Anatomy, classification and treatment of intracapsular hip fractures

Hip fractures are increasingly common, given the increasing ageing, osteoporotic population with significant medical comorbidities. This review summarizes the anatomy of the proximal femur, reviews classification systems and gives recommendations for use of each treatment modality.

Hip fractures are increasingly common, given the increasing ageing, osteoporotic population with significant medical comorbidities. They are responsible for the majority of fracture-related health-care expenditure and mortality in those over 50 years of age (Kanis et al, 2012).

A systematic review of hip fracture risk by the World Health Organization in 2012 showed marked heterogeneity in hip fracture risk worldwide, with European countries (e.g. Denmark, Sweden and Austria) exhibiting a much higher risk than regions such as Latin America (with the exception of Argentina), Africa and Saudi Arabia (Kanis et al, 2012). Analysis of data from 63 countries showed that the age-standardized incidence of hip fractures in women is roughly double that of men (Kanis et al, 2012).

Successful treatment of hip fractures depends upon a thorough knowledge of the osseous and vascular anatomy of the hip joint, as well as the biomechanics involved in causing such fractures. This article provides an in-depth review of this anatomy, an explanation of the commonly used classification systems, and rationale for the successful treatment of intracapsular fractures.

Anatomy

Osseous anatomy

Five groups of trabecular bone support the femoral head and neck (*Figure 1*). The densest cancellous bone is concentrated at the medial femoral neck, the calcar, and is known as the primary compressive trabeculae. Stretching in an arcuate fashion from the inferior part of the femoral head, across the superior region, and finishing in the lateral femur just distal to the greater trochanter lies the primary tensile group. These two groups of primary trabeculae cross in the centre of the femoral head, forming dense bone. However, an area of relative weakness, known as Ward's triangle (*Figure 1*), is present in the femoral neck, formed between the intersections of three groups of trabeculae.

The hip joint consists of crucial angular relationships. The neck–shaft angle in a normal adult is between 125 and 135°. Femoral anteversion is defined as the angle subtended by the long axis of the femoral head and transverse axis of the femoral condyles and has a mean value of 8° in anatomical studies, although a wide variation (-10° to 27°) is present in the general population (Ejnisman et al, 2013).

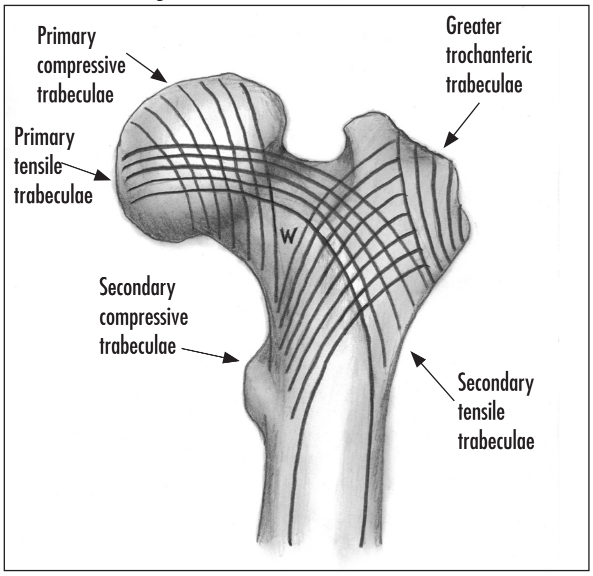
Vascular anatomy

The blood supply to the femoral head derives from three main sources:

1. Medial femoral circumflex artery
2. Lateral femoral circumflex artery
3. Obturator artery.

The epiphysis and metaphysis receive their blood from different branches of these arteries, hence the vessels can be divided into epiphyseal and metaphyseal arteries. The epiphyseal arteries are named lateral and medial, and the metaphyseal arteries superior and inferior, by virtue of their sites of entry into the bone.

Figure 1. Pattern of trabecular bone in the proximal femur. W = Ward's triangle.



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Epiphyseal arteries

The largest contributor to the blood supply of the femoral head, especially its posterior and superolateral aspect, is the medial femoral circumflex artery. The deep branch of the medial femoral circumflex artery runs towards the intertrochanteric crest between the pectineus and iliopsoas tendon. The main division of this deep branch perforates the capsule of the hip proximal to the insertion of the superior gemellus and distal to the piriformis, where it further divides into branches which course postero-superiorly along the femoral neck. Once these vessels occupy an intraosseous position within the femoral head, they become known as the lateral epiphyseal arteries.

The medial epiphyseal artery is a continuation of the artery within the ligamentum teres, which comes from the acetabular branch of the obturator artery. This artery does not contribute significantly to the blood supply to the femoral head.

Metaphyseal arteries

The medial femoral circumflex artery also gives rise to the superior metaphyseal arteries that enter and supply the superior aspect of the femoral neck and the area previously occupied by the epiphyseal plate. The lateral femoral circumflex artery gives rise to the inferior metaphyseal artery close to the inferior margin of the articular cartilage, which enters and supplies the inferoanterior aspect of the femoral head.

The above vessels can collectively be referred to as the ascending retinacular vessels while they course along the femoral neck. At this point, they travel within the thick capsule, and hence are at risk of disruption in the event of a femoral neck fracture, thus leading to a substantial risk of developing osteonecrosis.

Classification of intracapsular hip fractures

Intracapsular hip fractures can be classified using two common methods:

1. Garden's classification (*Figure 2*)
2. Pauwels classification (*Figure 3*).

Garden's classification

Garden's classification was published in 1961 and is based on the pattern of femoral head trabeculae on antero-posterior plain radiographs (Garden, 1961). It divides intra-capsular fractures into four categories, each one a progression of the previous.

Stage 1: This consists of an incomplete fracture, with the fracture line starting at the upper cervico-capital junction but not passing completely through the inferior cortex of the neck, which remains unbroken but deformed as in a greenstick fracture. This gives a valgus position of the femoral head trabeculae.

Stage 2: With more force the inferior cortex breaks, resulting in a complete fracture that is undisplaced.

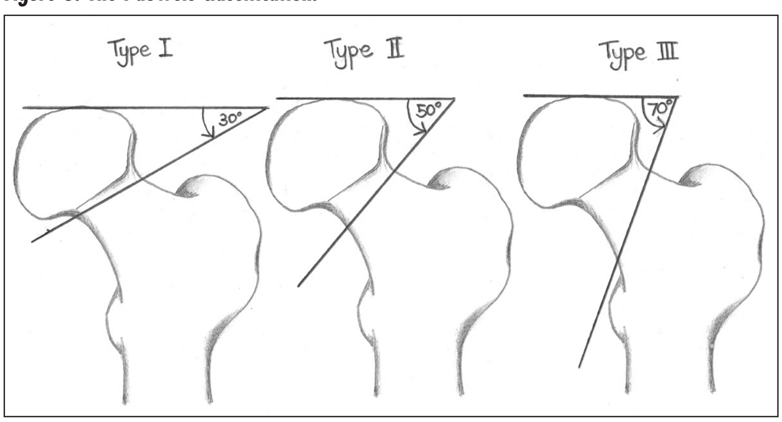
Stage 3: The complete fracture undergoes partial displacement. The proximal and distal fragments retain their posterior retinacular attachment, so as the distal fragment externally rotates, it forces the proximal fragment into internal rotation and abduction.

Stage 4: As the external rotation continues, the retinaculum strips from the neck until it is fully detached. At this point, both fragments are separated from each other leaving the proximal fragment free to return to a more normal position in the acetabulum. The trabeculae of the proximal fragment lie in alignment with the trabeculae in the pelvis (Garden, 1961).

Although historically important, use of this classification is now doubtful, as there is poor inter-observer reliability, there are questions over the true existence of

Figure 2. Garden's classification. a. Stage 1. b. Stage 2. c. Stage 3. d. Stage 4.

Figure 3. The Pauwels classification.



incomplete fractures with modern imaging techniques, and there is a lack of significant radiological difference in displacement between stages 3 and 4 (Chen et al, 2012).

Pauwels classification

The Pauwels classification was first described in 1935 and defines the Pauwels angle as the angle created by the fracture line of the distal fragment and the horizontal plane (Pauwels, 1935). The Pauwels classification is divided into three types depending on the Pauwels angle:

- Type 1: angle <30°
- Type 2: angle between 30 and 50°
- Type 3: angle >50°.

The angle relates to the shearing angle of the fracture surface, and the greater the Pauwels angle, the greater the risk of non-union (Pauwels, 1935). However, studies have since shown that there is no significant association between the Pauwels angle and incidence of non-union in intracapsular fractures, and there is poor interobserver reliability (van Embden et al, 2011).

Although both Garden's and Pauwels classifications have flaws, knowledge of them allows a greater understanding of the pathoaetiology of hip fractures. However, the authors believe that these classifications have limited use for determining treatment options, and the most important factor is whether the fracture is displaced or undisplaced.

Management of hip fractures

The key priorities for treating any patient suffering a hip fracture are medical optimization, expedited surgical management, and early mobilization and rehabilitation (National Institute for Health and Care Excellence, 2011).

The role of the orthogeriatrician

A key development in the treatment of hip fractures in recent years has been the importance of a multidisciplinary approach, involving surgeons, anaesthesiologists and geriatric physicians (Liem et al, 2013). Patients treated using a shared care model with regular geriatric and orthopaedic input benefit from this approach (Liem et al, 2013). Leung et al (2011) found a reduction in 1-year mortality and an improvement in function in those patients treated jointly by orthogeriatricians and orthopaedic surgeons compared to those treated conventionally.

It now recommended that medical expertise, in the form of geriatricians, is sought throughout the hospital admission (National Institute for Health and Care Excellence, 2011; Liem et al, 2013). The main goals of orthogeriatric input are to reduce complication and mortality rates, and return patients to their premorbid functional status as soon as possible (Liem et al, 2013).

Timing of surgery

Controversy exists regarding the relative urgency of fixation of hip fractures in the old and young. In the geriatric population, meta-analyses by Moja et al (2012) and Simunovic et al (2010) have shown a significant reduction in the risk of hospital-acquired pneumonia, pressure ulcers and death in those patients treated earlier. In addition, Al-Ani et al (2008) found a delay to surgery of more than 36 hours after admission reduced the likelihood of patients returning to independent living.

In general, geriatric patients with a hip fracture should be operated upon within 48 hours of admission, unless significant acute medical comorbidities cannot be optimized in this time. Surgery should be undertaken on planned trauma lists during daytime hours.

The potential benefits of early fixation of intracapsular hip fractures in the young are the reduced rate of non-union and femoral head avascular necrosis because of the prompt restoration of bony and vascular anatomy and reduction in intracapsular pressure (Ehlinger et al, 2011). Historically, studies reported an increased rate of avascular necrosis following delayed surgical fixation. Jain et al (2002) compared early (<12 hours) and delayed (>12 hours) fixation of subcapital hip fractures in 38 patients aged 60 years or less. Avascular necrosis developed in 16% and these were all in the delayed group.

More recent studies have found no effect of surgical timing on non-union or avascular necrosis. A meta-analysis by Damany et al (2005) involving 564 fractures and a prospective study of 1023 patients by Loizou and Parker (2009) both showed no increased incidence of non-union or avascular necrosis when comparing early or delayed surgery.

Owing to the limited quality of evidence available, it is difficult to form a rule as to the timing of surgery in a young patient with an intracapsular hip fracture. A sensible strategy for the young patient suffering a hip fracture would be surgical fixation on the next available planned trauma list.

Surgical treatment of intracapsular hip fractures

The treatment options for intracapsular fractures are internal fixation or arthroplasty. The decision about which option to use must take into account the displacement of the fracture, the patient's age, medical comorbidities, and premorbid social circumstances.

Undisplaced intracapsular fractures

Internal fixation, via cannulated screws or a sliding hip screw, may be favoured in undisplaced or minimally displaced fractures to reduce the risk of fracture displacement, hence reducing the need for arthroplasty surgery in future, which carries a greater morbidity (Parker et al, 2008).

Cannulated screws use the principle of three-point fixation of the femoral head, calcar and lateral cortical bone (*Figure 4*). They also allow axial compression along the axis of the femoral neck perpendicular to the fracture line. Many studies have evaluated the placement of cancellous screws for the treatment of intracapsular hip fractures. Selvan et al (2004) performed a biomechanical study which showed that a triangular configuration had a higher peak load and less displacement than other configurations. A clinical study of 202 patients by Yang et al (2013) showed that screw fixation in the triangle configuration was associated with a higher risk of non-union compared to the inverted triangle configuration. It has been speculated that the triangle configuration results in weaker fixation for two reasons. First, the two distal screws pass through Ward's triangle, an area of decreased bone density. Second, the central and superior part of the femoral head has denser trabeculae than the inferior portion, benefitting the inverted triangle configuration.

A sliding hip screw with a two-hole lateral plate may be considered as an alternative to cannulated screws. A sliding hip screw may also be preferred in basicervical fractures with comminution and Pauwels type 3 fractures. Basicervical fractures represent a transition between intracapsular and extracapsular hip fractures, and therefore may benefit from fixation with a sliding hip screw. Blair et al (1994) found that sliding hip screws withstood a higher axial load compared with cannulated screws in basicervical fractures, so recommended their use in the fixation of these fractures. Biomechanical studies have also shown the sliding hip screw to be effective in the treatment of high shear angle Pauwels type 3 fractures (Bonnaire and Weber, 2002).

Intracapsular fractures in young patients

In patients who are less than 60 years old, one may wish to attempt to preserve the femoral head to allow a return to the patient's high premorbid functional status and avoid arthroplasty. Anatomical reduction and internal fixation may then be used independent of fracture displacement.

The risks of internal fixation, no matter what the patient's age, are the high rate of non-union and avascular necrosis. In two randomized controlled trials, the rates of non-union were 34.5% and 36%, with avascular necrosis occurring in 4.9% and 6% respectively (Parker et al, 2002; Frihagen et al, 2007). In these trials, the reoperation rate after internal fixation was 40% and 42% respectively. These risks may be acceptable in a young, fit patient with a high functional demand, but may be unattractive in an elderly, institutionalized patient where one definitive operation is more desirable.

Displaced intracapsular fractures in the elderly

Many studies have compared internal fixation *vs* hemiarthroplasty in elderly patients (Frihagen et al, 2007; Hedbeck et al, 2013; Støen et al, 2014). *Table 1* summarizes the potential risks and benefits of these treatments.

Frihagen et al (2007) showed better functional outcomes in patients treated by hemiarthroplasty at 2-year follow up, with no significant difference at 6 years (Støen et al, 2014). A randomized controlled trial by Hedbeck et al (2013) found no difference in mortality between internal fixation and hemiarthroplasty, but noted significantly higher health-related quality of life scores and lower reoperation rate in those treated with hemiarthroplasty. Leonardsson et al (2013) found similar results when reviewing 4467 patients, with those treated by arthroplasty also having less pain and higher satisfaction. All these studies showed high reoperation rates in the internal fixation group.

Therefore, arthroplasty is recommended for all displaced intracapsular fractures in the elderly because of the

Figure 4. a. Anteroposterior and (b) lateral fluoroscopic radiograph showing fixation of a right-sided, minimally displaced intracapsular hip fracture with cannulated screws in the inverted triangle configuration.

Table 1. Internal fixation *vs* arthroplasty in the elderly

	Advantages	Disadvantages
Internal fixation	Preservation of femoral head	Non-union (Frihagen et al, 2007)
	No difference in mortality (Hedbeck et al, 2013; Leonardsson et al, 2013)	Avascular necrosis (Frihagen et al, 2007)
		Higher reoperation rate (Hedbeck et al, 2013; Leonardsson et al, 2013)
		Increased long-term pain (Hedbeck et al, 2013; Leonardsson et al, 2013)
		Lower patient satisfaction (Hedbeck et al, 2013; Leonardsson et al, 2013)
Arthroplasty	Lower long-term pain (Leonardsson et al, 2013)	Infection
	Higher patient satisfaction (Hedbeck et al, 2013; Leonardsson et al, 2013)	Dislocation
	Higher patient function (Hedbeck et al, 2013; Leonardsson et al, 2013)	Acetabular wear (Inngul et al, 2013)
	Lower reoperation rate (Hedbeck et al, 2013; Leonardsson et al, 2013)	Implant loosening
	No difference in mortality (Hedbeck et al, 2013; Leonardsson et al, 2013)	Periprosthetic fracture

higher patient-related outcomes, lower reoperation rate and lack of difference in mortality when compared with internal fixation (National Institute for Health and Care Excellence, 2011). Arthroplasty should also be considered in any patient with significant medical comorbidities or a low functional state pre-fracture, who may be best treated with a single definitive operation that allows immediate mobilization.

Arthroplasty options for the treatment of intracapsular hip fractures include:

1. Uncemented or cemented hemiarthroplasty with unipolar or bipolar head design (*Figure 5*)
2. Total hip arthroplasty (*Figure 6*).

The debate about the use of cemented or uncemented prostheses continues. Various randomized controlled trials and meta-analyses of randomized controlled trials (Jameson et al, 2013; Langslet et al, 2014) have shown cemented hemiarthroplasty gives patients better mobility and less pain than uncemented hemiarthroplasty at long-term follow up, with no difference in mortality. However, more recent data from the Scottish, Australian and Norwegian Joint Registries show a higher risk of immediate perioperative mortality in patients undergoing cemented hemiarthroplasty, especially in those with increasing age (>80 years) and medical comorbidities (Costain et al, 2011; Talsnes et al, 2013; Middleton et al, 2014). However, there is no difference in mortality after this period, and cemented implants have a significantly lower reoperation rate.

Bipolar hemiarthroplasty has the potential advantage of reducing acetabular wear, especially in those with a longer life expectancy. However, these are invariably more expensive than unipolar designs. There is limited evidence comparing the two designs with adequate length of follow up (Enocson et al, 2012; Inngul et al, 2013). A randomized controlled trial by Inngul et al (2013) showed higher patient-related outcomes in those with bipolar prostheses at 48 months. However, there was no significant difference in acetabular erosion between the two groups. In addition, there is no significant difference in reoperation or dislocation rates in unipolar *vs* bipolar prostheses (Enocson et al, 2012; Inngul et al, 2013).

Total hip arthroplasty has an increasing role in the treatment of intracapsular factures and should be considered in medically fit patients with a high premorbid function. It may also be used in patients with pre-existing, symptomatic osteoarthritis of the hip and pathological fractures. Systematic reviews of trials comparing total hip arthroplasty *vs* hemiarthroplasty have shown better patient-related outcomes in those treated with total hip arthroplasty, but a significantly higher dislocation rate (Hopley et al, 2010; Yu et al, 2012). Mortality is equal in both groups.

A cemented unipolar hemiarthroplasty should be first-line treatment for elderly, low demand patients. However, an uncemented prosthesis may be considered in those at extremes of age with significant medical comorbidities. Total hip arthroplasty may be preferable in younger, higher functioning patients. Bipolar prostheses are a theoretical option for those who may have a longer life expectancy, but are deemed not suitable for total hip arthroplasty.

Conclusions

This article summarizes the osseous and vascular anatomy of the proximal femur, describes the common classification systems for intracapsular hip fractures and provides the latest evidence behind the various treatment options for these fractures. Using this knowledge, surgeons will be able to formulate treatment goals and practical management plans. **BJHM**

Figure 5. Anteroposterior radiograph showing a right-sided, cemented, bipolar hip hemiarthroplasty.

Figure 6. Anteroposterior radiograph showing a left cemented total hip replacement.

Conflict of interest: none.

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KEY POINTS

- Hip fractures are life-threatening injuries.
- All patients should have concurrent acute medical conditions investigated and treated on admission.
- All patients should be reviewed by a geriatrician.
- Patients should be operated upon within 36 hours, unless life-threatening, reversible medical conditions are present.
- Treatment options include internal fixation or arthroplasty.