscular forces acting on the dislocated hip. The physical examination is also important to identify any skin damage near the hip, such as Morel–Lavalle lesions, or open wounds particularly at the ipsilateral knee. A detailed neurologic examination is also important given the associated risk of sciatic nerve injury during this type of injury [2]. Finally, an ipsilateral knee examination is also required with attention paid to ligamentous stability, given that the hip dislocation is often the result of the knee striking the dashboard during a motor vehicle accident.

The classic mechanism of injury for femoral head fracture is traumatic posterior dislocation of the hip [6]. Shear forces against the femoral head as it exits the contained acetabulum are thought to cause the femoral head fracture during hip dislocation [7]. Due to the inherent stability of the hip joint, dislocation of the hip with associated femoral head fracture requires high amounts of energy, most often due to motor vehicle collisions, fall from a height, motor vehicle-pedestrian accidents, and sports injuries [8, 9]. A common position of the lower extremity during dislocation of the hip is akin to the position during a dashboard injury to the knee, in which the hip is positioned in flexion, adduction, and internal rotation [10].

Radiological classification

The fracture pattern is an important consideration when deciding upon treatment for femoral head fractures. Accurate radiographic evaluation is thus essential in guiding management and predicting outcomes for the patient. A fracture-dislocation of the hip is often evident and first realized on a routine trauma anteroposterior (AP) pelvis radiograph. A dislocated femoral head will appear incongruent with the acetabulum and is often displaced superiorly overlapping the acetabular sourcil with an apparent break in Shenton's line (Fig. 1). Prior to relocation of a dislocated hip, the orthopaedic surgeon should review the radiograph to determine whether an ipsilateral femoral neck fracture is also present. The ipsilateral lower extremity must be examined and radiographs obtained if there is concern for additional injuries/fractures. Once the dislocated hip is reduced, a repeat AP pelvis radiograph should be obtained to scrutinize the congruity of the reduction and determine the fracture pattern of the femoral head fracture. Judet oblique radiographs of the acetabulum should also be obtained in the setting of coexisting acetabular fractures and inlet and outlet pelvic radiographs in the setting of pelvic ring injuries.

Computed tomography (CT) of the pelvis should also be routinely performed following successful closed reduction as well as before open reduction of an irreducible hip dislocation. This CT scan is not only important for assessing

Fig. 1 **a** A fracture-dislocation of the hip is evident on the routine trauma anteroposterior (AP) pelvis radiograph. The dislocated femoral head is incongruent with the acetabulum and is displaced superiorly overlapping the acetabular sourcil with an apparent break in Shenton's line. There is also an associated femoral neck fracture. **b**. A posterior approach with a trochanteric-flip osteotomy provides excellent exposure for reduction and internal fixation (Adapted from [39], with permission). **c, d**. Post-operative radiographs demonstrate anatomic reduction and fixation of the femoral head and neck fractures, in addition to a congruent hip joint

the femoral head fracture pattern (size, location, comminution), but also to evaluate the congruity of the hip joint and determine the presence or absence of intra-articular loose fragments. Finally, one can also determine the plane of the femoral head fracture and make appropriate angled adjustments in patient positioning during plain radiographs to obtain a CT-directed pelvic oblique plain film. Radiographs are most effective in demonstrating fracture patterns when the plane of the fracture is parallel to the incident radiographic beam. The CT-directed pelvic oblique radiograph has been found to be a useful determinant of the extent of the fracture displacement and hip joint congruity [11]. With the ability to modify CT scan planes and with the advent of three-dimensional CT scanning, a CT-directed pelvic oblique radiograph is less important in the initial diagnosis of the femoral head fracture; however, it can be used in follow-up to assess the fracture either when treating non-operatively or after surgical fixation.

The Pipkin classification [12] is the most widely used classification system, which is based on the location of the femoral head fracture in relation to the femoral head fovea and the presence of any associated fractures. Type I femoral head fractures occur when the fracture is inferior to the fovea centralis, whereas type II femoral head fractures extend superior to the fovea centralis. Type III is any femoral head fracture that is associated with a concomitant femoral neck fracture, and a type IV is associated with an acetabular fracture. Brumback et al [13] designed a more comprehensive classification system with the attempt to eliminate the ambiguity of the Pipkin classification and to provide treatment guidelines for each fracture type. Fractures are divided into one of five categories and then are further delineated into subsets A and B. Many orthopaedists, however, continue to use the traditional Pipkin classification system when describing and reporting these fracture patterns.

Treatment

Fracture-dislocation of the hip is a true orthopaedic emergency. Provided that no contraindications exist (e.g., associated femoral neck fracture), emergent closed reduction should be attempted as soon as feasible, preferably within 6 hours, given the direct relationship between delayed reduction and the increased risk of femoral head osteonecrosis [1, 5]. An irreducible fracture-dislocation of the hip or a femoral head fracture with associated femoral neck fracture are indications for emergent open reduction. In these settings, a preoperative CT scan should be obtained if feasible in a timely manner.

The goals of definitive treatment of femoral head fractures are to achieve an anatomic reduction, achieve and

maintain joint stability, and remove any interposed bone fragments. This may be obtained either nonsurgically or surgically. The size, location, and displacement of the fracture are factors in this decision-making process.

Nonoperative treatment

Nonsurgical treatment of a femoral head fracture is acceptable when anatomic reduction is achieved and the hip joint is stable or if the fracture is inferior to the fovea and not problematic. This can be difficult to achieve when the fracture extends above the femoral head fovea (Pipkin II) into the weight-bearing region, given the inherent risk of displacement. If non-operative treatment method is chosen, serial radiographs should be performed to document maintained reduction. There is sparse literature with regard to nonoperative treatment of femoral head fractures. Epstein reported on a series of 39 femoral head fractures and noted that the worst results were in the 17 patients treated with closed reduction alone [9]. Swiontkowski et al [14] however demonstrated good/excellent short-term results in a series of three patients treated with closed reduction and skeletal traction for fractures with less than 1 mm of displacement on CT scan. Two of these patients had fractures that exited superior to the fovea. Kloen et al [15] also reported on the nonoperative treatment of seven patients with femoral head fractures, four of whom had fractures extending above the fovea. The majority of the patients had either fair or good results; however, one patient developed avascular necrosis and ultimately underwent a hip arthrodesis after a failed attempt at joint salvage with a proximal femoral osteotomy. Butler [16] compared a series of ten patients with Pipkin II fractures that were treated with either operative fixation or closed reduction and six weeks of Buck's traction. This series demonstrated that femoral head fractures extending above the fovea may be treated without operative fixation, given that all five patients treated with closed reduction and traction had either good or excellent results and radiographic evidence of union and normal anatomical relationships. These results suggest that nonoperative treatment can be associated with good clinical results for fractures extending superior to the fovea, as long as an adequate reduction is achieved and maintained. However, limitations in patient mobility, resulting in increased risk of deep vein thrombosis and pneumonia, in addition to the high cost of prolonged hospitalization, have led many to abandon this method of treatment.

Operative treatment

Most fractures of the femoral head are treated surgically, given the tendency for these fractures to have displacement and joint incongruity. The indications for surgical management include,

but are not restricted to, nonanatomic reduction of the femoral head articular surface, an unstable hip joint, and the presence of intra-articular incarcerated fragments that are preventing a congruent joint reduction. Controversy exists regarding the preferred surgical approach and whether fragments should be internally fixed or simply excised. Several surgical approaches have been used and recommended; however, each is associated with their own risks and benefits. Traditionally, the main approaches have been anterior (Smith-Petersen) and posterior (Kocher-Langenbeck). Recently, a posterior-based approach with a trochanteric flip osteotomy and surgical dislocation of the hip have gained popularity amongst surgeons, given the wide exposure and visualization that is obtained [17].

Anterior surgical dislocation

Historically, the anterior (Smith-Petersen) approach was discouraged due to the belief that this approach would further compromise the femoral head blood supply. Surgeons previously believed that a traumatic posterior hip dislocation resulted in damage to a portion of the blood supply and that if an anterior surgical approach was performed, with ligation of the ascending branch of the lateral femoral circumflex artery, the femoral head would be at increased risk for osteonecrosis [18]. However, recent cadaveric studies have shown this not to be true as the medial femoral circumflex is the dominant supply to the femoral head with almost no contribution from the lateral femoral circumflex [19]. The anterior approach is associated with a decrease in operative time and improved visualization; however, there is a higher rate of functionally significant heterotopic ossification when compared to a posterior Kocher-Langenbeck approach [14]. This is thought to be the result of the stripping of the abductors from the ilium in previous wide exposures. Evidence also exists to suggest that an anterior-based approach is associated with a lower incidence of avascular necrosis [14, 20].

A modified Smith-Petersen approach has recently been described [21] that allows anterior dislocation of the femoral head with complete visualization of the femoral head. The skin incision is extended from the palpable anterior superior iliac spine (ASIS) distally toward the lateral patella for a distance of 12 to 16 centimeters. The lateral femoral cutaneous nerve is identified and protected while the interval between the tensor fascia lata and sartorius is developed. The common tendon of the rectus femoris is then identified, incised, tagged with a suture, and retracted distally. The ascending branch of the lateral femoral circumflex artery is ligated only if needed to obtain additional retraction and visualization. The hip is then flexed approximately 30 to 45 degrees and the iliocapsularis muscle is elevated from the anterior capsule and retracted medially. This is followed by an oblique T-shaped capsulotomy with the vertical limb

parallel to the femoral neck and the upper limb parallel to the anterior acetabular wall, just lateral to the labrum. Retraction sutures are placed into each corner of the capsular limbs and the hip is rotated to visualize the fracture fragment(s). Visible joint debris, commonly located in the inferomedial recess, can be removed if visualized or with irrigation. If the femoral head fracture is visualized sufficiently at this point, fixation and/or excision can be performed. If further visualization is required, the ligamentum teres is divided, the fracture fragment, if intact, is removed and placed in saline moistened sponge, and the femoral head dislocated. Once pharmacologic relaxation is attained, longitudinal traction and external rotation is applied to anteriorly dislocate the femoral head.

After inspection of the acetabulum and removal of any remaining intra-articular debris, the femoral head fragment is anatomicallly reduced to the dislocated femoral head and provisionally held in place with small diameter Kirschner wires through the non-articular area of the fovea centralis. The free femoral head fragment(s) may be predrilled on the sterile back table or after they are reduced and provisionally held in place. Two or three 2.0- or 2.4-mm countersunk lag screws are used for fixation of the major fragment(s). Any fragment(s) that are unable to produce an accurate reduction are excised. The femoral head is then reduced and passively placed through a functional range of motion to ensure a stable, concentric and smooth articulation. Intraoperative biplanar hip fluoroscopy is utilized to confirm implant safety and adequacy of reduction. Any nonviable iliocapsularis muscle is debrided and the capsulotomy and rectus femoris tenotomy are anatomicallly repaired. The remainder of the wound is closed in layers over closed suction drains.

A recent investigation by Nork et al [21] demonstrated heterotopic ossification in 59 % of patients overall; however, only four patients (12 %) had functionally significant heterotopic ossification (Brooker grade III or IV). The two patients with symptomatic Brooker grade IV heterotopic ossification underwent excision with good results. Radiographic evidence of aseptic necrosis developed in two patients (6 %), each of whom had a suprafoveal fracture treated with ORIF. Ultimately, the final treatment consisted of a total hip arthroplasty in these two patients.

Surgical dislocation of the hip

Surgical dislocation of the hip, originally described by Ganz et al [22], involves an anterior dislocation of the hip from a posterior approach with a trochanteric flip osteotomy. This surgical technique can be performed based on the protection of the deep branch of the medial femoral circumflex artery. The cadaveric anatomical study that was previously performed by Ganz and colleagues [19] formed the basis for the development and use of this surgical approach. During

dislocation of the hip, this vessel is protected by the intact obturator externus muscle and thus preserves the blood supply to the femoral head [19].

The patient is positioned lateral decubitus and a Kocher-Langenbeck or Gibson-type incision is made exposing the fascia lata, which is incised longitudinally. Proximally, this split is carried slightly posterior to the interval between the tensor and the gluteus maximus, in line with the direction of the gluteus maximus fibers. A trochanteric osteotomy, either flat or step-cut [23], is extended from the posterosuperior edge of the greater trochanter distally to the posterior border of the vastus lateralis ridge. The trochanteric osteotomy is mobilized anteriorly and the capsule is exposed by elevating the gluteus minimus fibers away from the piriformis and the underlying capsule. The capsule is incised in a Z-shaped configuration along the anterolateral axis of the femoral neck and the leg is flexed and externally rotated to enable anterior dislocation of the hip. The ligamentum teres is surgically transected, which is followed by excision of the remaining stump of the ligamentum teres from the femoral head or femoral head fracture fragment. Positioning of the leg in 90 degrees of flexion, slight adduction by lowering the knee, and axial pressure by an assistant allows the surgeon 360° access to the femoral head in addition to the acetabulum and acetabular labrum. The femoral head fragment is either anatomically reduced and fixed or excised and the hip joint is then reduced by distal manual traction, internal rotation, and extension of the lower extremity. The capsulotomy is closed, and the greater trochanter is secured using two 3.5- or 4.5-mm cortical screws directed at the lesser trochanter.

In the original series of 213 patients that underwent surgical dislocation of the hip, there were no reported cases of avascular necrosis [22]. Gardner et al [17] described two case examples and the specific surgical technique of femoral head fractures treated with surgical dislocation. They emphasized that anterior shear fractures with large fracture surface areas are difficult to reduce via an anterior approach and surgical dislocation allows anatomic reduction and assures rotational alignment. Kloen et al [15] compared a series of patient with operatively treated femoral head fractures via either an anterior, anterolateral, posterior, or trochanteric flip approach with minimum of two year follow-up. Eighty percent of the patients in the trochanteric flip group had either excellent or good results, compared to 56 % overall. Sixty percent of the patients within the trochanteric flip group were noted to have functionally significant heterotopic ossification (Brooker grade III or IV), however there were no cases of avascular necrosis.

The main pitfall with this approach is the inherent risk of damage to the blood supply to the femoral head, and thus requires knowledge and protection of the vasculature. This approach, however, also offers the benefit of wide exposure

of the acetabulum should associated fractures exist and require operative fixation.

Hip arthroscopy

Epstein emphasized the high incidence of loose bodies after hip dislocation, reporting 91 % of 151 patients with loose bodies noted at the time of arthrotomy after dislocation [18]. He further described the importance of loose fragment removal, as any retained fragments could potentially lead to articular damage via third body wear. Hip arthroscopy techniques have advanced greatly over the past decade and many have advocated this technique to evaluate a hip with a prior dislocation and remove any interposed fragments/loose bodies. A recent study of 36 patients with hip dislocations or acetabular fractures that otherwise did not require surgery underwent arthroscopic evaluation after adequate radiographs and CT scans were performed [24]. Loose bodies were found and removed in 92 % of the patients at the time of diagnostic arthroscopy. There were nine patients within this series that did not have radiographic evidence of loose bodies and concentric reductions prior to arthroscopy; interestingly, seven of these nine patients were noted to have loose bodies at the time of arthroscopy (78 %).

Matsuda recently reported the first documented case of arthroscopic fixation of a suprafoveal femoral head fracture approximately seven days after injury [25]. The fragment, which was discovered on preoperative CT scan, was localized near the anterolateral aspect of the femoral neck and was mobilized and reduced into its anatomical position. Once reduced, the fragment was pinned in place and was followed with fixation with two Herbert screws. The acetabular articular cartilage, labrum, and ligamentum teres appeared otherwise normal. At ten months post-operatively, the patient had returned to full activities with symmetric motion to the uninjured hip.

Arthroscopy is a safe alternative to an arthrotomy, and includes less disruption of the capsuloligamentous structures of the hip, minimized blood loss, reduced potential for neurovascular injury, and faster recovery time. This procedure, however, does not come without risks. Overall complication rates are reported to be between 1 % and 6 % [26, 27]. Complications include traction neurapraxia (sciatic, femoral, and pudendal), direct injury of the lateral femoral cutaneous nerve, portal hematoma/bleeding, osteonecrosis, and iatrogenic articular cartilage injuries. There are even reports of extravasation of fluid from the hip and into adjacent structures [28–31]. Bartlett et al described a case of cardiac arrest secondary to fluid extravasation into the abdomen during hip arthroscopy, resulting in intra-abdominal compartment syndrome [31]. This patient was noted to have a both column acetabular fracture that was treated 12 days

prior with ORIF. One can reduce these risks by attention to surgical detail, minimizing excessive traction time, and monitoring the amount of fluid that is used and recovered during the case.

Fragment excision versus internal fixation

Most fractures of the femoral head are treated surgically, given the tendency for these fractures to have displacement and joint incongruity. Operative treatment of displaced femoral head fractures can be either in the form of internal fixation or simple excision of the fracture fragments. Earlier literature advocated the excision of all fragments, provided that the fragments constituted less than one third of the femoral head [2, 5, 9, 16, 32]. Past reports demonstrate similar outcomes between patients treated with femoral head fracture fixation and those treated with excision [20, 32]. However, it is difficult to directly compare these groups, given that the patients were not randomly assigned nor did they have similar fracture patterns. The patients that underwent excision tended to have fracture patterns that were not amenable to fixation, or were caudad to the fovea. A recent randomized control trial of Pipkin I fractures demonstrated better functional outcomes in the surgical excision group than the closed reduction group [33•]. A cadaveric investigation performed by Holmes et al [34] demonstrated no change in load and mean and peak pressures of the femoral head when comparing specimens with an intact femoral head and specimens with an excised Pipkin I femoral head fragment. However, larger fragments, such as those seen in Pipkin II fractures, resulted in greater contact area and mean pressures located centrally within the acetabulum when the fragment was excised. The normal peripheral loading pattern was altered in these specimens, with higher contact pressures focused more centrally. This mechanism is thought to be responsible for the rapid deterioration of the chondral surfaces after larger femoral head fragment excisions.

Many surgeons agree that the factors that influence treatment decisions include fragment size, degree of comminution, and location of the fragment in relation to the weight-bearing surface of the femoral head. A fracture fragment that is large enough to allow internal fixation should be attempted to be anatomically reduced and internally fixed with the goal of leaving the femoral head articular surface smooth. Once anatomic reduction is achieved, the fragment is provisionally held in place with Kirschner wires, preferably placed through the fovea centralis. Definitive fixation is subsequently performed with interfragmentary lag screws. In addition to burying pins or screws, some fractures are amenable to lag fixation from a non-articular entry point [35]. Multiple implant options have been described and include countersunk interfragmentary lag screws, self-

compression headless screws [36, 37], or bio-absorbable pins or screws [38]. One investigation reported an 80 % failure rate with the use of 3-mm cannulated screws with threaded washers due to back out and dissociation between the screw and the washer [20]. It is our preference to countersink small fragment screws with flat heads, such as 2.0-mm screws (Synthes, Paoli, PA) in the fragment. We also attempt to augment this fixation with additional lag screws entering the femoral head from a non-articular region to augment construct stability.

Conclusion

Femoral head fractures may have different personalities and the treating surgeon must have an understanding of the fracture pattern and location when deciding on the optimal treatment for the patient. Nonoperative treatment may be indicated in some fracture patterns; however, many femoral head fractures are treated operatively. The orthopaedic surgeon must determine whether internal fixation or excision is best, should operative treatment be performed. This is usually based on location of the fracture and degree of comminution, joint stability, and articular displacement. Newer operative exposures, including a modified Smith-Petersen approach with or without anterior dislocation, surgical dislocation of the hip, and hip arthroscopy, have allowed surgeons improved access and visualization of the hip joint. Knowledge of these advances will provide the orthopaedic surgeon with the appropriate tools for improved treatment of this less common injury.

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