On femoral neck fractures in the elderly

Lagergren, Johan

2023

Document Version:
Early version, also known as pre-print

Link to publication

Citation for published version (APA):
Lagergren, J. (2023). *On femoral neck fractures in the elderly*. [Doctoral Thesis (compilation), Department of Clinical Sciences, Malmö]. Lund University, Faculty of Medicine.

Total number of authors:
1

On femoral neck fractures in the elderly

Johan Lagergren

DOCTORAL DISSERTATION

Doctoral dissertation for the degree of Doctor of Philosophy (PhD) at the Faculty of Medicine at Lund University to be publicly defended on November 24th 2023 at 13.00 in Föreläsningssalen, Department of Orthopaedics, SUS Malmö

Faculty opponent
Anders Enocson MD, PhD

On femoral neck fractures in the elderly

Johan Lagergren

LUND UNIVERSITY

Faculty of Medicine, Institution for Clinical Sciences

Department of Orthopedic Surgery

ISBN 978-91-8021-476-6

ISSN 1652-8220

Printed in Sweden by Media-Tryck, Lund University

Lund 2023

Media-Tryck is a Nordic Swan Ecolabel certified provider of printed material. Read more about our environmental work at www.mediatryck.lu.se

MADE IN SWEDEN

To M, V & B

“Help the aged. One time they were just like you. Drinking, smoking cigs and sniffing glue.”

Jarvis Cocker, Pulp

Table of Contents

Abstract

Hip arthroplasty has gained popularity over the past decade as the primary treatment of displaced femoral neck fractures (dFNFs). This also extends to relatively young patients in Sweden. In contrast, internal fixation (IF) has seen a steady decline. For non-displaced fractures (nFNFs), there is still controversy concerning treatment modality. This thesis focuses on treating FNFs in older adults (defined as age ≥60 years).

Paper I conducted a prospective register-based cohort study on patients treated with IF or total hip arthroplasty (THA) for dFNFs. We investigated current treatment allocation in a group aged 60-69 years regarding patient-reported outcome measures (PROMs) and mortality. In Paper II, we studied nFNFs and the risk of conversion to arthroplasty in patients treated with IF. In Paper III, we revisited dFNFs to evaluate conversion rates after IF and revision rates in those treated with primary THA. Paper IV evaluated implants commonly used in IF and the differences in outcomes regarding the risk of subsequent conversion to arthroplasty.

We found that patients with a dFNF in the age group 60-69 years treated with IF or THA did not differ in reported PROMs 1-year post-injury. Nor did their mortality rates differ. 18% of patients treated with IF converted to arthroplasty within 1 year. Patients treated with arthroplasty had major revision surgery in 2% of all cases. Both rates are lower than those previously reported. For patients with an nFNF, conversion rates were much lower. Those aged 60-69 had rates of approximately 4% at 1 year and 10% at 5 years. Patients aged 70-79 had almost a 7% conversion rate at 1 year, an increased risk compared to their younger peers. Finally, we observed no distinction between different IF methods on the risk of later conversion to arthroplasty.

Given the risk of later conversion to arthroplasty after IF, our data support arthroplasty as the primary treatment in patients aged 60-69 with a dFNF. Regardless of treatment strategy, similar PROMs are open for shared decision making with the patient. In nFNFs, randomised clinical studies needs to confirm our suggested subgroups of patients especially prone to failure if treated with IF. After treatment with primary arthroplasty, the focus should be on the outcome rather than on new methods for IF. Additionally, fracture patterns leading to an increased risk of failure must be identified.

Populärvetenskaplig sammanfattning

Höftfrakturer delas in i tre typer; fraktur på lårbenshalsen (cervikala frakturer), pertrokantära frakturer och subtrokantära fraktuer. De cervikala frakturerna är vanligast och behandlas antingen med spikar eller skruvar (osteosyntes) eller med en höftprotes. Lämplig behandling avgörs av grad av felställning i frakturen men också av faktorer som ålder, aktivitetsnivå och samsjuklighet. Vid påtagligt felställd fraktur är ofta blodförsörjningen till ledhuvudet skadad. Att sammanfoga frakturen med skruvar eller spikar kan då leda till utebliven läkning och vävnadsdöd i ledhuvudet (osteonekros). Därför lämpar sig oftast höftprotes bättre som behandling, eftersom patienten blir smärtfri snabbare och därmed kan inleda sin träning tidigare. Höftprotes är ett större ingrepp men leder till färre reoperationer än osteosyntes. Frakturer med liten eller ingen felställning har bättre förutsättningar att läka och opereras vanligen med skruvar eller spikar.

Vid höftprotes väljer man mellan halvprotes och helprotes. Halvprotes innebär att man ersätter höftledskulan men behåller ledkoppen, med dess befintliga brosk. Vid helprotes ersätter man både ledkulan och ledkoppen. En nackdel med halvprotes är att aktiva patienter över tid, ofta flera år, får ett slitage av brosk och underliggande ben och protesens ledkula äter sig in i bäckenet. Därför lämpar sig halvprotes i första hand för inaktiva patienter med kort förväntad överlevnad. Helprotes ”håller längre” och kan därför vara ett alternativ hos friskare/yngre och aktiva patienter med höftfraktur. Man kan jämföra med dem som opererats med helprotes för artros, där 60 till 80% har kvar sin ursprungliga protes efter 20 år. Någon större skillnad på funktion eller komplikationer mellan halv- och helprotes har inte påvisats de första åren efter operation.

Avhandlingen studerar utfallet efter behandling av cervikala höftfrakturer såsom reoperationer, mortalitet och patientupplevt utfall. Även riskfaktorer för reoperation respektive död studeras. Ansatsen var att använda registerdata från Svenska Frakturregistret (SFR) och Svenska Ledprotesregistret (SAR). Läkaren registrerar patienter med höftfraktur i SFR. Vi gör olika val av behandling och registerdata återspeglar den kliniska vardagen på ortopedkliniker i Sverige. Detta till skillnad från randomiserade studier, där lotten avgör behandlingsval och grupperna därefter jämförs. I SAR eftersökte vi om patienterna som erhållit höftprotes i samma höft i ett senare skede. SAR bedömdes vara en säkrare källa för reoperationer än SFR, eftersom SAR är etablerat sedan flera decennier med en täckningsgrad nära 100%.

Delarbete I inkluderar ”unga äldre”, 60–69 år, med dislocerad (felställd) cervikal höftfraktur. I denna grupp finns både de som är aktiva, friska och har stora krav på sin funktion, samt de som är sjuka, ålderssköra och med nedsatt funktion. Därför är behandlingsvalet kontroversiellt. Man kan hävda att dessa patienter kan opereras med osteosyntes, trots en hög risk för komplikationer, eftersom många klarar av en senare reoperation med höftprotes. Fördelen är att bevara den egna höftleden om frakturen läker. Å andra sidan kan en operation med en höftprotes direkt vara en fördel, då risken för komplikationer är lägre. Vi jämförde därför höftprotes och osteosyntes baserat på patienternas egen-rapporterade resultat. Två enkäter skickades ut av SFR. Den första återspeglade funktion och livskvalitet veckan innan skadan, den andra hur detta var efter 1 år. Även skillnader i mortalitet mellan grupperna undersöktes. Vi såg ingen signifikant skillnad mellan de som opererats med höftprotes eller osteosyntes, trots att man kan anta att 1 av 6 av de med osteosyntes varit tvungna att genomgå en ny operation inom 1 år. Detta skulle man annars förmoda hade en negativ påverkan på livskvalitet under den tiden. Patienterna som behandlades med halvprotes skilde sig från de andra grupperna. De uppvisade högre mortalitet och sämre patientrapporterat utfall.

Delarbete II undersöker risken för senare reoperation efter osteosyntes vid odislocerad cervikal fraktur hos alla över 60 år. Vi vägde även in riskfaktorer i form av kön, ålder och kirurgens vana. I hela gruppen över 60 blev drygt 7% reopererade med höftprotes inom 1 år och 13% inom 5 år. För de unga äldre var siffran 4%. Kvinnor löpte högre risk för reoperation medan män uppvisade högre mortalitet.

Delarbete III följer upp delarbete I. Dislocerade cervikal frakturer hos unga äldre studerades här avseende risken för reoperation efter höftprotes respektive osteosyntes. Vi fann att 18 % av dem med osteosyntes reopereras inom 1 år och 31% inom 5 år. Motsvarande siffra för dem med höftprotes var 2 respektive 4%.

Delarbete IV undersöker om typen av osteosyntes påverkar risken för läknings-störning i höften. För alla över 60 år med cervikal höftfraktur jämfördes de vanligast förekommande implantaten; skruvar, spikar samt platta med glidskruv. Dislocerade och odislocerade frakturer analyserades även var för sig. Riskfaktorer som kön, ålder och kirurgens vana vägdes in. Inget av de i Sverige vanligt förekommande typerna av osteosyntesmaterial uppvisade ökad risk för senare protesförsörjning.

Givetvis bör man sträva efter att minimera risken för reoperation. Dock bör fördelarna med att behålla den egna höftleden vägas mot eventuella framtida problem med en höftprotes inom ett längre tidsförlopp. Kan 10 eller 30% reoperationer (dislocerad respektive odislocerad fraktur) vara försvarbart i vissa fall, eller bör alla få en protes med 4% risk i det korta förlopppet? Våra resultat kan användas vid samtal med speciellt de unga äldre med dislocerad fraktur om lämplig behandling, för att uppnå ett informerat samtycke. För odislocerad fraktur ger vår studie ett jämförelsematerial för de randomiserade studier som pågår.

List of Papers

I. **Displaced femoral neck fractures in patients 60-69 years old – treatment and patient-reported outcomes in a register cohort**
Johan Lagergren, Michael Möller, Cecilia Rogmark
Injury. 2020 Nov;51(11):2652-2657

II. **Conversion to arthroplasty after internal fixation of non-displaced femoral neck fractures**
Johan Lagergren, Sebastian Mukka, Olof Wolf, Emma Nauclér, Michael Möller, Cecilia Rogmark
J Bone Joint Surg Am. 2023 Mar 1;105(5):389-396

III. **The different strategies in treating displaced femoral neck fractures. Mid-term surgical outcome in a register-based cohort of 1283 patients aged 60-69 years.**
Johan Lagergren, Sebastian Mukka, Olof Wolf, Jonatan Nåtman, Michael Möller, Cecilia Rogmark
Acta Orthop. 2023 Oct;94:505-510.

IV. **Contemporary fixation methods for femoral neck fractures and the risk of later conversion to arthroplasty**
Johan Lagergren, Jonatan Nåtman, Cecilia Rogmark
In manuscript

Author's contribution to the papers

Paper I
Data curation, study design, statistical analysis, principal author.

Paper II
Data curation, study design, principal author

Paper III
Data curation, study design, principal author.

Paper IV
Data curation, study design, principal author.

Abbreviations

AO	Arbeitgemeinschaft für Osteosyntesefragen (AO Foundation)
BMI	Body mass index
CI	Confidence interval
CIF	Cumulative incidence function
EQ-5D	EuroQol Group standardised measure of health-related quality of life questionnaire
FNF	Femoral neck fracture
dFNF	Displaced femoral neck fracture
nFNF	Non-displaced femoral neck fracture
HA	Hemiarthroplasty
HRQoL	Health-related quality of life
ICD-10	International Statistical Classification of Diseases and Related Health Problems -Tenth Revision
IF	Internal fixation
OTA	The Orthopaedic Trauma Association
PIN	Personal identity number
PROM	Patient-reported outcome measure
QoL	Quality of life
RCT	Randomised controlled trial
SAR	Swedish Arthroplasty Register
SHS	Sliding hip screw
SMFA	Short Musculoskeletal Function Assessment
SFR	Swedish Fracture Register
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
THA	Total hip arthroplasty
VAS	Visual analogue scale
WHO	World Health Organisation

Preface

This project started in 2017 using data from the Swedish Fracture Register (SFR) to gain insight into the current treatment regimes of femoral neck fractures (FNFs) in Sweden. The SFR data are of particular value, as the SFR contains detailed information on fracture types and the surgeon's competence, information that cannot be retrieved from any other Swedish register.

According to data from the SFR, the use of internal fixation (IF) in displaced FNFs (dFNFs) has declined over the past 10 years in Sweden from about 10 to 5% in patients >60 years. Because many individuals aged 60-69 years are healthy and may better withstand treatment failure, reoperation and subsequent lengthened rehabilitation after a failed IF, some might be prone to "gamble" on IF, with the benefit of retaining the properties of a biologically intact hip joint. With a plausible long remaining lifespan of 20 to 30 years, an arthroplasty as primary treatment may result in long-term complications, such as aseptic loosening, periprosthetic fractures and late infections.

In the first study, the patient-reported outcome (PROM) at 1 year evaluated potential differences in reported EQ-5D and the Short Musculoskeletal Function Assessment (SMFA) between patients treated with either IF or THA, the main options for healthy, independent patients in this age interval. The following studies focused on reoperations and reoperation-related risk factors. Most patients treated with IF who suffer a major complication will be offered a conversion to arthroplasty. In contrast, major revision surgery is needed for serious complications for patients treated with arthroplasty as primary treatment. Therefore, we chose cross-referencing based on personal identity numbers (PINs) with the Swedish Arthroplasty Register (SAR), a mature register with high completeness for revision surgery.

Despite their pitfalls and risk of confounding, register data offer insight into current treatments and outcomes. Working with these data and witnessing the SFR's evolution over the past decade has been a fascinating journey. Our data and upcoming register randomised controlled trials (rRCTs) in progress might lead us closer to a conclusive treatment algorithm for FNFs.

Alingsås, October 2023

Introduction

History of femoral neck fracture treatment

Femoral neck fractures (FNFs), first described in the 1600s by French surgeon Ambrose Pare, were considered untreatable by surgery. The modern treatment era began in the early 1800s when Sir Astley Paton Cooper published a novel classification for FNFs divided into intracapsular and extracapsular, in which the former was considered almost impossible to treat (1). Opposing this view was British surgeon Henry Earle, who attempted to treat these fractures using a specially designed traction bed, similar to modern hospital beds (2).

Internal fixation

Franz König described the first successful internal fixation (IF) in 1875 by percutaneous insertion of a gimlet under aseptic conditions, obtaining union of the fracture. Various fixation methods were attempted during the late 1800s and early 1900s with varying results. In 1931, the American surgeon Smith-Petersen

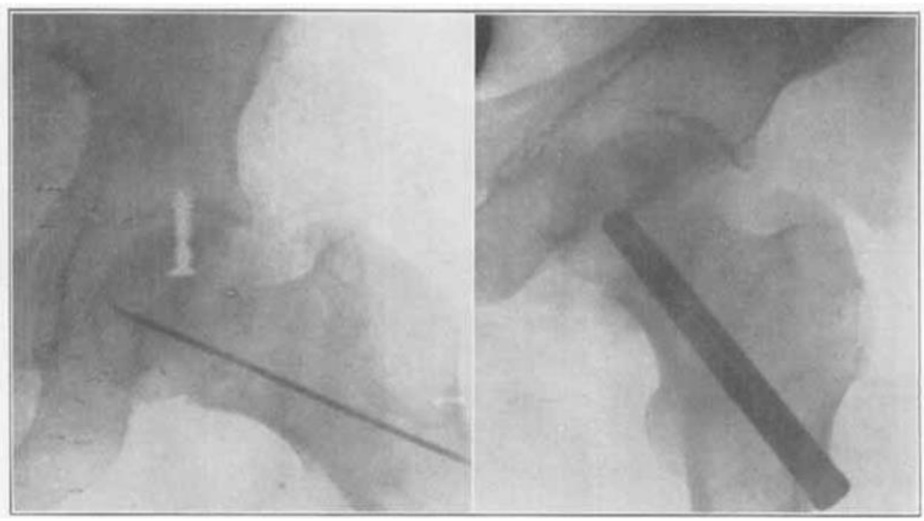

Figure 1 The use of a 2 mm in diameter wire to guide the modified Smith-Petersen nail in the femoral neck (image from the 1932 paper by Johansson).

presented a three-flanged femoral neck nail (trifin nail) that was inserted after open fracture reduction, enabling early mobilisation of the patient. Sven Johansson, a

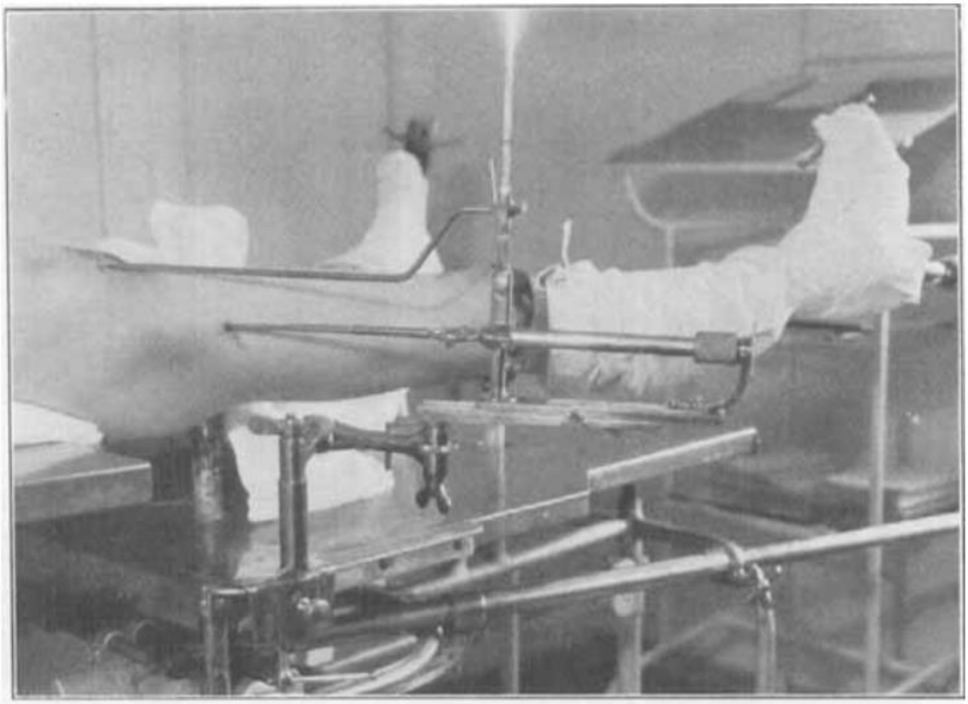

Figure 2 Sven Johansson's guide device for positioning the wire in the femoral neck (image from the 1932 paper)

Swedish orthopaedic surgeon, had the ambition to minimise exposure with closed reduction and developed a pin-guided nailing system (3). He made a central canal in the Smith-Petersen-type nail to be inserted over a previously placed "strong metal wire." Thus, the canulated technique for hip surgery was born (Figure 1 and 2). Johansson also built new operating facilities in Gothenburg that allowed intraoperative X-rays (skiagrams) to confirm correct wire placement, voiding the need to roll back and forth to the X-ray department during the procedure. In the 1980s, the Asnis cannulated screws were introduced and are still used today (4), among other types of canulated screws (two to four) in varying configurations. Other nails and pins have also been introduced in Sweden. The most commonly used nails/pins are the Olmed screw (Olmed; DePuy/Johnson & Johnson, Sollentuna, Sweden) (5) and the LIH, or Hansson hook pin, with integrated locking blade (Hansson Pin® System, Swemac, Linköping, Sweden) (6). Because of the early drawbacks of primary arthroplasty, Scandinavian countries preferred IF as the primary treatment of dFNFs until the millennium (see below).

Arthroplasty

In the 1950s, several hip arthroplasty systems were developed to minimise failures after IF. These were primarily hemiarthroplasty (HA) systems, such as Thompson (1950), Austin-Moore (1950) and Lippmann (1952) (7-9). Some of these were also placed with a metal acetabulum component, including the one developed by George McKee in 1953 based on the Thompson stem, although primarily for arthritis (10). The birth of low-friction arthroplasty must be attributed to Sir John Charnley, who, in the 1960s, developed the blueprint for modern total hip arthroplasty (THA) systems still used today (Figure 3). He proposed a metal stem with a metal head integrated and a polyethylene acetabular component, both fixed with acrylic bone cement (initially borrowed from dentists) (11). Using THA as the primary FNF treatment was burdened in the 1970s by persistently high failure rates (12).

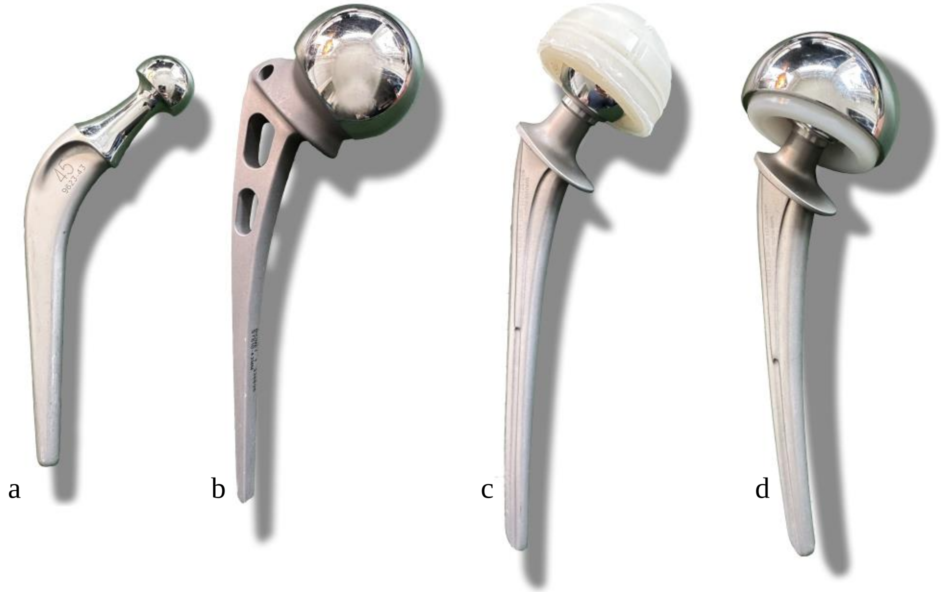

Figure 3 From left to right: two outdated arthroplasty stems; a) Charnley stem for THA, b) Austin-Moore monoblock HA. Two modern implants; c) Lubinus SP II with polyethylene cup (THA), d) Lubinus SP II with VarioCup (bipolar HA)

Anatomy of the hip

The hip constitutes the most proximal part of the femur. It has a trochanteric region that acts as the origin for many muscles and is thus well-supplied with blood vessels. Then there is the femoral neck, which is mainly intraarticular. This region is not as well supplied with blood, and the few vessels supplying blood are prone to injury if the neck is fractured (13). If these vessels are compromised, the femoral neck will likely see healing disturbances ranging from delayed union to non-union. The femoral neck terminates in the femoral head, which is covered in cartilage and creates a "ball and socket" type of joint to the pelvis. The cartilage receives nutrients from the synovial fluid, but the underlying cancellous bone depends on the endosteal blood supply.

The hip fractures classification distinguishes between intracapsular (femoral neck and head) and extracapsular fractures. Most intracapsular fractures are FNFs and can be further divided into non-displaced or displaced fractures, with the degree of displacement affecting healing potential and influencing treatment decisions (14). According to data from the 2022 SFR, 12% of all hip fractures were nFNFs and 36% were dFNFs in patients ≥60 years.

Extracapsular fractures (trochanteric and subtrochanteric fractures) do not have the same healing problems as FNFs, as they rarely affect the blood supply to the proximal femur. Trochanteric fractures, which occur in the metaphyseal bone between the greater and lesser trochanters, constitute 35% of all hip fractures in Sweden. In contrast, subtrochanteric fractures, which occur within 5 cm distal to the lesser trochanter, account for 8% of all hip fractures (15).

Epidemiology

The hip fracture is regarded as the fracture of the elderly. Despite declining trends in incidence in most countries, prevalence worldwide is projected to rise because of an ageing population (16). The WHO predicts that the population aged ≥65 will increase almost three-fold from 2010 to 2050 (17) while population growth in the young will subside. Because of variations in the coverage of national quality registers and lack of laterality and miscoding in administrative registers, we do not know the exact annual rate of hip fractures in Sweden. SFR data suggest approximately 15,000 hip fractures per year over the past years, but the completeness of the SFR is closer to 85% (18), suggesting a somewhat higher prevalence (i.e., about 18,000). The majority (96%) of hip fractures registered in the SFR are in patients ≥60 years of age (Figure 4). In Sweden, the lifetime risk of hip fracture is 11% for men and 20% for women (19).

Recent evidence suggests that for the patient age group above 50 years, the Nordic countries have one of the highest age- and sex-standardised incidences globally (16). However, precise comparisons between countries are difficult as regards data standardisation (20). FNFs constitute about 50% of all hip fractures reported in Sweden (15).

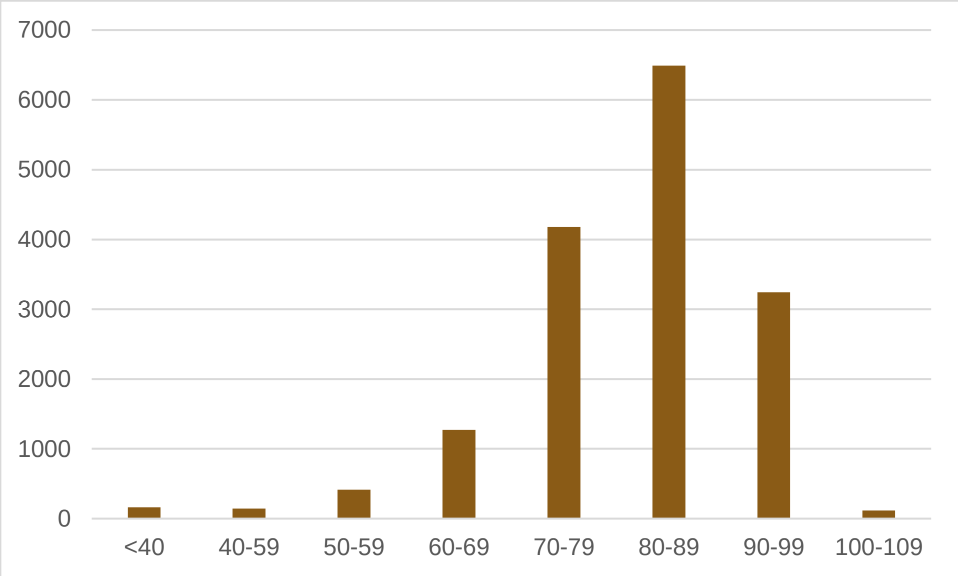

Figure 4 Age distribution of all hip fractures in the SFR 2022

Osteoporosis

Osteoporosis is a serious bone disease, increasing the risk of fractures. Fundamentally, the condition is an imbalance between bone-resorbing (osteoclasts) and bone-forming cells (osteoblasts) in favour of the osteoclasts. In women, the leading cause is rapid hormonal changes related to menopause, resulting in net bone resorption. In men, the decline in sex hormones is much slower, causing a milder net increase in bone resorption (21). It is a major public health problem, previously thought mainly to affect postmenopausal women. Newer research has highlighted osteoporosis as an underlying factor in at least hip fractures in all ages and sexes (22). The most common manifestation is hip, spine, upper arm, forearm or pelvis fractures. Hip and spine fractures are the most severe injuries resulting in suffering, disability and high societal costs (23). Several medical treatments are available to prevent osteoporosis, but diagnosing the condition before it manifests as a fracture is challenging. WHO has published diagnostic criteria for osteoporosis in postmenopausal women based on T-score for bone mineral density below -2.5 standard deviations (SDs) from the young female adult mean (24). Applying this definition, approximately 6% of men and 21% of women aged 50-84 years have osteoporosis in Sweden (25).

Geriatric considerations and the concept of frailty

The risk of fracture is further increased by the ageing process. Adding to the burden of osteoporosis is loss of proprioception, muscle mass loss, dizziness and vertigo. Problems such as dizziness increases steadily with age, and the incidence in patients >65 is approximately 30%, rising to 50% in people >85 (26). Age is also known to correlate with depression and isolation and does not necessarily manifest as affective disorder but as cognitive impairment (27). Cognitive impairment is also associated with a higher risk of hip fracture. The prevalence of cognitive impairment in hip fracture patients is estimated at up to 55% (28). Frailty is an attempt to gather health-threatening aspects of ageing into a single concept. Frailty can be categorised into five groups: slowness, weakness, weight loss, low activity and fatigue. If an individual is deficient in three or more domains, the individual is classified as frail. Frailty is associated with an increased risk of falls, death, and a decline in health-related quality of life (HRQoL) (29).

Hip fractures are a significant cause of morbidity and mortality in older adults, with over 10 million cases occurring worldwide annually (30). Patients over 60 are particularly vulnerable to hip fractures, with the incidence of hip fractures increasing exponentially with age. The burden of hip fractures on healthcare systems and individuals is significant, with high mortality rates, morbidity and disability, as well as spiralling health care costs (31-34).

Old? Says WHO?

The thesis opted for the arbitrary age cut-off of 60 years to define the elderly population in concordance with the definition of WHO and the UN when developing the Decade of Healthy Ageing 2021-2030 (35). Studies on hip fractures in ‘the elderly’ sometimes even include patients from 50 years of age. To make matters more complicated, the orthopaedic research community still has no consensus on an age limit (36). Hip fractures usually occur in patients over 60 (Figure 4). Ageing is heterogeneous and chronological age is a crude instrument to describe it, although it is easily comprehended. Therefore, it might be more appropriate to determine the biological age of the patient, which encompasses genetics, lifestyle, environmental exposure and diseases (37). Determining the extent of frailty (see above) is an attempt to define biological age more precisely.

Classification of fractures

Several classification systems for FNFs have been proposed, but all suffer from low inter-rater reliability (38). Two major classifications are still used today: the first biomechanical classification by Pauwel, presented in 1935, and Garden's classification from 1961 (39, 40). Although Garden's classification offers higher reliability than Pauwel's (41, 42), it still suffers from low inter-rater reliability and low ability to predict outcome for malunion and avascular necrosis (43-45). The main weakness is differing Garden grades I and II fractures. Therefore, a simplified Garden classification has been proposed using only two instead of four levels (non-displaced and displaced) to increase reliability (45, 46). Non-displaced FNFs are also called undisplaced, although the Garden I type can be displaced in a valgus

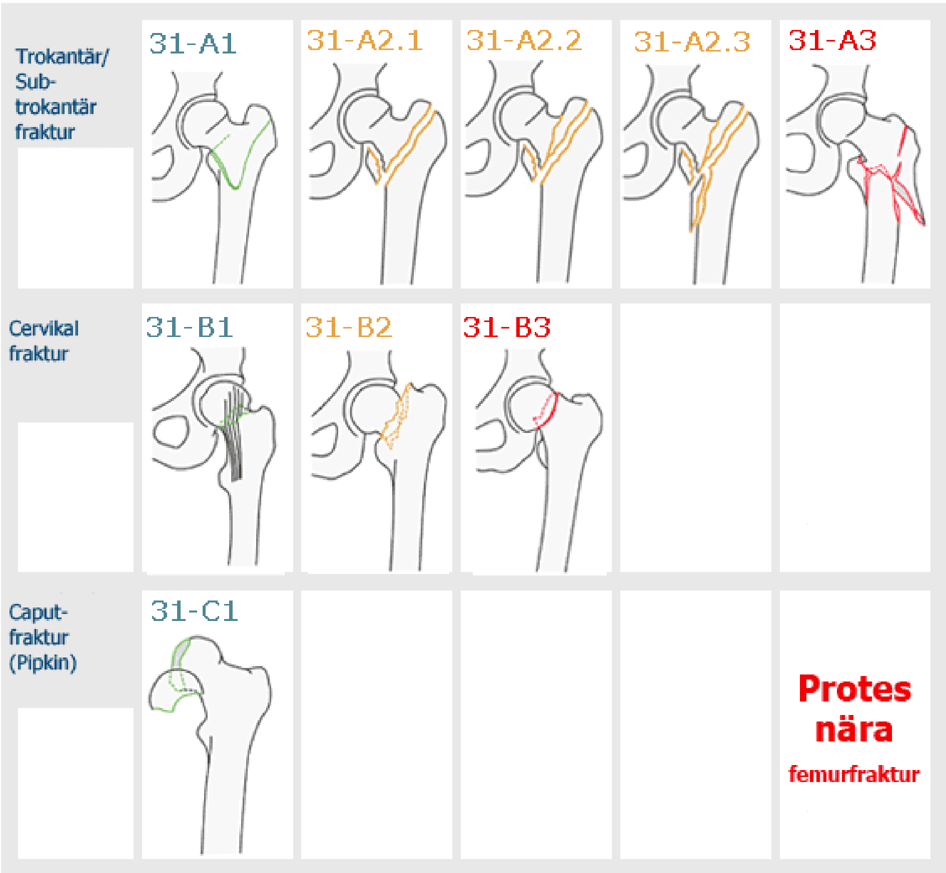

Figure 5 Classification of proximal femoral fractures in the SFR web interface

direction. This thesis chose the term “non-displaced,” adhering to the North American nomenclature. The SFR uses the 2007 AO/OTA system, classifying non-displaced fractures as 31-B1 and displaced fractures as 31-B3. This classification corresponds to Garden I-II and III-IV (Figure 5).

Several publications in the recent decade have also used the lateral image to evaluate posterior displacement of the femoral head in addition to the Garden classification. Some authors conclude that posterior tilt predicts a higher risk of later complications in treating nFNFs with IF (47-49).

Surgical treatment

Internal fixation

IF (or osteosynthesis) in hip fractures refers to fixing the fracture with 2-4 parallel hook pins or screws, with or without an additional plate coupling. A single screw or pin sliding in a socket connected to a larger supporting extramedullary plate, i.e., a sliding hip screw (SHS), can also be used. Whether one method has benefits over another has been extensively discussed. Still, results are divergent, and no implant has shown any clear advantage over the other regarding reduced complication rates (44, 50). The SHS has gained popularity after the FAITH study, suggesting that it is better in the subgroups of smokers and those with basicervical fractures (51).

The IF procedure is often employed for nFNFs of all ages and dFNFs in young and middle-aged individuals (52, 53). The advantage of IF is that it is a quick procedure with minimal surgical exposure and blood loss and preserves the patient’s femoral head. However, in elderly patients with a dFNF, the reoperation rate is as high as 30-50% due to blood supply disruption and subsequent healing complications (54-56).

Figure 6 Common implants for IF in Sweden. From left to right: Hansson hook pin, Olmed canulated screw, sliding hip screw

Arthroplasty

Over the past two decades, the treatment of dFNFs in Sweden has shifted from IF to arthroplasty, which is now the most common surgical technique, even for patients ≥50 years (57, 58). In Sweden, just over one third of all patients sustaining a hip fracture undergo arthroplasty. The increasing use of the method is due to lower reoperation rates and the benefit of a stable hip joint, allowing immediate postoperative mobility (25)

During hip arthroplasty, the femoral head and neck are removed and replaced with a metal stem that can be fixed with bone cement or uncemented with a coating to allow the ingrowth of cancellous bone. Hemiarthroplasty (HA) involves replacing only the head and neck of the femur, while total hip arthroplasty (THA) also includes inserting a cup in the acetabulum. HA has a larger head diameter than THA, reducing the risk of dislocation. Recurrent dislocations in THA and HA after hip fracture result in persisting deterioration of HRQoL (59). Occasionally, HA can cause acetabular erosion due to direct articulation against the cartilage. To reduce erosion and risk of dislocation, bipolar HAs have been developed, consisting of a smaller head articulating against a larger mobile head that articulates against the acetabular cartilage (Figure 3, d). Although studies have produced conflicting and inconsistent results in the articulation patterns in bipolar prostheses over time (60-62), they do not seem to reduce overall complication risk (63) or acetabular erosion compared to unipolar (64, 65). This thesis groups modern, modular hemiarthroplasties as there are no clear differences in the long run (64).

Although THA results in longer surgery and more blood loss than HA, mortality seems similar. No clinically meaningful difference in revisions, function and quality of life (QoL) between THA and HA has been found (64, 66). In Sweden, as in the UK, there is a national discrepancy in using THA or HA as a treatment for FNFs. The NICE guidelines (evidence-based recommendations for health and care in England) (67) state that THA should be offered to patients who can walk independently, are medically fit for the procedure and are without cognitive impairment. Still, the use of THA varies between 1 and 60% in NHS hospitals. In Sweden, we see an even greater variation; THA is used as the primary treatment of displaced FNFs in patients ≥65 years in between 1 and 93% of the cases at different hospitals (68, 69). In the USA, there is a trend towards increased use of THA in FNFs, especially in privately insured patients, perhaps reflecting the younger population with the potential for surgeon selection (70).

Comparing internal fixation and arthroplasty

Compared to IF, the benefits of arthroplasty are lower reoperation rates, which RCTs have established with long-term follow-ups of 10-15 years (55, 56, 71). Pain and functional outcomes after IF without healing complications have not shown superiority to successful arthroplasty (HA or THA) beyond a 1-year follow-up (56).

The most common complications after hip fracture-related arthroplasty are periprosthetic joint infection (PJI) and dislocation (63). These complications can be divided into early complications, such as PJI and dislocation, and later complications, such as periprosthetic fracture, septic or aseptic loosening, pain and acetabular erosion. The complication profile for arthroplasty differs from IF, where early displacement and non-union are diagnosed during the first 6 months, and avascular necrosis between 6 and 24 months. Thereafter, few complications occur.

The clinical results for patients with an acute fracture as a cause for their (total) hip arthroplasty cannot be derived from studies on patients treated because of osteoarthritis, as they are two groups of patients regarding overall health and life expectancy (72). Fracture patients have a higher risk of complications due to pre-existing co-morbidity and higher mean age (73). Some long-term complications are associated with advanced age and frailty. Although fracture patients were relatively fit and active when treated with a THA, they may be prone to periprosthetic fracture and late PJI when they reach advanced age. Nevertheless, most individuals suffering a hip fracture face a reduced life span compared to un-fractured age-peers (see below). Consequently, many will die with their initial arthroplasty in place.

Mortality

Individuals with hip fractures are often characterised by significant co-morbidities and frailty. Therefore, it is hard to disentangle whether the fracture causes post-fracture deaths or if they would have occurred anyway. It has been estimated that 17 to 32% (74) of deaths are causally related to the fracture itself. When considering that estimation, hip fracture leads to similar mortality rates as breast cancer or diabetes in Sweden in men and women >60 (74). Patients with hip fractures have a doubled mortality risk in the first year after injury compared to age-matched controls (75). Many factors have been identified as risks for excess mortality in these patients, including male sex, cognitive impairment, time to surgery and early discharge from the ward (76-80). Co-morbidity indices (e.g., the American Society of Anaesthesiologists score, ASA) are often used to estimate the risk of dying.

The Swedish Fracture Register

The SFR (81) was launched in 2011 to become a national quality register. To date, over 870,000 fractures have been registered. Coverage today is 100% and completeness for hip fractures is 81%, according to the latest analysis in 2023. FNFs are classified in the SFR according to the 2007 AO/OTA classification (82) as non-displaced (31-B1), basicervical (31-B2) and displaced (31-B3). Treatment is entered by the treating physician and transformed into its NOMESCO NCSP procedure codes (83). A validation study found a substantial inter- and intra-observer agreement for femoral fracture classification (84).

The patient-reported outcome measure (PROM) questionnaires used in the SFR contain an HRQoL instrument (the EQ-5D) (85) and a health-related functional status (the SMFA) (86). The questions are answered by the patients or a proxy (i.e., a relative or caregiver). Either alternative is recorded in the questionnaire.

The patient receives questionnaires by postal mail after the registration is complete. This procedure, called the PROM 0, evaluates, by recall, the patient's status the week before the hip fracture event. This method has previously been proven valid (87). Then, 1 year later, the same questionnaire is sent to the patient again, called PROM 1. Only those who return a PROM 0 and are still alive will be eligible for the PROM 1-questionnaire.

The Swedish Arthroplasty Register

The Swedish Hip Arthroplasty Register is one of Sweden's oldest registers, established in 1979, and is today merged with the Swedish Knee Arthroplasty Register into the SAR in 2020. The SAR prospectively collects data from all units performing arthroplasty in Sweden and thus has a coverage of 100%. The completeness has been reported to be up to 98%. Specific completeness for SAR is presented in each paper, depending on the date interval for data acquisition.

Both registers use the Swedish PINs, enabling researchers to follow patients across different registers in Sweden. The registers are automatically updated daily with data from the Swedish National Population Register (Swedish Tax Agency) to establish mortality rates.

Patient-reported outcome measure

EQ-5D

The EQ-5D is a well-established questionnaire for evaluating perceived health in five dimensions: mobility, self-care, daily activities, pain/discomfort and anxiety/depression. In each dimension, the patient can choose among three levels: no problems "1", some problems "2" and extreme problems "3". Thus, a score of "1,1,1,1,1" would indicate perfect health (no problems in any of the five dimensions). In addition, the EQ VAS grades self-rated health on a vertical visual analogue scale (VAS) ranging from "the worst health you can imagine" to "the best health you can imagine" (85). For the EQ-5D and EQ VAS, higher scores indicate better HRQoL.

With the 3-level EQ-5D (EQ-5D-3L) used in the SFR, one problem is the presence of a "ceiling effect". This ceiling effect occurs when too large a proportion of responders achieve the highest score on the questionnaire (i.e., when the responders' scores are clustered around the best possible score, defeating the purpose of the questionnaire). To mitigate this issue, the EQ-5D-5L was developed. While the resolution of possible scores amounts to $3^5 = 243$ discrete values in the EQ-5D-3L, the EQ-5D-5L has the benefit of $5^5 = 3125$ discrete values as it adds two more levels: no "1", slight "2", moderate "3", severe "4" and extreme problems "5". The EQ-5D-3L was used in the SFR until it was replaced by the EQ-5D-5L in 2019.

SMFA

The SMFA was developed in the late 1990s (86) to gauge physical function in patients and has since been translated and cross-culturally validated in multiple languages, including Swedish (88). It is divided into two indices: “the function index” (34 items) and “the bother index” (12 items). The functional index focuses on difficulties in performing certain activities, while the bother index evaluates how troubled the patient is by these limitations. The function index comprises 25 questions addressing limitations in various activities and 9 questions on how often these limitations occur. Both indices have responses ranging from “not at all difficult” to “unable to do” (function) and “not at all bothered” to “extremely bothered” (bother). In the time domain, answers range from “none of the time” to “all of the time”. Low scores on the SMFA denote better function.

Aims of the thesis

This thesis aims to study the current treatment regimens in patients >60 years of age with an FNF. The thesis specifically focuses on:

- Outcomes of treatment in older patients, including mortality rates, functional outcomes and QoL
- Surgical treatment options for FNFs and the choice of surgical technique, such as THA, HA or IF

The aim is to provide an updated, comprehensive overview of treatment and outcomes, thereby contributing to the current knowledge to improve care. Ultimately, this goal is to improve the outcomes and QoL of patients with hip fractures, reduce health care costs and address the increasing burden of hip fractures on healthcare systems and societies.

Specific aims

Paper I: The primary aim is to describe the treatment of dFNFs in patients aged 60-69, patient characteristics and crude mortality. A second aim is to compare PROMs and mortality 1 year after treatment with THA or IF.

Paper II: The primary aim is to describe the conversion rate to arthroplasty after IF of a nFNF in patients aged ≥60 years within 5 years of primary treatment. The secondary objective is to explore the conversion rate in different age groups and risk factors for conversion surgery and mortality.

Paper III: The primary aim is to describe the cumulative rate of conversion/revision arthroplasty and mortality within 5 years after IF and primary THA in patients aged 60-69 with a dFNF. A further purpose is to analyse risk factors for reoperations.

Paper IV: The aim is to analyse any difference in risk of conversion to arthroplasty after IF in a register cohort of prospectively collected data on FNF in patients ≥60 years.

Methods

Paper I

Study design

A cohort study of patients with a dFNF prospectively registered in the SFR.

Participants

Patients ≥60 years old with a dFNF were identified in the SFR by the fracture type AO/OTA 31-B3. The study period was from 2013 to 2016, resulting in 9,564 patients with eligible dFNFs. Of these 9,564 patients, 883 (9.2%) were 60-69 years old (Figure 7).

Data collection

All data were collected from the SFR, including epidemiological data (sex, age) patient reported outcome (EQ-5D and SMFA) and mortality. The database was checked for erroneous registrations (e.g., time and date errors and double registrations). Treatment options included arthroplasty (HA or THA) or IF (screws or hook pins), defined by their NOMESCO procedure codes (83) (Table 1).

Treatment codes in the SFR			
Arthroplasty		**Internal fixation**	
NFB09	HA, uncemented	NFJ49.1	IF, 2 pins
NFB19	HA, cemented	NFJ49.12	IF, >2 pins
NFB29	THA, uncemented	NFJ79.1	IF, 2 screws
NFB39	THA, hybrid	NFJ79.12	IF, >2 screws
NFB49	THA, cemented		

Table 1 Treatment codes in the SFR

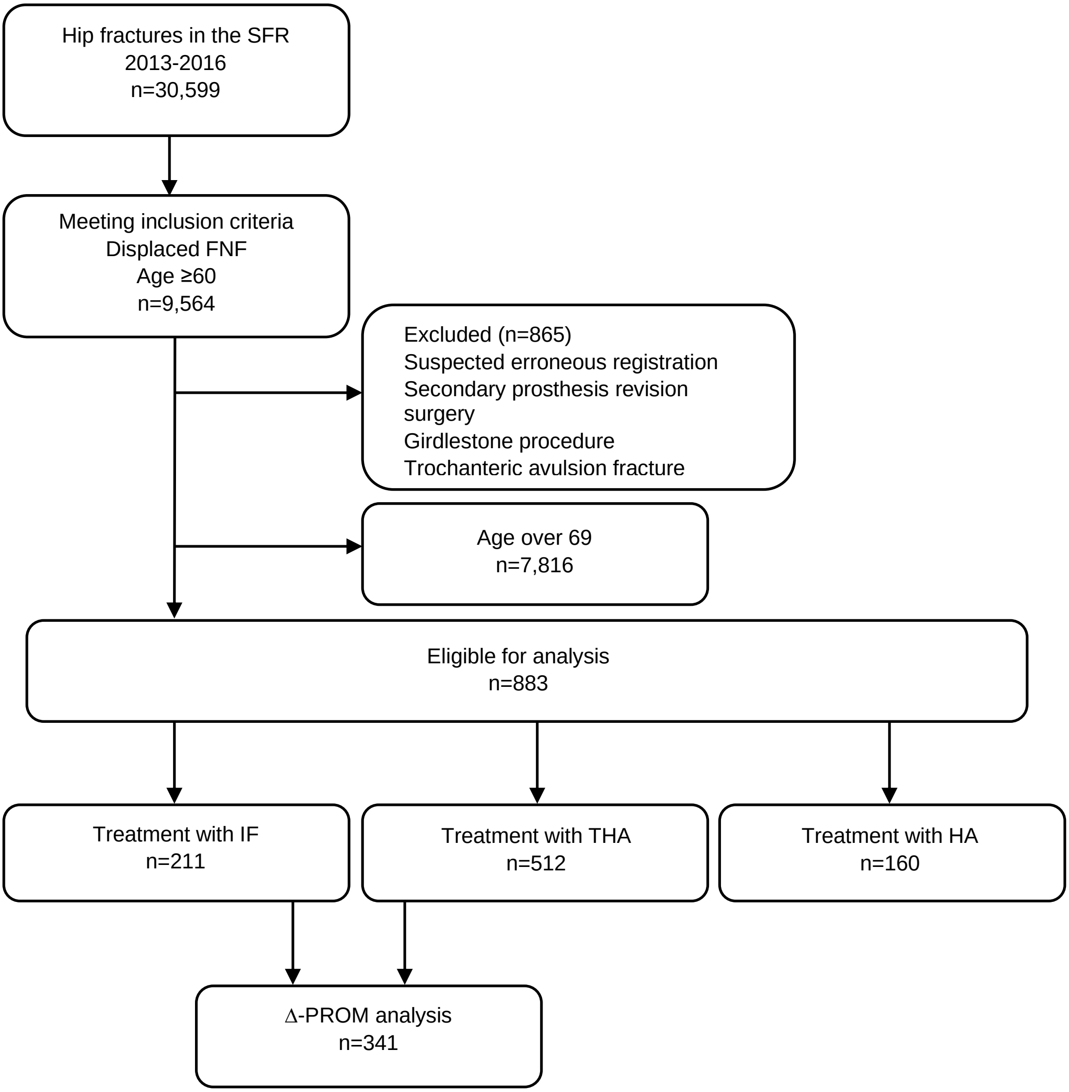

Figure 7 Flowchart of included and excluded patients in Paper I

Paper II

Study design

Papers II-IV were observational cohort studies based on data from the SFR in 2012-2018 and from the SAR up to the end of 2019, following the STROBE guidelines (89). We cross-referenced cases in the SFR with the SAR to establish conversion rates to arthroplasty (after IF) and revision rates (after THA).

Participants

From 47,487 hip fracture registrations, 6,076 (13%) were classified as nFNFs (AO/OTA 31-B1) in patients aged ≥60 years. The exclusion criteria were errors in treatment codes or dates, repeated fracture in the same or contralateral hip, trochanteric avulsion fracture, the Girdlestone procedure and arthroplasty. After applying the exclusion criteria, the final sample comprised 5,428 cases treated with IF (Figure 8).

Data collection

Information about injury type, sex, age, surgeon experience and mortality were obtained from the SFR. Cases with an nFNF treated with IF, as defined in Table 1 with the addition of NFJ89 for SHS, were cross-referenced with the SAR using the patient's PIN.

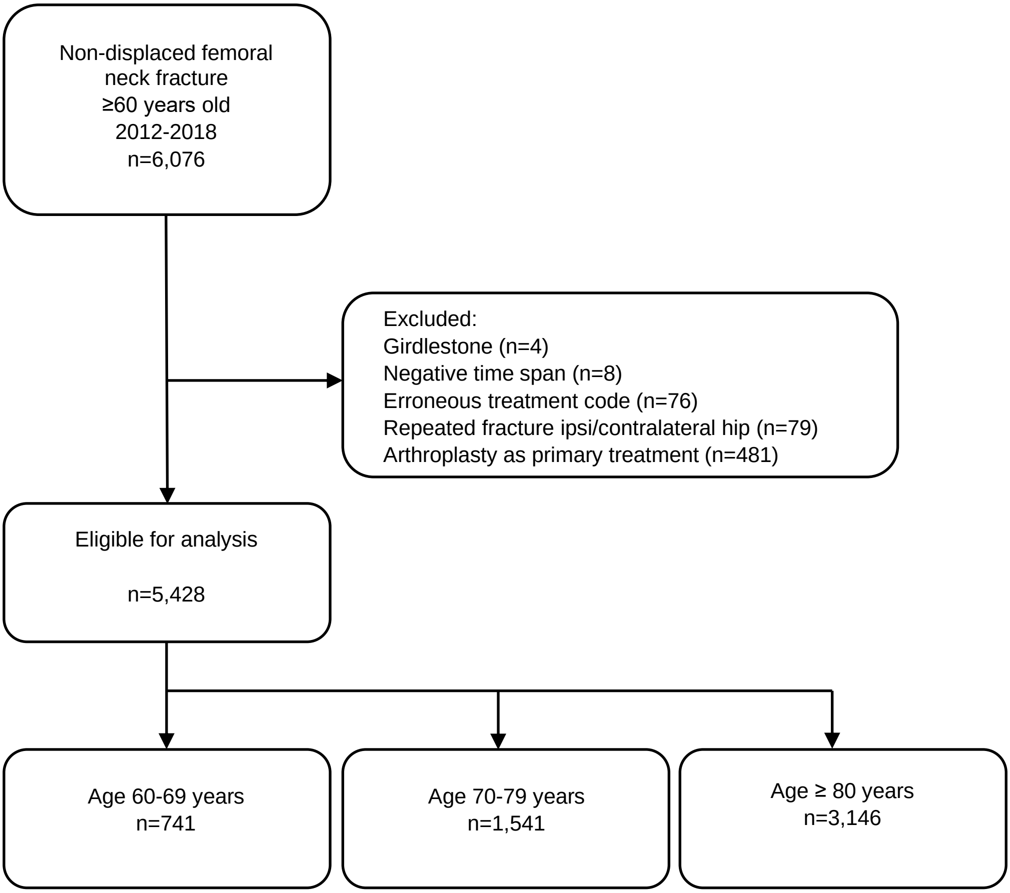

Figure 8 Flowchart of included and excluded patients in Paper II

Paper III

Study design

See Paper II.

Participants

Patients aged 60-69 with a dFNF treated with IF or THA were included. For IF cases, conversion to THA was the primary outcome. A major revision was the primary outcome measure for patients treated with THA. This arrangement rendered a study cohort of 1,238 patients, where 359 were treated with IF and 879 with THA (Figure 9).

Data collection

The same treatment codes for IF were used as in Paper I, with the addition of NFB89 for SHS. NFB29, NFB39 and NFB49 indicated THA (Table 1).

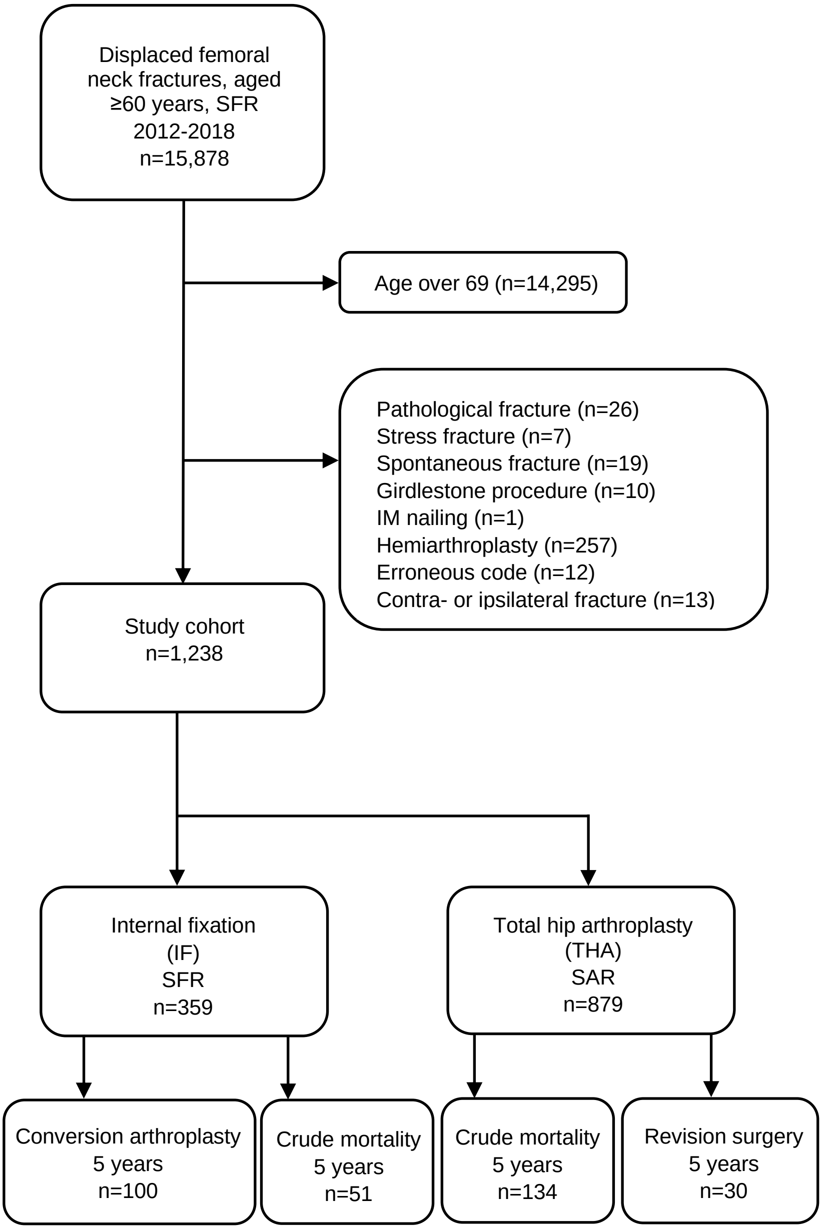

Figure 9 Flowchart of included and excluded patients in Paper III

Paper IV

Study design

See Paper II.

Participants

21,951 FNFs (AO/OTA 31-B1 or 31-B3) in patients aged ≥60 were found in the SFR. Patients with incorrect registration codes or dates, pathological, stress and spontaneous fractures were excluded. In addition, patients treated with intramedullary nails or the Girdlestone procedure were excluded. After exclusion, 6,464 patients treated with IF were analysed (Figure 10).

Data collection

Basic epidemiological variables (age, sex, type of injury and IF type) were collected from the SFR. Cross-matching between the SFR and SAR was performed similarly to Papers II-III. IF was defined as in Table 1 with the addition of NFJ89 for SHS.

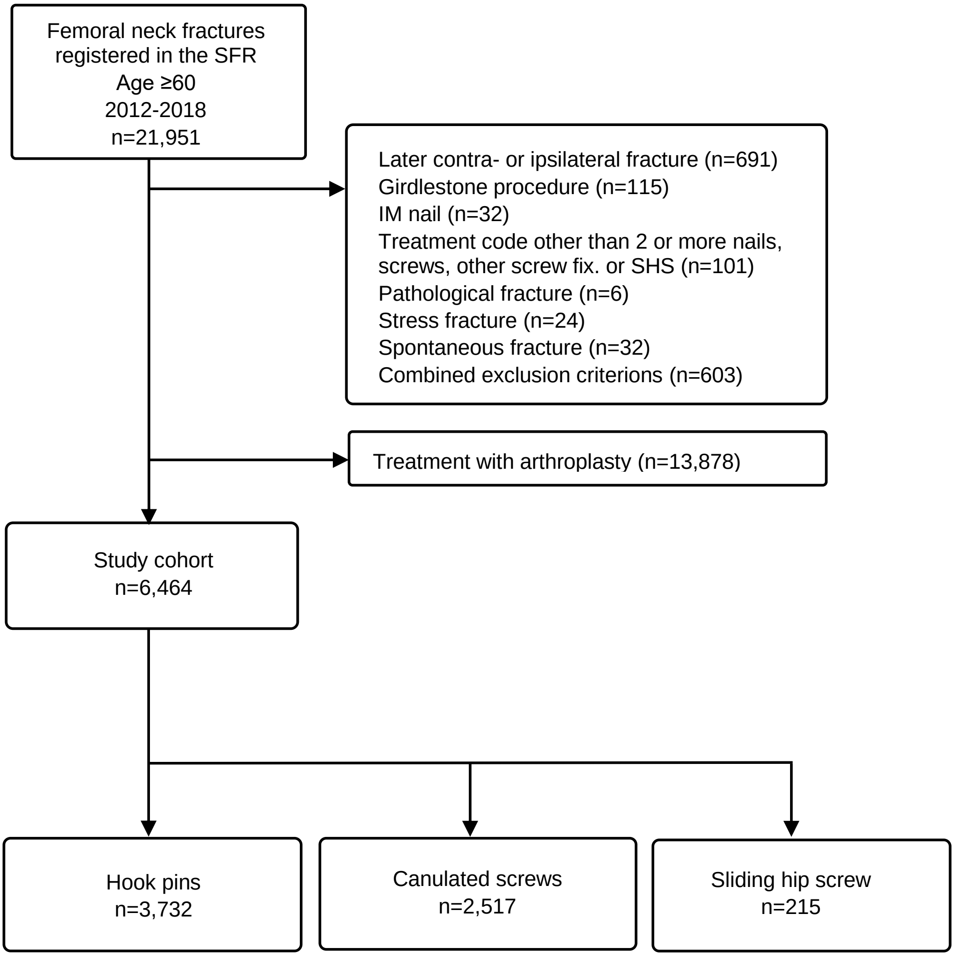

Figure 10 Flowchart of included and excluded patients in Paper IV

Statistics

Paper I

Baseline characteristics and means in EQ-5D and SMFA indices were analysed and compared between the three groups (THA, HA, IF) by analysis of covariance (ANCOVA) using age and sex as covariates and bootstrapping with 1000 samples to adjust for skewness in PROM scales and Bonferroni-adjusted post hoc analysis. Demographics, smoking, need for proxy and response rates were compared at baseline using Kruskal-Wallis (ANOVA) with Tukey's post-hoc analysis. Survival curves for patients treated with THA, IF and HA were generated with the Kaplan-Meier estimator. PROM means for THA and IF patients were compared with a general linear model (ANCOVA, univariate GLM). Treatment and sex were factors in the model and age (at the time of injury) and the respective baseline value of the PROM were included as continuous covariates. Results from this model were used to estimate the mean difference between groups and associated confidence limits. Paired samples t-tests were used for mean differences within treatment groups (THA and IF) using bootstrapping to compensate for skewness. The Pearson chi-square test was executed for PROM 1 response rates, the need for proxy and 1-year crude mortality. All p-values were two-tailed with a significance level (alpha) of 0.05. All analyses were computed using SPSS v25, IBM Corp.

Papers II-IV

Patient characteristics were described using counts with proportions and means with standard deviations (SD) and with interquartile ranges in Paper III (age). A competing risk model was used in Papers II-III to estimate conversion rates with death as a competing event as well as mortality using the "cmprsk" package in R statistics, rendering a cumulative incidence function (CIF) as a result, presented as percentages (95% confidence interval (CI)). In Papers II-III, the Cox proportional hazard model was used to stratify the risk of conversion to arthroplasty based on age, sex and surgeon experience. In paper IV, a similar model was employed to look at the risk of conversion to arthroplasty (dependent variable) with type of IF as the factorial variable and age, sex and surgeon experience as covariates. The assumption of proportional hazards was assessed by plotting Schoenfeld residuals. Hazard ratios (HRs) were presented with 95% CIs. The analyses were conducted using R version 4.0.2, R Foundation for Statistical Computing, Vienna, Austria.

Ethical considerations

Many countries highly trust research (and researchers) and believe in societal equality and shared responsibility. The research community must strive to preserve this trust. One reason is to maintain the high completeness and coverage of the Swedish national registers. Research questions must also be scrutinised and proven to move medical research forward by filling gaps in our knowledge to maintain the public's trust that their contribution matters. Cross-referencing between registers facilitates large cohort studies. With this comes the responsibility to not harm or expose individuals. Gathering large amounts of data on individuals from various registers can be seen as a breach of personal integrity. Before extraction, the data must be converted so PINs cannot be used to identify individuals.

Vigilance must be a priority in how data are presented. In "big data" research, some correlations might be of no clinical significance, or worse, false due to confounding. A sound interpretation based on clinical medicine is needed to avoid misinterpretation by media, politicians or patients.

Obtaining informed consent is considered not feasible when conducting register-based research. In the SFR and SAR, this is instead done on inclusion in the register(s). Information is given in written form, on the websites, in the ward and on PROM questionnaires. Individuals can deny their data to be used by the register, ca

All studies were conducted in accordance with the Helsinki Declaration. Paper I was approved by the Central Ethical Review Board in Gothenburg (dnr 63-2017). Papers II-IV were approved by the Central Ethical Review Board in Gothenburg (ref. 830-17) and by The Swedish Ethical Review Authority (diary number 2019-05024 and 2022-00972-02). The datasets are not publicly available, which is a requirement for ethical approval and is also regulated by the law on public access and secrecy; chapter 21, paragraph 7 and chapter 25, paragraph 1.

Funding for the studies was obtained from the Western Sweden County Council Research Fund, the independent trusts Axel Linder Foundation and Guldbyxan Foundation and the Gothenburg Society of Medicine.

Results

Paper I

THA was used in 512 (58%) patients and HA in 211 (18%). IF was used in 211 patients (24%). THA was more common in female patients. Patients treated with HA differed from those treated with IF and THA, with significantly lower scores in EQ-5D in their PROM 0, indicating lower overall perceived health before injury. They also had lower response rates to PROM and significantly higher mortality during the first year after their injury.

We found no PROM differences between patients treated with THA or IF (Table 2). Comparing PROM 0 and PROM 1 in patients treated with THA or IF, there was a significant decline in both EQ-5D and SMFA scores on follow-up. No difference in mortality was noted between THA and IF.

PROM (95% CI)	**THA**	**IF**	**p-value**	
EQ-5D Index	0.734 (0.697-0.767)	0.667 (0.614-0.726)	0.626	a
EQ-5D VAS	72.51 (69.1-75.9)	71.7 (66.4-76.7)	0.433	a
SMFA Dysfunction Index	24.1 (21.8-26.5)	25.6 (21.6-29.8)	0.928	a
Daily Activity Index	27.9 (24.3-31.8)	27.5 (22.3-33.3)	0.637	a
Emotional Index	30.4 (27.7-33.4)	33.8 (29.2-38.6)	0.779	a
Arm Hand Index	9.93 (7.88-12.0)	9.45 (6.15-13.3)	0.978	a
Mobility Index	27.4 (24.8-30.1)	31.4 (26.4-36.5)	0.478	a
SMFA Bother Index	21.5 (18.7-24.2)	24.9 (20.4-30.0)	0.236	a
PROM 1 response rate (%)	245/512 (48%)	96/211 (45%)	0.564	b
PROM 1 by proxy (%)	29/225 (13%)	8/85 (9%)	0.400	b
One year mortality (%)	19/512 (3.7%)	13/211 (6.7%)	0.145	b

a. ANCOVA adjusted for age, sex and baseline (PROM 0) representing differences

b. Pearson chi square test

Table 2 Differences in PROM means comparing treatment with THA and IF. General linear model.

Paper II

Low-energy trauma was the injury mechanism in 5,105 (94%) patients. In patients ≥80 years, 621/3,146 (20%) suffered injuries at any institutional living. The most common primary treatment method was “pins,” most likely Hansson hook-pins (n=3,106, 57.2%), followed by “screws” (n=2,084, 38.4%). SHS was used in 145 cases (2.7%).

Cumulative conversion rates to arthroplasty were 6.3%, 8.1% and 10.1% at 1, 2 and 5 years, respectively. Conversion rates within 2 years were 6.5%, 9.6% and 7.8% in age groups 60-69, 70-79 and ≥80, respectively (Figure 11, Table 3). Women had a higher risk of conversion, HR=1.49 (95% CI 1.19-1.87). Cumulative mortality was 21.3% (95% CI 20.3-22.5), 31.3% (95% CI 30.0-32.6) and 54.9% (95% CI 53.1-56.7) at 1, 2 and 5 years, respectively. Mortality was higher in males at all time points and the adjusted 1-year HR (aHR) was 1.79 (95% CI 1.61-2.00).

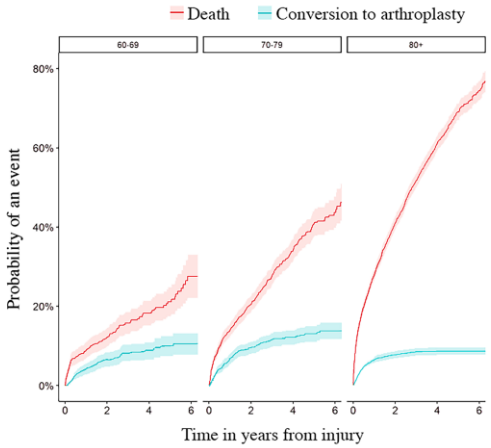

Figure 11 Conversion rates by age group. CIF in a competing risk regression model.

Age	Crude rate (%)	CIF (95% CI)
60-69 (n=741)		
1 year	31 (4.2%)	4.2 (3.0-5.9)
2 years	47 (6.3%)	6.5 (4.9-8.6)
5 years	61 (8.2%)	10.0 (7.7-12.9)
70-79 (n=1,541)		
1 year	104 (6.7%)	6.8 (5.6-8.1)
2 years	144 (9.3%)	9.6 (8.2-11.2)
5 years	174 (11.3%)	13.0 (10.6-15.1)
≥80 (n=3,146)		
1 year	205 (6.5%)	6.5 (5.7-7.4)
2 years	242 (7.7%)	7.8 (6.9-8.8)
5 years	261 (8.3%)	8.7 (7.7-9.8)

Table 3 Conversion rates in the three age groups.

Paper III

Some 359 of 1,238 patients were treated with IF (29%) and 879 (71%) with THA. THA patients were slightly older (median age 67 versus 64) and more often women (64 versus 50%). Low-energy trauma caused the fracture in over 9 of 10 cases.

The rate of conversion to arthroplasty after IF was 18% (95% CI 14-22) at 1 year. The crude rate was 63/359 patients. At 5 years, the cumulative rate rose to 31% (95% CI 26-37) with a crude rate of 100/359 (Figure 12). In the group treated with primary THA, the cumulative revision rate was 2% (95% CI 1-3) at 1 year, and the crude rate was 16/879 patients. At 5 years, the cumulative revision rate increased to 4% (95% CI 3-6) with a crude rate of 30/879 (Figure 13).

The 1- and 5-year mortality rates were 6% (95% CI 4-9) and 20% (95% CI 16-27) in the IF group compared to 3% (95% CI 2-5) and 23% (95% CI 20-28) in the THA group. Age, sex or surgeon experience did not influence the risk of secondary surgery in a Cox regression analysis.

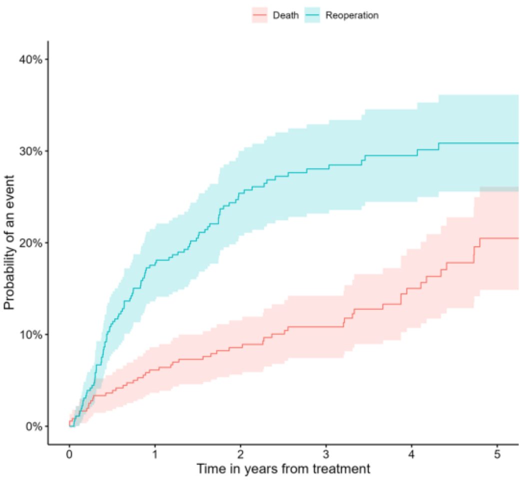

Figure 12 Conversion rate after IF in dFNF and mortality

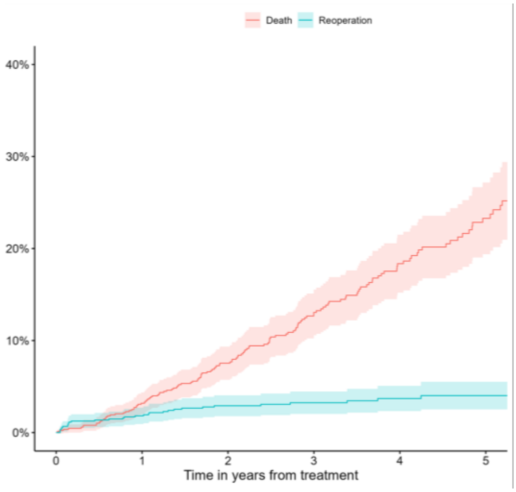

Figure 13 Major revisions after THA and mortality

Paper IV

The most common type of IF in Sweden during the study period was hook pins, with 3,732 (58%) cases, followed by canulated compression screws (2,517 or 39%). Only 215 patients (3%) were treated with SHS. A minority of cases were reported as more than two screws or hook pins (3%), which was more common in dFNFs (10 vs. 5%).

None of the commonly used implants in Sweden was associated with any significantly elevated risk of subsequent conversion to arthroplasty for the entire cohort. Female sex was a significant factor for later conversion to arthroplasty (HR 1.4, 95% CI 1.2-1.7) (Table 4). The most significant risk factor for later conversion was fracture displacement, where dFNFs had an HR of 2.23 (95% CI 1.89-2.64). In a subgroup analysis of nFNFs and dFNFs, we found no significant difference in risk of conversion related to implant selection. However, female sex remained significant for nFNFs (HR=1.57, 95% CI 1.26-1.95). In dFNFs, increasing age had a negative effect on risk of conversion (HR=0.98, 95% CI 0.97-0.99).

	HR	95% CI	p-value
dFNF	2.23	1.89-2.64	<0.001
Canulated screws	1.04	0.89-1.21	0.63
Sliding hip screw	1.11	0.76-1.63	0.58
Age	0.99	0.98-0.99	0.05
Female sex	1.45	1.22-1.72	<0.001
Surgeon experience*	1.10	0.94-1.28	0.22

* consultant

Table 4 Hazard ratios for conversion to arthroplasty. Hook pins and nFNF were the reference in the regression model.

Discussion

Surgical considerations

Displaced FNFs

In the geriatric population, the evidence is strong that arthroplasty is superior to IF in dFNF cases regarding failure, revision surgery and PROM (90-93). There are fewer studies on the "young old", but three RCTs have found better functional outcome and fewer reoperations after arthroplasty in patients >60 years (36, 54, 94). In line with this finding, we focused on patients aged 60-69, where arthroplasty as primary treatment is not as established as in older patients. 22% of this age group were treated with IF during 2012-2018 (data from the SFR website). The age threshold for IF versus arthroplasty varies between and within countries. When designing Paper III, we conducted an informal survey sent to orthopaedic trauma units reporting to the SFR. Most of the 23 responders used a mean age cut-off of 65 years for IF, where older patients would be treated with arthroplasty. IF may be a joint-preserving option with conversion arthroplasty as an established salvage procedure. However, from a patient's perspective, one third will experience prolonged pain and disability during the period leading up to a reoperation. As acute primary treatment, THA will, on the other hand, sacrifice the joint, including those whose fracture would have healed if treated with IF (54). When analysing treatments in dFNFs, we noticed a sharp decline in IF usage in patients aged 65-70 but a gradual increase in patients aged ≥85. This pattern may be explained by IF being used as an alternative to arthroplasty in certain frail or terminally ill patients (Figure 14).

Non-displaced FNFs

In patients >60, arthroplasty has increased as primary treatment from 4 to 20% during 2012 to 2022, according to the SFR. This trend could reflect more focus on the degree of posterior tilt of the fracture. It might also be caused by the HipSTHeR-rRCT allocating patients >75 years to either IF or arthroplasty (95). IF performs better in nFNFs compared to dFNFs, with lower but still palpable reoperation rates of about 10-20% (96). Despite this, IF is considered the standard treatment in Sweden and other countries, while some countries have transitioned to using arthroplasty in most cases (e.g., New Zealand and Australia) (97). The best fixation method is under debate, although no apparent difference between hook pins, screws or SHS has been reported (25-27). This finding aligns with our results in Paper IV, where we found no association between implant types and conversion arthroplasty within 5 years post treatment. A systematic review demonstrated no difference between screws and fixed angle plates in functional status, HRQoL, 1-year mortality or unplanned return to theatre. No difference was seen in mortality when comparing screws and hook pins (50). Nevertheless, recommendations has moved from only using screws (98) to that a SHS may have advantages in some patients (51).

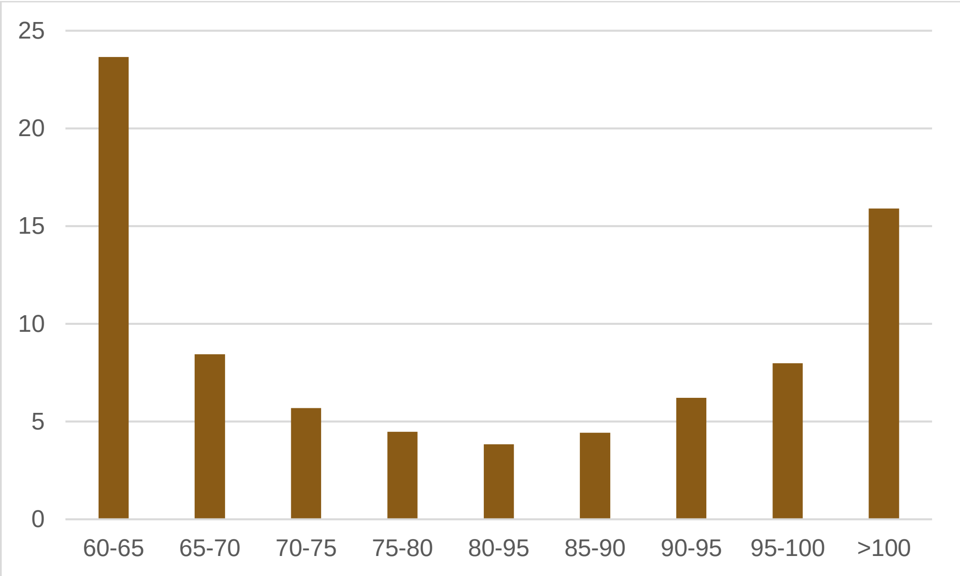

Figure 14 Proportion (%) of dFNF cases treated with IF in different age groups

Is the longevity of the implant a concern?

In cases with uneventful healing after IF, the role of the implant will diminish as the normal bone and joint resume load distribution and articulation. Some patients might experience discomfort because of protruding material, but this can be addressed with minor surgery, albeit with a small risk of refracture after hardware removal (99). On the other hand, arthroplasty is an artificial joint subjected to friction with a large surface of non-biological material. Thus, it has a theoretically limited longevity. A recent register report investigating implant survival for THA for all indications found 10-year revision rates at 5% or lower for patients >60 years (100). The cumulative revision rate at 15 years is 8% for fracture-related THA, according to the SAR annual report (63), but revision as outcome clearly underestimates the actual numbers of dislocation and infection. This observation concurs with our finding in Paper III of 4% major revisions within 5 years after treatment. Here, we need to extrapolate the future risk of (re-)revisions in the group of patients who survive decades after their fracture. In women <75 years, >20% may be alive after 20 years. The corresponding rate for same-age men is approximately

15% (101). The challenge lies in identifying these individuals at the time of injury to choose an implant that will serve them during a potentially long period.

The skills of the surgeon

No associations were found between the risk of reoperations and surgeon experience in Papers II, III and IV, although surgical skills might affect outcome after IF and arthroplasty. The quality of reduction is essential to reduce the risk of healing complications after IF (102). Mal-reduction and trochanteric shortening predict re-displacement in dFNFs (103). A Norwegian register study found that surgeons with <3 years of experience had an increased risk for reoperation after IF in dFNFs but not in nFNFs (104). In arthroplasty, dislocation is a common complication. Besides patient factors, such as elevated body mass index (BMI), neurological disease and cognitive impairment, surgical-related factors, such as femoral retroversion, increase the risk of dislocation (105). Losina et al. reported that high-volume elective arthroplasty surgeons have lower revision rates than their low-volume peers (106), which may also apply to THA after FNF.

Complications and mortality

The studies constituting this thesis focus on major reoperations, defined as conversion to arthroplasty for patients treated with IF or major revisions for those treated with arthroplasty. Other terminology has been employed depending on the primary treatment. In an older Cochrane review, the term “moderate” reoperation was used for patients treated with conversion to arthroplasty after IF, whereas “major” reoperation was reserved for conversion of HA to THA, the Girdlestone procedure or DAIR (107). In our studies, minor reoperations, such as wound debridement, removal of fixation hardware or closed reduction of dislocations, have not been included. This exclusion was mainly due to uncertainty in completeness in reporting reoperations to the SFR and difficulties in interpreting the severity of such procedures. Any reoperation is a burden for the patient and the healthcare system but removing an implant after successful healing should not be regarded as a complication. Also, one dislocation may be considered “minor,” provided the hip remains stable.

High failure rates are reported in dFNFs treated with IF (approximately 40%) (108). With a similar age group as ours, an RCT on dFNFs in ‘young elderly’ found minor reoperations in 16% of patients and major reoperations in 51% after IF. Corresponding percentages for THA were 4 and 0% (109). We found a lower conversion rate (31%) 5 years after IF but a somewhat higher rate of revision surgery in patients treated with THA (4%). The differences might be explained by different treatment regimens, selection bias and study design. RCTs provide good internal validity, i.e., reflecting the veracity of the patient group in the study. Register studies provide external validity, as patients and providers represent real-world situations. However, selection bias will be difficult to adjust for, as we cannot map all the reasons surgeons base their decisions on. We interpret the lower conversion rate in Paper III as a purposeful selection, i.e., surgeons can identify the patients/fractures with a lower risk of healing complications after IF. Although Sweden has a long history of registers with reporting results on the hospital level, treatment allocation differs between units (69), an illustration of how local traditions, in combination with the skills represented by local staff, influence the choices of methods.

Reoperation rates after IF for nFNFs of 8 to 16% have been reported (110). In Paper II, we found that every tenth patient with an nFNF treated with IF had a subsequent hip arthroplasty within 5 years and most conversions occurred within 1 year. The conversion rate to arthroplasty was highest in women and patients aged 70-79. These results may be attributed to a higher complication rate due to age-related causes, but in patients with higher functional demands compared to their octogenarian peers. A recent RCT found a major reoperation rate of 20% within 2 years after IF (96). This discrepancy in outcome between non-randomised and randomised trials has previously been described (111).

Failure of IF and subsequent need for arthroplasty conversion is a severe complication in older patients. The prolonged pain and discomfort caused by the complication are already detrimental. There have been concerns that a conversion arthroplasty after fixation failure may have an inferior outcome compared to primary hip arthroplasty (112, 113). A recent study contradicts those findings in patients aged 60-70 on the additional risk of revision (114), which may support the findings in Paper I. A reduction in reoperations using arthroplasty as primary treatment could benefit mobilisation and potentially decrease morbidity (115).

Whether implant choice could interfere with mortality is uncertain (110, 116, 117). Known factors associated with higher mortality rates are severe disease burden combined with marked cognitive impairment (80), as well as prolonged waiting time for surgery (118). In Paper I, patients treated with HA had significantly higher mortality, reflecting purposeful treatment allocation to this procedure due to shorter life expectancy and lower functional demands. The mortality rate was relatively low, and no difference was detected between patients treated with THA or IF. This lack of a difference could be expected, as these patients are generally not burdened with as many co-morbidities as older patients.

Patient factors will interfere with the risk of complications and death. For example, individuals with cognitive dysfunction treated with THA have an increased dislocation rate (32%) compared to 12% in cognitively intact peers (55) when the posterolateral approach was used, with a known correlation to dislocations (119, 120). Increased age-adjusted mortality risk has also been seen in men after hip fracture (121). In contrast, a pooled analysis (122) of the cohorts from the FAITH and HEALTH trials (51, 123) found only older age, lower BMI, higher co-morbidity score, pre-fracture use of ambulatory aid and kidney disease to be associated with increased mortality risk. In concordance with Danish and Australian studies (120, 123), Paper II found an elevated age-adjusted mortality risk in men. Similar to ours, both cohorts had higher mean ages in the FAITH and HEALTH studies.

Functional outcome and PROM

Gathering PROM on a national level calls for purposeful use of the data. Paper I was the first time PROM data from the SFR were analysed to compare treatment outcomes. Because IF has a failure rate of approximately one third in these patients (124, 125), we expected this to be reflected in lower satisfaction in the IF group. However, no differences in PROM outcome between the THA and the IF groups were found at 1 year. One interpretation of the limited decline in PROM after IF is that a patient treated with IF is well informed that the risk of fixation failure is high and that THA will be a suitable salvage procedure. If failure occurs, the patient may accept it better and recover during the first year. Another explanation may be that the PROM questionnaires are not sensitive enough to detect clinical changes in PROM for this group of hip fracture patients. Our findings are contradicted by another Swedish study showing that patients treated with THA were more satisfied than those treated with IF for a dFNF (126). Similarly, a Norwegian study reported better EQ-5D and EQ VAS in patients treated with THA (127). These two studies (126, 127) did not measure PROM at baseline, whereas Paper I analysed differences in 1-year changes in PROM between THA and IF.

Age and ageing

Individuals with a hip fracture at about age 65 constitute a heterogenic group. Most fracture their hip due to low-energy trauma, but some have sports-related injuries (128). The biological age span is wider than the chronological, but chronological age is the measurement that dominates clinical research. Determining biological age requires multiple parameters (37, 129), making it impractical in this setting. As an example, we analysed baseline PROM in all age groups when curating the data for Paper I and found that patients aged 60-69 treated with HA resembled those aged ≥80 regarding their HRQoL (EQ-5D) (Table 3).

	THA	IF	HA	p-value
60-69	0.75 (0.71-0.78)	0.68 (0.62-0.75)	0.55 (0.46-0.65)	<0.001 [a]
70-79	0.79 (0.77-0.81)	0.61 (0.50-0.71)	0.52 (0.48-0.56)	<0.001 [a]
≥ 80	0.72 (0.69-0.75)	0.45 (0.37-0.53)	0.53 (0.51-0.55)	<0.001 [a]

a. ANCOVA (adjusted for age and sex)

Table 3 EQ5D Index score - means at baseline in all ages with standard deviations

Paper II showed a decreasing rate of conversions to arthroplasty in patients aged ≥80. This reduction in rate might be due to severe co-morbidities, disqualifying the patient from major surgery. Another explanation could be that the geriatric population, either unfit or unwilling to seek health care, might mask the breadth of issues related to implant failure, avascular necrosis and non-union after IF. The most common barriers to seeing a physician in the USA are 'doctors lack of responsiveness to patients concerns', medical bills, transportation and street safety (130), where at least the first issue might also be apply to Sweden.

Similar findings of increasing age reducing the risk of major reoperations have been described in revision surgery from HA to THA (131, 132).

Age-related biological deterioration with decreased bone and muscle mass, vertigo, impaired vision, cognitive and neurological diseases, polypharmacy, and social isolation impose challenges in rehabilitation after hip fractures. In our first cohort (Paper I), patients treated with HA represented a frailer and unhealthier group, reflected in baseline PROM, than those receiving THA or IF. In addition, they responded to PROM to a lesser extent. Therefore, we focused our outcome analyses on the majority treated with either THA or IF, assuming they better represented the healthier and more active group the orthopaedic community refers to when discussing arthroplasty or IF in FNFs.

Injury and fracture classification

In baseline data for Papers II-IV, about 94% of all injuries were due to low-energy trauma. This percentage corresponds well with the literature stating that 96% of all hip fractures were caused by low energy trauma, i.e., fall from standing height and most often directly impacting the greater trochanter (133). Still, it would be worth seeing how a more active lifestyle in older people will affect the future distribution of trauma mechanisms. Reduced bone density is also discovered in high-energy trauma, as shown in younger hip fracture populations, below 60 years (22).

The most common mechanism in FNFs is a failure in tension between the anterior femoral neck and the compression in the posterior neck. Thus, there is usually posterior comminution as well as a posterior tilt of the femoral head in relation to the femoral neck. In nFNFs, preoperative posterior tilt >20° may increase the risk of failure requiring major reoperation (49, 134). However, even the less common anterior tilt of >10° may be linked to a significant risk of treatment failure (135). A novel classification, including the posterior/anterior tilt, might better predict outcomes in these fractures. Here, careful consideration must be given to which fractures were classified as nFNFs in Paper II because Swedish orthopaedic surgeons now tend to consider the lateral image, possibly classifying more fractures as dFNFs.

Financial aspects

Treatment options must be patient-oriented regarding treatment and outcome, but also cost-effective. We used a competing risk model in Papers II-III, which is a good fit for estimating cost given that only those that survive to experience a reoperation are counted. In dFNF, the conversion rate of 31% raises the question of cost burden, especially in a tax-financed healthcare system, considering additional costs of managing pain, outpatient consultations, sick leave or prolonged need of assistance in activities of daily living. The exact age limit at which to transit from IF and instead opt for arthroplasty has not been clearly defined. In younger patients, both options have potential drawbacks. IF may lead to non-union and osteonecrosis, while arthroplasty may need revision due to long-expected survival. Looking at dFNFs treated with IF, THA and HA, Swart et al. found that THA became more cost-effective than IF over the age of 54, and HA over the age of 68 (136).

Limitations

Response rates in Paper I were similar to those of the Norwegian Hip Fracture Register, approximately 60%. Notwithstanding, we acknowledge the limitations concerning non-responders (137). A previous study on SFR data concluded that non-responders do not differ in EQ-5D or SMFA compared to responders (138). Therefore, we argue that PROM results are reliable in patients treated with THA or IF, where using a proxy for filling out questionnaires is less common (19%) than in patients treated with HA (54%). Response rates to PROM questionnaires may depend on age, educational level and distribution method (e-mail, regular mail) (139). There is no scientifically proven low threshold to an acceptable response rate.

In Papers II-III, a competing risk model was developed with death as a competing event. Kaplan-Meier estimates, more commonly used for these estimations, tend to overestimate the status variable, death or other events. The competing risk model might explain why our findings of conversion to arthroplasty and revisions in THA are in the lower spectrum compared to similar studies. One could argue that results from a competing risk model are more complex to transform into patient information about risk - formulating the risk as "if you survive, the risk at time t is x." On the other hand, Kaplan-Meier estimates the risk regardless of mortality, which might be easier to understand for the patient. The strength of this approach is that it may be more appropriate for health care economics together with PROM to calculate cost-effectiveness and quality-adjusted life years.

All data contained in this thesis are based on what is available in the Swedish national registers, meaning that parameters such as radiograph data on co-morbidities and cognitive impairment are lacking. Such parameters are known to influence mortality risk and complication rates. In particular, as mentioned above, the surgical technique, including the placement of implants, can interfere with the risk of complications after IF or arthroplasty.

We focused on the two major complications following IF and THA: conversion arthroplasty and major revision surgery. Thus, we did not include milder complications, such as discomfort due to protrusion of implants, symptomatic femoral neck malunion, superficial infections, limb shortening or lengthening and general joint pain. Also not included are dislocation or periprosthetic fractures treated without revision surgery. Even if these conditions do not necessarily lead to subsequent surgery, they cause considerable pain, functional deficit and varying degrees of dissatisfaction.

In Paper II, we chose not to use PROM from the SFR as the response rate decreased in the older age groups. Thus, we were concerned about selection bias, i.e., that only those with low biological age would be the ones answering. For Paper III, we believe that the patient's viewpoint is covered by the design and results of Paper I. Finally, we did not find it plausible that minor differences in implant design would affect PROMs in Paper IV.

The strength of the four studies of this thesis lies in the prospectively collected register data, reflecting pragmatic clinical treatment choices yielding high external validity. In Papers II-IV, the high completeness of a relevant outcome is also considered a strength.

Conclusions

Displaced femoral neck fractures

THA is the most commonly used implant for dFNFs in patients aged 60-69 years, followed by IF and HA. Compared internationally, the use of THA is high in Sweden. The HA group differed from the IF and THA groups, with worse pre-fracture PROM and significantly higher mortality.

There were no differences in patient-reported outcomes or mortality between patients aged 60-69 treated with THA or IF at 1 year post-operatively. THA and IF appear as comparable treatments for patient-reported outcomes in these patients.

One third of patients with IF required conversion arthroplasty within 5 years. We discovered that 1 in 25 patients who underwent THA needed revision surgery. We consider the methods not directly comparable, given that their pros and cons are difficult to weigh against each other. Nevertheless, the risk of secondary surgery should be considered when discussing treatment options with patients in this age group (60-69 years).

Non-displaced femoral neck fractures

Patients ≥60 years with an nFNF have an acceptable surgical outcome; 1 of 10 converted to arthroplasty during the 5-year follow-up. We interpret our result to support the current regime with the fixation of an nFNF as the first choice for most patients. Nevertheless, a somewhat higher risk of conversion in women and in patients aged 70-79 can suggest subgroups in which primary arthroplasty should be studied.

Choice of implant

The choice of implant among those commonly adopted in Sweden does not seem to influence the risk of later conversion to arthroplasty in either nFNF or dFNF.

Clinical perspectives and future research

The number of patients around retirement age treated with IF for dFNFs is decreasing. According to the SFR data, it was 10% in 2022, which is less than half of the corresponding number in 2012. Therefore, the burden of conversion surgery might be expected to have decreased over this period.

Besides analysing how this decrease in IF will affect the current and future need for conversion and revision surgery, future research should focus on determining the most suitable treatment for each patient in the 'grey zone' where no clear evidence can support method choice. Such a process considers the contemporary demands on person-centred care by which the well-informed patient participates in treatment decisions. The challenge is determining for whom short-term complications (IF) or long-term outcomes (arthroplasty) should be decisive.

It seems the implant type of IF is less critical, as current implants have been proven over time, and no differences in outcome on conversion to arthroplasty can be seen. Instead, the focus should be on patient selection regarding co-morbidity, age, sex and fracture morphology. Computer-aided multi-variable analysis of risks for reoperations and mortality may be superior to the established fracture classifications. Moreover, advances in AI image interpretation might be a future solution if proven sufficient in predictive performance.

For treatment allocation, the main objective is to minimise risks for the patient while maximising results for mobility and overall patient satisfaction. Based on large data sets in the SAR, tools have been developed to aid risk assessment in planned arthroplasty for mortality and infection. A viable future goal could be to create a similar instrument for FNFs regarding the risk of either conversion to arthroplasty or revision of a primary arthroplasty.

Hard outcomes (e.g., reoperations and mortality) are not enough to describe outcomes after hip fracture surgery. Future research on, for example, HRQoL in the SFR with the EQ-5D-5L might yield novel knowledge related to treatment outcomes. The SFR now also enjoys 100% coverage to represent all treating units in Sweden.

As treating surgeons, we spend about an hour in surgery while leaving rehabilitation for the patient and physiotherapists for months or even years. We should dedicate our efforts to patients with hip fractures because only about half of those with independent mobility pre-fracture regain independent mobility (140). Such an approach would ensure that every unit offers a proven rehabilitation regime following discharge.

Acknowledgements

Many will go unmentioned. But in such a supportive and creative community of researchers, none are forgotten. You all have my sincere gratitude.

Cecilia Rogmark – principal supervisor. You made this happen, encouraging me all these years while mostly keeping remarkably cool.

Michael Möller – co-supervisor. The engine of the SFR. Thank you for your support and dedication to register-based research in Sweden.

Jan Ekelund, for all the help with the statistical work in Paper I and Hanne Carlsen for acute help with final statistics on Paper IV.

My co-authors in Papers II-III – Sebastian Mukka, Olof Wolf, Emma Nauclér, Sebastian Strøm Rönnquist and Jonatan Nåtman. Thank you for enduring the lengthy mail correspondences and my inability to understand tracking changes in Word. All colleagues in Sweden registering in the SAR and SFR and the coordinators of the SFR, especially Karin Pettersson and Monica Sjöholm – keep up the excellent work!

All patients who contribute to the register data, your participation improves future health care.

My colleagues at NÄL and Sjukhusen i Väster. Thank you for keeping a stiff upper lip in my absence while I was working on these papers.

My family. Maria, Vera and Bodil. I love you – always.

References

1. Cooper A. A Treatise on Dislocations, and on Fractures of the Joints. Ed 2. London: Longman, Hurst. 1823:114-76, 571-9.
2. Earle H. Practical Observations on Fractures at the Upper Part of the Thigh, and Within the Hip-Joint; with Critical Remarks on Sir A. Cooper's Work on this Subject. In: Earle H (ed). Practical Observations in Surgery London: Underwood. 1823:1-125.
3. Johansson S. On the Operative Treatment of Medial Fractures of the Neck of the Femur. Acta Orthopaedica Scandinavica. 1932;3(3-4):362-92.
4. Wood DJ, Gale DW, Stevens J. The ASNIS guided system for fixation of subcapital femoral fractures. Injury. 1991;22(3):190-2.
5. Olerud C, Rehnberg L, Hellquist E. Internal fixation of femoral neck fractures. Two methods compared. J Bone Joint Surg Br. 1991;73(1):16-9.
6. Hansson LI. Osteosynthesis with the hook-pin in slipped capital femoral epiphysis. Acta Orthop Scand. 1982;53(1):87-96.
7. Thompson FR. Vitallium intramedullary hip prosthesis, preliminary report. New York state journal of medicine. 1952;52(24):3011-20.
8. Moore AT. Metal hip joint; a new self-locking vitallium prosthesis. South Med J. 1952;45(11):1015-19.
9. LIPPMANN RK. Transfixion Hip Prosthesis: SEQUENTIAL CLINICAL AND ROENTGENOGRAPHIC OBSERVATIONS OF SIXTY-FOUR PATIENTS FOLLOWED FOR FIVE TO FIFTEEN YEARS. JBJS. 1967;49(5):876-90.
10. McKee GK, Watson-Farrar J. REPLACEMENT OF ARTHRITIC HIPS BY THE McKEE-FARRAR PROSTHESIS. The Journal of Bone & Joint Surgery British Volume. 1966;48-B(2):245-59.
11. Charnley J. Arthroplasty of the hip. A new operation. Lancet. 1961;1(7187):1129-32.
12. Greenough CG, Jones JR. Primary total hip replacement for displaced subcapital fracture of the femur. J Bone Joint Surg Br. 1988;70(4):639-43.
13. Zuckerman JD. Hip fracture. N Engl J Med. 1996;334(23):1519-25.
14. Kani KK, Porrino JA, Mulcahy H, Chew FS. Fragility fractures of the proximal femur: review and update for radiologists. Skeletal Radiol. 2019;48(1):29-45.
15. Swedish Fracture Register Annual Report 2021 (in Swedish) https://registercentrum.blob.core.windows.net/sfr/r/-rsrapport-SFR-2021-Uppslag-SkglmOgLuc.pdf. 2022.

16. Sing CW, Lin TC, Bartholomew S, Bell JS, Bennett C, Beyene K, et al. Global Epidemiology of Hip Fractures: Secular Trends in Incidence Rate, Post-Fracture Treatment, and All-Cause Mortality. J Bone Miner Res. 2023;38(8):1064-75.
17. World Health Organization. Global Health and Aging. 2011. Geneva: World Heath Organization.
18. Swedish Fracture Register Annual Report 2022 (in Swedish) https://registercentrum.blob.core.windows.net/sfr/r/-rsrapport-SFR-2022-By_ps8PU3.pdf. 2023.
19. Karampampa K, Ahlbom A, Michaelsson K, Andersson T, Drefahl S, Modig K. Declining incidence trends for hip fractures have not been accompanied by improvements in lifetime risk or post-fracture survival--A nationwide study of the Swedish population 60 years and older. Bone. 2015;78:55-61.
20. Johansen A, Hall AJ, Ojeda-Thies C, Poacher AT, Costa ML. Standardization of global hip fracture audit could facilitate learning, improve quality, and guide evidence-based practice. Bone Joint J. 2023;105-b(9):1013-9.
21. Riggs BL, Khosla S, Melton LJ, 3rd. Sex steroids and the construction and conservation of the adult skeleton. Endocrine reviews. 2002;23(3):279-302.
22. Strøm Rönnquist S, Viberg B, Kristensen MT, Palm H, Jensen JB, Madsen CF, et al. Frailty and osteoporosis in patients with hip fractures under the age of 60-a prospective cohort of 218 individuals. Osteoporos Int. 2022;33(5):1037-55.
23. Becker DJ, Kilgore ML, Morrisey MA. The societal burden of osteoporosis. Curr Rheumatol Rep. 2010;12(3):186-91.
24. Kanis JA. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: synopsis of a WHO report. WHO Study Group. Osteoporos Int. 1994;4(6):368-81.
25. Kanis JA, Johnell O, Oden A, Jonsson B, De Laet C, Dawson A. Risk of hip fracture according to the World Health Organization criteria for osteopenia and osteoporosis. Bone. 2000;27(5):585-90.
26. Jönsson R, Sixt E, Landahl S, Rosenhall U. Prevalence of dizziness and vertigo in an urban elderly population. Journal of Vestibular Research. 2004;14:47-52.
27. Kok RM, Reynolds CF, 3rd. Management of Depression in Older Adults: A Review. Jama. 2017;317(20):2114-22.
28. Holmes J, House A. Psychiatric illness predicts poor outcome after surgery for hip fracture: a prospective cohort study. Psychological medicine. 2000;30(4):921-9.
29. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, et al. Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci. 2001;56(3):M146-56.
30. Wu A-M, Bisignano C, James SL, Abady GG, Abedi A, Abu-Gharbieh E, et al. Global, regional, and national burden of bone fractures in 204 countries and territories, 1990–2019: a systematic analysis from the Global Burden of Disease Study 2019. The Lancet Healthy Longevity. 2021;2(9):e580-e92.

31. Borgström F, Zethraeus N, Johnell O, Lidgren L, Ponzer S, Svensson O, et al. Costs and quality of life associated with osteoporosis-related fractures in Sweden. Osteoporos Int. 2006;17(5):637-50.
32. Guirant L, Carlos F, Curiel D, Kanis JA, Borgström F, Svedbom A, et al. Health-related quality of life during the first year after a hip fracture: results of the Mexican arm of the International Cost and Utility Related to Osteoporotic Fractures Study (MexICUROS). Osteoporos Int. 2018;29(5):1147-54.
33. Svedbom A, Borgstöm F, Hernlund E, Ström O, Alekna V, Bianchi ML, et al. Quality of life for up to 18 months after low-energy hip, vertebral, and distal forearm fractures-results from the ICUROS. Osteoporos Int. 2018;29(3):557-66.
34. Leal J, Gray AM, Prieto-Alhambra D, Arden NK, Cooper C, Javaid MK, et al. Impact of hip fracture on hospital care costs: a population-based study. Osteoporosis International. 2016;27(2):549-58.
35. WHO's work on the UN Decade of Healthy Ageing. Internet. 2022.
36. Frihagen F, Nordsletten L, Madsen JE. Hemiarthroplasty or internal fixation for intracapsular displaced femoral neck fractures: randomised controlled trial. BMJ. 2007;335(7632):1251-4.
37. Tian YE, Cropley V, Maier AB, Lautenschlager NT, Breakspear M, Zalesky A. Heterogeneous aging across multiple organ systems and prediction of chronic disease and mortality. Nature Medicine. 2023;29(5):1221-31.
38. DeVellis RF. Inter-Rater Reliability. In: Kempf-Leonard K, editor. Encyclopedia of Social Measurement. New York: Elsevier; 2005. p. 317-22.
39. Bartonícek J. Pauwels' classification of femoral neck fractures: correct interpretation of the original. J Orthop Trauma. 2001;15(5):358-60.
40. Garden RS. Low-angle fixation in fractures of the femoral neck. J Bone Joint Surg Br. 1961;43B(4):647-63.
41. Gašpar D, Crnković T, Durović D, Podsednik D, Slišurić F. AO group, AO subgroup, Garden and Pauwels classification systems of femoral neck fractures: are they reliable and reproducible? Med Glas (Zenica). 2012;9(2):243-7.
42. van Embden D, Roukema GR, Rhemrev SJ, Genelin F, Meylaerts SA. The Pauwels classification for intracapsular hip fractures: is it reliable? Injury. 2011;42(11):1238-40.
43. Thomsen NO, Jensen CM, Skovgaard N, Pedersen MS, Pallesen P, Soe-Nielsen NH, et al. Observer variation in the radiographic classification of fractures of the neck of the femur using Garden's system. Int Orthop. 1996;20(5):326-9.
44. Parker MJ. Prediction of fracture union after internal fixation of intracapsular femoral neck fractures. Injury. 1994;25 Suppl 2:B3-6.
45. Van Embden D, Rhemrev SJ, Genelin F, Meylaerts SA, Roukema GR. The reliability of a simplified Garden classification for intracapsular hip fractures. Orthop Traumatol Surg Res. 2012;98(4):405-8.
46. Frandsen PA, Andersen E, Madsen F, Skjodt T. Garden's classification of femoral neck fractures. An assessment of inter-observer variation. J Bone Joint Surg Br. 1988;70(4):588-90.

47. Sjöholm P, Sundkvist J, Wolf O, Sköldenberg O, Gordon M, Mukka S. Preoperative Anterior and Posterior Tilt of Garden I-II Femoral Neck Fractures Predict Treatment Failure and Need for Reoperation in Patients Over 60 Years. JB JS Open Access. 2021;6(4).
48. Lapidus LJ, Charalampidis A, Rundgren J, Enocson A. Internal fixation of garden I and II femoral neck fractures: posterior tilt did not influence the reoperation rate in 382 consecutive hips followed for a minimum of 5 years. J Orthop Trauma. 2013;27(7):386-90; discussion 90-1.
49. Palm H, Gosvig K, Krasheninnikoff M, Jacobsen S, Gebuhr P. A new measurement for posterior tilt predicts reoperation in undisplaced femoral neck fractures: 113 consecutive patients treated by internal fixation and followed for 1 year. Acta Orthop. 2009;80(3):303-7.
50. Lewis SR, Macey R, Eardley WG, Dixon JR, Cook J, Griffin XL. Internal fixation implants for intracapsular hip fractures in older adults. Cochrane Database Syst Rev. 2021;3:CD013409.
51. Fixation using Alternative Implants for the Treatment of Hip fractures I. Fracture fixation in the operative management of hip fractures (FAITH): an international, multicentre, randomised controlled trial. Lancet. 2017;389(10078):1519-27.
52. Bhandari M, Devereaux PJ, Tornetta P, 3rd, Swiontkowski MF, Berry DJ, Haidukewych G, et al. Operative management of displaced femoral neck fractures in elderly patients. An international survey. J Bone Joint Surg Am. 2005;87(9):2122-30.
53. Rogmark C, Kristensen MT, Viberg B, Ronnquist SS, Overgaard S, Palm H. Hip fractures in the non-elderly-Who, why and whither? Injury. 2018;49(8):1445-50.
54. Chammout GK, Mukka SS, Carlsson T, Neander GF, Stark AW, Skoldenberg OG. Total hip replacement versus open reduction and internal fixation of displaced femoral neck fractures: a randomized long-term follow-up study. J Bone Joint Surg Am. 2012;94(21):1921-8.
55. Johansson T. Internal fixation compared with total hip replacement for displaced femoral neck fractures: a minimum fifteen-year follow-up study of a previously reported randomized trial. J Bone Joint Surg Am. 2014;96(6):e46.
56. Leonardsson O, Sernbo I, Carlsson A, Akesson K, Rogmark C. Long-term follow-up of replacement compared with internal fixation for displaced femoral neck fractures: results at ten years in a randomised study of 450 patients. J Bone Joint Surg Br. 2010;92(3):406-12.
57. Rogmark C, Spetz CL, Garellick G. More intramedullary nails and arthroplasties for treatment of hip fractures in Sweden. Acta Orthop. 2010;81(5):588-92.
58. Swedish Fracture Register Annual Report 2018 (in Swedish) https://registercentrum.blob.core.windows.net/sfr/r/sfr_2018_web-SJxxQsru4H.pdf. 2019.
59. Enocson A, Pettersson H, Ponzer S, Törnkvist H, Dalén N, Tidermark J. Quality of life after dislocation of hip arthroplasty: a prospective cohort study on 319 patients with femoral neck fractures with a one-year follow-up. Qual Life Res. 2009;18(9):1177-84.

60. Chen SC, Badrinath K, Pell LH, Mitchell K. The movements of the components of the Hastings bipolar prosthesis. A radiographic study in 65 patients. J Bone Joint Surg Br. 1989;71(2):186-8.
61. Phillips TW. The Bateman bipolar femoral head replacement. A fluoroscopic study of movement over a four-year period. J Bone Joint Surg Br. 1987;69(5):761-4.
62. Verberne GH. A femoral head prosthesis with a built-in joint. A radiological study of the movements of the two components. J Bone Joint Surg Br. 1983;65(5):544-7.
63. W-Dahl A KJ, Rogmark C, Nauclér E, Nåtman J, Bülow E, et al. The Swedish Arthroplasty Register: Annual report2023. Available from: https://registercentrum.blob.core.windows.net/slr/r/Ledprotesregistret-A-rsrapport-2023_SE-rkgP8dzo6h.pdf.
64. Lewis SR, Macey R, Parker MJ, Cook JA, Griffin XL. Arthroplasties for hip fracture in adults. Cochrane Database Syst Rev. 2022;2(2):Cd013410.
65. Lewis SR, Macey R, Stokes J, Cook JA, Eardley WG, Griffin XL. Surgical interventions for treating intracapsular hip fractures in older adults: a network meta-analysis. Cochrane Database Syst Rev. 2022;2(2):Cd013404.
66. Ekhtiari S, Gormley J, Axelrod DE, Devji T, Bhandari M, Guyatt GH. Total Hip Arthroplasty Versus Hemiarthroplasty for Displaced Femoral Neck Fracture: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. J Bone Joint Surg Am. 2020;102(18):1638-45.
67. Ftouh S, Morga A, Swift C, Guideline Development G. Management of hip fracture in adults: summary of NICE guidance. BMJ. 2011;342:d3304.
68. W-Dahl A KJ, Rogmark C, Nauclér E, Nåtman J, Bülow E, et al. The Swedish Arthroplasty Register: Annual report2022. Available from: https://registercentrum.blob.core.windows.net/slr/r/Svenska-Ledprotesregistret-rsrapport-2022_SE-2--BkxW4idh1s.pdf.
69. Hernefalk B, Rydberg EM, Ekelund J, Rogmark C, Möller M, Hailer NP, et al. Inter-departmental variation in surgical treatment of proximal femoral fractures: A nationwide observational cohort study. PLoS One. 2023;18(2):e0281592.
70. Stronach BM, Bergin PF, Perez JL, Watson S, Jones LC, McGwin G, et al. The rising use of total hip arthroplasty for femoral neck fractures in the United States. Hip Int. 2020;30(1):107-13.
71. Parker MJ, Pryor G, Gurusamy K. Hemiarthroplasty versus internal fixation for displaced intracapsular hip fractures: a long-term follow-up of a randomised trial. Injury. 2010;41(4):370-3.
72. Charette RS, Sloan M, Lee G-C. Not all hip arthroplasties are created equal. The Bone & Joint Journal. 2019;101-B(6_Supple_B):84-90.
73. Qin CD, Helfrich MM, Fitz DW, Hardt KD, Beal MD, Manning DW. The Lawrence D. Dorr Surgical Techniques & Technologies Award: Differences in Postoperative Outcomes Between Total Hip Arthroplasty for Fracture vs Osteoarthritis. The Journal of Arthroplasty. 2017;32(9, Supplement):S3-S7.
74. Kanis JA, Oden A, Johnell O, De Laet C, Jonsson B, Oglesby AK. The components of excess mortality after hip fracture. Bone. 2003;32(5):468-73.

75. Abrahamsen B, van Staa T, Ariely R, Olson M, Cooper C. Excess mortality following hip fracture: a systematic epidemiological review. Osteoporos Int. 2009;20(10):1633-50.
76. Al-Ani AN, Samuelsson B, Tidermark J, Norling A, Ekstrom W, Cederholm T, et al. Early operation on patients with a hip fracture improved the ability to return to independent living. A prospective study of 850 patients. J Bone Joint Surg Am. 2008;90(7):1436-42.
77. Bretherton CP, Parker MJ. Early surgery for patients with a fracture of the hip decreases 30-day mortality. Bone Joint J. 2015;97-B(1):104-8.
78. Johnell O, Kanis JA, Oden A, Sernbo I, Redlund-Johnell I, Petterson C, et al. Mortality after osteoporotic fractures. Osteoporos Int. 2004;15(1):38-42.
79. Nordstrom P, Gustafson Y, Michaelsson K, Nordstrom A. Length of hospital stay after hip fracture and short term risk of death after discharge: a total cohort study in Sweden. BMJ. 2015;350:h696.
80. Soderqvist A, Ekstrom W, Ponzer S, Pettersson H, Cederholm T, Dalen N, et al. Prediction of mortality in elderly patients with hip fractures: a two-year prospective study of 1,944 patients. Gerontology. 2009;55(5):496-504.
81. Wennergren D, Ekholm C, Sandelin A, Moller M. The Swedish fracture register: 103,000 fractures registered. BMC Musculoskelet Disord. 2015;16:338.
82. Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, et al. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. J Orthop Trauma. 2007;21(10 Suppl):S1-133.
83. NOMESCO N. NOMESCO Classification of Surgical Procedures (NCSP), version 1.16 [Internet]. Copenhagen; 2011. Available from: http://urn.kb.se/resolve?urn=urn:nbn:se:norden:org:diva-4605 2011. Available from: http://urn.kb.se/resolve?urn=urn:nbn:se:norden:org:diva-4605.
84. Knutsson SB, Wennergren D, Bojan A, Ekelund J, Moller M. Femoral fracture classification in the Swedish Fracture Register - a validity study. BMC Musculoskelet Disord. 2019;20(1):197.
85. EuroQol G. EuroQol--a new facility for the measurement of health-related quality of life. Health Policy. 1990;16(3):199-208.
86. Swiontkowski MF, Engelberg R, Martin DP, Agel J. Short musculoskeletal function assessment questionnaire: validity, reliability, and responsiveness. J Bone Joint Surg Am. 1999;81(9):1245-60.
87. Marsh J, Bryant D, MacDonald SJ. Older patients can accurately recall their preoperative health status six weeks following total hip arthroplasty. J Bone Joint Surg Am. 2009;91(12):2827-37.
88. Ponzer S, Skoog A, Bergstrom G. The Short Musculoskeletal Function Assessment Questionnaire (SMFA): cross-cultural adaptation, validity, reliability and responsiveness of the Swedish SMFA (SMFA-Swe). Acta Orthop Scand. 2003;74(6):756-63.

89. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453-7.
90. Gjertsen JE, Vinje T, Engesaeter LB, Lie SA, Havelin LI, Furnes O, et al. Internal screw fixation compared with bipolar hemiarthroplasty for treatment of displaced femoral neck fractures in elderly patients. J Bone Joint Surg Am. 2010;92(3):619-28.
91. Rogmark C, Johnell O. Primary arthroplasty is better than internal fixation of displaced femoral neck fractures: a meta-analysis of 14 randomized studies with 2,289 patients. Acta Orthop. 2006;77(3):359-67.
92. Gao H, Liu Z, Xing D, Gong M. Which is the best alternative for displaced femoral neck fractures in the elderly?: A meta-analysis. Clin Orthop Relat Res. 2012;470(6):1782-91.
93. Jiang J, Yang CH, Lin Q, Yun XD, Xia YY. Does Arthroplasty Provide Better Outcomes Than Internal Fixation At Mid- and Long-term Followup? A Meta-analysis. Clin Orthop Relat Res. 2015;473(8):2672-9.
94. Keating JF, Grant A, Masson M, Scott NW, Forbes JF. Randomized comparison of reduction and fixation, bipolar hemiarthroplasty, and total hip arthroplasty. Treatment of displaced intracapsular hip fractures in healthy older patients. J Bone Joint Surg Am. 2006;88(2):249-60.
95. Wolf O, Sjoholm P, Hailer NP, Moller M, Mukka S. Study protocol: HipSTHeR - a register-based randomised controlled trial - hip screws or (total) hip replacement for undisplaced femoral neck fractures in older patients. BMC Geriatr. 2020;20(1):19.
96. Dolatowski FC, Frihagen F, Bartels S, Opland V, Saltyte Benth J, Talsnes O, et al. Screw Fixation Versus Hemiarthroplasty for Nondisplaced Femoral Neck Fractures in Elderly Patients: A Multicenter Randomized Controlled Trial. J Bone Joint Surg Am. 2019;101(2):136-44.
97. ANZHFR Bi-National Annual Report of Hip Fracture Care 2021. Australian and New Zealand Hip Fracture Registry. 2021.
98. Parker MJ, Blundell C. Choice of implant for internal fixation of femoral neck fractures. Meta-analysis of 25 randomised trials including 4,925 patients. Acta Orthop Scand. 1998;69(2):138-43.
99. Barquet A, Giannoudis PV, Gelink A. Femoral neck fractures after removal of hardware in healed trochanteric fractures. Injury. 2017;48(12):2619-24.
100. Nugent M, Young SW, Frampton CM, Hooper GJ. The lifetime risk of revision following total hip arthroplasty. Bone Joint J. 2021;103-B(3):479-85.
101. von Friesendorff M, McGuigan FE, Wizert A, Rogmark C, Holmberg AH, Woolf AD, et al. Hip fracture, mortality risk, and cause of death over two decades. Osteoporos Int. 2016;27(10):2945-53.
102. Nyholm AM, Palm H, Sandholdt H, Troelsen A, Gromov K, Collaborators tDFD. Osteosynthesis with Parallel Implants in the Treatment of Femoral Neck Fractures:: Minimal Effect of Implant Position on Risk of Reoperation. JBJS. 2018;100(19):1682-90.

103. Parker MJ, Kendrew J, Gurusamy K. Radiological predictive factors in the healing of displaced intracapsular hip fractures. A clinical study of 404 cases. Hip Int. 2011;21(4):393-8.
104. Authen AL, Dybvik E, Furnes O, Gjertsen JE. Surgeon's experience level and risk of reoperation after hip fracture surgery: an observational study on 30,945 patients in the Norwegian Hip Fracture Register 2011-2015. Acta Orthop. 2018;89(5):496-502.
105. Hernigou P, Barbier O, Chenaie P. Hip arthroplasty dislocation risk calculator: evaluation of one million primary implants and twenty-five thousand dislocations with deep learning artificial intelligence in a systematic review of reviews. International Orthopaedics. 2023;47(2):557-71.
106. Losina E, Barrett J, Mahomed NN, Baron JA, Katz JN. Early failures of total hip replacement: effect of surgeon volume. Arthritis Rheum. 2004;50(4):1338-43.
107. Parker MJ, Gurusamy KS. Internal fixation versus arthroplasty for intracapsular proximal femoral fractures in adults. Cochrane Database of Systematic Reviews. 2006(4).
108. Ramadanov N, Jóźwiak K, Hauptmann M, Lazaru P, Marinova-Kichikova P, Dimitrov D, et al. Cannulated screws versus dynamic hip screw versus hemiarthroplasty versus total hip arthroplasty in patients with displaced and non-displaced femoral neck fractures: a systematic review and frequentist network meta-analysis of 5703 patients. J Orthop Surg Res. 2023;18(1):625.
109. Bartels S, Kristensen TB, Gjertsen JE, Frihagen F, Rogmark C, Dolatowski FC, et al. Total Hip Arthroplasty Leads to Better Results After Low-Energy Displaced Femoral Neck Fracture in Patients Aged 55 to 70 Years: A Randomized Controlled Multicenter Trial Comparing Internal Fixation and Total Hip Arthroplasty. J Bone Joint Surg Am. 2022;104(15):1341-51.
110. Onativia IJ, Slullitel PA, Diaz Dilernia F, Gonzales Viezcas JM, Vietto V, Ramkumar PN, et al. Outcomes of nondisplaced intracapsular femoral neck fractures with internal screw fixation in elderly patients: a systematic review. Hip Int. 2018;28(1):18-28.
111. Bhandari M, Tornetta P, 3rd, Ellis T, Audige L, Sprague S, Kuo JC, et al. Hierarchy of evidence: differences in results between non-randomized studies and randomized trials in patients with femoral neck fractures. Arch Orthop Trauma Surg. 2004;124(1):10-6.
112. Blomfeldt R, Tornkvist H, Ponzer S, Soderqvist A, Tidermark J. Displaced femoral neck fracture: comparison of primary total hip replacement with secondary replacement after failed internal fixation: a 2-year follow-up of 84 patients. Acta Orthop. 2006;77(4):638-43.
113. Mahmoud SS, Pearse EO, Smith TO, Hing CB. Outcomes of total hip arthroplasty, as a salvage procedure, following failed internal fixation of intracapsular fractures of the femoral neck: a systematic review and meta-analysis. Bone Joint J. 2016;98-b(4):452-60.

114. Schmitz PP, Hannink G, Somford MP, Schreurs BW, Van Susante JLC. Revision risk of salvage compared with acute total hip arthroplasty following femoral neck fracture: an analysis from the Dutch Arthroplasty Register. Acta Orthop. 2023;94:399-403.

115. Kristensen PK, Thillemann TM, Soballe K, Johnsen SP. Are process performance measures associated with clinical outcomes among patients with hip fractures? A population-based cohort study. Int J Qual Health Care. 2016;28(6):698-708.

116. Afaq S, O'Hara NN, Schemitsch EH, Bzovsky S, Sprague S, Poolman RW, et al. Arthroplasty Versus Internal Fixation for the Treatment of Undisplaced Femoral Neck Fractures: A Retrospective Cohort Study. J Orthop Trauma. 2020;34 Suppl 3:S9-S14.

117. Viberg B, Froslev T, Overgaard S, Pedersen AB. Mortality and revision risk after femoral neck fracture: comparison of internal fixation for undisplaced fracture with arthroplasty for displaced fracture: a population-based study from Danish National Registries. Acta Orthop. 2021;92(2):163-9.

118. Welford P, Jones CS, Davies G, Kunutsor SK, Costa ML, Sayers A, et al. The association between surgical fixation of hip fractures within 24 hours and mortality : a systematic review and meta-analysis. Bone Joint J. 2021;103-b(7):1176-86.

119. Lindgren V, Garellick G, Karrholm J, Wretenberg P. The type of surgical approach influences the risk of revision in total hip arthroplasty: a study from the Swedish Hip Arthroplasty Register of 90,662 total hipreplacements with 3 different cemented prostheses. Acta Orthop. 2012;83(6):559-65.

120. Hailer NP, Weiss RJ, Stark A, Karrholm J. The risk of revision due to dislocation after total hip arthroplasty depends on surgical approach, femoral head size, sex, and primary diagnosis. An analysis of 78,098 operations in the Swedish Hip Arthroplasty Register. Acta Orthop. 2012;83(5):442-8.

121. Kannegaard PN, van der Mark S, Eiken P, Abrahamsen B. Excess mortality in men compared with women following a hip fracture. National analysis of comedications, comorbidity and survival. Age Ageing. 2010;39(2):203-9.

122. Bzovsky S, Comeau-Gauthier M, Schemitsch EH, Swiontkowski M, Heels-Ansdell D, Frihagen F, et al. Factors Associated With Mortality After Surgical Management of Femoral Neck Fractures. Journal of Orthopaedic Trauma. 2020;34:S15-S21.

123. Investigators H, Bhandari M, Einhorn TA, Guyatt G, Schemitsch EH, Zura RD, et al. Total Hip Arthroplasty or Hemiarthroplasty for Hip Fracture. N Engl J Med. 2019;381(23):2199-208.

124. Karantana A, Boulton C, Bouliotis G, Shu KS, Scammell BE, Moran CG. Epidemiology and outcome of fracture of the hip in women aged 65 years and under: a cohort study. J Bone Joint Surg Br. 2011;93(5):658-64.

125. Upadhyay A, Jain P, Mishra P, Maini L, Gautum VK, Dhaon BK. Delayed internal fixation of fractures of the neck of the femur in young adults. A prospective, randomised study comparing closed and open reduction. J Bone Joint Surg Br. 2004;86(7):1035-40.

126. Leonardsson O, Rolfson O, Hommel A, Garellick G, Akesson K, Rogmark C. Patient-reported outcome after displaced femoral neck fracture: a national survey of 4467 patients. J Bone Joint Surg Am. 2013;95(18):1693-9.
127. Bartels S, Gjertsen JE, Frihagen F, Rogmark C, Utvag SE. High failure rate after internal fixation and beneficial outcome after arthroplasty in treatment of displaced femoral neck fractures in patients between 55 and 70 years. Acta Orthop. 2018;89(1):53-8.
128. Al-Ani AN, Neander G, Samuelsson B, Blomfeldt R, Ekström W, Hedström M. Risk factors for osteoporosis are common in young and middle-aged patients with femoral neck fractures regardless of trauma mechanism. Acta Orthopaedica. 2013;84(1):54-9.
129. Jackson SH, Weale MR, Weale RA. Biological age--what is it and can it be measured? Arch Gerontol Geriatr. 2003;36(2):103-15.
130. Fitzpatrick AL, Powe NR, Cooper LS, Ives DG, Robbins JA. Barriers to health care access among the elderly and who perceives them. American journal of public health. 2004;94(10):1788-94.
131. Grosso MJ, Danoff JR, Thacher R, Murtaugh TS, Hickernell TR, Shah RP, et al. Risk factors for conversion surgery to total hip arthroplasty of a hemiarthroplasty performed for a femoral neck fracture. Hip Int. 2018;28(2):168-72.
132. Rogmark C, Fenstad AM, Leonardsson O, Engesaeter LB, Karrholm J, Furnes O, et al. Posterior approach and uncemented stems increases the risk of reoperation after hemiarthroplasties in elderly hip fracture patients. Acta Orthop. 2014;85(1):18-25.
133. Parkkari J, Kannus P, Palvanen M, Natri A, Vainio J, Aho H, et al. Majority of hip fractures occur as a result of a fall and impact on the greater trochanter of the femur: a prospective controlled hip fracture study with 206 consecutive patients. Calcif Tissue Int. 1999;65(3):183-7.
134. Nielsen LL, Smidt NS, Erichsen JL, Palm H, Viberg B. Posterior tilt in nondisplaced femoral neck fractures increases the risk of reoperations after osteosynthesis. A systematic review and meta-analysis. Injury. 2020;51(12):2771-8.
135. Sjoholm P, Sundkvist J, Wolf O, Skoldenberg O, Gordon M, Mukka S. Preoperative Anterior and Posterior Tilt of Garden I-II Femoral Neck Fractures Predict Treatment Failure and Need for Reoperation in Patients Over 60 Years. JB JS Open Access. 2021;6(4).
136. Swart E, Roulette P, Leas D, Bozic KJ, Karunakar M. ORIF or Arthroplasty for Displaced Femoral Neck Fractures in Patients Younger Than 65 Years Old: An Economic Decision Analysis. JBJS. 2017;99(1):65-75.
137. Norwegian National Advisory Unit on Arthroplasty and Hip Fractures 2019. Available from: http://nrlweb.ihelse.net/eng/Rapporter/Report2019_english.pdf.
138. Juto H, Gartner Nilsson M, Moller M, Wennergren D, Morberg P. Evaluating non-responders of a survey in the Swedish fracture register: no indication of different functional result. BMC Musculoskelet Disord. 2017;18(1):278.
139. Neve OM, van Benthem PPG, Stiggelbout AM, Hensen EF. Response rate of patient reported outcomes: the delivery method matters. BMC Med Res Methodol. 2021;21(1):220.

140. Dyer SM, Crotty M, Fairhall N, Magaziner J, Beaupre LA, Cameron ID, et al. A critical review of the long-term disability outcomes following hip fracture. BMC Geriatrics. 2016;16(1):158.

Appendix

Paper I: Displaced femoral neck fractures in patients 60-69 years old –treatment and patient reported outcomes in a register cohort

Paper II: Conversion to arthroplasty after internal fixation of undisplaced femoral neck fractures. Results from a national register cohort of 5,428 individuals aged 60 years or older.

Paper III: The different strategies in treating displaced femoral neck fractures. Mid-term surgical outcome in a register-based cohort of 1,283 patients aged 60-69 years.

Paper IV: Contemporary fixation methods for femoral neck fractures and the risk of later conversion to arthroplasty – a register based prospective cohort study