Dislocation after hip fracture related arthroplasty - Incidence, risk factors and prevention

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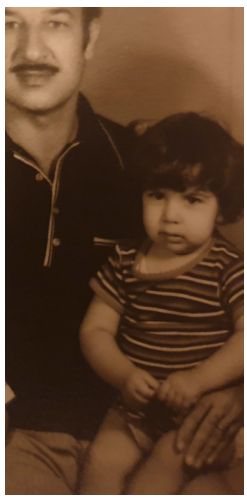

Many years have passed and many miles have been crossed since this picture. The father dedicated his life to political freedom for the people of Iraq and Kurdistan. He wanted to give his children better opportunities in life. From Baghdad, to Damascus, to Rosengård in Malmö.

This book is a small contribution from the son to his new country that gave him so much. Tomorrow, perhaps, a ten-year-old boy will take his first steps in Sweden. Years later he might make this country an even better place.

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LUND
UNIVERSITY

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Title and subtitle

Dislocation after hip fracture related arthroplasty - incidence, risk factors and prevention

Abstract

Femoral neck fracture is a common type of hip fracture. Arthroplasty is a widely accepted treatment of a displaced femoral neck fracture in elderly patients. Dislocation is a major complication and together with infection the most frequent reasons for revision surgery.

Paper I is an observational cohort study, based on cross-matching data from the Swedish Hip Arthroplasty Register, the National Patient Register and Statistics Sweden. The aim of the study was to find the "true" dislocation rate of fracture-related total hip arthroplasties (THA) and to study factors influencing the risk of dislocation. We found the dislocation rate for THA to be 8.4% (posterior approach 13.4%, direct lateral approach 4.8%).

Paper II is an observational cohort study, with the same design as Paper I. Here, the aim of the study was to find the "true" dislocation rate of fracture-related hemiarthroplasties (HA) and to study factors influencing the risk of dislocation. Dislocation rate for HA was 4.8% (posterior approach 7.2 %, direct lateral approach 2.7 %).

Paper III is a cluster-randomised study of 394 patients. The aim was to study the need of rehabilitation precautions and mandatory assistive equipment to prevent dislocation when direct lateral approach is used for hemiarthroplasty after hip fracture. The results show no association with the risk of dislocation.

Paper IV is an observational cohort study of 9040 patients based on data from the Nordic Arthroplasty Register Association. The aim was to evaluate both overall revision risk and specific revision causes (including dislocation) of the dual mobility acetabular cup (DMC), compared to conventional THA. The use of DMC as primary treatment for hip fracture was associated with a lower risk of revision in general and due to dislocation in particular.

In conclusion we found the total dislocation rate after THA and HA as treatment of hip fracture to be high. Posterior approach is the most important risk factor for dislocation. Male gender and severe comorbidity are associated with an increased risk of dislocation after THA. Dementia is associated with an increased risk of dislocation after HA. Precautions do not seem to be needed to prevent dislocation after HA in hip fracture patients, if direct lateral approach is used. Finally, DMC after hip fracture is associated with a lower overall risk of revision and due to dislocation in particular, compared with conventional THA.

Key words

hip fracture, femoral neck fracture, dislocation, hip precautions, DMC

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Coverphoto by the father. “The happiest reduction and when you see your research in everything.”

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To Dahlia, Enja, Noel & Elin

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List of papers

This thesis is based on the following papers, referred to in the text by their Roman numerals.

I. **High risk of dislocation of total hip arthroplasty after hip fracture when posterior approach is used. Result from a national cohort of 6,736 individuals in the Swedish Hip Arthroplasty Register.**

Ammar Jobory, Johan Kärrholm, Susanne Hansson, Anne Garland, Cecilia Rogmark. *Submitted.*

II. **Dislocation of hemiarthroplasty after hip fracture is common and the risk is increased with posterior approach. Result from a national cohort of 25,678 individuals in the Swedish Hip Arthroplasty Register.**

Ammar Jobory, Johan Kärrholm, Susanne Hansson, Kristina Åkesson, Cecilia Rogmark**.** *Submitted.*

III. **Hip precautions not meaningful after hemiarthroplasty due to hip fracture. Cluster-randomized study of 394 patients operated with direct anterolateral approach.**

Ammar Jobory, Ola Rolfson, Kristina Åkesson, Cecilia Arvidsson, Inger Nilsson, Cecilia Rogmark.

Injury, 50(7), 1318-1323. 2019.

IV. **Reduced Revision Risk for Dual-Mobility Cup in Total Hip Replacement Due to Hip Fracture. A Matched-Pair Analysis of 9,040 Cases from the Nordic Arthroplasty Register Association (NARA).**

Ammar Jobory, Johan Kärrholm, Søren Overgaard, Alma Becic Pedersen, Geir Hallan, Jan-Erik Gjertsen, Keijo Mäkelä, Cecilia Rogmark.

JBJS, 101(14), 1278-1285. 2019.

Abbreviations

ADL	Activities of daily living. Self-care activities necessary for feeding, hygiene, transportation and work
DLA	Direct lateral approach – one of two common surgical hip incisions in Sweden
DMC	Dual mobility cups – modification of the acetabular cup in THA
HA	Hemiarthroplasty – replacement of the femoral side of the hip joint
NARA	Nordic Arthroplasty Register Association
NPR	National Patient Register
PA	Posterior approach – one of two common surgical hip incisions in Sweden
SCB	Statistics Sweden
SHAR	Swedish Hip Arthroplasty Register
THA	Total hip arthroplasty – replacement of the entire hip joint

Thesis at a glance

	Paper I	Paper II	Paper III	Paper IV
Type of study	Register	Register	Cluster-randomised	Register
Question	What is the dislocation rate for **THA** after hip fracture? What are the risk factors?	What is the dislocation rate for **HA** after hip fracture? What are the risk factors?	Do we need precautions if DLA is used for **HA**?	Do **DMCs** have lower revision risk in general and due to specific causes in hip fracture patients?
Population/year	6,736 hip fractures 2005-2011	25,678 hip fractures 2005-2011	394 patients 2010–2014	9,040 hip fractures 2001–2014
Resultat	Total 8.4%. PA 13.4%	Total 4.8%. PA 7.2%	No.	Yes.
Clinical perspective	Use DLA.	Use DLA.	Up & go!	If you insist on PA, use DMC.

Populärvetenskaplig sammanfattning

Årligen drabbas ca 17 000 svenskar av en höftfraktur. Hälften av alla kvinnor över 90 år har haft en höftfraktur. Att behandla och vårda individer med höftfraktur utgör en central del av ortopedin och sjukvården. Hälften av höftfrakturerna är cervikala (brott på lårbenshalsen). Det är en etablerad metod idag att operera in en höftprotes, en konstgjord led. Ca 6000 höftfrakturer behandlas med proteser årligen i Sverige.

Det finns huvudsakligen två typer av höftproteser, så kallade halvproteser (HA) och totalproteser (THA). Båda utgörs av en stam och en kula. Skillnaden är att man i en THA även ersätter höftens ledskål med en cup (plastskål). Den naturliga ledskålen lämnas som den är i en halvprotes. Traditionellt har man betraktat THA som den protes som ger bäst rörlighet i jämförelse med HA. Varför får inte alla patienter THA? Svaret på denna fråga är att patienter med THA har ökad risk för luxation (urledvridning) i jämförelse med HA. Luxation är en av de allvarliga komplikationer en patient med en höftprotes kan drabbas av. Det är ett smärtsamt tillstånd, och oftast krävs lätt nedsövning för att häva luxationen. Det räcker vanligen att man gör detta genom ett slutet ingrepp på akutmottagningen, d.v.s. att en läkare genom yttre drag och tryck för leden på plats, utan att behöva göra en öppen operation (snitt genom huden och vävnaden). Först efter upprepade luxationer kan det bli aktuellt med en omoperation.

Svenska Höftprotesregistret (SHAR) samlar in information om i princip alla höftprotesoperationer som svenska patienter genomgår. På detta sätt kan vi följa upp alla protestyper och sträva efter förbättring. Den långa traditionen av ortopediska register är unik för Sverige och ganska få länder har liknande register. När det gäller luxation, är det bara den andel patienter som genomgått öppen operation p.g.a. en luxation som rapporteras till SHAR. Således vet vi inte hur många patienter som reellt drabbas av en luxation; bara en mindre andel behöver öppen kirurgi. Detta är bakgrunden till studie I och II. Genom att ta hjälp av patientregistret, som registrerar koder för medicinska sjukdomar och åtgärder, kunde vi efterfråga vilka åtgärder höftfrakturpatienterna i våra studier hade genomgått. I studie I undersöktes patienter med THA och vi fann att drygt åtta procent drabbades av en luxation. I studie II med HA-patienter var motsvarande siffra knappt fem procent. Dessa siffror är något mer än vi förväntat oss. Vi kunde även titta på vilka riskfaktorer som påverkar risken för luxation. I båda studierna var den starkaste riskfaktorn snittföringen.

I Sverige dominerar två operationssnitt, det bakre och det främre. Sistnämnda är en inte helt korrekt benämning då snittet snarare är från sidan (direct lateral approach, DLA). Vi kunde se att patienter som opererades med det bakre snittet hade en betydligt ökad risk för luxation i jämförelse med de som opererades med det främre snittet. För THA steg risken från 4,8 % till 13,4 % när bakre snittet användes. Samma siffror för HA var 2,7 % respektive 7,2 %.

De flesta operatörer ordinerar patienter begränsningar för rörligheten efter en höftprotesoperation, så kallade restriktioner. Det erbjuds även rutinmässigt hjälpmedel exempelvis strumppåtagare, sittkudde med mera. Dessa är till för att patienten inte ska vrida höften ur led. I studie III undersökte vi hur nödvändiga dessa restriktioner är hos patienter med HA som är insatta med främre snitt. På två av de fyra ortopediska avdelningarna i Malmö, tog vi bort samtliga restriktioner och rutinmässiga hjälpmedel. På de andra två avdelningarna behöll vi det som det var tidigare. Vi följde upp patienterna och kunde konstatera att restriktioner inte påverkade risken för luxation. Dessa restriktioner har avskaffats i Malmö, och på andra sjukhus, efter denna studie.

I studie IV tittade vi på en speciell protestyp, dubbelartikulerande cup (DMC), som är en THA med ytterligare en rörlig del innanför cupen. Denna protestyp är i Sverige relativt ny. För att få ett tillräckligt stort antal studiedeltagare gjordes studien genom ett samarbete mellan de nordiska höftprotesregistren (NARA). Här jämfördes DMC med standard-THA. Vi kunde påvisa att för patienter med höftfraktur, medför operation med DMC mindre risk för omoperation och framförallt omoperation p.g.a. luxation.

Sammanfattningsvis kan vi konstatera att vi kan påverka luxationsrisken genom olika åtgärder såsom val av snittföring och protestyp. Vi tror att fokus på en individanpassad rehabilitering av patienten, och inte på rutinmässiga restriktioner, är att bättre hushålla med rehabiliteringspersonalens arbetstid. Slutligen har vi gett en klarare bild av DMC och dess roll i framtida kirurgisk behandling av höftfrakturpatienter.

Introduction

Hip fracture – anatomy and treatment

Hip fracture is a major concern for the patient and for healthcare. Approximately 17,000 hip fractures occur in Sweden every year (78). Depending on the anatomical location, hip fractures are traditionally classified into extracapsular and intracapsular (Figure 1). Half of the hip fractures are intracapsular (85). These fractures, also known as femoral neck fractures or cervical hip fractures, are often displaced. The displacement disrupts the blood supply to the femoral head (Figure 1), which may interfere with healing or lead to avascular necrosis of the femoral head. If a displaced femoral neck fracture is fixed with screws or pins, at least one third of the patients will encounter these healing complications and need a secondary hip arthroplasty (33). To replace the injured hip with a hip arthroplasty will reduce the risk of hip complications, provide better function and less pain (33). Therefore, arthroplasty has become a widely accepted treatment (6, 58). More than 90% of elderly with displaced femoral neck fractures are treated with arthroplasty in Sweden (41). There are two types of hip replacement: hemiarthroplasty (HA) and total hip arthroplasty (THA).

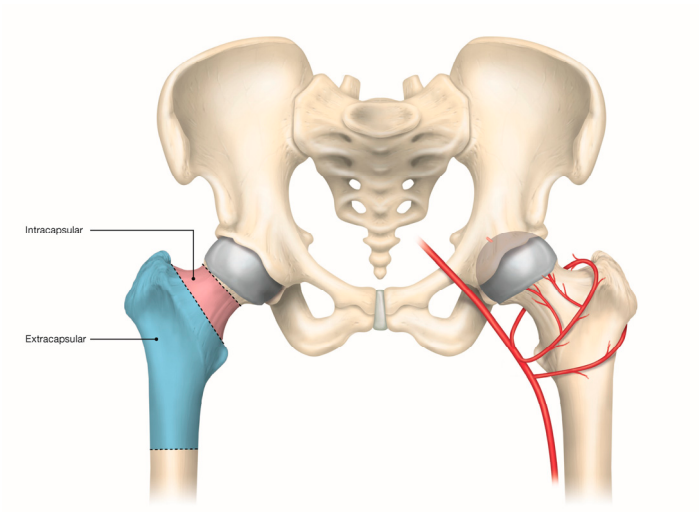

Fig 1. Hip fracture classification and blood supply to the femoral head.

Hemiarthroplasty and total hip arthroplasty

A hip arthroplasty consists of a femoral stem and head. The main difference between the two major types is that in HA the acetabulum is left intact while in THA the acetabulum is replaced, a cup is inserted.

Fig 2. From left: Monoblock HA, unipolar HA, bipolar HA and THA.

Hemiarthroplasty was developed as fracture treatment in the 1950s and was initially of monoblock design (the stem and the head are manufactured as one part) (60). In the 1970's the modular hemiarthroplasty was developed (Figure 2). The later can either be unipolar or bipolar. A unipolar HA has a large femoral head that articulates directly against the acetabulum. This can lead to erosion of the acetabular cartilage (4, 12). In order to reduce this risk the bipolar HA was introduced. A bipolar HA has an additional smaller head that articulates within the larger one, and thereby reduces the wear on the acetabulum – at least in theory. The two heads rotate in relation to each other. The idea is to increase mobility and stability by primary mobility taken between the heads and in extreme positions between the larger head and the acetabulum. The use of bipolar HA has however been decreasing in Sweden during the last decade in favour of unipolar HA (48) (Figure 3). This is probably because there seems to be no difference in prosthesis survival, and the less expensive unipolar model is chosen (48).

Total hip arthroplasty was originally developed to treat osteoarthritis and other non-traumatic hip disorders. In the late 1970s, THA was put forward as an alternative for fracture patients as well (16). In Sweden, THA was more of an option for failed internal fixation than a primary treatment for several decades. Since 2000, the frequency of THA as primary fracture treatment has been steadily increasing.

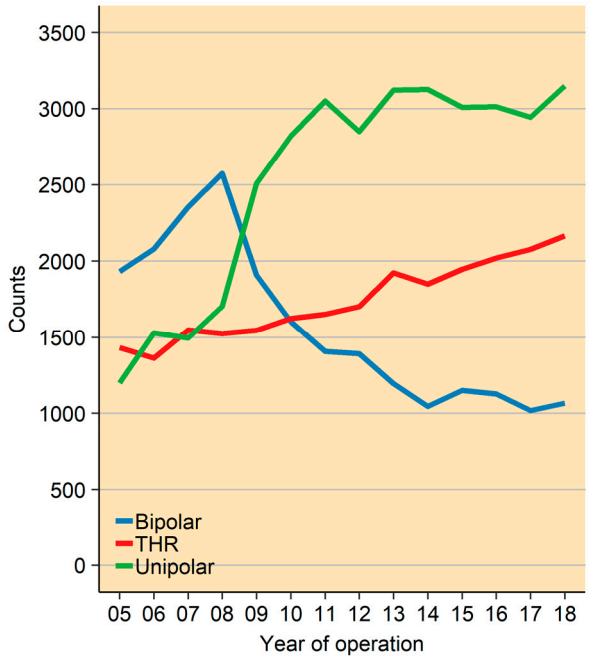

Fig 3. Frequency of different implant types as fracture treatment in Sweden (Copyright SHAR).

The choice between THA and HA for hip fracture patients is debatable. THA has been shown to provide better functional outcomes and better mobility than hemiarthroplasty in four randomised controlled trials (RCTs) (4, 40, 44, 56). The study population in these four RCTs were aged 60–75 years and more healthy and active than the typical geriatric fracture patient. Three other RCTs (20, 62, 89) studied more "ordinary" hip fracture patients and could not detect any differences in terms of function, revision (re-operation with exchange or removal of any part of the prosthesis) rate of the prosthesis, minor and major complications. As the risk of acetabular erosion seems to be associated with high activity (4), HA is preferred for biologically elderly patients with low activity level (71, 94). The advantages of HA are a lower dislocation risk (14), shorter surgery duration (4, 10) and lower rate of intraoperative blood loss (10, 89) compared to THA. Two thirds of the patients with femoral neck fractures in Sweden are treated with HA (48).

Dual mobility cups

Dual mobility cups (DMC) were introduced in 1970s by Bousquet (11) in France. DMC is a type of THA with a two-articulation design. The acetabular cup is fixed to the acetabulum with or without bone cement. Between the cup and the head an additional polyethylene (PE) liner is inserted (Figure 4). The head rotates in the PE liner and when the neck reaches the points of neck impingement (see below "The Head" part) the liner rotates in the cup, leading to increased range of motion and increased stability (38). This mechanism acts in the same way as in a bipolar HA, but here the acetabulum is protected by the fixed cup.

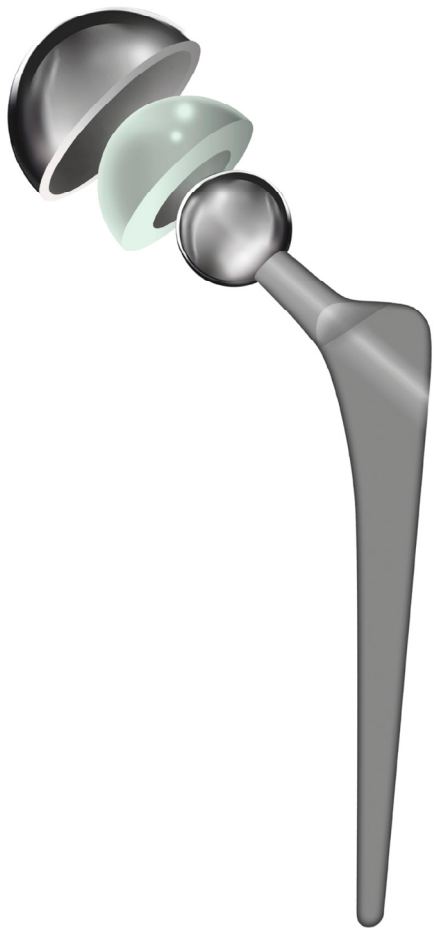

Fig 4. A dual mobility cup (DMC).

Approximately one third of all primary THA treatments (i.e. mostly osteoarthritis cases) in France in 2009 were DMC (29). On routine basis, DMC was first used in Sweden 2003 but in recent years it has been used increasingly (Figure 5). In 2017 4.6% of all primary THA treatments (due to osteoarthritis, hip fracture or other diagnoses) were DMC (48). Two third of these patients were treated with DMC after a hip fracture or revision after initial hip fracture (48). The DMC as treatment for hip fracture is associated with a lower rate of dislocation compared to conventional THA (7, 66, 87). These studies are based on sample sizes from 42 to 175 patients. But less is known about the overall revision risk especially in hip fracture patients, and larger studies are lacking. There has also been some concern about an increased risk of infection associated with the DMC, suggested by a few studies (46, 75), and the cost effectiveness of the implant.

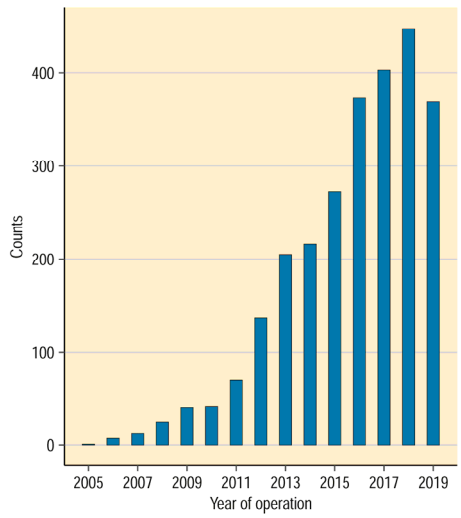

Fig.5. DMC as primary treatment for acute hip fractures in Sweden (Copyright SHAR).

The dislocation issue

Dislocation is a major complication after hip arthroplasty (28, 51) and together with infection the most common reasons for implant revision in fracture patients (34, 48). Dislocation occurs when the prosthesis head during motion comes to an extreme position, where it leaves the cup or the acetabulum and slides into the soft tissue. This is a painful condition which often requires sedation for reduction. In the vast majority of cases closed reduction is enough and there is no need for open reduction. The rate of dislocation is reported in the literature to be between 1.5 and 15% for HA (25, 31, 51, 70, 83). For THA in fracture patients, most commonly 6–8% have

been reported, but also figures up to 20% (4, 28, 74, 86, 89). The majority of dislocations occur within the first six weeks (25, 28). Around half of the HA patients who suffer one dislocation will have recurrent dislocations in the future (25, 69, 83).

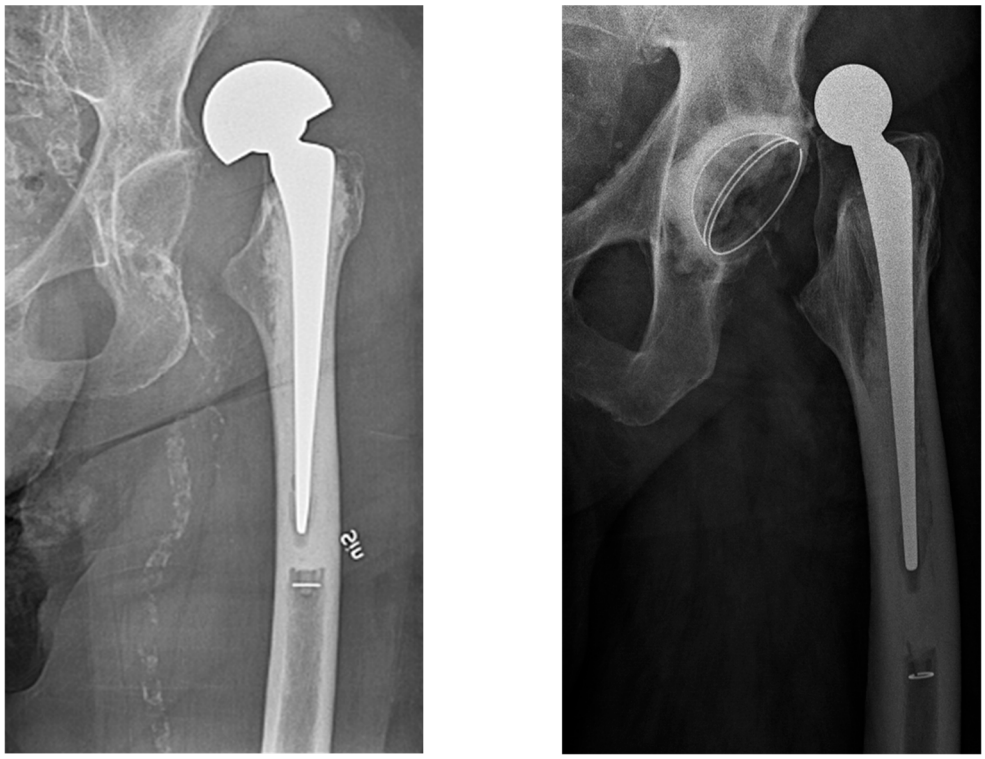

Fig 6. Dislocation of bipolar HA (left) and THA (right)

From a patient's point of view, a dislocation is a sudden, stressful and painful event, which reduces the health-related quality of life (27). In particular recurrent dislocations, even if they "only" are treated with repeated closed reductions, often leave the patient with a persistent feeling of insecurity and apprehension of future dislocations. Also, in the interest of the healthcare organisation, dislocations must be prevented as they result in additional hospital costs. A single dislocation, treated with closed reduction, is suggested to equal one fifth of the costs of a THA procedure, whilst a revision due to dislocation may equal 150% of a primary THA (18, 79).

Since some of the hips remain stable after a single dislocation, the treatment strategy after one dislocation is to wait and see. In some cases, a brace designed to avoid future dislocations maybe recommended. After the first, or at least after the second dislocation, a thorough radiological analysis of the implant position and other reasons for increased risk of dislocation must be performed. When dislocations

become recurrent, the surgeon and the patient have to agree on whether to revise the implant or not. In other words, dislocation is a relative, but not a pressing, indication for implant revision. This is in contrast to, for example, periprosthetic fractures and deep infection, where a vast majority of the patients need secondary open surgery. The revision rate after dislocation may therefore vary; Svenoy et al. reported that 10 of 11 patients with recurrent HA dislocations required revision, and when counting all those who suffer any dislocation only half of them ended up with revision (83). Enocson et al. reported for THA, that two thirds of those with one dislocation suffered recurrent dislocation later on. Only one fourth of patients with dislocation underwent revision (28). Using revision as outcome will underestimate the dislocation problem. As in the case of a dislocating HA, attempts at non-surgical treatment are common. This may be bracing or precautions, where the patient is told to avoid certain bodily positions.

Surgical technique, component design and patient factors all contribute to the risk of dislocation.

Risk factors for dislocation

The approach

Traditionally, two surgical approaches dominate hip arthroplasty surgery. The posterior approach (PA), first described by Moore 1957 (61), and the direct lateral approach (DLA). DLA was first described by Hardinge (39) in 1982 with the patient in a supine position, followed by Gammer (32) who preferred the patient to lie in a lateral position. Several studies suggest that PA increases the risk of dislocation for HA (1, 25, 51, 83, 90) and THA (28, 50). In PA the surgical exposure will weaken the soft tissue on the posterior aspect of the hip joint. It is important to reconstruct the posterior structures; an accurate repair of the short external rotators (mm. piriformis, obturator internus and gemelli) and posterior joint capsule when finishing the surgery (28). For PA, the area of weakness will be affected during flection, adduction and internal rotation; for example, when tying shoe laces, grasping an object from the floor from a standing position or other common bodily movements. On the contrary, the surgical exposure in the DLA includes dividing the abductor complex (mm. gluteus medius and minimus) and anterior joint capsule. This results in risk of instability during hip extension, abduction and external rotation, i.e. a not so natural position.

Historically, patients have been prescribed movement restrictions and mandatory use of assistive devices to reduce the risk of dislocation, and such precautions are to a certain extent still used (21) – see *Rehabilitation after hip arthroplasty.*

With the dislocation risk in mind, why does not every surgeon use DLA? Osteoarthritis patients having a THA via the PA have reported better outcome in terms of satisfaction and pain (54). This association between surgical approach and functional outcome in patients with hip fracture is however not clear (42, 63). The downside of DLA is, without doubt, the risk of abductor weakness and Trendelenburg gait due to the transgluteal technique (3, 22, 59). Still, the lesser risk of dislocation has led Swedish orthopaedic surgeons to embrace DLA increasingly (48) (Figure 7).

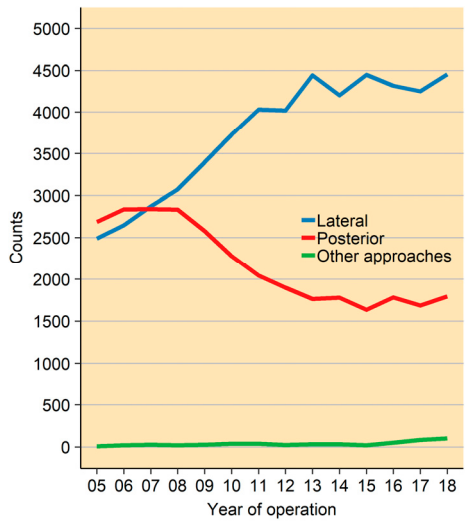

Fig 7. Frequency of different approaches used in fracture cases in Sweden (Copyright SHAR)

Other surgical factors

In addition to the approach there are multiple other factors in the surgical technique that affect the risk of dislocation. Faulty positioning of the cup in THA in osteoarthritis patients has been shown to increase the risk of dislocation (47). The cup should be placed with inclination of 40 ±10° and anteversion of 15 ±10°, the stem with anteversion of 10 ±5° (52). These positions are not just optimal for stability, but also mimic the anatomical position of the acetabulum and the femur. The function of a hip arthroplasty will thereby be optimised. Presumably, by cementing the stem and the cup, it is easier for the surgeon to control the position of the implant parts. This may explain the decreased risk of dislocation associated with cement in osteoarthritis patients (47). Still, no difference between cemented versus uncemented implants regarding the risk of dislocation has been shown in fracture patients treated with HA (1, 31, 90). The effect of cementation in fracture THA has not been studied, to our knowledge.

It is also essential to restore the tension and function of the abductor complex (mm. gluteus medius and gluteus minimus) (30). Weakened abductor complex will decrease the abductor lever arm, leading to increased risk of dislocation and a Trendelenburg lurch when walking. There may be patient related factors (see below) for abductor complex dysfunction, but also surgical considerations, such as restoring the femoral neck length and consequently the head offset (30).

Discrepancy in head offset increases the risk of dislocation in osteoarthritis THA (47). The effect of head offset in HA is contradictory in the literature (45, 53, 57, 64, 67). Short head offset can also result in bony impingement of the greater trochanter against the pelvis during abduction. Besides pain, this leads to hip levering and increased instability. On the other hand, a long head offset can cause lateral hip pain and trochanteric bursitis.

The head size

The size of the femoral head in a THA is associated with risk of dislocation. To understand why, it is essential to understand the biomechanics of a hip arthroplasty. The primary arch range is the arc allowed between the two points of neck impingement (Figure 8). As long as the head moves in this range it will not dislocate. When the neck reaches the impingement point the caput will begin to lever out until a point when the dislocation occurs. This range is called the lever range. The excursion distance is the distance the head moves before dislocation (Figure 8).

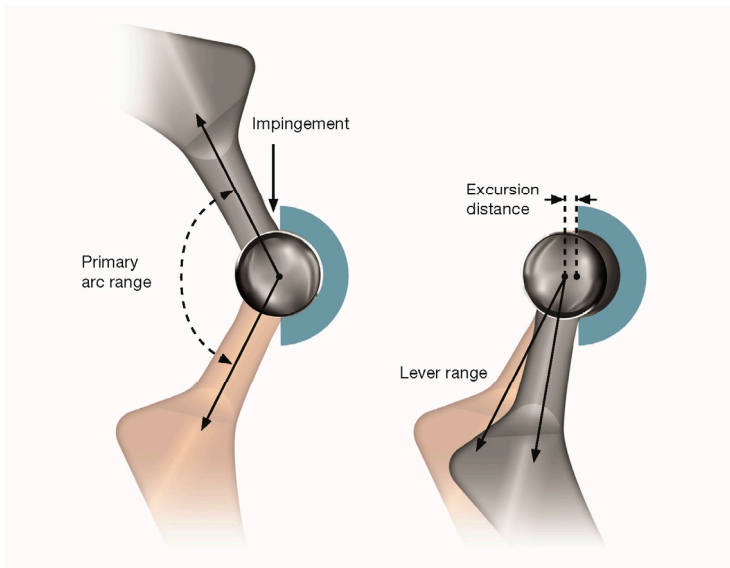

Fig 8. Biomechanics of a total hip arthroplasty.

Consequently, this distance is always the radius of the head. A larger head will increase the primary arch and the lever range (Figure 9), leading to increased stability and decreased risk of dislocation (9).

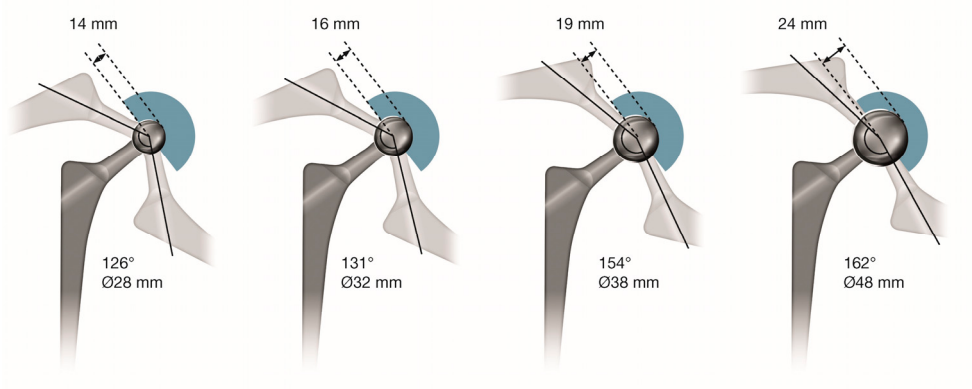

Fig 9. The effect of different head sizes in total hip arthroplasty.

However the larger the head, the higher the volumetric wear and the risk of osteolysis (88). A 32 mm head, instead of a 28 mm head, is recommended for hip fracture patients treated with THA (9, 95). In recent decades there has been a shift towards a larger head in hip fracture patients treated with THA in Sweden (48) (Figure 10).

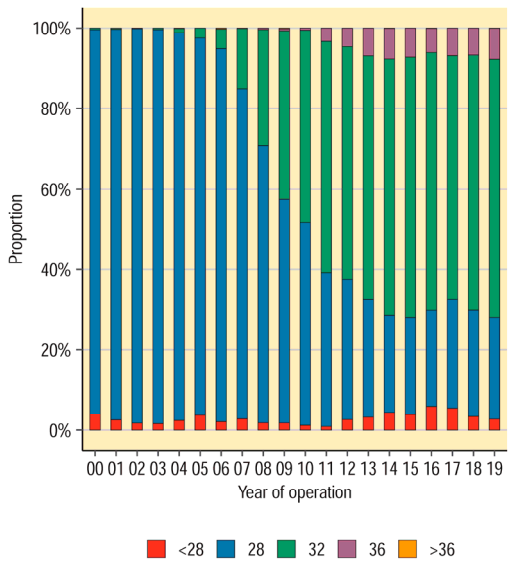

Fig 10. Proportion of different head sizes used in THA as fracture treatment in Sweden (Copyright SHAR)

Patient factors

Unlike the surgical factors, the patient-related factors cannot be affected by the surgeon, just taken into account. The stability of the hip is controlled by the central nervous system (CNS), the peripheral nervous system (PNS) and local soft tissue integrity surrounding the hip. Disruption of any of these systems may affect the stability of the joint, and increase the risk of dislocation. CNS and PNS dysfunction leads to weakened muscle control and sensation, impaired balance and coordination. Cognitive loss of restraint and compliance difficulties are consequences of CNS impairment.

Arthroplasty due to fracture, compared to osteoarthritis, has an increased risk of dislocation (8, 47, 48). The hip fracture patient is often older, more fragile and has inferior soft tissue, due to weaker muscles or contractures. The weaker soft tissue may also explain the increased risk of dislocation after revision surgery (47, 48) and for arthroplasty due to non-traumatic osteonecrosis and inflammatory arthritis (8, 47).

Few studies describe the risk factors for THA dislocation after hip fracture. Earlier studies on fracture patients show age not to have any influence, neither on the dislocation risk after HA (1, 25, 26, 45), nor after THA (28, 50). Gender seems not to be associated with dislocation after HA (1, 25, 45, 57). Leonardsson et al. reported male gender to increase the risk of dislocation in fracture THA patients (50), whereas Enocson et al. reported no influence of gender (28).

Assumingly, patients with dementia and neurological diseases have increased risk of dislocation caused by CNS and PNS impairment. Li et al. reported neurological disease and dementia to increase the risk of dislocation of HA (53), but several other studies did not find any association between dementia and risk of dislocation (1, 57, 67, 83). Comorbidity (45, 57, 64, 83) seems not to be associated with increased risk of dislocation in fracture HA, in contrast to osteoarthritis THA (47).

Rehabilitation after hip arthroplasty

Many orthopaedic wards have a standard postoperative regime for the patient to avoid dislocation (21), in particular when the posterior approach is used, for reasons described earlier. This typically includes movement precautions and mandatory activities of daily living (ADL) equipment during the recovery phase.

The standard postoperative precautions are movement restrictions including limited flexion of the hip to 90° (avoid reaching down to toes or bringing knee up beyond 90°) and limited adduction of the hip (avoid sleeping on side or crossing legs at knees or ankles).

The ADL equipment usually includes a long-handled reacher and stocking application aid in order to avoid flexing the hip when putting on pants, stockings or picking up objects on the floor. For the same reason, patients are instructed only to use higher furniture (chair, bed) and a raised toilet seat. In addition, a knee immobiliser (knee brace) can be prescribed for a certain postoperative period, particularly in patients with cognitive limitations. ADL equipment can be recommended for a period, most often around 3 months (21).

The meaningfulness of postoperative precautions and mandatory aids is questioned. Studies of THA in osteoarthritis patients operated with direct lateral approach such measures seemed not to affect the dislocation risk (72, 91). Precautions have even been associated with less satisfaction, slower return to ADL and higher costs in patients with THA (21). The scientific support for precautions in osteoarthritis patients is limited (5), and there are virtually no studies on fracture patients (81). When guidelines are written, these issues are guided by expert opinion only (13), suggesting precautions to be unnecessary if DLA is used.

Swedish Hip Arthroplasty Register

The aim of the Swedish Hip Arthroplasty Register (SHAR) is to collect important data from every hip replacement surgery performed in Sweden. Type of prosthesis, details on surgical technique, patient data and patient-reported outcome measures (PROMs) are registered. SHAR has a coverage of 100% for all surgical hospitals in Sweden, both public and private. It has a completeness of approximately 98% for THA and 96% for HA, and approximately 93% for reporting all revisions (both HA and THA) (48).

By continuous monitoring and evaluation, SHAR gives caregivers tools to improve the healthcare. Besides a commission of quality improvement, SHAR, like other national quality registers, provides large cohorts with prospectively collected data for research purposes. The SHAR database was used in Papers I and II. The Nordic Arthroplasty Register Association (NARA) is a collaboration between the national hip arthroplasty registers of Sweden, Denmark, Norway and Finland, which started in 2007 (73). NARA can provide pooled and individually anonymised data, linking all the Nordic arthroplasty datasets together. The advantage is a large number of cases, and more variability in implant choice and surgical techniques than within a country. Such data was used in Paper IV.

National Patient Register and Statistics Sweden

On behalf of the Swedish National Board of Health and Welfare, the National Patient Register (NPR) collects data on diseases, surgical treatments and medical care measures. This includes all in-patient periods, in both public and private hospitals, out-patient visits including day surgery, and psychiatric care provided by both private and public caregivers (55, 65). The codes of the International Statistical Classification of Diseases and Related Health Problems (ICD-10 codes) (92) are used for main and secondary diagnosis. Statistics Sweden (SCB, Swedish for Statistiska Centralbyrån) (80) is responsible for official statistics in Sweden. SCB develops, produces and disseminates statistics on Swedish residents. By cross-matching the data from SHAR, NPR and SCB registers we conducted the study reported in paper I with a focus on THA and in paper II with a focus on HA.

Aims

The overall aim of this thesis is to give a better understanding of the dislocation problem after hip fracture related arthroplasty. What factors affect the dislocation risk and what can we improve to prevent dislocations?

Specific aims

- **Paper I.** To describe the "true" dislocation rate for THA after hip fracture and to ascertain which factors affect the risk of dislocation, in a Swedish cohort.
- **Paper II.** To describe the "true" dislocation rate for HA after hip fracture and to ascertain which factors affect the risk of dislocation, in a Swedish cohort.
- **Paper III.** To compare two treatment regimes, one with and one without postoperative precautions, after HA via direct lateral approach, on the risk of dislocation in a hospital cohort.
- **Paper IV.** To examine the risk of revision in general and revision due to specific causes in hip fracture patients treated with dual mobility cups, in a Nordic cohort.

Patients and methods

Papers I and II are SHAR-based studies. Paper III is based on a cohort from Skåne University hospital, Malmö. Paper IV is a NARA-based study.

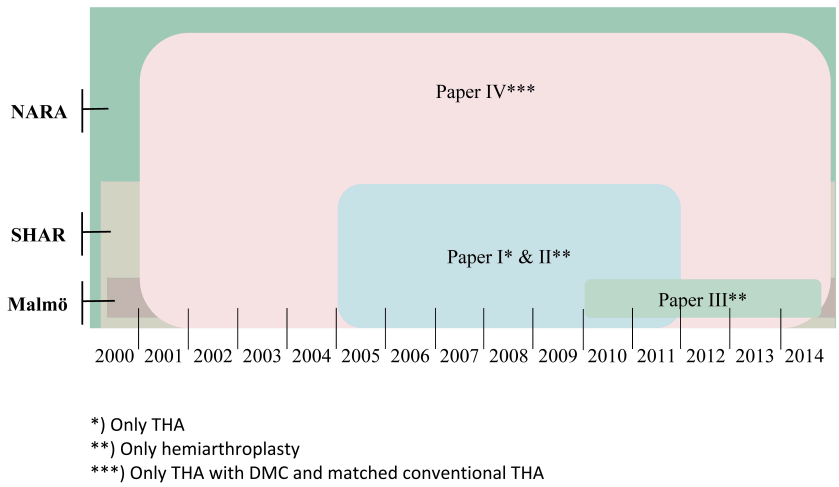

Fig 11. Simplyfied depiction of the cohorts' relation to each other

Papers I and II

Patients included in papers I and II are from a dataset containing cross-linkage data from SHAR, NPR and SCB. All Swedish residents have a personal identity number allowing us to cross-match data from these registers. The included patients were treated with arthroplasty caused by hip fracture fractures during 2005–2011. Paper I is an observational cohort study of 6,736 hip fractures treated with THA. Paper II is an observational cohort study of 25,678 hip fractures treated with HA. The SHAR reports on open surgery only. It can therefore be deceptive to estimate the dislocation rate, because closed reduction of a dislocation is not reported. An alternative way to address this is to use the diagnosis and procedural codes that are reported to NPR. ICD-10 codes were used for main and secondary diagnosis (92).

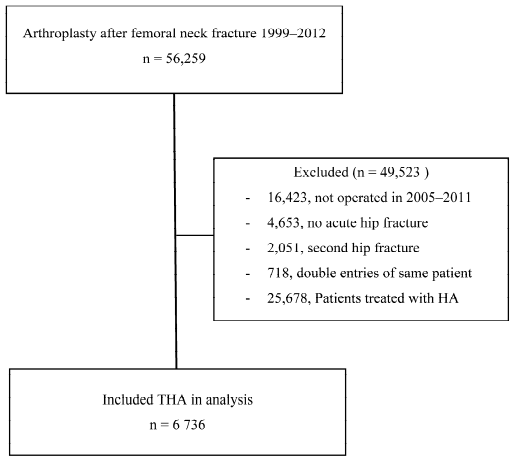

Fig 12. Flowchart of Paper I

For procedural codes, NOMESCO codes (68) were used. The codes used to define hip prosthesis dislocation were M24.3-4, M24.4F, S73.0, T93.3 and all NFH-codes. We wanted to describe the dislocation rate with a minimum of one-year follow-up. This led to exclusion of operations during 2012. To avoid including the same patient twice, only the first hip surgery was included in patients with a second surgery to the contralateral hip. Co-morbidity was analysed using the Elixhauser index (24), regrouped into four categories (0, 1, 2 and 3+). Possible confounders such as education and marital status were extracted from the socioeconomic data obtained from SCB.

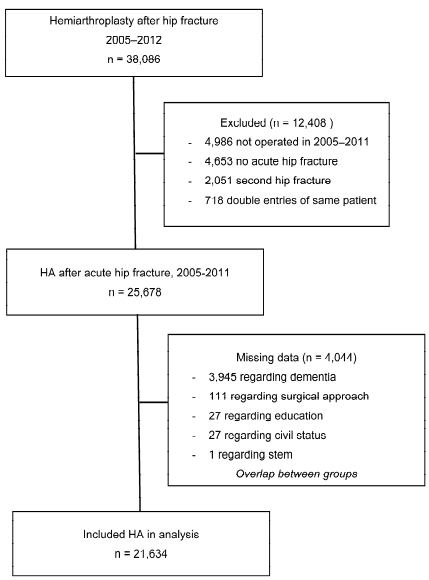

Fig 13. Flowchart of Paper II

Paper III

During 2010–2014, 394 patients participated in a cluster-randomised study at Skåne University Hospital, Malmö. Inclusion criteria were a displaced femoral neck fracture treated with a bipolar hemiarthroplasty inserted via a DLA. All potential study participants were invited to the study by an occupational therapist within the first postoperative days. If a patient was not capable of making decisions, relatives were asked.

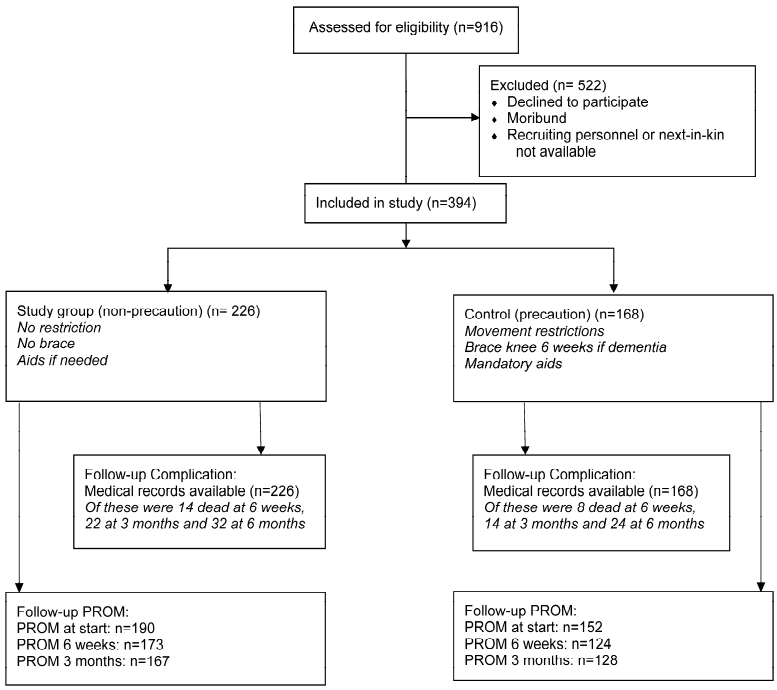

Fig 14. Flowchart of Paper III

Each of four wards managing hip fracture patients was assigned either to provide the standard postoperative hip precaution regime or the non-precaution regime during the entire study period. On two of the wards, the precaution group (PG) had standard postoperative hip precautions included limited flexion of the hip to 90° (avoid reaching down to toes or bringing knee up beyond 90°) and limited adduction of the hip (avoid sleeping on side and avoid crossing legs at knees or ankles). The mandatory assistive equipment to use for at least 3 months consisted of a reacher and a stocking application aid. The patients were instructed only to use elevated

chair, bed and toilet in order not to flex more than 90° in the hip. For the same reason a brace over the knee was prescribed for up to 6 weeks, particularly in patients with cognitive limitations. The non-precaution group (NPG) consisted of patients treated on the other two wards. Patients in the NPG had no restrictions on mobility, i.e. they were encouraged to move freely during the recovery phase and assistive equipment was prescribed only if needed. Admittance of a patient to either of the wards was only determined by bed availability, i.e. the health status of the patient or any other factors did not influence the allocation of patients. We recruited 168 patients to the PG and 226 patients to the NPG. The size difference is explained by variation in the number of beds available for fracture patients during the study period. The initial power analysis was based on dislocation rate as the primary outcome. Functional assessment was made in both groups by an occupational therapist as part of standard-of-care. The work burden of the rehabilitation personnel (occupational therapists and physiotherapists) during hospital stay was estimated by themselves. The patients were followed up with postal questionnaire at 6 weeks and 3 months including patient-reported measures: EQ-5D and a visual analogue scale on pain and satisfaction (0–100). Medical records from all hospital departments (except psychiatry) were reviewed and all adverse events (unintended injury or complication resulting in temporary or permanent disability, death or prolonged hospital stay) up to 6 months postoperatively were recorded.

Paper IV

The study was performed within the NARA collaboration. In this study, Finland was excluded because few DMCs had been used in that country.

The study population comprised patients in whom a hip fracture had been treated with primary THA with a DMC or with conventional bearings including a femoral head with a diameter of 32 or 36 mm (3,228 and 1,292, respectively). The outcomes studied were either any type of revision or revision of the cup. The indications for revision specified in the database were dislocation, periprosthetic femoral fracture, aseptic loosening, deep infection, pain, and other reasons. The NARA data set included 510,781 primary THAs implanted from 2001 to 2014. Of these, 42,359 were performed because of hip fracture in Denmark, Norway or Sweden. The cups included in the control group were designed for a metal or ceramic head with a diameter of 32 or 36 mm. When a patient had been operated on both sides during the study period, the second hip was excluded from the study, as were cases with missing data on key variables; this left 4,520 hips with a DMC cup and 10,029 control cases for matching. After matching, there were 4,520 hips in each group.

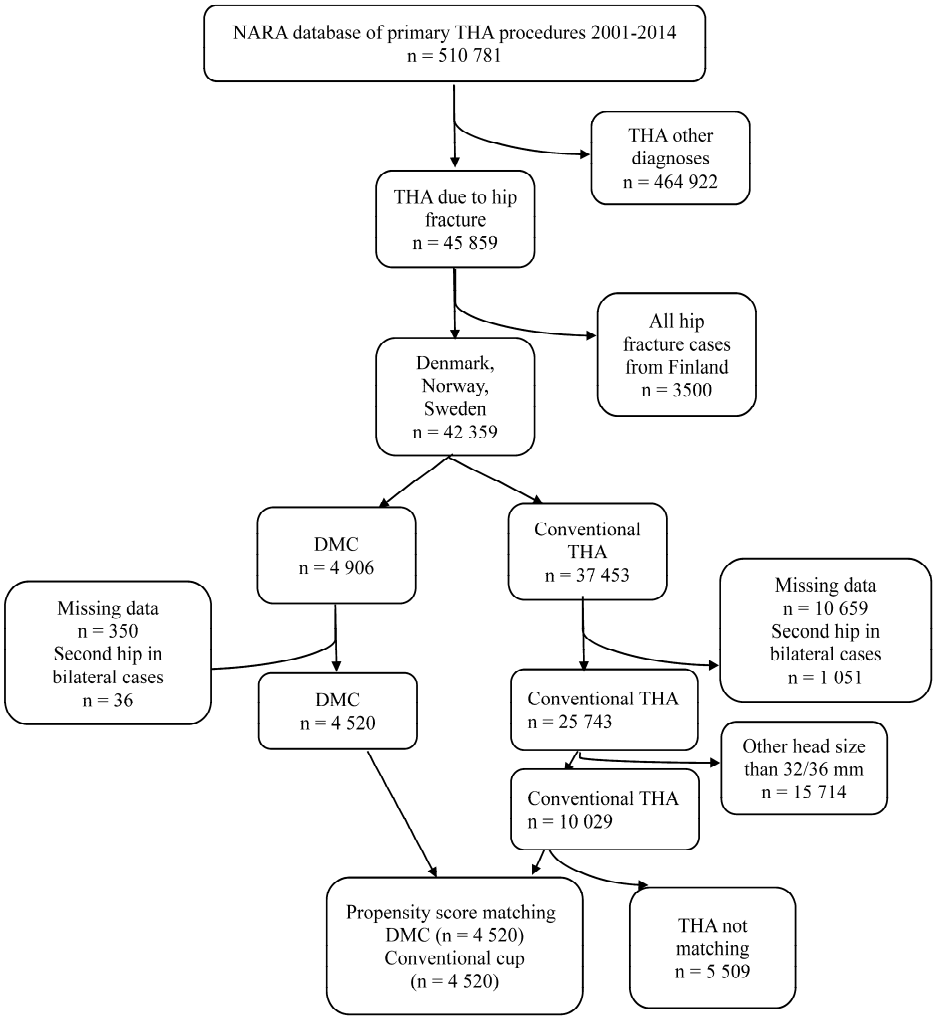

Fig 15. Flowchart of Paper IV

Statistics

The statistical software used was IBM SPSS Statistics 24 and R. In Papers I and II the cross linkage of data was performed by statisticians at SHAR. The first author (AJ) made the calculations. The incidence of dislocation was calculated with chi-squared test. Logistic regression model was used to analyse possible confounders. In Paper III the first author (AJ) reviewed adverse events and made the calculation with the support of a statistician (LJ) at the department of Orthopaedics, Lund University. For description of data crosstabs were used. Nominal variables were tested by the chi-squared test and Fisher's exact test. The results were considered significant at $p<0.05$. The Wilson procedure with a correction for continuity was also used. The gathering of patient-reported measures was done by a co-author (CR) and analysis of this data was performed by another co-author (OR). Uni- and multivariable linear regression models were used to investigate the association between hip precautions and patient-reported measures. In paper IV the calculations were performed by two co-authors (JK, ABP). Logistic regression analysis was used to calculate a propensity score for each DMC and control group patient, resulting in a set of patients, or surgical interventions, with a similar probability of receiving either of the two implant types based on the matching variables. Adjustments were made for surgical approach, as a posterior approach is a strong risk factor for dislocation. Survival analysis was performed with the Kaplan-Meier method.

Ethical considerations

Papers I and II were approved by the regional Ethical Review Board in Gothenburg, Sweden (271-14).

Paper III was approved by the Regional Ethical Review Board in Lund on condition that all participants, regardless of group, or their next-of-kin gave written consent (2009/754). Since the study was deemed to pose only minimal risk and minimal burden on the participants (one group receiving standard-of-care, the other less restraining rehabilitation, warning levels to stop the study were not required), the next-of-kin consent was considered ethically acceptable. In addition, we considered recruiting patients with dementia to clinical hip fracture studies to be highly relevant. Firstly, they constitute one third of that population and, secondly, any evidence-based guidelines should be based on studies including all relevant patient groups, this group as well.

Paper IV was approved by the Danish Data Protection Agency (reference number 2012-41-0515) and the Regional Ethical Review Board in Gothenburg, Sweden (734-14).

In Papers I, II and IV, with data collected from SHAR, there was no personal contact between the researchers and the study subjects. All patients are informed in writing before registration that participation in a national quality register is voluntary and can be withdrawn at any time. Conducting different types of studies evokes ethical considerations during the work process. In the register-based studies (Papers I, II and IV) with a large numbers of patients included, it is difficult to "see" the patient behind the data. This most certainly fosters a strict and analytical view of data and results. This is in contrast to the participants in Paper III, who were included locally at the author's workplace. Those patients were meet and treated daily by the author and co-authors. During follow-up and journal reading after six months, I had a clear image of some the patients. While reviewing the journal, serious complications or death made me think of the affected patient on a personal level. The difference was good continuous training in the ethical aspects of research.

Results

The risk of dislocation after THA (Paper I)

The overall frequency of dislocation was 8.4% (567/6,736). Patients treated with posterior approach showed a frequency of 13.4% (374/2,797) compared to 4.8% (186/3,843) in those treated with direct lateral approach. Logistic regression analysis showed that posterior approach was the greatest risk factor for dislocation ($p<0.001$, OR=3.01; 95% CI 2.50–3.63) followed by male gender ($p<0.001$, OR=1.42; 95% CI 1.17–1.71). Patients in Elixhauser groups 1, 2 and 3 had increased risk compared to Elixhauser group 0. A subgroup analysis of 1,138 individuals with severe comorbidity (Elixhauser 2 or more) showed that 46 of 644 (7.1%) patients operated through a direct lateral approach dislocated, compared to 83 of 494 (16.8%) of those operated on with posterior approach.

The risk of dislocation after HA (Paper II)

Overall, the risk of dislocation was 4.8% (1220/25,678). Patients treated with posterior approach had a dislocation risk of 7.2% (850/11,834) compared to 2.7% (366/13,769) with direct lateral approach. Using logistic regression analysis, posterior approach was found to be the most pronounced factor for dislocation ($p<0.001$, OR=2.67; 95% CI 2.32–3.07). Higher age was associated with a lower risk of dislocation ($p=0.002$, OR=0.99 per year of age; 95% CI 0.99–1.00). In the 21,733 patients with complete data on cognitive status, dementia was associated with increased risk ($p<0.001$, OR=1.29; 95% CI 1.12–1.47). In a subgroup analysis of 6,709 patients with either manifest dementia or suspected cognitive impairment 129 of 3,962 (3.3%) patients with direct lateral approach dislocated, compared to 220 of 2,747 (8.0%) of those with posterior approach. Gender, choice of uni- or bipolar design and type of fixation had no significant influence on the risk of dislocation.

Postoperative precautions and dislocations (Paper III)

There were no significant differences between the groups. Dislocation occurred in one patient in each group, resulting in a dislocation rate of 0.4% in the NPG and 0.6% in the PG. Reoperations occurred in 7 of 226 (3%) in the NPG and 13 of 168 (8%) of the PG (p=0.038); corresponding to a total reoperation rate of 5%. Four and 8 had deep infections, 3 and 5 periprosthetic fractures. Total in-hospital mortality was 10/394 (3%), without differences between groups. Within 6 months, 71 (31%) in the NPG and 45 (27%) in the PG had severe adverse events such as death (32 and 24) and/or pneumonia (31 and 17), while thromboembolic events were uncommon (8 and 4). The work burden of the rehabilitation personnel during hospital stay, both occupational therapists and physiotherapists, reported shorter work effort (both $p < 0.001$). Regarding PROM, 190 (84%) patients in the NPG and 152 (90%) patients in the PG were able to complete different parts of the pre-fracture and follow-up questionnaire. Response rate at 3 months was 167 (74%) and 128 (76%) respectively. Mean values for pain and satisfaction after 6 weeks and 3 months were almost identical between groups. EQ5D index scores at pre-fracture, 6 weeks and 3 months, were similar for the two groups. Neither univariable nor multivariable regression models could identify relationships between precaution regimen and the PROMs; EQ-5D, pain VAS and satisfaction VAS.

DMC and the revision risk (Paper IV)

The posterior approach was more frequently used in the DMC group. There were 243 revisions (5.4%) in the conventional cup group and 181 (4.0%) in the DMC group. The DMCs had a lower overall risk of revision compared with the conventional THAs (AHR = 0.75 [95% CI = 0.62 to 0.92]). This was consistent with the findings after we adjusted for approach. Furthermore, the DMCs had a lower risk of revision due to dislocation. No significant difference was identified regarding revision due to infection. After adjustment for approach, use of the DMC was associated with a slightly lower risk of aseptic loosening. Revision of the cup due to dislocation or any reason was lower in the DMC group, both with and without adjustment for surgical approach. Other reasons for cup revision were not analysed separately because of infrequent events. Crude mortality was higher in the DMC group, with an AHR of 1.5 (95% CI = 1.4 to 1.6) compared with those treated with a conventional cup.

General discussion

Dislocation after arthroplasty due to hip fracture is a major concern. With this thesis we wanted to quantify the problem and analyse the risk factors. Especially regarding THA due to an acute hip fracture, few studies have been performed. There are reasons to believe that the postoperative rehabilitation can be improved when we focus on the things that matter for the individual patient. We wanted to give a clearer picture of how dual mobility cups perform in terms of overall revision risk in general and risk of revision due to dislocation in particular. The clinical aim of this thesis is to improve the results of surgery and treatment for a large and important subgroup of the orthopaedic trauma population.

How common is dislocation?

We observed an overall dislocation rate of 8% in patients operated with THA due to hip fracture. The dislocation rate of THA is on par with smaller clinical studies, where the researchers have read medical records to confirm the dislocation diagnosis (4, 28, 89). The overall dislocation risk for HA was lower, close to 5%. Here the rates from previous studies span from 1.5 to 15% (25, 31, 70, 83).

Our results for dislocation rates of THA and HA on a national level are an important complement to data from national orthopaedic registers, such as SHAR (48), as the registers only reports on open reduction and/or revision due to dislocation. According to SHAR the rate of revison due to dislocation is 1.1% (48). In Paper I, we found the rate of revision caused by dislocation to be 1.3%. Thereby, revision as outcome measure appears quite meaningless in a fracture population, as it underestimates the clinical problem. This theory is supported by another Swedish study, were only one fourth of the patients with dislocations had revision surgery (28). Still, dislocations requiring closed reduction only can be devastating for the patient in terms of reduced health-related quality of life (27) and result in additional hospital costs (18, 79). Both the surgeon and the hip fracture patient may hesitate to accept an implant exchange procedure, as many of these patients are old and frail.

The role of the surgical approach

In both Papers I and II, the choice of surgical approach was decisive: Posterior approach was associated with dislocation in every eight patient treated with THA, whilst after direct lateral approach only one in twenty had a dislocation. The very high rate of dislocation after THA with PA is confirmed by the finding of 12–14% by Enocson et al., who tracked down all dislocations in a cohort of 713 individuals (28).

In patients treated with HA the rate of dislocation after DLA 2.7% increased to 7.2% after PA. Comparing with the literature, some clinical series show an even higher dislocation rate after hemi with PA; around 8–15% (1, 7, 25).

Our results support earlier studies, both clinical and register work; PA increases both the risk of dislocation for HA (1, 25, 51, 83, 90) and THA (28, 50). In the SHAR database, we have no information on whether the posterior approach was performed with or without posterior repair. Not to reconstruct the stabilising posterior structures is associated with even further increased risk of dislocation for HA (25, 45) and THA (28). However, there are reasons to believe that posterior approach with posterior soft tissue repair dominated in Sweden during the study period (25).

Other surgical concerns

We found no difference in dislocation risk between bipolar and unipolar HA in adjusted analysis. Our observation is supported by earlier studies (25, 26, 90), with one exception; Leonardsson et al. found the bipolar design to be associated with increased risk of revision caused by dislocation (51).

In agreement with earlier studies (1, 31, 49, 90) we found no difference between cemented versus uncemented HA regarding the risk of dislocation. Our work contributes a new finding that cementation of the cup or the stem in fracture-THA is not associated with dislocation risk.

A register study precludes the access to postoperative radiographs to analyse implant positioning. A meta-analysis regarding dislocation of elective THA has shown that faulty positioning mainly of the cup, but also of the stem, use of short or long femoral neck, use of uncemented fixation and an inexperienced surgeon may increase the risk of dislocation (47). A one-surgeon series, comparing DLA and PA, proved that very low and similar dislocation rates can be achieved by a highly specialised hip fracture surgeon (70). We lacked information about surgeons' experience, but in Sweden both residents and consultants do emergency hip fracture surgery. According to the Swedish Fracture Register, approximately 15% of the

fracture-THAs are performed by residents, 20% are by highly specialised trauma consultants, less than 10% by highly specialised arthroplasty consultants and the rest by other consultants (82). Regarding HA, approximately 25% are performed by residents, 20% are by highly specialised trauma consultants, less than 5% by highly specialised arthroplasty consultants and the rest by other consultants (82). We therefore believe our data to reflect everyday practice in Sweden, with good generalisability to at least other public health care systems.

Neck length and use of DMC was not included in our dataset for Papers I and II. However very few patients were treated with primary DMC within the time frame of the study, as seen in paper IV (Figure 5). Regrettably we had no information on head size. Femoral heads with a diameter of 28 mm dominated in Sweden during the first years of our study, to gradually become replaced by 32 and 36 mm heads (25, 47, 48) (Figure 10).

Patient factors associated with dislocation

Several studies have shown age not to be a risk factor for dislocation of HA (1, 57, 64, 67, 83). In contrast, we found that older patients have lower risk of dislocation. Another Swedish register study found that patients under 75 years of age were at higher risk of reoperation due to dislocations than those over 85 (51). Younger patients may have a more active lifestyle and are therefore more prone to dislocation. Using open secondary surgery as outcome measure can also introduce selection bias, as younger patients more often may be recommended reoperation, whilst the old and frail patients more frequently may be treated with repeated closed reductions only. Therefore, we believe that our result, including virtually all dislocations, confirms the lesser risk among the oldest patients treated with HA.

In patients treated with THA, however, we could not detect any effect of age on the risk of dislocation risk, which is in line with one previous study of hip fracture patients with THA (28). This is in contrast to elective THA, where older patients have increased risk of dislocation (47).

We found men to have a higher risk of dislocation of THA. To our knowledge, only one previous study has observed the same gender difference in fracture cases (50). Regarding HA, a smaller retrospective study reported male gender as a risk factor (67), but neither we nor several other studies (1, 25, 26, 45, 51, 57, 83) identified gender as a risk factor.

In THA patients, a high degree of comorbidity was associated with a higher risk of dislocation. This may be explained by inferior soft tissues, muscle weakness and lack of postural control due to frailty and sickness. We cannot find that comorbidity has been studied as a risk factor in fracture patients treated with THA before. Our

findings are in accordance with earlier findings on patients treated with elective THA (47). Many treatment guidelines already advise against the use of THA as fracture treatment in the frailer group (58). The reasons for this have been longer surgery time and increased intra-operative blood loss, combined with no clear gain in function (15, 89). Now our results show that these patients are at higher risk of dislocation as well. In contrast, after HA, comorbidity seems not to affect the risk of dislocation, in accordance with previous studies (45, 57, 64, 83).

We found dementia to be associated with an increased risk of dislocation in patients treated with HA. This is in line with Li et al. (53), but in contrast to other studies concluding that dementia is not associated with dislocation rate (1, 45, 57, 67, 83). All these studies comprise smaller patient groups and may lack statistical power. The subgroup analysis of individuals with either manifest dementia or suspicion of cognitive impairment showed an increased risk of dislocation with the posterior approach compared to the direct lateral approach. The results underline the importance of cognitive screening among these frail patients, and a tailored treatment rationale including prevention of dislocation.

Dementia is not reported to the SHAR for patients treated with THA. It is widely accepted in Sweden that HA is the first-hand choice of treatment for dementia patients with femoral neck fracture, in particular, as one of the classic Swedish RCTs on arthroplasty vs internal fixation found a deterrent high dislocation rate for patients with dementia treated with THA and posterior approach (43).

Patient compliance usually influences the choice between THA and HA in clinical everyday life, mainly because of the risk of dislocation. Poor compliance and imprudence are assumed to increase the risk of dislocation, even if the literature is weak or contradictory. For example, no association between dislocation risk and alcohol or other drug abuse has been verified, neither regarding elective THA (47) nor HA after hip fracture (57, 83). However, obtaining reliable data on whether a patient is addicted is difficult, as both medical records and register data will underestimate the problem. As a blunt proxy variable for socioeconomic distress, we used education and marital status in our adjusted analyses. However, we did not find socioeconomic factors to affect the dislocation rate.

Do we need precautions if direct lateral approach is used?

The short answer for HA seems to be no. Hip precautions and mandatory use of assistive devices were not associated with the risk of dislocation after HA due to hip fracture, when DLA was used. In another paper from the same study (77), we found that the post-discharge use of assistive devices did not adhere to the prescriptions

from the hospital, regardless of precautions or not. The study participants used higher furniture to the same extent, regardless of precautions or not. Other devices were more common in the precaution group. The compliance of knee bracing was low. Our results support the national guidelines from the UK (13) (although these were based on experts' opinion) and two earlier randomised studies on patients with THA because of osteoarthritis (72, 91).

There were more reoperations in the group with precautions, although we find it less plausible to be due to precautions per se. The reasons for reoperations were deep infections and periprosthetic fractures. There were no statistically significant differences regarding these complications, or other early complications such as in-hospital mortality, studied separately. We assumed that there would be fewer adverse events if patients were able to move more freely, but complications at 6 months, with adverse events such as death, thromboembolism and stroke, did not differ between groups. The only exception is ischaemic heart attack, overrepresented in the NPG, for which we have no scientific explanation. Regarding health-related quality of life, pain and satisfaction, there were no statistically significant differences between the two groups. In contrast to our hypothesis, precautions did not play such an important role for patients' well-being. In general, hemiarthroplasty patients were satisfied with the result and free of hip pain at 3 months, when the whole group was analysed. Their health-related quality of life was at its lowest at 6 weeks, and at 3 months still lower than pre-fracture.

Exemption from restrictions also reduces the routine work load for rehabilitation personnel. We concluded that, from both a scientific and health-economic point of view, recommending precautions is not warranted. This has also been put forward by others (5, 23). Time and efforts should instead be spent on structured and prolonged rehabilitation (19).

Dual mobility cups – risks and benefits.

In a Nordic cohort of hip fracture patients, the use of a DMC was associated with a lower overall risk of revision and of revision due to dislocation in particular. Our findings support findings of a lower risk of revision due to dislocation in previous clinical trials (7, 66, 84, 87). But, in contrast to earlier studies, we focused on all complications leading to revision surgery and not selectively on dislocation. A new implant may have clinical benefit in one aspect, which can be outweighed by increasing other complications.

Regarding DMCs, there has been much focus on dislocation while the risks of aseptic loosening and infection have not been fully investigated. Regrettably, an attempt to perform an RCT recently failed because of the nature of the patients with hip fracture (36). We found no differences in the risk of revision due to infection

between DMCs and conventional THAs. In another study from the NARA group on patients with osteoarthritis, DMCs were more often revised for infection than conventional THAs (46). The authors suggested that selection of frailer and therefore more infection-prone patients for treatment with a DMC was the most likely explanation for this. Such a selection bias is likely less pronounced in our patient cohort, which included exclusively those with a hip fracture. In addition, a greater reluctance to perform revisions in fracture cases because of high morbidity may play a role.

In Paper IV, DMCs were associated with a somewhat lower risk of revision due to aseptic loosening. This issue was not identified in earlier studies (2, 7, 87, 93). According to a study of patients treated for osteoarthritis (17), DMCs were associated with a higher risk of aseptic loosening and were not recommended for young, active patients. That study may not be relevant to patients with a fracture. Patients with osteoarthritis and those with a fracture have different activity levels, comorbidities, and remaining life expectancy. Remaining life expectancy may be the most important factor as aseptic loosening is a long-term complication. We found that patients selected to DMC had a higher mortality rate. We assume that surgeons regard DMC as an option between conventional THA and hemiarthroplasty. Since current knowledge seems to guide us to use hemiarthroplasty in the most frail, least active patients and to use THA in those without physical or cognitive limitations (76), there is an intermediate group with particular needs to address. It may be that these are individuals with distinct risk factors for dislocation (high degree of comorbidity), in whom DMCs appear as a suitable method. Regrettably, the Nordic databases do not record the same comorbidity indexes, so we were unable to adjust for general health status.

The higher mortality rate of patients with a DMC is most probably related to patient factors. Surgeons might tend to select DMC for frail patients, but this source of bias could not be addressed in our study. The possibility that the DMC cups themselves have an influence on mortality cannot be completely ruled out, but it seems very unlikely. Dislocation, on the other hand, is to a great extent implant-related.

Within the Nordic countries, the choice of approach varies between countries (35, 37). By adjusting for approach, we aimed to overcome this. The total number of fractures (9,040) included in this DMC study exceeds the numbers in any other study of DMC treated fractures published so far. Our study does not cover implant complications and inferior clinical outcomes *not* resulting in a revision, and closed reduction(s) only after dislocation are not included. On the other hand, closed reduction of dislocated conventional THA is easier to do than reduction of a dislocated DMC (84). This will further fortify the argument for DMC if we assume that a majority of DMC dislocations end up in open surgery

Limitations

In register studies, the external validity is high because all patients are included. On the other hand, selection bias is inherent as surgeons' choices of treatment method are based on patient factors that are not available for adjustment in a limited data set. Some other limitations are mentioned earlier, such as lack of some surgical details and unavailable radiographs. Our co-processing with other national register resulted in more relevant factors to study, giving us a better option to study a dislocation rate as close as possible to the "true" national rate. On the other hand, co-processing data from several registers is complicated and usually takes time, which can make the data "old" at the time of final analysis. The lack of information on laterality in the NPR may have led to a slight overestimation of the dislocation rate. I.e. a dislocation on the opposite side may have be included. We expect these events to be equally distributed. Furthermore, there is conformity between our dislocation rates and those found in the smaller, clinical studies reporting on total dislocation rate, as mentioned above.

The major limitation of our clinical study is the low participation rate. Difficulties to enrol geriatric hip fracture patients are a well- recognised problem, also encountered by others (36). Recruitment difficulties also forced us to close the study prematurely. As a clinically significant effect was not discernible in a relatively large cohort, we dare to consider our findings relevant for departments that discuss whether to abandon hip precautions or not. It is important to underline that our study patients were treated using a DLA and we cannot draw any conclusion if PA is used.

Conclusions

- The total dislocation rate after THA and HA as treatment of hip fracture is high: 8% and 5%, respectively, suffer at least one dislocation.
- Posterior approach is the most important risk factor, and is associated with a higher risk of dislocation than direct lateral approach.
- When using posterior approach, the rate of dislocation increases to 13% and 7% after THA and HA, respectively. The corresponding rate for direct lateral approach is 5 and 3%.
- Male gender and severe comorbidity are associated with an increased risk of dislocation after total hip arthroplasty.
- Dementia is associated with an increased risk of dislocation after hemiarthroplasty.
- Precautions are not needed to prevent dislocation after hemiarthroplasty in hip fracture patients, if direct lateral approach is used. This makes more time available for the rehabilitation personnel to focus on more individualised rehabilitations.
- DMC after hip fracture is associated with a lower overall risk of revision and due to dislocation in particular, compared with conventional THA.

Clinical implication

The main clinical relevance of the thesis is that the choice of surgical incision is a modifiable risk factor for the risk of dislocation after fracture THA and HA. This observation is based on data from every day-surgery performed in all Swedish hospitals. Posterior approach is associated with a higher risk of dislocation compared to direct lateral approach.

Advanced comorbidities will further increase the risk of postoperative dislocation after THA. Hemiarthroplasty inserted through a direct lateral approach appears to be a better alternative for these patients, to minimise the risk of dislocation.

Patients with dementia tend to have an increased risk as well. As many hip fracture patients have a manifest cognitive impairment or will be affected by acute delirium in connection with the trauma, this is another reason not to use the posterior approach. Our data refute bipolar head as a risk factor for dislocation.

Furthermore, our study shows that precautions are not needed to prevent dislocation after hemiarthroplasty in hip fracture patients if direct lateral approach is used. The rehabilitation personnel would expend less work effort during hospital stay if routine precautions were abandoned, and time can be used for more important rehabilitative measures. This is important in times when the healthcare has limited resources.

DMC may play a bigger role in primary arthroplasty after hip fracture. DMC can be suited for patients in the borderline between THA and HA. Furthermore, surgeons preferring to insert THA through a posterior approach should consider DMC. The combination of PA and DMC may even compensate for the downside of DLA, the risk of abductor weakness and Trendelenburg gait

Future research

The role of arthroplasty is increasing in hip fracture treatment. We are moving towards arthroplasty as the first choice of treatment in displaced femoral neck in patients below 60 years as well, and maybe also in elderly with non-displaced femoral neck fracture. Regardless of patient group, we should always offer the patient a scientifically well-established treatment, optimising the factors we can control, e.g. surgical approach.

Studies are lacking on the need of precautions in THA for patients with hip fracture, and for any arthroplasty inserted via posterior approach. One can argue for these to be conducted in the future. On the other hand, we may dare to extrapolate the results from HA and direct lateral approach. Some facts speaks in favour of that: The number of THA patients is small, therefore it would be challenging to include sufficient individuals to obtain statistical power. We know little of the adherence to restrictions, the compliance, as many patients either have cognitive limitations or alcohol overconsumption. This may be one of many questions where healthcare seems to accept a lack of profound evidence and base routines on experience only. Still, unnecessary actions should be abandoned, in the interest of both patients and healthcare.

In our DMC study, a large number of patients were treated with posterior approach. It would be interesting to see how DMC performs in RCT versus conventional THA if only direct lateral approach is used. Given the low rate of dislocation rate when direct lateral approach is used, DMC may or may not decrease the dislocation rate further. We may perhaps not need more advanced cups if we improve our surgical technique.

The increase embracing of direct lateral approach by Swedish orthopaedic surgeons, in combination with larger femoral heads and more DMC, makes an updated cross-linked database valuable, to see if there is a change in the dislocation rate.

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