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Title: Facts and fiction in hip fracture treatment
Issue Date: 2016-02-17

Chapter 1

Introduction, aims and outline of the thesis

INTRODUCTION

As the number of hip fracture patients has increased dramatically over the years, the need for high quality, multidisciplinary and patient centred fracture treatment continues to grow. General international demographics show that the average age of male hip fracture patients is 69 and 79 for female patients.[1] About 75% of all hip fracture patients is female. Most patients suffer from a hip fracture after a low energy trauma such as a fall, whereas in the young patients (under 50 years) more sports related and high energy trauma mechanisms are seen.[2] The total number of deaths occurring in the first year after an osteoporotic fracture was 143,000 in the EU in 2010 and around 50% of these patients had a hip fracture. An overall increase of 32% in hip fracture patients in the European Union (EU) is expected by the year 2025, resembling 199,432 patients per year. The average incidence of hip fractures in the Netherlands is 275 per 100,000 (368/100,000 women, 164/100,000 men). An increase of the number of patients with a hip fracture of 40% is expected by the year 2025, which would result in almost 24,000 patients a year. The predicted growing incidence would cause a 30% (246 million Euro) increase of health care costs in the Netherlands by the year 2025.[3, 4]

ANATOMY

Hip fractures are typically fractures of the proximal femur. The proximal femur consists of a femoral head, neck and trochanteric area, which comprises a lesser and greater trochanter. The hip joint capsula is a strong ligamentous structure attached to the intertrochanteric line incorporating the femoral head and neck. Fractures of the femoral head and neck are therefore named intra-capsular fractures. Extra-capsular proximal femur fractures are trochanteric fractures (fractures within the margin of the lesser or greater trochanter) or subtrochanteric fractures. Subtrochanteric fractures are defined as the area from the lesser trochanter to 5 centimetres distally and are more common to result from a high-energy trauma mechanism, but may in the elderly very well occur after a low-energy fall.

Vascular anatomy

The vascular anatomy of the hip is another important anatomic factor influencing hip fracture treatment. Arteries of the proximal femur are divided into three parts: the extra-capsular arterial ring located at the base of the femoral neck, the ascending cervical branches of the extra-capsular arterial ring on the surface of the femoral neck and the arteries of the round ligament. The extra-capsular arterial ring is formed by a large branch of the medial femoral circumflex artery and by branches of the lateral femoral circumflex artery. In femoral neck fractures, especially in displaced fractures, the vascularization of the femoral head is at risk. The most important blood supply, provided by the intra-osseous cervical vessels that cross the marrow spaces from distally, is disrupted in case of a displaced femoral neck fracture. Alternative ways of blood supply such as the ligamentum teres and the branches of the extra-capsular arterial ring are not sufficient in many elderly patients. Insufficient post-traumatic blood supply in the hip may result in avascular necrosis (AVN). AVN rarely occurs in extra-capsular fractures.[5]

CLASSIFICATION

Intra-capsular fractures

The Pauwels classification (1935)[6] was the first biomechanical classification of femoral neck fractures. In the Pauwels classification the *fracture line angle* is used to identify three groups of femoral neck fractures, based on the shearing angle of the fracture line of the distal fragment. It was suggested by Pauwels that a greater vertical shear is related to an increase of the incidence of non-union in femoral neck fractures as it increasingly interferes with the blood supply of the femoral neck.
In daily practice, the Garden-classification (1961)[7] is still the most frequently used classification for femoral neck fractures. It is based on the amount of *fracture displacement*. Four types of fractures are distinguished: Garden grade I is an incomplete femoral neck fracture, with valgus impaction[8], Garden grade II is a complete but non-displaced fracture; a Garden grade III fracture is a complete and partially displaced fracture with alignment of the femoral neck relative to the neck in varus deformity and Garden grade IV is a complete fracture with complete displacement. The Garden grade I and II fractures are considered 'non-displaced' and Garden grade III and IV fractures are considered 'displaced' and are believed to be associated with higher complication rates.
Both the Garden and the Pauwels classification are commonly used in literature, treatment guidelines, research, and pre-operative planning. The 31-B AO classification[9], which consists of nine subtypes, incorporating both fracture line and fracture displacement, is less frequently used for femoral neck fractures.

Extra-capsular fractures

Trochanteric femoral fractures are the most common type of extra-capsular hip fractures and account for 34-46% of the total number of hip fractures.[10] The number of patients with a trochanteric fracture is increasing faster than that of the femoral neck fractures. This might in part be due to the fact that the trochanteric fracture type seems to be more associated with osteoporosis than femoral neck fractures.[11, 12] A number of classification systems have been developed for trochanteric hip fractures. In 1949 Evans[13] described an anatomical classification based on the number of fragments and whether or not the lesser trochanter is split off as a separate fragment, which was later revised by Jensen.[14] The AO-classification of Müller[9] for trochanteric fractures is comprehensive when only used for subdivision into 31A1, A2 and A3. Currently, no single classification system for trochanteric fractures is unanimously accepted, because most classifications show low inter- and intra-observer agreement and are therefore considered unreliable.[15-17]

TREATMENT OPTIONS

Non-operative treatment

In the Netherlands, impacted or non-displaced femoral neck fractures are sometimes treated non-operatively. Non-operative treatment may be considered for non-displaced femoral neck fractures of healthy patients and patients who can support weight on the fractured hip during walking. This type of non-operative treatment could result in secondary displacement of the fracture in around one-third of the patients. The patients that suffer from secondary displacement of a femoral neck fracture will be treated by (hemi-)arthroplasty because it is likely to have caused a disruption of the blood supply of the head of the femur. Head-preserving treatment results in high rates of non-union or AVN.
Non-operative treatment of trochanteric fractures is uncommon in the Western world but could be considered when no operative treatment facilities are available or when the patient is terminally ill, e.g. as a result of an advanced malignancy.[18, 19]

Surgical treatment

Femoral neck fractures can be treated by internal fixation or by hemi- or total arthroplasty. It has been proven that internal fixation is associated with less perioperative complications but more fixation failures and subsequent reoperations than arthroplasties.[20] However, many studies on these rates fail to report important fracture criteria such as fracture classification. It is therefore, despite the large numbers of studies on the topic, still not clear what the best treatment is for the different subtypes of fractures. When preservation of the femoral head is intended, non-displaced intra-capsular fractures can be treated with either a sliding hip screw (e.g. dynamic hip screw: DHS) or three cannulated screws (CS). In displaced femoral neck fractures, most surgeons tend to choose for hemi-arthroplasty in the elderly patients (above 75 years).[21] In patients younger than 75 and in good health, preservation of the femoral head is generally intended, even when some dislocation might have occurred. Younger healthy patients are less prone to AVN because of a better vascular status. Furthermore, the alternative, arthroplasty, is in many cases associated with major revision surgery after a period of 10-15 years.[22]

Trochanteric fractures, both stable and unstable, are commonly fixated using extra-medullary implants such as a Dynamic Hip Screw or intramedullary devices such as the Gamma-nail System or Proximal Femoral Nail Antirotation (PFNa). Currently, sliding hip screw devices are most commonly used for the stable fractures such as the type AO 31-A1 fractures and intramedullary devices are most commonly used for AO 31-A3 fractures. The optimal treatment device for the AO 31-A2 fractures still is topic of debate. Recent studies showed some advantages of the more expensive intramedullary nails, although most of these studies did not analyse for the separate fracture subtypes.[23-25] For the AO 31-A3fractures, which consist of the transverse and reversed trochanteric fractures, consensus exists on implant type: this fracture is best treated by intramedullary implant. In studies the AO 31-A3 fracture was proven to be a biomechanical different type of fracture compared to the type A1 and A2. For instance, treating an A3 fracture by extramedullary implant leads to high rates of fixation failure, since the hip screw does not cross the primary fracture line.[26, 27]

Fixation failure

All above mentioned implants are associated with fixation related complications such as cut-out of the implant, AVN and delayed- or non-union. Fixation related complications are reported in up to 30% of the proximal femur fractures. They tend to vary strongly, depending on fracture type and choice of treatment: 4% in non-displaced femoral neck fractures[28] and up to 30% in displaced femoral neck fractures.[22] In trochanteric fractures reoperation rates are reported between 2% and 30%.[24, 25, 29] Many of these complications relate to the biomechanical characteristics of both the fracture and the fixation device and to patient or surgeons related factors such as the quality of the bone, operation technique and fracture reduction.

AIMS AND OUTLINE OF THIS THESIS

The first aim of this thesis is to provide a better understanding of fracture patterns and fracture classification, in other words: the *personality of the fracture*. The second aim is to *personalize hip fracture treatment*: What fracture, patient or surgeons' characteristics may lead to improvement of hip fracture care?
In order to achieve our aims we have tried to answer the questions outlined below.

Personality of the fracture

In *Chapter 2* increased insight in the trochanteric fracture anatomy was intended by quantifying the properties of the fracture line in terms of the fracture line angle and its anatomical location. We aimed to answer the question:

- *What anatomical fracture properties of trochanteric fractures may lead to an improved classification that is more appropriate for guiding treatment and outcome?*

An ideal fracture classification system should provide information on fracture pattern and stability, and, more importantly, it should guide the choice of treatment. In order to be of clinical value a classification should have a high degree of reproducibility. The reliability of the most frequently used classifications for proximal femur fractures were studied in *Chapters 3*, *4*, *5* and *6*. These studies intended to answer the following questions:

- *What is the agreement among surgeons on current fracture classifications for proximal femoral fractures?*
- *What is the agreement among surgeons on choice of treatment and fracture stability based on fracture classification?*
- *Does agreement of fracture classification and agreement on choice of treatment on trochanteric fractures improve with additional computed tomography (CT) analysis of the fracture?*

Personlized hip fracture treatment

Although not scientifically substantiated so far, rotational instability appears to play a significant role in fixation failure. In *Chapter 7* the amount of rotational instability in hip fractures, related to type of fracture and modern implants was studied in order to answer the question:

- *Is it possible to create a migration profile, in terms of rotation and shortening and identify those patients at risk for fixation failure?*

Chapter 8 presents the results of a retrospective cohort study concerning the pre- and post-operative radiographic fracture characteristics in relation to patient age and the occurrence of reoperation. The following question was studied:

- *What patient and fracture properties of femoral neck fractures might attribute to fixation failure?*

The surgeons' intra-operative estimations of the femoral anteversion angle during placement of a hemi-arthroplasty are relevant for the post-operative outcome of femoral neck fractures. These estimations are studied in *Chapter 9*. The study aimed to answer the question:

- *How well does the surgeon intra-operatively estimate a femoral anteversion angle during placement of a hemi-prosthesis?*

In *Chapter 10* a systematic review regarding the treatment dilemmas in non-displaced femoral neck fracture intends to answer the question:

- *When should a surgeon treat a non-displaced femoral neck fracture non-operatively?*

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