On femoral neck fractures in the elderly

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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 non-displaced 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.

Key words: Femoral neck fracture, cohort study, register study, epidemiology, internal fixation, arthroplasty

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To M, V & B

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

Jarvis Cocker, Pulp

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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, åldersskröra 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

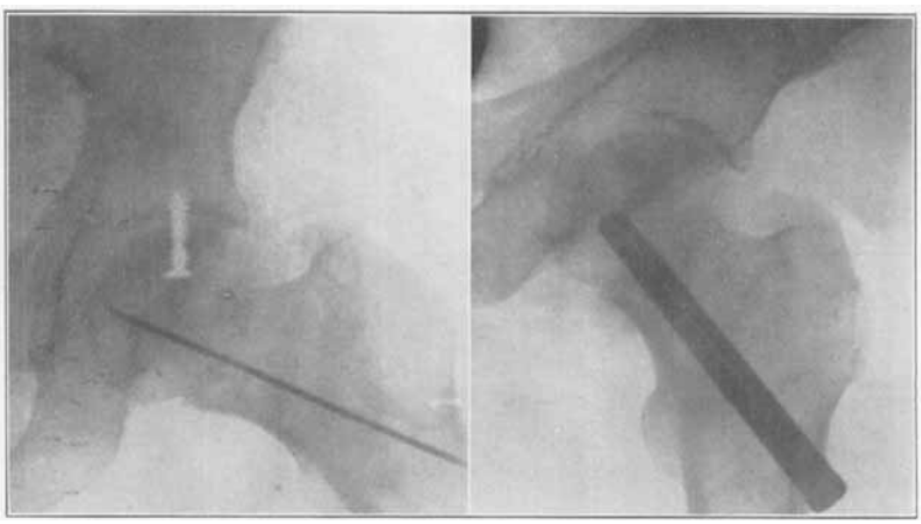

Figure 1 The use of a 2 mm in diameter wire to guide the modified Smith-Petersen nail in the femoral neck (image from the 1932 paper by Johansson).

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

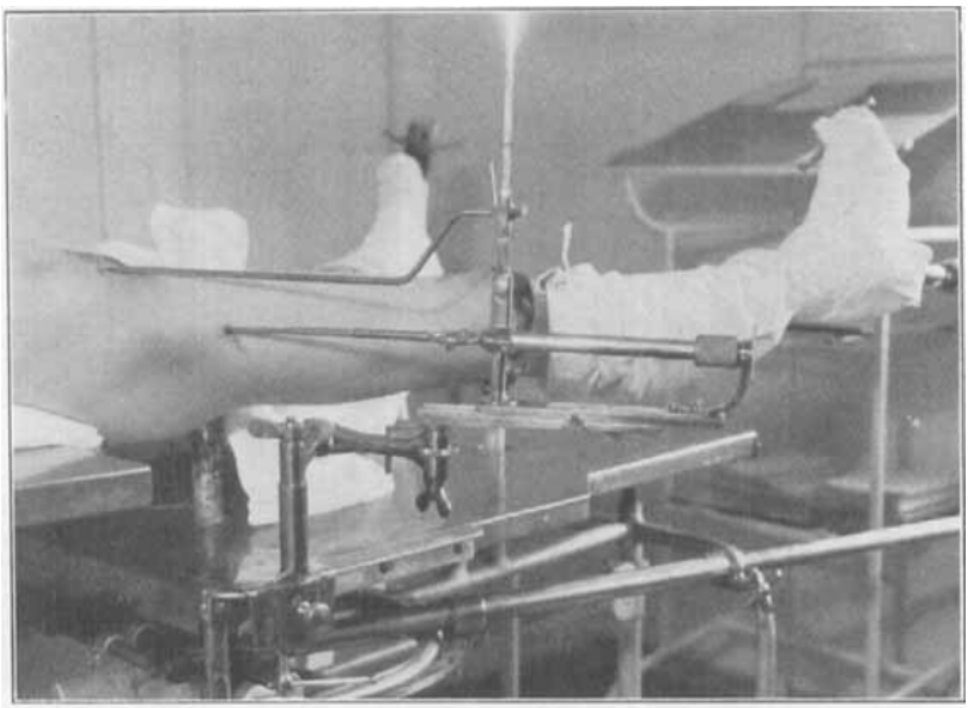

Figure 2 Sven Johansson's guide device for positioning the wire in the femoral neck (image from the 1932 paper)

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).

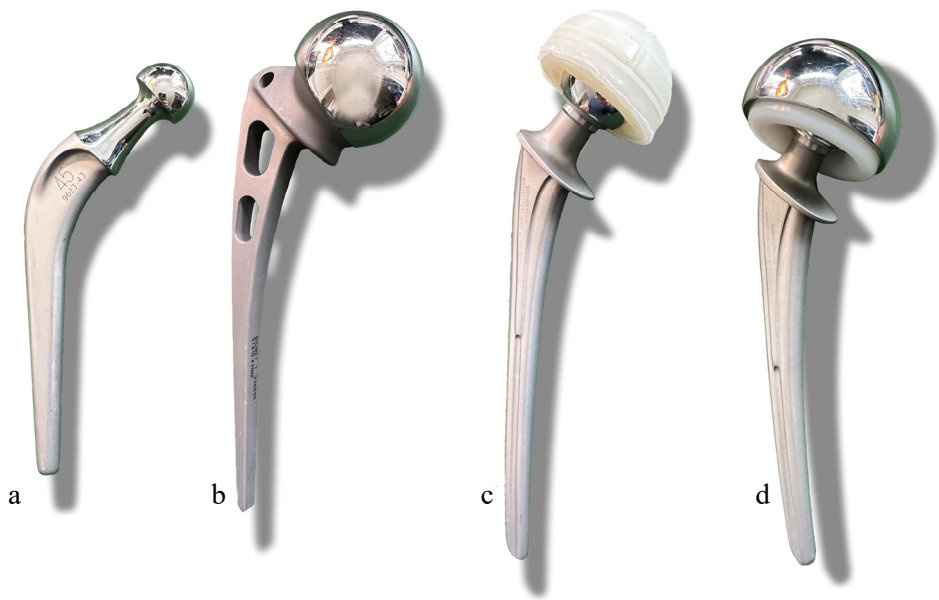

Figure 3 From left to right: two outdated arthroplasty stems; a) Charnley stem for THA, b) Austin-Moore monoblock HA. Two modern implants; c) Lubinus SP II with polyethylene cup (THA), d) Lubinus SP II with VarioCup (bipolar HA)

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).

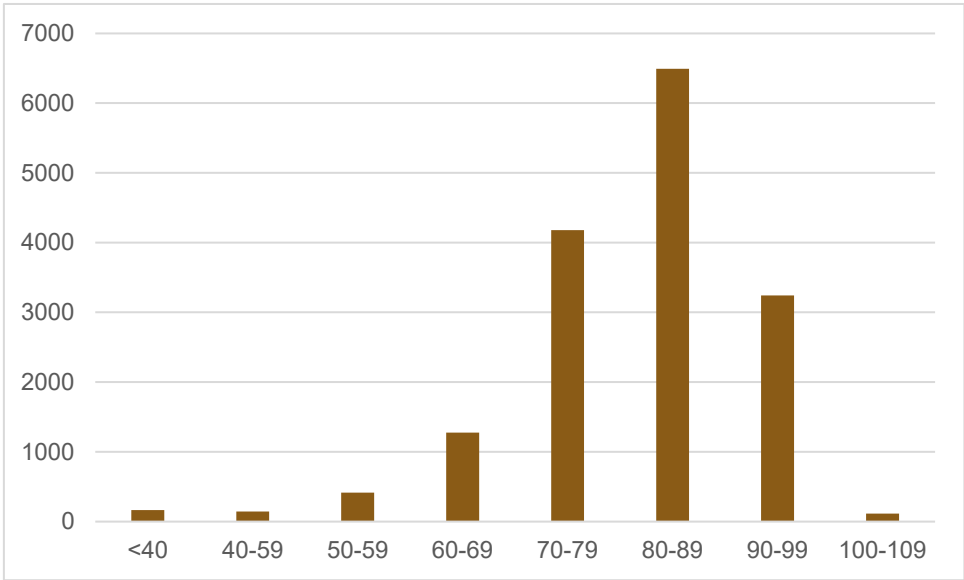

Figure 4 Age distribution of all hip fractures in the SFR 2022

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

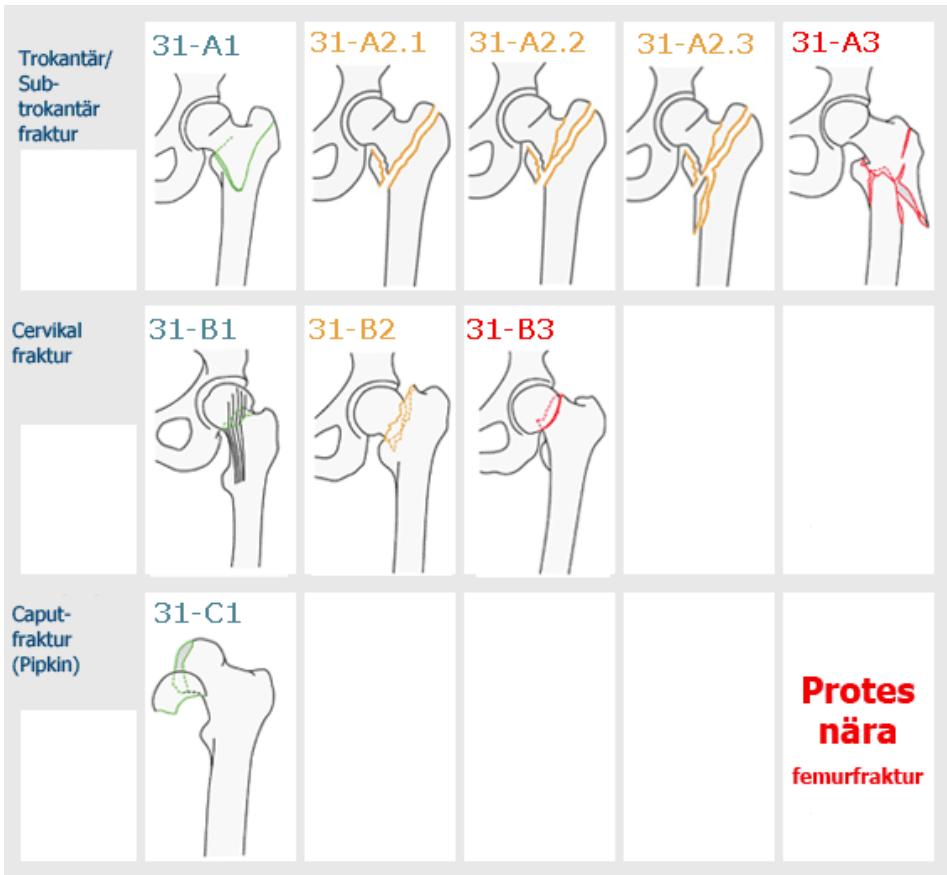

Figure 5 Classification of proximal femoral fractures in the SFR web interface

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

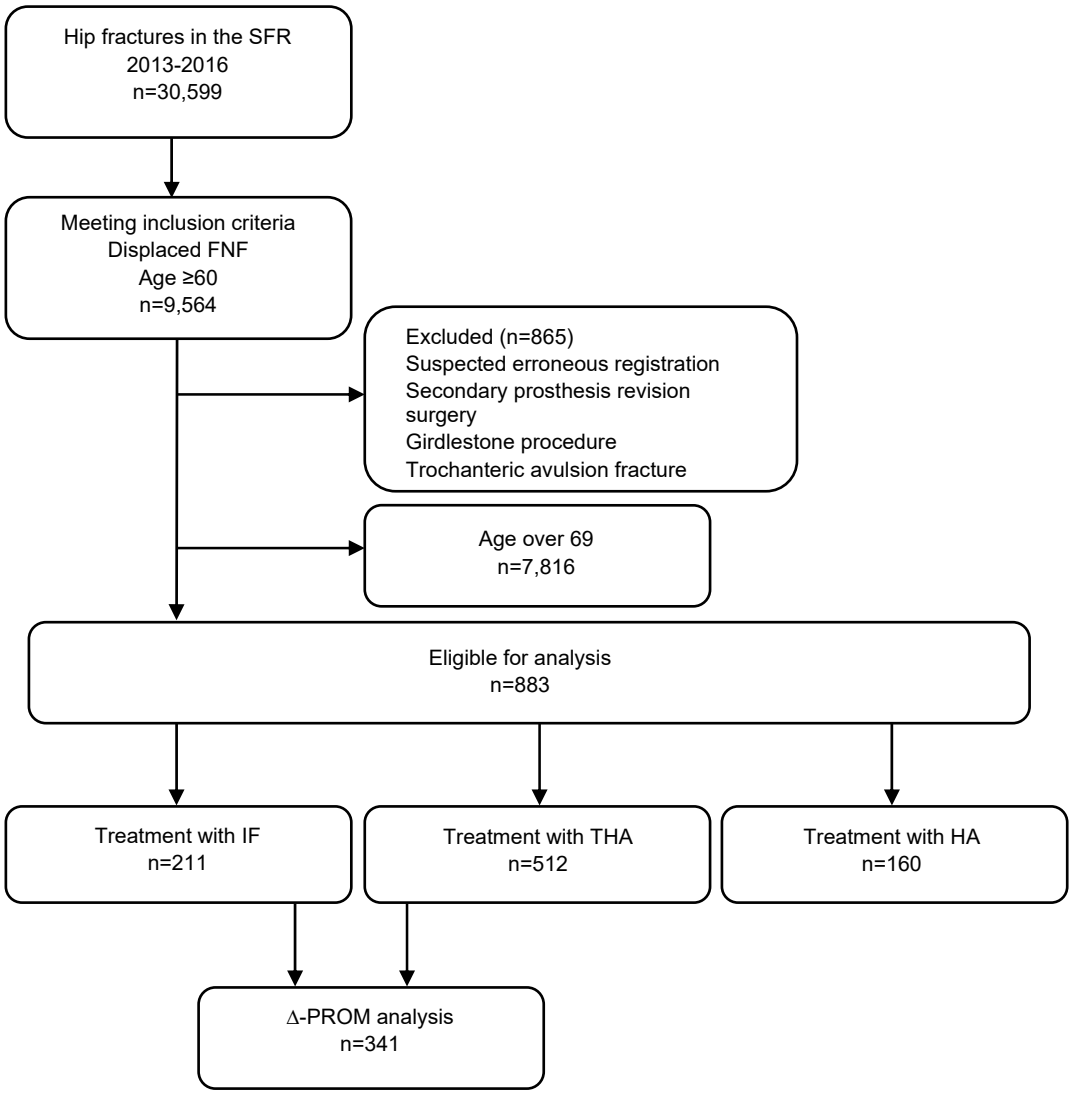

Figure 7 Flowchart of included and excluded patients in Paper I

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.

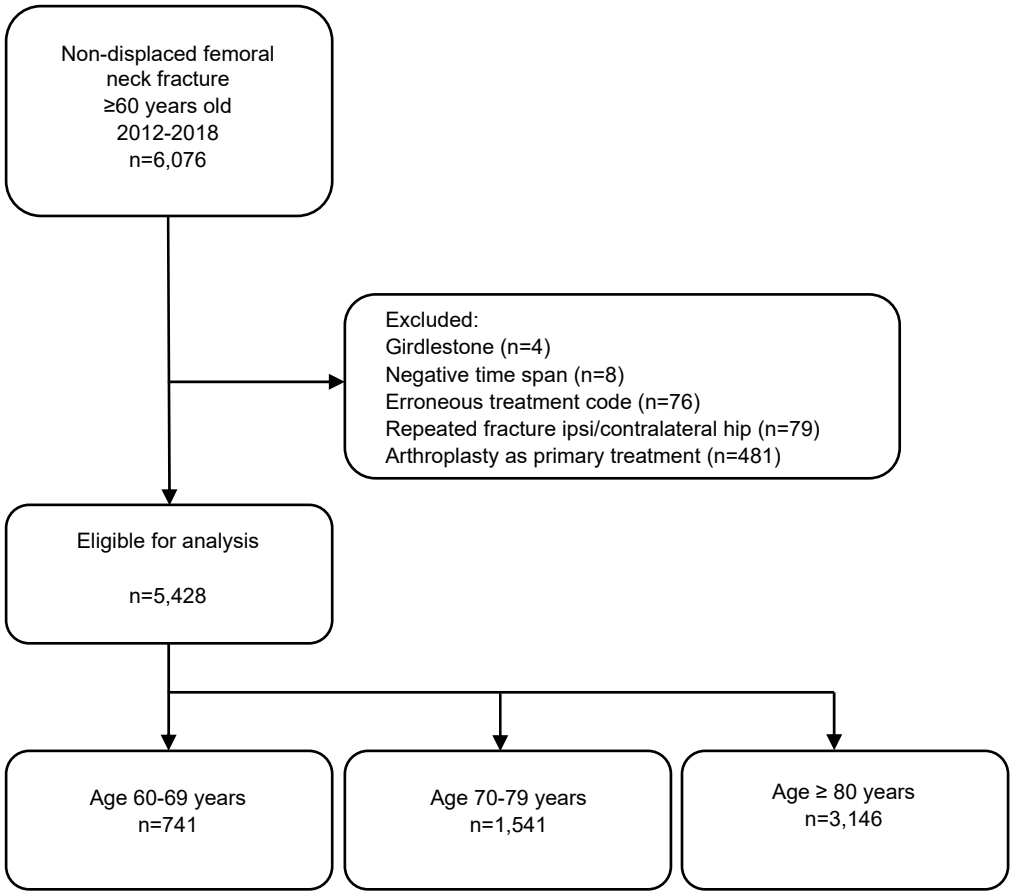

Figure 8 Flowchart of included and excluded patients in Paper II

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).

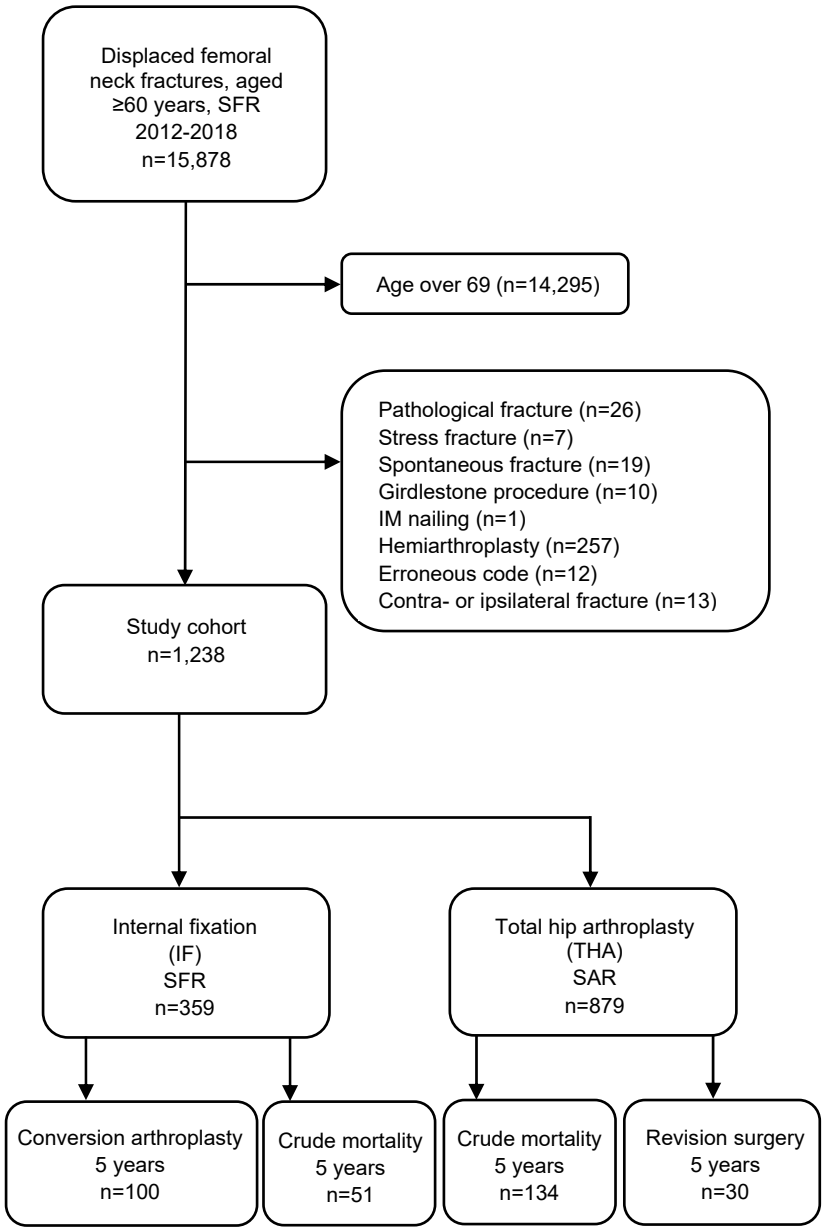

Figure 9 Flowchart of included and excluded patients in Paper III

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.

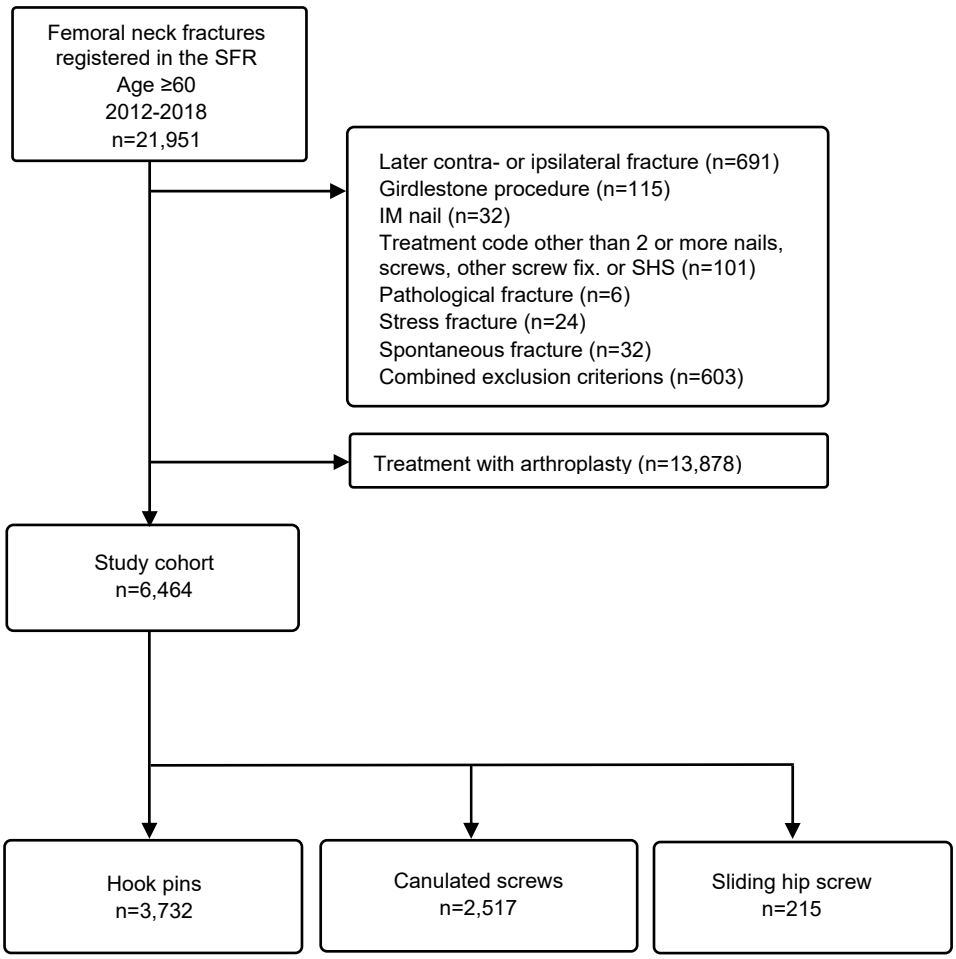

Figure 10 Flowchart of included and excluded patients in Paper IV

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).

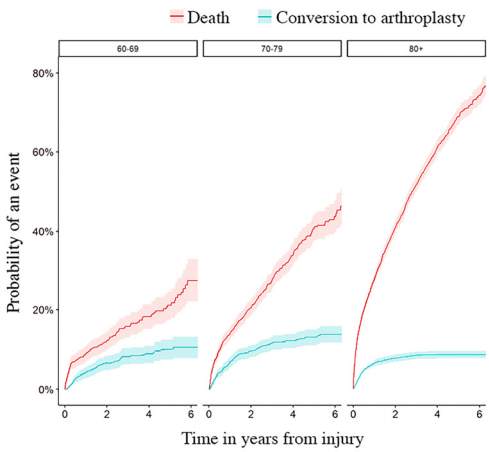

Figure 11 Conversion rates by age group. CIF in a competing risk regression model.

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.

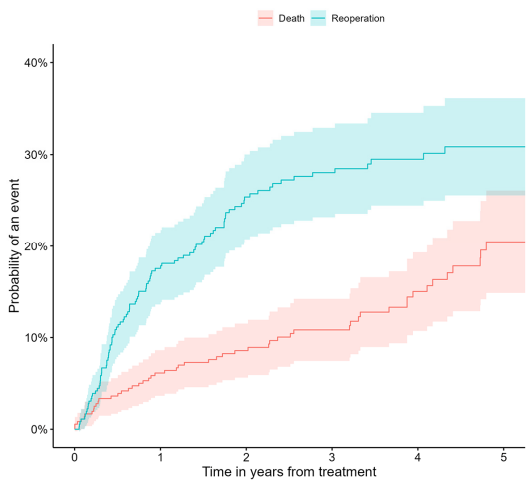

Figure 12 Conversion rate after IF in dFNF and mortality

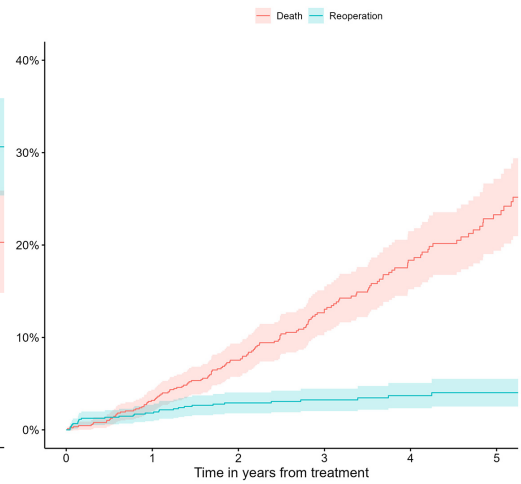

Figure 13 Major revisions after THA and mortality

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).

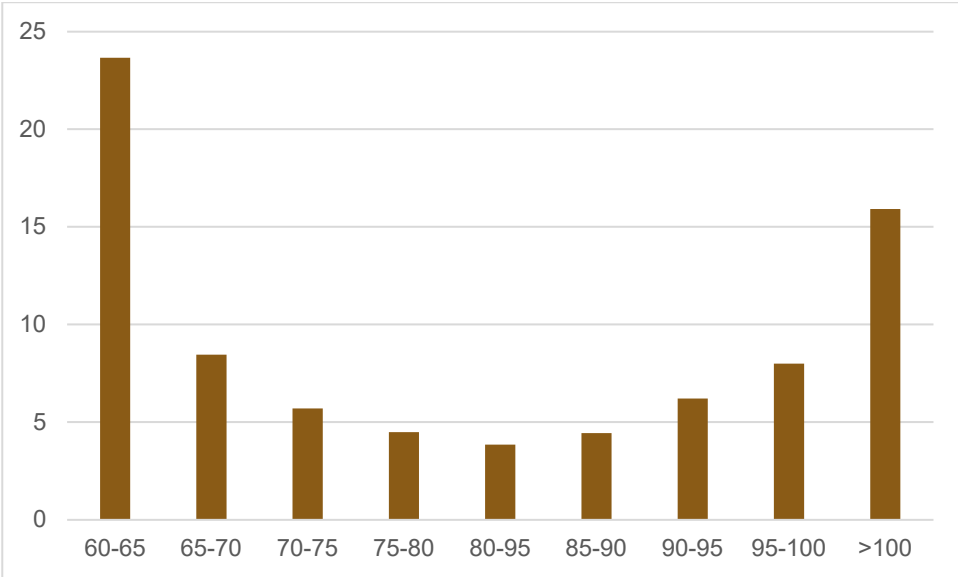

Figure 14 Proportion (%) of dFNF cases treated with IF in different age groups

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.

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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

Paper I

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

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ABSTRACT

Background: Several randomized studies have compared arthroplasty and internal fixation (IF) and found better patient reported outcome measure (PROM) and fewer reoperations for arthroplasty. But consensus is lacking regarding which method to use in the "young elderly" patients aged 60-69; IF tend to fail in up to 1/3 of the cases but can offer the benefits of a biologically intact hip if successful. To add to this, revision of failed IF with secondary arthroplasty has increased risk for complications. This register study aims to describe current treatment and mortality rates for displaced hip fractures based on register data, with focus on young elderly. A secondary aim is to compare changes in PROM between treatments.

Methods: Data was retrieved from the Swedish Fracture Register, SFR. We found 9,564 femoral neck fractures classified as displaced (AO/OTA 31-B3) in patients 60 years or older. 883 patients were aged 60-69 years. In the final analysis of treatment allocation and PROM mean differences, 723 of these met the inclusion criteria. We adjusted for age, sex and baseline PROM, in patients treated with either IF or total hip arthroplasty (THA) in a regression model.

Results: In the 60-69 years group, THA was used in 512 (58%), IF 211 (24%) and hemi arthroplasty (HA) 160 (18%) of the patients. As HA patients differed from those selected to THA and IF in regards to baseline characteristics and response rates, we omitted them from the PROM-analysis. When comparing only THA and IF we found no significant differences in mortality nor PROM means one year after injury. Treatment with THA was more common in women.

Conclusions: : In young elderly patients THA is a common treatment for displaced FNF in Sweden. Patients in this segment treated with HA differ from patients treated with THA and IF, with baseline results in PROM indicating poorer health and function, as well as higher mortality and lower response rates. We found no differences in crude mortality between IF and THA treatment, and no significant influence from treatment on PROM outcome comparing THA and IF.

Introduction

There is convincing evidence that displaced femoral neck fractures (FNF) in the elderly should mainly be treated with arthroplasty [1–5]. The choice between total hip arthroplasty (THA) and hemiarthroplasty (HA) depends on age, comorbidity and activity level. Previous studies have shown a tendency for better patient reported outcome measures (PROM) in elderly patients treated with THA versus HAc [6,7]. The younger the patient, the more closed reduction and internal fixation (IF) seems a viable option. But this is not without controversy. In patients under 65-70 years, a failure or revision rate of up to 33% has been reported with IF [8,9], compared to 3,8% after THA in a recent study[10]. In active patients with a long expected lifespan, THA has potential limitations as increased wear on head and liner could cause aseptic loosening with subsequent need for revision surgery[11].

Younger, healthier individuals can better withstand a failure of internal fixation and subsequent salvage surgery with arthroplasty. Nevertheless, there is an increased risk for complications in salvage surgery of failed IF [12–14]. In addition, more pain and lower satisfaction after IF compared to arthroplasty has been reported in patients 60-70 years old [10].

It is hard to define cut-offs for treatment choice based only on age as other factors, as the general health status, activity level and

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Table 1
Treatment codes used in this study.

NFB09	Hemiarthroplasty, uncemented
NFB19	Hemiarthroplasty, cemented
NFB29	Total arthroplasty, uncemented
NFB39	Total arthroplasty, hybrid
NFB49	Total arthroplasty, cemented
NFJ49.1	Internal fixation, 2 nails
NFJ49.12	Internal fixation, >2 nails
NFJ79.1	Internal fixation, 2 screws
NFJ79.12	Internal fixation, >2 screws

frailty will also play a significant role for the clinical result. The decision is most often based on arbitrary factors and surgeons' experience and preference. Patients may also express other functional demands that impacts the choice of method, such as certain sports and recreational activities.

A Swedish cohort study, analyzing postoperative PROM-data on displaced FNFs, found significant differences in PROM related to treatment choice and age [15]. By using data in the Swedish Fracture Register we can, in contrast to that study, also include prefracture data on similar patients.

Objectives

The study consisted of two parts: first, a description of the treatment (HA, THA and IF) of displaced femoral neck fractures in "young elderly" patients (60-69 years old), the patient characteristics and crude mortality. The second part was a comparison of the two major groups, patients treated with either THA or IF, with PROM results as primary outcome, and mortality as secondary outcome. Both were measured at 1 year after the hip fracture. PROM response rates were also analysed.

Materials and methods

Study design and participants

This is a cohort study of patients with displaced FNFs, aged 60-69 years, that have been prospectively registered in the Swedish Fracture Register between 2013 and 2016. Patients are identified by their unique personal identity number given to all Swedish citizens. Patients visiting, or immigrants applying for citizenship, are not registered in the SFR, nor are Swedish citizens injured while abroad. Treatment options included arthroplasty (HA or THA) or internal fixation (screws or hook pins), defined by their procedure codes [16] (Table 1).

From the SFR we extracted all displaced FNFs (AO/ASIF 31-B3) between 2013 and 2016 in patients over 60 years of age, resulting in 9,564 displaced FNFs. Of these, 883 (9.2%) were 60-69 years old.

The register

The SFR [17] was started in 2011 with the aim to become a national quality register. During the study period, coverage increased from 18% to 46% in hip fractures due to an increased number of hospitals participating. To date, over 400,000 fractures have been registered in total. FNFs are classified in the SFR according to the AO/OTA-classification [18] as undisplaced (31-B1), basocervical (31-B2) and displaced (31-B3). Treatments are registered and reported on-line by the physician. The patient receives questionnaires by postal mail after the registration is complete. This is called the PROM 0, and evaluates, by recall, the status of the patient the week before the hip fracture. Then, one 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. When a registered patient dies, the date of death is automatically added to the database.

The PROM questionnaires contain a health-related quality-of-life instrument, EQ-5D 3L [19] and a health-related functional status, the Short Musculoskeletal Function Assessment (SMFA) [20]. The questions are answered by the patients themselves, or by a proxy (relative or care giver). Either alternative is recorded in the questionnaire.

EQ5D

The EQ5D 3L is a validated five-dimensional questionnaire that is highly adopted in medical research. These five dimensions are: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Each which has three levels of severity (1-3). We assessed the EQ5D index (Dolan valuation method) resulting in a value ranging from -0.594 to 1.0 [21], as well as the EQ5D visual analog scale (EQ5DVAS). Higher values indicate better well-being.

SMFA

The SMFA measures two health indices: dysfunction index (DI) with 34 items and bother index (BI) with 12 items. The dysfunction items are grouped into four categories: daily activities, emotional status, function of the arm/hand and mobility. Each item has five levels of severity (1 for good, 5 for poor function), thus in contrast to EQ5D, lower values indicate better function.

Ethics

Ethics were approved from the Central Ethical Review Board in Gothenburg (ref. 63-2017).

Statistics

Baseline characteristics and means in EQ5D and SMFA indices were analyzed and compared between the three groups by analysis of covariance (ANCOVA) using age and gender as covariates and utilizing 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 was generated with Kaplan-Meier estimator.

Comparing THA and IF

PROM means for THA and IF patients are compared with general linear model (ANCOVA, univariate GLM). Treatment and gender are factors in the model and age (at time of injury) and the respective baseline value of the PROM are included as continuous covariates. Results from this model are used to estimate the mean difference between groups and associated confidence limits. Paired samples t-test is used for mean differences within treatment groups (THA and IF) using bootstrapping to compensate for skewness. Pearson Chi square test is used for PROM 1 response rates, need for proxy and 1-year crude mortality.

All p-values were 2-tailed with a significance level (alpha) of 0.05 using SPSS v25, IBM Corp.

Results

883 (9.2%) patients met the inclusion criteria (Fig. 1). THA was the most common treatment (512, 58%), followed by IF (211, 24%)

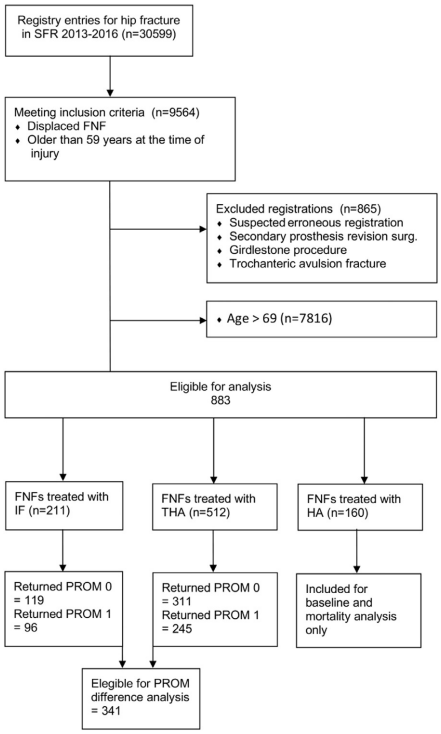

Fig. 1. Flowchart.

and HA (160, 18%). THA was more common in women and patients treated with IF are younger. Additional characteristics are shown in Table 2. The HA group displayed a significantly lower response rate as well as worse baseline PROM (Table 2) in most of the indices. Patients in the HA group were also more prone to use a proxy when answering the questionnaire. Overall mortality was 11/883 (1.2%) within 30 days and 68/883 (7.7%) at one year. Patients treated with HA displayed higher mortality in the age group 60-69 years (Fig. 2).

In the THA vs. IF group, 430 individuals responded to PROM 0 (59%). Respectively, 276 (62%) of the women and 154 (56%) of the men responded (RR 0.90, 95% CI 0.80 -1.0, p=0.09). For PROM 1, 341 (47%) patients responded. Of these 221 (50%) were women, and 120 (43%) men (RR 0.91, 95% CI 0.81-1.02, p=0.103). There was no difference between the THA- and IF-group in crude mortality (Table 3) at 365 days. PROM 0- and 1-results were compared using means of indices in both EQ5D and SMFA. Mean differences were not statistically significant between treatment groups (Table 3). When comparing THA and IF, treatment did not influence response rates (Table 3). Within groups we noted general decline in PROM after fracture (Table 4).

Discussion

In Sweden, THA is the most common treatment for displaced FNF in patients between 60 and 69 years. International comparisons are difficult as many countries do not have national registration of hip fracture procedures, and those who do have a different degree of granularity in their register reports. The National Hip Fracture Database, UK [22], reports that THA is used in 31.4% of "eligible patients", suggesting underutilization of this procedure. In Norway, one fifth of those between 55 and 70 years received a THA [10]. The Australian and New Zealand Hip Fracture Registry (ANZHFR) [23] reports HA in 41%, THA in 49% and IF in 10% of the patients in the age group 60-69 years during 2015-2018 (personal communication 2019-04-02, Elizabeth Armstrong. Australian Hip Fracture Registry Manager – Australian and New Zealand Hip Fracture Registry). In other words, Sweden has the highest rate of THA compared to these countries.

Individuals who suffer a hip fracture around the age of 65 are a heterogenic group. Some fracture their hip due to low-energy trauma, while others have sports related injuries [24]; the biological age span is wider than the chronological. In our cohort, 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 a lesser extent. Therefore, we decided to focus our outcome analyses on the majority treated with either THA or IF, assuming that they better represented the healthier and active group the orthopedic community refers to when discussing arthroplasty or internal fixation.

Table 2
Baseline characteristics.

	THA	IF	HA	p-value THA/IF	p-value THA/HA	p-value IF/HA	
Total number	512	211	160				
Mean age (95% CI)	66.2 (66.0-66.4)	64.3 (63.9-64.7)	66.4 (66.1-66.7)	<0.001	0.631	<0.001	[a]
Women %	66%	51%	53%	0.001	0.011	0.955	[a]
Preop means (95% CI)							
EQ5D Index	0.75 (0.71-0.78)	0.68 (0.62-0.74)	0.56 (0.46-0.65)	0.254	0.001	0.022	[b]
EQ5D VAS	79.5 (76.9-82.3)	73.5 (68.4-78.3)	67.2 (60.3-74.2)	0.178	0.002	0.157	[b]
SMFA Dysfunction Index*	17.6 (15.5-19.9)	22.3 (17.7-26.6)	39.5 (32.7-46.6)	0.193	0.001	0.001	[b]
Daily Activity Index	20.8 (18.0-23.9)	25.7 (20.4-31.9)	51.7 (42.7-60.1)	0.308	0.001	0.001	[b]
Emotional Index	23.6 (21.1-25.9)	27.9 (24.0-32.3)	38.3 (32.1-44.6)	0.212	0.001	0.003	[b]
Arm Hand Index	11.5 (8.18-15.2)	14.5 (7.86-21.3)	40.8 (29.2-51.9)	0.173	0.001	0.001	[b]
Mobility Index	17.9 (15.4-20.2)	22.3 (18.0-27.4)	34.7 (27.6-41.6)	0.267	0.001	0.002	[b]
SMFA Bother Index	15.5 (13.4-17.8)	18.5 (14.2-22.7)	31.4 (25.2-37.9)	0.413	0.001	0.001	[b]
PROM 0 overall response rate (%)	311 (61%)	119 (56%)	61 (38%)	0.525	0.001	0.001	[a]
PROM 0 by proxy (%)	46/251 (18%)	20/104 (19%)	28/52 (54%)	0.980	<0.001	<0.001	[a]
Active smoker (%)	80/268 (30%)	36/105 (34%)	14/50 (28%)	0.706	0.963	0.709	[a]

[a] ANOVA, Tukey's post hoc analysis.
[b] ANCOVA adjusted for sex and age, Bonferroni post hoc analysis.
* lower values indicating better perceived function.

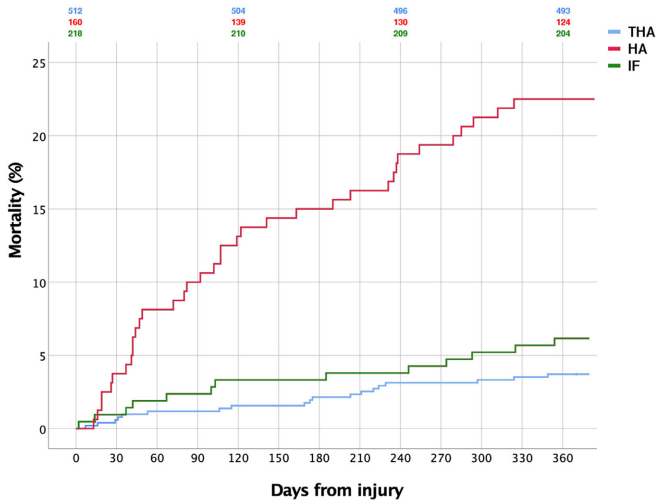

Fig. 2. Kaplan-Meier curves for the three treatment groups and mortality within 365 days. Number of patients in each group displayed on top.

Table 3
General linear model comparing means in PROM 0 and 1 between patients treated with THA or IF.

PROM (95% CI)	THA	IF	p-value	
EQ5D index	0.734 (0.697-0.767)	0.667 (0.614-0.726)	0.626	[a]
EQ5D 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 in pre- and post fracture PROM means (general linear model).
[b] Pearson Chi square test.

Table 4
Unadjusted changes in PROM for patients treated with THA and IF.

THA	PROM 0	95% CI	PROM 1	95% CI	Diff.	95% CI	p
EQ5D							
Index	0.795	0.761-0.827	0.734	0.699-0.768	0.062	0.023-0.103	0.004
VAS	81.9	78.5-85.0	72.5	69.0-75.6	9.38	5.52-13.0	0.001
SMFA*							
Dysfunction Index	15.4	13.0-17.9	24.1	21.7-26.8	-8.7	-10.8 - -6.37	0.001
Daily Activity	17.3	14.1-20.5	27.9	24.2-31.7	-10.6	-13.8- -7.48	0.001
Emotional Index	21.2	18.6-23.6	30.4	27.7-33.2	-9.29	-12.0- -6.66	0.001
Arm Hand Index	7.60	5.88-9.40	9.93	7.92-12.3	-2.33	-4.00- -0.66	0.007
Mobility Index	15.6	13.1-18.3	27.4	24.8-30.0	-11.8	-14.6 - -9.23	0.001
Bother index	13.4	10.9-16.1	21.5	18.8-24.2	-8.02	-10.6- -5.26	0.001
IF							
EQ5D							
Index	0.719	0.642-0.783	0.667	0.606-0.722	0.052	-0.010- 0.113	0.111
VAS	77.0	71.6-82.4	71.7	66.5-76.7	5.31	-0.190- 10.9	0.069
SMFA*							
Dysfunction Index	17.5	13.3-22.5	25.6	21.7-30.1	-8.06	-11.2- -4.84	0.001
Daily Activity	19.6	14.2-26.0	27.5	22.2-33.3	-7.88	-12.0- -3.57	0.001
Emotional Index	24.9	20.2-29.2	33.8	29.3-37.9	-8.97	-13.0- -5.10	0.001
Arm Hand Index	7.95	4.49-12.2	9.45	6.05-13.4	-1.51	-3.13- 0.116	0.065
Mobility Index	18.3	13.4-23.3	31.4	26.5-36.6	-13.2	-17.4- -8.70	0.001
Bother index	14.6	10.7-18.6	24.9	20.3-29.7	-10.3	-14.3- -6.66	0.001

* Higher value means worse result

As IF has a failure rate of approximately one third in these patients [8,9] we expected this to be reflected in lower satisfaction in the IF group. But, in contrast to Leonardsson et al. [15], we found no difference in PROM outcome between the THA and the IF groups. The explanation could be that we analyzed a difference between pre- and post-fracture PROM values, whereas Leonardsson only analyzed one-year PROM. I.e. their results might more reflect the selection bias from different implant choice in different fracture types. Getting prefracture PROM in hip fracture patients is a challenge, and very few quality registers includes fracture patients in their PROM programs. The response rate in this study is at the level of the Norwegian Hip Fracture Register [25]. Still, we acknowledge the limitations with respect to non-responders, as below.

The most benevolent interpretation of the limited decline in PROM after IF is that a patient treated with IF is thoroughly informed that the risk of fixation failure is high and that THA will be a good salvage procedure. If failure then occurs, he or she may accept it better and will also 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.

In a geriatric population in general, the evidence is strong that arthroplasty is superior to IF in displaced FNFs, in terms of failure, revision surgery and PROM [1,27–29]. For the "young old", there are fewer studies, but three RCTs found better functional outcome and fewer reoperations after arthroplasty, already in patients over 60 years [30–32] RCTs are the gold standard, but may lack external validity , as they often are conducted in centers of excellence and comprising selected patients. We consider this register study as an important complement. It is more pragmatic in its nature, reflecting "real life"-allocation of treatments and including patients from all kinds of settings affiliated with the SFR. Our results support a previous register study on the same age group from Norway [10].

The mortality rate was relatively low and no difference could be seen between patients treated with THA or IF. This could be expected as these patients are generally not burdened with as many comorbidities as older patients.

Strengths and limitations

The SFR is unique in its kind; striving for prospective registration of all fractures, not just those surgically treated. The register aims for 100% completeness on a national basis. In 2019, 42 of the 54 Swedish hospitals treating orthopaedic trauma reported to the register. In addition, PROM data is collected both for prefracture status as well as one-year outcome. Register data provides larger number of observations and reflects every-day clinical practice. Just to describe the different utilization of treatment modalities in a certain group for a certain injury is more or less impossible to do by other means. Questionnaires to surgeons will only produce an estimation [4] and official health registers do not contain data of fracture displacement as they utilize ICD-10 for coding.

Underreporting of reoperations is a problem that the register addresses for the future. The current dataset could not be used for reoperations as an outcome. Even in this relative healthy subgroup of patients with FNF, only half of the patients responded on PROM. Only those who reported prefracture data to SFR are invited to the one-year survey. This results in somewhat fewer responses but more meaningful data as the difference pre- and postfracture can be assessed.

Non-responders in the SFR have been found to report similar function compared to initial responders [33]. Thus, not responding may be considered a random event. Furthermore, some units in the SFR only send one PROM-questionnaire while other units use reminders to non-responders. Customary, national cohorts from quality registers are not regarded as samples, i.e. power calculations are not undertaken. When we, in the current study, for the first time planned to analyse PROM for hip fracture patients at a national level, we assumed a higher response rate. Therefore, we supplemented the study design with a post hoc power analysis for the calculation of EQ5D Index mean differences between THA and IF. Using a MCID of at least 0.08 [26] and an allocation ratio of 2.5:1 (THA:IF) that was found in this study, a beta of 0.2 and alpha of 0.05 with the standard deviation of 0.734 (THA group as reference) we would need a sample size of 297 patients in the THA arm and 119 patients in the IF arm. Our sample approximated these figures.

Conclusion

In Sweden THA is the most common implant used for displaced FNF in patients aged 60-69 years, followed by IF and HA. Compared internationally, the utilization of THA is also high. Prefracture PROM was worse and mortality was significantly higher in the HA group, reflecting selection bias. There were no differences in patient reported outcome at 1 year between patients treated with THA or IF, when adjusted for age, sex and baseline PROM. Nor were there any difference in crude mortality during the first year. THA and IF appear as comparable treatments in respect to patient reported outcomes in patients aged 60-69 years.

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Paper II

A commentary by James C. Krieg, MD, is linked to the online version of this article.

Conversion to Arthroplasty After Internal Fixation of Nondisplaced Femoral Neck Fractures

Results from a Swedish Register Cohort of 5,428 Individuals 60 Years of Age or Older

Johan Lagergren, MD, Sebastian Mukka, MD, PhD, Olof Wolf, MD, PhD, Emma Nauclér, PhD, Michael Möller, MD, PhD, and Cecilia Rogmark, MD, PhD

Background: Although most nondisplaced or minimally displaced femoral neck fractures are routinely treated with internal fixation, high rates of secondary surgical procedures are common, especially in the elderly population. Primary arthroplasty in elderly patients has been proposed as an alternative treatment to reduce the need for a secondary surgical procedure. The objective of this study was to describe the rate of conversion to arthroplasty within 5 years after internal fixation of nondisplaced femoral neck fractures in patients ≥60 years of age.

Methods: In this observational cohort study of prospectively collected data from the Swedish Fracture Register (SFR) between 2012 and 2018, cross-matched with the Swedish Arthroplasty Register (SAR), 5,428 nondisplaced femoral neck fractures in patients ≥60 years of age were included. Competing risk analysis was used to estimate conversion rates to arthroplasty and mortality in various age groups at 1, 2, and 5 years.

Results: The cumulative incidence function (CIF) for conversion to arthroplasty was 6.3% at 1 year, 8.1% at 2 years, and 10.1% at 5 years. The conversion rates within 2 years were 6.5% in 60 to 69-year-olds, 9.6% in 70 to 79-year-olds, and 7.8% in ≥80-year-olds. Women had a higher risk of conversion; the hazard ratio (HR) was 1.49 (95% confidence interval [CI], 1.19 to 1.87). The cumulative mortality was 21.3% (95% CI, 20.3% to 22.5%) at 1 year, 31.3% (95% CI, 30.0% to 32.6%) at 2 years, and 54.9% (95% CI, 53.1% to 56.7%) at 5 years. Mortality was higher in men at all time points, and the adjusted 1-year HR was 1.79 (95% CI, 1.61 to 2.00).

Conclusions: One in 10 patients ≥60 years of age treated with internal fixation for a nondisplaced femoral neck fracture underwent conversion to arthroplasty within 5 years, and more than one-half of the conversions occurred within the first year. The risk of conversion was highest in women and in patients 70 to 79 years of age. These data warrant further studies in this frail patient group to identify subgroups of patients who would benefit from primary arthroplasty for nondisplaced femoral neck fractures.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

Nondisplaced or minimally displaced femoral neck fractures are commonly treated with internal fixation, because of its less invasive and less time-consuming nature, as well its retention of the biological properties of the hip. Internal fixation with screws or pins is the current clinical routine in Sweden. However, the authors of some recent studies in elderly patients have suggested that the use of hip arthroplasty, rather than internal fixation, as the primary treatment for nondisplaced femoral neck fractures has benefits of lower reoperation and mortality rates as well as improved mobility[1-5]. Some countries have implemented primary arthroplasty as the treatment for nondisplaced femoral neck fractures in patients ≥60 years of age. The 2021 annual report of the Australian & New Zealand Hip Fracture Registry showed that approximately 50% of nondisplaced femoral neck fractures were treated with arthroplasty during 2020[6]. In Sweden, internal fixation has

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJS/H376).

been reported to be used in 87% of patients ≥60 years[7] and arthroplasty is used only in selected cases[8]. There is an increasing interest in the degree of posterior tilt[9]. In an informal questionnaire in 2021, a majority of hospitals in Sweden reported that they were also guided by the lateral radiograph when choosing the surgical method (unpublished data). Some hospitals use only parallel screws, some use only parallel hook pins, and some use both. The principles of fixation are the same for both. Biplanar fluoroscopy is used in most but not all hospitals. These variations illustrate the lack of solid scientific evidence regarding the optimal treatment of this common fracture and also the lack of national guidelines in Sweden. As hip fracture surgery is performed in every emergency hospital by a variety of orthopaedic surgeons, we sought to explore the results after internal fixation for nondisplaced femoral neck fractures in contemporary everyday practice.

The objective of this observational study was to describe the conversion rate to arthroplasty within 5 years after internal fixation of nondisplaced femoral neck fractures in patients ≥60 years of age, using a competing-risk analysis with death as a competing event. In addition, we explored the conversion rate in various age groups, as well as risk factors for conversion surgery and mortality.

Materials and Methods

Ethics

Ethical approval was granted from the Central Ethical Review Board in Gothenburg (ref. 830-17) and from the Swedish Ethical Review Authority (diary numbers 2019-05024 and 2022-00972-02).

Study Design

This observational cohort study was based on data derived from the Swedish Fracture Register (SFR) and the Swedish Arthroplasty Register (SAR), following the STROBE (Strengthening The Reporting of OBservational studies in Epidemiology) guidelines[10].

The SFR is a national quality register for the management of fractures and was established in 2011[11,12]. Data on patients and fracture characteristics, injury mechanism, and treatment are recorded online by each affiliated department via a digital form completed by the treating orthopaedic surgeon. The aim is to register the treatment (both operative and nonoperative) of all fractures. Patients with a permanent Swedish personal identification number and a fracture that occurred in Sweden are registered. There is a newer version of fracture classification[13], but when the SFR was established in 2011, it used the OTA/AO 2007 classification system, which was found at the time to have high accuracy and validity as implemented in the register, and has continued using this classification system since then. Therefore, in the current study, we have used the same fracture classification system because it was the version in place when the database began and it has not been updated[14]. During the study period, completeness compared with the National Patient Register (NPR) increased from 18% in 2012 to 54% in 2018 for hip and femoral fractures, due to the stepwise national implementation of the SFR. The completeness for femoral fractures was 83% in 2021, and coverage was 100%, meaning that all orthopaedic departments report to the register. A completeness analysis is performed annually by both the SFR and the SAR, by cross-matching against the NPR[15]. Swedish law mandates that both privately and publicly funded hospitals deliver data to the NPR, and all inpatient hospitals and outpatient visits are included.

In the SFR, femoral neck fractures are classified according to the simplified OTA/AO classification[16] as nondisplaced (31-B1), basicervical (31-B2), or displaced (31-B3), on the basis of an anteroposterior radiograph, which has been shown to have moderate interobserver reliability[17]. The treatment is entered by the treating physician and transformed to its Nordic Medico-Statistical Committee (NOMESCO) Classification of Surgical Procedures (NCSP) procedure code[18]. Internal fixation was defined by NCSP codes in the SFR and was grouped into fixation with pins, screws, a sliding hip device, or other fracture fixation (Table I).

The SAR has an annual completeness of approximately 98% for total hip arthroplasty and 97% for hemiarthroplasty[7], our main outcomes. The SAR contains all diagnoses leading to a hip (or knee) arthroplasty, and thus includes both patients primarily treated with arthroplasty for arthrosis or femoral neck fracture as well as patients undergoing an arthroplasty after the failure of internal fixation. Within the registers and in the linking of registers, patients are identified by their unique personal identity number given to all Swedish citizens. By use of this personal identity number, all secondary surgical procedures and deaths can be linked to the first registered procedure (thus making lifelong follow-up possible, relying on reporting from the Swedish hospitals). The completeness of the SAR for revision surgical procedures was 94% in 2020 and 2021.

TABLE I Characteristics of the 5,428 Patients Treated with Internal Fixation

Characteristic	Values (N = 5,428)
Age* *(yr)*	80.5 ± 8.9
Women†	3,693 (68.0%)
Low-energy trauma†	5,105 (94.0%)
Fall at care facility	
Total†	789 (14.5%)
Age group‡	
60 to 69 years (n = 741)	25 (3.4%)
70 to 79 years (n = 1,541)	143 (9.3%)
≥80 years (n = 3,146)	621 (19.7%)
Treatment†	
Hook pins	3,106 (57.2%)
Screws	2,084 (38.4%)
Sliding hip device	145 (2.7%)
Other	93 (1.7%)

*The values are given as the mean and the standard deviation. †The values are given as the number of patients, with the column percentage in parentheses. ‡The values are given as the number of patients, with the row percentage in parentheses.

Both the SFR and the SAR are cross-matched every 24 hours with a national population database, based on the personal identity numbers, to update mortality rates. The mortality dates used in the present study were derived from the SFR.

Patient Selection

This was a registry-based cohort study of patients ≥60 years of age with nondisplaced femoral neck fractures treated with internal fixation who had been prospectively registered in the SFR between January 2012 and December 2018 at the time of the injury. Of 47,487 registered hip fractures, 6,076 were classified as nondisplaced femoral neck fractures (AO/ASIF 31-B1) in patients ≥60 years of age. Exclusion criteria were subsequent ipsilateral or contralateral hip fracture, treatment other than internal fixation, Girdlestone procedure, and erroneous coding or dates (Fig. 1). After exclusion, there were 5,428 patients in the study.

Outcome Measures

The main outcome measure was the conversion rate to arthroplasty after treatment with internal fixation, using a competing-risk model with mortality as the competing event. We also assessed hazard ratios (HRs) for conversion to arthroplasty based on sex and surgeon experience. The variables available for analysis were limited to those collected in the SFR. Age, sex, and surgeon experience were used in the regression analysis for mortality and conversion rates. Surgeon experience was dichotomous and was defined as "surgeon in training," corresponding to a resident, and "specialist," corresponding to a consultant orthopaedic surgeon with finished training.

Confounders

Before the beginning of the study, we decided to include the variables of age, sex, and surgeon experience. These variables have previously demonstrated an association with both the exposure and outcome and are not considered to be in the causal pathway between potential risk factors for conversion to arthroplasty and/or mortality and the outcome.

Statistical Analysis

Patient characteristics were described using counts with proportions and means with standard deviations. A competing-risk model was used to estimate conversion rates, with death as a competing event, as well as mortality rates, utilizing the "cmprsk" package in R version 4.0.2 (The R Foundation for Statistical Computing). The results are presented as the cumulative incidence function (CIF) and 95% confidence interval (CI), expressed as percentages. The mortality risk at 1 year and the reoperation risk at 2 years were analyzed using Cox regression adjusted for age, sex, and surgeon experience. HRs are presented with 95% CIs.

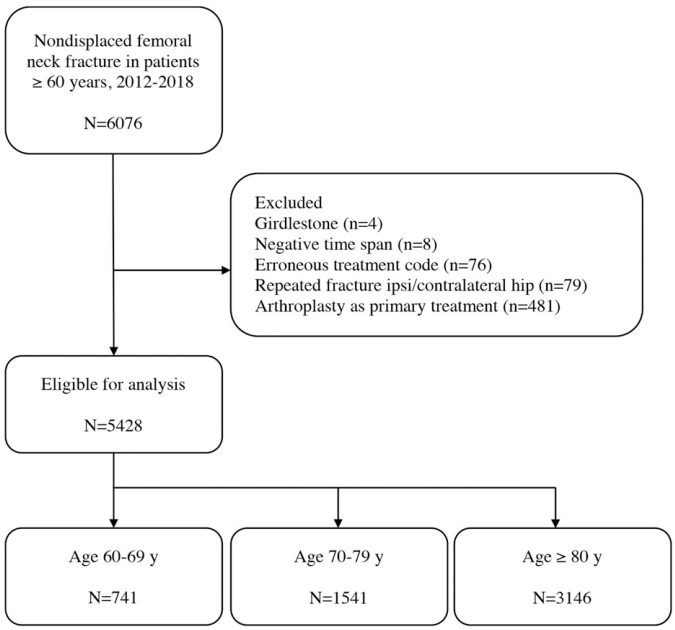

Fig. 1

Flowchart for the study cohort.

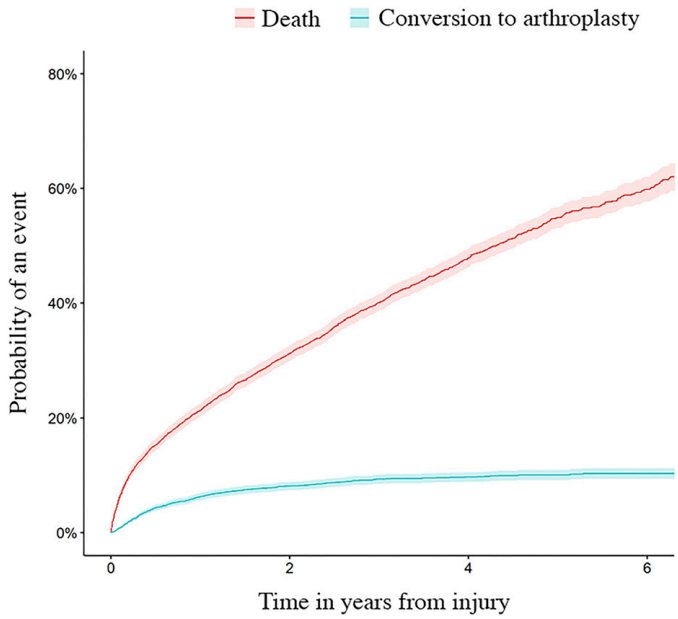

Fig. 2

CIFs from competing-risk modeling of conversion to arthroplasty and death after internal fixation of nondisplaced femoral neck fractures. The shading indicates the 95% CI.

The assumption of proportional hazards was assessed by plotting Schoenfeld residuals.

Source of Funding

Funding was received from the Axel Linders Foundation, an independent trust.

Results

Patients and Descriptive Data

The study cohort included 5,428 patients with a nondisplaced femoral neck fracture (mean age, 81 years; 68% women) registered in the SFR between January 1, 2012, and December 31, 2018. Almost 96% of the nondisplaced femoral neck fractures treated with internal fixation received either hook pins (57.2%) or screws (38.4%) (Table I).

Conversion to Arthroplasty

The estimated CIF for conversion to arthroplasty in the entire cohort was 6.3% (95% CI, 5.7% to 6.9%) at 1 year, 8.1% (95% CI, 7.4% to 8.9%) at 2 years, and 10.1% (95% CI, 9.2% to 11.0%) at 5 years (Fig. 2, Table II).

The CIF at 5 years was 10.0% (95% CI, 7.7% to 12.9%) in 60 to 69-year-olds, 13.0% (95% CI, 10.6% to 15.1%) in 70 to 79-year-olds, and 8.7% (95% CI, 7.7% to 9.8%) in ≥80-year-olds (Fig. 3, Table III). Women had a higher cumulative conversion rate of 14.9% (95% CI, 13.3% to 16.4%), compared with 8.8% (95% CI, 7.1% to 10.5%) for men.

Risk Factors for Conversion to Arthroplasty

Women had a higher risk of conversion compared with men (HR, 1.49 [95% CI, 1.19 to 1.87]). Surgeon experience did not influence the risk of conversion to arthroplasty (HR, 1.1 [95% CI, 0.9 to 1.3]) in a regression model adjusted for age and sex. Patients 70 to 79 years of age also had an increased risk of conversion (HR, 1.5 [95% CI, 1.1 to 2.0]).

TABLE II Conversion to Arthroplasty by Year

Time	No. at Risk	Cumulative Events	CIF*
1 year	3,919	340	6.3% (5.7% to 6.9%)
2 years	2,640	433	8.1% (7.4% to 8.9%)
3 years	1,646	479	9.3% (8.6% to 10.2%)
4 years	935	489	9.7% (8.9% to 10.6%)
5 years	450	496	10.1% (9.2% to 11.0%)

*The values are given as the CIF, with the 95% CI in parentheses.

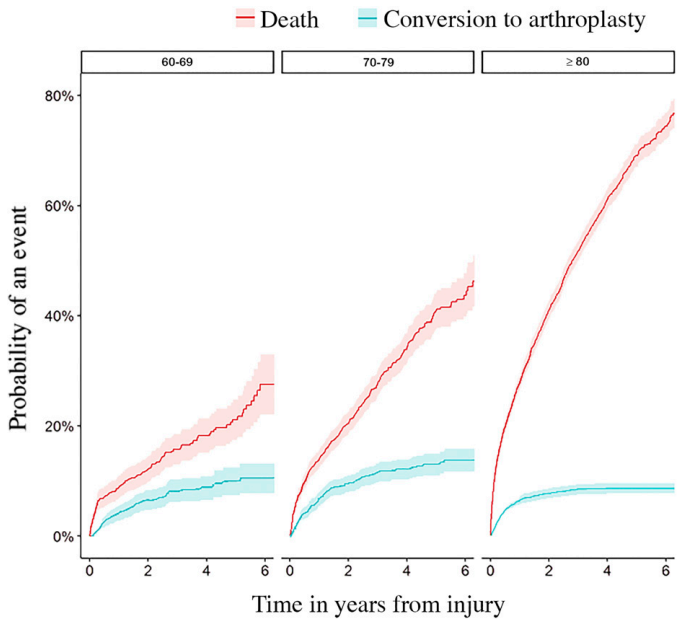

Fig. 3

CIFs from competing-risk modeling of conversion to arthroplasty and death after internal fixation in 3 age groups.

Mortality

Mortality in all patients ≥60 years of age was 21.3% (95% CI, 20.3% to 22.5%) at 1 year, 31.3% (95% CI, 30.0% to 32.6%) at 2 years, and 54.9% (95% CI, 53.1% to 56.7%) at 5 years. Patients ≥80 years of age had the highest mortality rate at all time points (Table IV). Mortality was higher in men at all time points, and their adjusted HR at 1 year was 1.79 (95% CI, 1.61 to 2.00).

Discussion

In this large cohort of patients ≥60 years of age with a nondisplaced femoral neck fracture treated with internal fixation, 1 in 10 had a subsequent hip arthroplasty within 5 years, and more than one-half of the conversions had already occurred by 1 year. The conversion rate to arthroplasty was highest in women and patients who were 70 to 79 years of age.

A failure of internal fixation resulting in the need for a conversion to hip arthroplasty is a severe complication in older patients. Not only does an arthroplasty after fracture fixation failure have an inferior outcome compared with primary hip arthroplasty[19-22], but also the prolonged period of pain and discomfort caused by the complication is detrimental. Selecting arthroplasty as the primary treatment could allow faster mobilization and could potentially decrease morbidity and mortality after the surgical procedure[23], although the difference

TABLE III Conversion to Arthroplasty by Age Group and Time

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

*The values are given as the number of patients, with the percentage of the group total in parentheses. †The values are given as the CIF, with the 95% CI in parentheses.

TABLE IV Mortality by Age Group and Time

Age Group and Time	Cumulative Events*	CIF†
60 to 69 years (n = 741)		
1 year	66 (8.9%)	8.9% (7.1% to 11.2%)
2 years	88 (11.9%)	12.1% (10.0% to 14.7%)
5 years	124 (16.7%)	21.2% (17.8% to 25.2%)
70 to 79 years (n = 1,541)		
1 year	216 (14.0%)	14.0% (12.4% to 15.9%)
2 years	307 (19.9%)	20.5% (18.6% to 22.7%)
5 years	459 (29.8%)	40.9% (37.6% to 44.5%)
≥80 years (n = 3,146)		
1 year	876 (27.8%)	27.9% (26.3% to 29.5%)
2 years	1,255 (39.9%)	41.0% (39.3% to 42.8%)
5 years	1,738 (55.2%)	69.0% (66.9% to 71.2%)

*The values are given as the number of patients, with the percentage of the group total in parentheses. †The values are given as the CIF, with the 95% CI in parentheses.

in mortality between internal fixation and arthroplasty is not clear in the literature[2,5,24].

Conversion rates of 8% to 16% after internal fixation of nondisplaced femoral neck fractures have been reported in the literature[5]. Our results are in concordance with a recent cohort study including 1,505 patients in which the conversion rate was 10% (7% to total arthroplasty and 3% to hemiarthroplasty) and the total reoperation rate was 17% at a mean follow-up of 3.2 years[20]. However, 20% of patients in a recent randomized controlled trial (RCT)[1] underwent major reoperations within 2 years after internal fixation. The discrepancy in results between observational studies and RCTs has been noted previously[25]. This discrepancy could be explained by the inclusion of healthier and more vital patients in RCTs[26].

Individual radiographs are not available in observational register studies such as the present one. Nondisplaced femoral neck fractures are not uniform; rather, there are subgroups of fracture patterns with different risks of reoperation[7,24,27]. A preoperative posterior tilt of >20° may increase the risk of failure requiring a major reoperation[19,27], and an anterior tilt of >10° may also be associated with a risk of treatment failure requiring a major reoperation[20]. In contrast, occult nondisplaced femoral neck fractures (fractures that are not visible on radiographs but are visualized with magnetic resonance imaging) have low reoperation rates[21]. Differences in inclusion of these subgroups between RCTs and observational studies could contribute to the differences in reported reoperation rates. In addition, the effect of age may be confounded by greater reluctance of elderly individuals to seek health care for complications such as implant failure, osteonecrosis, and nonunion after internal fixation, and greater reluctance of surgeons to treat these complications in individuals who are frailer or have a shorter life expectancy; this has the potential to at least partially account for our finding of lower conversion rates in patients ≥80 years of age.

The type of internal fixation could also affect the rate of conversion to arthroplasty; however, no apparent differences between pins, screws, and sliding hip devices have been reported[28-31]. Two pins or screws were used almost exclusively in this cohort, in accordance with the current clinical practice for internal fixation in Sweden.

An important limitation of the present study was the lack of patient-reported outcomes, which are important in the comparison of internal fixation and arthroplasty. In their RCT, Dolatowski et al. concluded that hemiarthroplasty led to better mobility compared with internal fixation[1]. Their findings suggested that certain elderly patients with a nondisplaced femoral neck fracture may benefit from being treated with a latest-generation hemiarthroplasty rather than internal fixation. This is possibly also true for the subgroups with a dorsal or anterior fracture tilt, which increases the risk of reoperation[20]. However, there is a need for further high-level evidence to evaluate these claims, and large, randomized studies such as SENSE[31], HipSTHeR[32], and FRUITI[33] are ongoing.

The present study had limitations stemming from its register-based design. As mentioned, we did not have radiographs or data on frailty, comorbidities, or cognitive impairment. The unavailability of radiographs eliminated the possibility of assessing fracture displacement, which would have been a major confounder of these results. The other mentioned factors might also have influenced conversion rates and thus introduced a risk of residual confounding.

We chose to focus on conversion to arthroplasty as it is the most common major reoperation to treat failure after internal fixation[5] and the high completeness of the SAR for arthroplasties provided us with reliable data for this outcome. The unique Swedish personal identity number enabled us to link data between the SFR and the SAR and ensured a high completeness of the data used to calculate the conversion rate. However, it is important to note that the results of the present study do not reflect the total complication or reoperation rates after internal fixation. In particular, other types of reoperations such as implant removal, excision arthroplasty, and refixation were not analyzed due to inadequate data sources, and complications and reoperations need not be associated (e.g., a complication may be treated nonoperatively, or routine screw removal may be performed in patients without complications).

In conclusion, using the need for conversion to arthroplasty as a marker of major complications, internal fixation of a nondisplaced femoral neck fracture in patients ≥60 years of age had an acceptable outcome; 9 of 10 patients did not have this type of secondary surgical procedure during a 5-year follow-up. More than one-half of the patients died within 5 years. Most of the conversions took place in the first year, but attention must be paid to late-occurring complications as well. Until large RCTs have compared internal fixation and arthroplasty for patients with a nondisplaced femoral neck fracture in terms of postoperative pain and function, we interpret our result as supporting the current regime in which fixation is the first choice for a majority of patients. Nevertheless, the somewhat

higher risk of conversion in women and in patients who were 70 to 79 years of age underlines the need for studies to further identify subgroups of patients who would benefit from primary arthroplasty for a nondisplaced femoral neck fracture. ■

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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

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Background and purpose — In patients around retirement age controversy exists as to whether to treat displaced femoral neck fracture (dFNF) with internal fixation (IF) or arthroplasty. An arthroplasty in this age group may need revision due to a long expected remaining lifetime. IF carries a higher risk of early failure but a maintained native hip if healing occurs. We aimed to determine the cumulative 5-year rate of conversion to arthroplasty after IF and implant revision after primary total hip arthroplasty (THA), respectively.

Patients and methods — In this longitudinal cohort study, patients aged 60–69 years registered with a dFNF in the Swedish Fracture Register (SFR) 2012–2018 were cross-referenced with available data from the Swedish Arthroplasty Register (SAR) until December 31, 2019. Conversion to arthroplasty or revision were analyzed utilizing competing risk, with death as competing event.

Results — At 5 years, the cumulative rate of conversion to arthroplasty after IF was 31% (95% confidence interval [CI] 26–37). For primary THA, the 5-year rate of revision was 4.0% (CI 2.8–5.8). The 5-year mortality did not differ, being 20% (CI 16–27) and 23% (CI 20–28) after IF and THA, respectively. Regression analyses did not identify any risk factors for conversion arthroplasty based on the variables in the register.

Conclusion — A follow-up of 5 years catches most reoperations after IF, resulting in a 31% conversion rate. The 4% revision rate at 5 years after primary THA should be seen as an intermediate result, as late complications may occur.

Hip arthroplasty is regarded as the gold standard for treatment of displaced femoral neck fractures (dFNF) in the elderly, whilst internal fixation (IF) is the preferred method for younger patients [1]. Traditionally, the Scandinavian countries have been more prone to treat with IF primarily and to perform secondary arthroplasty in case of failed fixation. Over the last decades, the age limit for arthroplasty as primary treatment for dFNF has gradually decreased in Scandinavia from around 70 to 60 years [2-4]. In Sweden, primary total hip arthroplasty (THA) is now the most common treatment choice in the current age group [5].

The potential benefits from preserving the femoral head after a fixed, healed fracture are weighted against the known high risk of reoperation due to healing disturbances [6], which might lead to pain and prolonged inactivity before the decision to reoperate is taken. In addition, a conversion arthroplasty may be associated with poorer results than THA as primary treatment [7]. Arthroplasty as primary treatment leads to significantly fewer major reoperations than IF, but poorer outcome than elective THA for osteoarthritis [8,9]. In younger age groups, an arthroplasty may need revision due to a long expected remaining lifetime [10]. In a previous study, we could not detect any differences between IF and THA as primary treatment in patients aged 60–69 years regarding crude mortality or patient satisfaction [11].

Arthroplasty as primary treatment for geriatric patients with dFNF is supported by several randomized controlled studies (RCTs) [12-14], but controversy still exists for patients around retirement age. IF can be defended, as more healthy and active individuals can better tolerate secondary surgery in the case of fixation failure. Successful fracture healing may

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give the patient the benefit from a maintained native hip joint, thus avoiding implant-related complications associated with arthroplasty.

We aimed to describe the cumulative rate of conversion/revision arthroplasty and mortality within 5 years after IF and primary THA, respectively but not to compare treatments as such. Secondarily, we analyzed risk factors for reoperations.

Patients and methods

Study design

This register-based cohort study was based on prospectively collected data from the Swedish Fracture Register (SFR) and the Swedish Arthroplasty Register (SAR). The STROBE guidelines were followed for reporting of the present study [15].

Setting

The SFR was initiated in 2011 [16], and over 810,000 fractures have been registered at the time of writing. The coverage has gradually improved due to a stepwise introduction and since 2021 all orthopedic departments in Sweden participate in the register, i.e., 100% coverage. During the study period 2012–2018, the completeness of hip fracture registrations in the SFR increased from 18% to 55% compared with the National Patient Register [17], due to the stepwise activation of more hospitals. The SFR has decided to continue with the 2007 AO/OTA classification, to maintain longitudinally homogeneous data. Thus, FNFs are classified accordingly as undisplaced or minimally displaced subcapital (31-B1), basicervical (31-B2), and displaced subcapital (31-B3) [18]. Each treating physician registers data on patient level for the injury, fracture classification, and treatment through a secure web-based portal. SAR is the national quality register for arthroplasty of the hip and knee in Sweden. The coverage of SAR is 100% of all departments performing hip arthroplasties, both public and private. For the study period, the completeness was 98% for THA and 92% regarding revisions of THA [19]. The registers are updated concerning date of death by regular co-processing every 24 hours with the population register (the Swedish Tax Agency).

Patients

Data for all patients aged 60–69 years at injury and registered with an FNF (defined by the ICD code S72.00) in SFR from 2012 to 2018 were extracted and cross-referenced with available data from SAR for each individual from the date of the index fracture until December 31, 2019. To provide trustable co-processing between registers regarding subsequent surgeries and/or death, the unique personal identity number given to each Swedish citizen was used. The dFNFs (AO/OTA 31-B3, Garden 3–4) were further examined for eligibility and other fracture types were excluded. Only the first registered hip fracture for each individual was included in the study; contralateral and subsequent ipsilateral fractures and duplicate registrations were excluded. Pathological, stress, and spontaneous fractures were identified by their ICD-10 diagnosis codes (M84.4, M84.8, M84.3) in the injury mechanism registration and excluded. Patients with treatment other than IF or primary THA, e.g., intramedullary nail, excision arthroplasty (Girdlestone procedure), and hemiarthroplasty, were also excluded from analysis. Based on the registered primary treatment, fractures treated with either IF (parallel pins/screws, sliding hip screw) or THA were identified and analyzed (Figure 1).

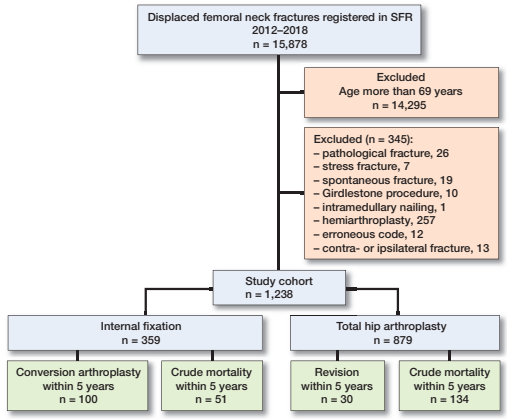

Figure 1. Flowchart of study cohort.

For patients treated with IF, the studied reoperations were limited to conversion arthroplasty. Screw extraction, which is a common (minor) reoperation after IF [12], was omitted here as such procedures also may be undertaken in cases of uneventful healing, due to local irritation. For arthroplasty, only revisions, i.e., exchange or extraction of any implant, were included.

Study variables

Basic demographic variables (age, sex, and trauma mechanism), data on the primary fracture treatment (surgeon experience defined as performed by either a resident or consultant orthopedic surgeon), and any date of death were extracted from the SFR. The SAR was sought for the occurrence of any conversion to arthroplasty after IF or primary THA revision. Length of follow-up was defined as time from injury date to date of death or end of study period on December 31, 2019.

Study outcomes

The main outcomes were either conversion to arthroplasty after IF or revision of a primary THA, both at 5 years. For primary THA, we used treatment codes indicating revision (NFU09, NFU19, NFCxx) in the SAR to identify major revisions. We also assessed mortality within a competing risk regression model.

Table 1. Characteristics of patients included in the study. Values are count (%) unless otherwise specified

Characteristics	Internal fixation (n = 359)	Total hip arthroplasty (n = 879)
Median age (IQR)	64 (62–67)	67 (64–68)
Women	180 (50)	563 (64)
Trauma type		
High-energy trauma	14 (4.0)	20 (2.0)
Low-energy trauma	319 (89)	813 (92)
Missing data/unknown	26 (7.0)	46 (5.0)
Primary treatment		
Parallel hook pins (2 pins)	176 (49)	–
Parallel hook pins (> 2 pins)	16 (4.5)	–
Wires or cerclage	6 (1.7)	–
Parallel screws (2 screws)	130 (36)	–
Parallel screws (> 2 screws)	7 (1.9)	–
Sliding hip screw	24 (6.7)	–
Uncemented THA	–	33 (3.8)
Hybrid THA	–	60 (6.8)
Cemented THA	–	786 (89)

IQR = interquartile range.

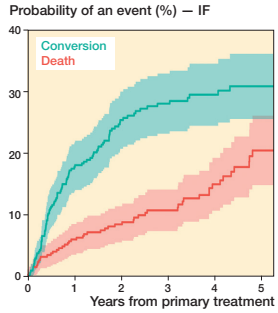

Figure 2. Competing risk analysis of conversion to arthroplasty after IF as primary treatment.

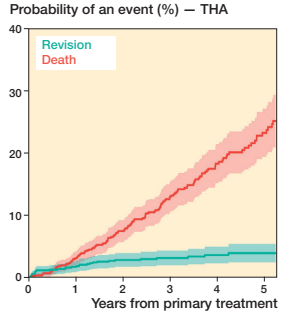

Figure 3. Competing risk analysis of revision after THA as primary treatment.

Statistics

Patient characteristics were described using frequencies with proportions and interquartile range (IQR). We analyzed the time from IF to death, to conversion arthroplasty, or until end of study, whichever came first, and time from THA to death, to revision, or until end of study period, whichever came first. Patients who either died or who were still alive without any conversion arthroplasty/revision at the end of the study were censored.

Cox regression was utilized to explore associations between secondary surgery (conversion/revision) and risk factors available in the register data: sex (categorical), age (continuous), and treating surgeon (factorial—resident vs. consultant). Schoenfeld's test for proportionality assumption was utilized.

Competing risk analysis was used to estimate conversion arthroplasty after IF, revision surgery after THA, and mortality in the two treatment groups respectively. Cumulative incidence functions (CIF) are presented with 95% confidence intervals (CI). Competing risk analysis was done utilizing the "cmprsk" package in R version 4.0.2 (R Foundation for Statistical Computing, Vienna, Austria).

Ethics, data sharing, funding, and disclosures

Ethical approval was granted from the Central Ethical Review Board in Gothenburg (ref. 830-17) and from the Swedish Ethical Review Authority (diary number 2019-05024, 2022-00972-02). To ensure confidentiality for patients included in this study, the dataset is not publicly available. This is a requirement for ethical approval and is also regulated by the law on public access and secrecy; Chapter 21, §7, Chapter 25, §1 (https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/offentlighets-och-sekretesslag-2009400_sfs-2009-400). Requests to access this data should go through the senior author and/or Lund University to ensure proper measures are taken in conjunction with the legislation as well as the ethical approval. Any sharing of data beyond what is presented in this paper will involve approval from the Swedish Ethical Review Authority.

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Results

Patients

15,878 dFNFs were found in the SFR. After exclusion, 1,238 patients treated with either IF (n = 359) or THA (n = 879) were analyzed (Figure 1). Median age was slightly higher in patients treated with THA and this treatment was also more common in women. The fracture was caused by low-energy trauma in more than 9 out of 10 cases (Table 1).

Conversion to arthroplasty after IF

The rate of conversion to arthroplasty after IF was 18% (CI 14–22) at 1 year (Figure 2, Table 2). The crude rate was 63 of 359 patients. At 5 years the cumulative rate increased to 31% (CI 26–37) with a crude rate of 100 of 359 patients.

Revision of primary THA

In the group treated with primary THA, the cumulative rate of revision was 2% (CI 1–3) at 1 year. The crude rate was 16 of 879 patients. At 5 years it increased to 4% (CI 3–6) with a crude rate of 30 of 879 patients (Figure 3, Table 3).

Table 2. Conversion to arthroplasty and mortality after internal fixation (IF) as primary treatment

Years	At risk	Conversion to arthroplasty after IF Cumulative events	CIF (CI) (%)	Mortality Cumulative events	CIF (CI) (%)
1	274	63	18 (14–22)	22	6.1 (4.1–9.2)
2	189	88	25 (21–31)	30	8.6 (6.1–12)
3	143	95	28 (24–33)	36	11 (7.9–15)
4	91	98	30 (25–35)	44	15 (11–20)
5	46	100	31 (26–37)	51	21 (16–27)

CIF = cumulative incidence function.

Table 3. Major revisions and mortality after total hip arthroplasty (THA) as primary treatment

Years	At risk	Revision after THA Cumulative events	CIF (CI) (%)	Mortality Cumulative events	CIF (CI) (%)
1	834	16	1.8 (1.1–3,0)	28	3.2 (2.2–4.6)
2	640	25	2.9 (2.0–4.3)	63	7.5 (5.9–9.6)
3	435	27	3.2 (2.2–4.7)	97	13 (11–16)
4	279	29	3.7 (2.6–5.4)	120	18 (16–22)
5	162	30	4.0 (2.8–5.8)	134	23 (20–28)

CIF = cumulative incidence functions.

Table 4. Cox regression with hazard ratios (HR) for conversion after internal fixation (IF) and revision after total hip arthroplasty (THA)

	IF HR (CI)	THA HR (CI)
Age	0.99 (0.98–1.1)	1.0 (0.87–1.1)
Male sex	0.71 (0.48–1.1)	0.92 (0.43–2.0)
Specialist surgeon	1.2 (0.81–1.9)	0.64 (0.28–1.4)

Mortality

The 1- and 5-year mortality was 6% (CI 4–9) and 20% (CI 16–27) in the IF group and 3% (CI 2–5) and 23% (CI 20–28) in the THA group, respectively (Tables 2 and 3).

Risk factors for reoperation

Neither sex, age, nor surgeon experience interfered with the risk of secondary surgery in a Cox regression analysis (Table 4).

Discussion

We aimed to describe the cumulative rate of conversion/revision arthroplasty and mortality within 5 years after IF and primary THA. We found that, within 5 years, nearly one-third of the patients treated with IF underwent conversion to arthroplasty, whereas only 4% of those treated with primary THA underwent revision. Due to the different nature of the methods, the aim was not to compare them. IF may be a joint-preserving option with conversion arthroplasty as an established salvage procedure. However, from a patient's point of view, the period leading up to any reoperation will be painful and disabling. THA as acute primary treatment will on the other hand sacrifice the joint, including in those whose fracture would have healed if treated with IF [12]. Within 5 years, most complications after IF are identified [12]. After THA, late complications such as aseptic loosening and late-presenting periprosthetic fractures, and dislocations due to wear may occur, and a follow-up of up to 20 years is warranted to establish a true revision rate [12].

When comparing literature on IF with our results, we found comparable conversion rates. Bartels et al. [3] reported conversion rates of 27% for patients treated with IF for dFNF within 5 years, also utilizing a competing risk analysis. A Danish register study reported a 19% reoperation rate after IF within 1 year [4]. In contrast, RCTs show higher 2-year reoperation rates of 37–51% [20,21]. The difference may represent a selection of patients or fractures more suitable for IF or THA in clinical practice reflected in the observational register studies.

Our results on THA as acute treatment align well with a Norwegian register study reporting 2.8% revisions within 5 years [3]. A systematic review found a pooled revision rate of 1.18 per 100 component years for THA in the hip fracture population [22]. Applied to our data this would predict close to 6% revisions within 5 years for patients treated with THA assuming linearity. In RCTs, the reoperation rate is reported as 4–9% at 2 years, with a somewhat wider definition of "major reoperations" [20,21].

The disadvantages of a conversion arthroplasty in terms of poorer surgical results than primary arthroplasty [7,23] is questioned by some studies [24-26]. Regardless, the main concern must be the loss of health-related quality-of-life during the period leading up to conversion arthroplasty [7].

From a clinical perspective, the fact that 2 out of 3 patients in this age group kept their native hip joint after 5 years could be interpreted as promising. We cannot assess their function or perceived pain based on our data, but in a previous study on the same age group we found no differences in patient-reported outcome between IF and primary THA [11].

So how should the risk of reoperation be weighed when initial treatment is chosen? Clinical variables such as comorbidity, activity, and the patient's preferences play a role in determining whether he or she is a candidate for IF or not. The gradually lower age threshold for primary THA [5] may seem contradictory to longer life span and healthier older years. One can expect more retirees to perform sports and maintain a physically active lifestyle. Also, the focus on patient-centered care puts more emphasis on the surgeon being able to inform and share the treatment decision with the patient to best meet his or her expectations.

The age threshold for IF versus arthroplasty varies internationally. When designing this study, we conducted an informal survey sent to orthopedic trauma centers reporting to the SFR on how they allocate to the different treatments. Most of the 23 centers that answered used a mean age cut-off of 65 years for IF, whereby older patients would be treated with arthroplasty.

Regardless of surgical procedure, surgical skills are essential. As poor reduction quality is reported in recent studies [4,20], one can speculate in whether reduction and IF of a dFNF has become so rare a procedure that surgeons have lost their skills to handle it.

Strength and limitations

A strength of the study is that the surgical outcome is derived from a national register with high completeness and the excellent reliability of death dates.

A limitation is that the 5-year follow-up does not address the concerns of a poorer long-term prognosis for those treated with a primary THA [12]. Ideally, a comorbidity index and data on pre-fracture activity would have shed more light on how the 2 treatment methods were chosen, but such data is not available in the SFR. The initially low completeness of the SFR might lead to some bias, as not all Swedish trauma centers contributed during the first years. Nevertheless, the outcome was retrieved from the SAR, a register with a stable and high completeness and coverage.

As with all register-based data, the risk for residual confounding is apparent and when comparing implants and any differences in mortality should be interpreted more as a sign of residual confounding than an effect of the implant per se [27]. If the surgeon based the implant choice on patient factors like vitality or level of physical activity, this selection bias will overshadow inherent implant characteristics, interfering with the risk. Predictors available in our data such as sex, age, and surgeon experience have previously been associated with risk for reoperation and mortality. Also, there is a risk of selection and indication bias for who gets a conversion to arthroplasty, where frailer patients might be considered for minor reoperations or nonoperative treatment. However, in the current group, the young old, we believe this to be less of an issue than in older cohorts.

Conclusion

IF for dFNF carries a significant risk of complications even in the young old, around retirement age. In our study, one-third of patients needed conversion arthroplasty within 5 years. When patients received THA as primary treatment, 1 in 25 needed revision surgery in the same time span. Due to different surgical magnitude, the methods are not directly comparable, but the risk of secondary surgery should be considered when discussing treatment options with patients in this age group.

JL: author, study design, data acquisition, curation, and interpretation. SSR: author, data interpretation. OW: author, data interpretation. SM: author, data interpretation, study design. MM: author, draft manuscript preparation and project supervision. JN: data acquisition, statistics and interpretation of data. CR: author, study design, data acquisition, interpretation of data. project supervision.

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Paper IV

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

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Abstract

Background

In the last century several methods for internal fixation of femoral neck fractures have been developed and evaluated. Some have proven reliable while others have been abandoned due to poor outcome in terms of early mechanical failure and pain due to instability. In Sweden, different implants have been used but are nowadays limited to a handful of products. These include canulated screws, hook pins and sliding hip screw. The objective of this study is to evaluate, based on register data, if any of the commonly used implants is associated with a higher risk for later conversion to arthroplasty within a 6 year follow up.

Methods

In this observational cohort study of prospectively collected data from the Swedish Fracture Register (SFR) we co-processed registrations with the Swedish arthroplasty register (SAR) to find ipsilateral arthroplasty performed after initial internal fixation of femoral neck fractures (FNF). Patients were 60 years or over. We found 6,558 patients eligible for final analysis. Patients were included 2012-2018 in SFR and follow until the end of 2019 in SAR. A Cox regression model was utilized to estimate risk for conversion to arthroplasty for displaced and non-displaced FNF. Co-variates in the model was patient age, surgeon experience and sex.

Results

Type of implant did not affect the risk for conversion to arthroplasty either for displaced nor non-displaced FNFs. Age and female sex were the only variables in the model that showed statistically significantly effect on risk for later conversion arthroplasty. Women had a 45% higher risk compared to men, increasing age was associated with reduced risk in displaced FNFs.

Introduction

Non-displaced or minimally non-displaced femoral neck fractures (nFNF) are commonly treated with internal fixation (IF). Because of the less invasive and less time-consuming procedure – as well as the idea of retaining the biological properties of the hip – IF with canulated screws or hook pins is the current clinical routine in Sweden. Also, younger adults with a displaced femoral neck fracture (dFNF) are predominately treated with reduction and IF. IF is here performed with the hope of patients retaining their biological hip with benefits of lower risk of infection and better proprioceptive signaling from an intact capsule and ligamentous complex. Nevertheless, a study with long-term follow-up has shown that patients treated with IF, without signs of healing complications, do not report any better result than patients treated with total hip arthroplasty (THA) in terms of pain and mobility (1). Also, in those aged 60-70 years, patient-reported outcome is similar at 1 year, in both the IF and the THA group (2).

In Sweden, IF is reported to be used in 84% of patients >60 years with nFNFs and arthroplasty in 10%. The corresponding numbers for dFNFs are 7% IF and 90% arthroplasty (3). Although the topic has been studied for decades (4), there is limited and very low certainty evidence on which type of implants to prefer when fixing femoral neck fractures (FNF) (5). The type of implant and number of screws/pins is a controversial issue, where different solutions are sought to reduce the rate of secondary surgery. This leads to international variations, where many countries use three or more parallel screws (6) and the discussion is focused on how these should be placed within the femoral neck and head. In contrast, the Scandinavian countries mostly use two screws, or two smooth hook pins inserted parallel (7, 8). There is also growing interest in sliding hip screw (SHS) for intracapsular fractures as well, in particular for those with a vertical and/or basicervical fracture line. Here the SHS design can provide better stability (9, 10).

The latest Cochrane review only comprise randomised studies, which often are small and heterogenous (5). Except for Danish reports (8, 10) there are few register-based studies comparing implants. We therefore conducted a comparison between canulated screws, hook pins and sliding hip screw for fixation of non-displaced and displaced FNF, respectively, regarding the risk for conversion to arthroplasty with a follow up time of 6 years.

Objectives

The main objective of this study was to analyze any difference in risk for conversion to arthroplasty after IF in a register cohort of prospectively collected data on FNF in patients 60 years or over.

Patients and methods

Study design

This register-based cohort study was based on prospectively collected data from the Swedish Fracture Register (SFR) and the Swedish Arthroplasty Register (SAR). The STROBE guidelines were followed for reporting of the present study (11).

Setting

Primary injury was collected from the Swedish Fracture Register (SFR) including data on mortality, surgeon experience, sex and age. The SFR also contains data on fracture classification and treatment. The SFR was initiated in 2011 (12), and over 810,000 fractures have been registered at the time of writing. The coverage has gradually improved due to a stepwise introduction and since 2021, all orthopedic departments in Sweden participate in the register, i.e. 100% coverage. During the study

period 2012-2018, the completeness for hip fracture registrations in the SFR increased from 18% to 55% compared to the National Patient Register (13) due to the step wise activation of more hospitals. The SFR has decided to continue with the 2007 AO/OTA-classification, to maintain longitudinally homogenous data. Thus, FNFs are classified accordingly as non-displaced or minimally displaced subcapital (31-B1), basicervical (31-B2) and displaced subcapital (31-B3) (14). Each treating physician registers data on patient level for the injury, fracture classification, and treatment through a secure web-based portal.

Data on subsequent arthroplasty in the same hip was collected from the Swedish Arthroplasty Register (SAR). It is the national quality register for arthroplasty surgery of hip and knee in Sweden. The coverage of SAR is 100% including all departments performing hip joint replacement surgery, both public and private. For the study period, the completeness was 98% for THA (15). The registers are updated regarding date of deaths by regular co-processing every 24 hours with the population register (the Swedish Tax Agency).

Patients

Data for all patients aged 60 years and older at injury and registered with a nFNF or dFNF using the AO/OTA classification 31-B1 and 31-B3 in SFR from 2012 to 2018 were extracted and cross-referenced with available data from SAR for each individual from the date of the index fracture until December 31, 2019. To provide trustable co-processing between registers regarding subsequent surgeries and/or death, the unique personal identity number given to each Swedish citizen, was used. The nFNFs (AO/OTA 31-B1, Garden 1-2) and dFNFs (AO/OTA 31-B3, Garden 3-4) were analyzed as subgroups. Only the first registered hip fracture for each individual was included in the study. Pathological, stress and spontaneous fractures identified by their ICD-10 diagnose codes (M84.4, M84.8, M84.3) in the injury mechanism registration were excluded and are presented in the flowchart as “pathological fracture” (Figure 1). Patients with Girdlestone procedure as primary treatment were excluded. Also, patients with combinations of exclusion criterions were excluded. Finally all patients with arthroplasty as primary treatment were excluded.

Study variables

Basic demographic data, available in the SFR (age, sex, surgeon experience) and fracture classification (non-displaced/displaced) and date of death was utilized in a regression model. Surgeon experience was defined as resident or consultant (dichotomous). From the SAR we extracted date for first arthroplasty in the same hip. Length of follow-up was defined as time from injury date to date of death or end of study period on December 31, 2019.

Study outcomes

The main outcomes were risk for conversion to arthroplasty after primary fixation with IF. A regression model (Cox) was used to establish risk-factors (fracture class, implant, age, sex, surgeon experience) in the cohort as well as in the subgroups uFNF and dFNF.

Statistics

Patient characteristics were described using frequencies with proportions and means. The time from treatment with IF to death, to conversion arthroplasty, or until end of study, whichever came first, was used in the analysis in the IF group. Cox regression was utilized to explore associations between fracture class, type of implant and secondary surgery (conversion to arthroplasty) and risk factors available in the register data: sex (categorical), age (continuous) and treating surgeon (factorial -

resident vs consultant). Hazard ratios are presented with 95% confidence intervals (CI). Schoenfeld's test for proportionality assumption was utilized. All statistics was done with R version 4.0.2.

Ethics, data sharing and funding

Ethical approval was granted from the Central Ethical Review Board in Gothenburg (ref. 830-17) and from The Swedish Ethical Review Authority (diary number 2019-05024, 2022-00972-02). To ensure confidentiality for patients included in this study, the dataset is not publicly available. This is a requirement for ethical approval and is also regulated by the law on public access and secrecy; Chapter 21, §7, Chapter 25, §1 (https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/offentlighets--och-sekretesslag-2009400_sfs-2009-400). Requests to access this data should go through senior author and/or Lund University to ensure proper measures are taken in conjunction with the legislation as well as the ethical approval. Any sharing of data beyond what is presented in this paper will involve an approval from the Swedish Ethical Review Authority.

Funding was received from the independent trust Axel Linder Foundation as well as the Swedish Research Council funding for clinical research in medicine (ALF).

Results

Patients and Descriptive Data

21,951 FNFs in patients 60 years or older were found in the SFR. After exclusion, 6,464 patients treated with were analyzed (Figure 1). Patients with pathological (n=6), stress (n=24) and spontaneous (n=32) fractures were excluded as well as patients treated with intramedullary nails (n=32), as this might indicate multiple fractures in the femur. The Girdlestone procedure were used in 115 patients (1.8%) and these cases were excluded. Patients treated with arthroplasty were excluded (n=13,878). The fracture was caused by low energy trauma in more than 9 of 10 cases. Hook pins were the most common treatment in Sweden during the studied period (58%) followed by canulated compression screws (39%). Only 215 cases were treated with sliding hip screw (3%) (Table 1). A minority of cases was reported as more than 2 screws or pins (3%) and this was more common in dFNF's (10% vs. 5%).

Risk of conversion to arthroplasty after IF

None of the commonly used implants in Sweden was associated with any significantly elevated risk of subsequent conversion to arthroplasty for the entire cohort (Table 2). Female sex was a significant factor for later conversion to arthroplasty (HR 1.45, 95% CI 1.2-1.7). The most significant risk factor for later conversion was fracture displacement, where dFNFs had an HR of 2.23 (95% CI 1.9-2.6) (Table 3). 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=1.59, 95% CI 1.3-2.0). In dFNFs, increasing age had a negative effect on risk of conversion (HR=0.98, 95% CI 0.96-0.99) (Table 4).

Discussion

In a large cohort, we did not find any difference between commonly used implant for internal fixation of FNF regarding risk for subsequent conversion to arthroplasty. There are several different types of fixation methods available today – from canulated compression screws, to hook pins, sliding hip screw (SHS) and intramedullary nailing. During the last two decades, recommendations has moved from using screws (4) to that a SHS may be preferable (16). Still, a systematic review including 38 studies demonstrated no difference between screws and fixed angle plates in functional status, health-related

quality of life, 1-year mortality or unplanned return to theatre. When comparing screws and pins no difference was seen in mortality (17).

More emphasis is put on the number of screws nowadays. Improved fracture stability can be obtained by increasing from 2 to 3 screws (18, 19) The optimal construct for osteoporotic femoral neck fixation is suggested to be an inverted triangle configuration with 3 parallel screws (20). For a femoral neck fracture with severe posterior cortical comminution, an additional fourth screw may increase the strength of the construct (21). Still, one must bear in mind that several of the studies are biomechanical, which is not a mirroring of the clinical situation (22). Our results are in line with the register study by Nyholm et al., reflecting clinical practice in Denmark, that found no association between the number of screws used and reoperation (8). Neither the latest Cochrane report was able to recommend a particular implant or number of implants over the other (23).

It may be futile to look for differences between implants of similar nature, as initial fracture displacement and suboptimal fracture reduction have been shown to be much stronger risk factors for failure (24, 25). Also, how the implants are positioned, including avoiding a varus angle of the implants may interfere with the risk of reoperation (8, 26-28). Finally, as our results suggest, patient characteristics will also be associated with a risk of reoperations. Supporting earlier results, we found female sex and increasing age to be risk factors (29). Increasing age was associated with a somewhat lesser risk of conversion to arthroplasty in dFNF's. This could be explained by lower functional demand in advanced age, but more certainly because elderly selected to IF for a dFNF may be in a life-threatening situation at the time of the fracture, and – if surviving – are not optimal candidates for secondary in the case of healing complications. For uFNF female sex was a significant risk for later conversion to arthroplasty in our data, but not in the case of dFNF's. A unifactorial explanation to this is hard to find but the higher prevalence of osteoporosis in women may cause higher risk of fixation failure in the non-displaced fractures, that are more commonly treated with IF.

Strengths

Our cohort is larger than the 7 clinically studies summarized in the Cochrane report (5) and the cohorts in the Danish register studies (8, 10). The unique Swedish personal identity number enables us to link data between registers and our outcome is retrieved from a national quality register with high completeness,

Limitations

Due to the register-based study design, neither radiographs, nor data on frailty, comorbidities, or cognitive impairment are available. As these factors might influence reoperation rates, there will be a risk of residual confounding. As arthroplasty is the most common major reoperation for failure after IF (30) we decided to focus on conversion to arthroplasty as outcome. We underline that conversion to arthroplasty does not reflect the total complication rate after IF. In addition to minor reoperation as screw removal, there will also be cases when either the surgeon or the patient refrain from major secondary surgery, i.e. the outcome we chose will admit a risk of selection and indication bias. As Swedish orthopedic surgeons prefer two parallel implants, our national sample precludes analyses on any differences between two, three and four implants.

Conclusion

Choice of implant, among those commonly adopted in Sweden and Scandinavia, does not seem to influence risk for later conversion to arthroplasty in either uFNF or dFNF. In uFNFs, female sex is associated with an increased risk for conversion, which needs to be considered when deciding treatment regime.

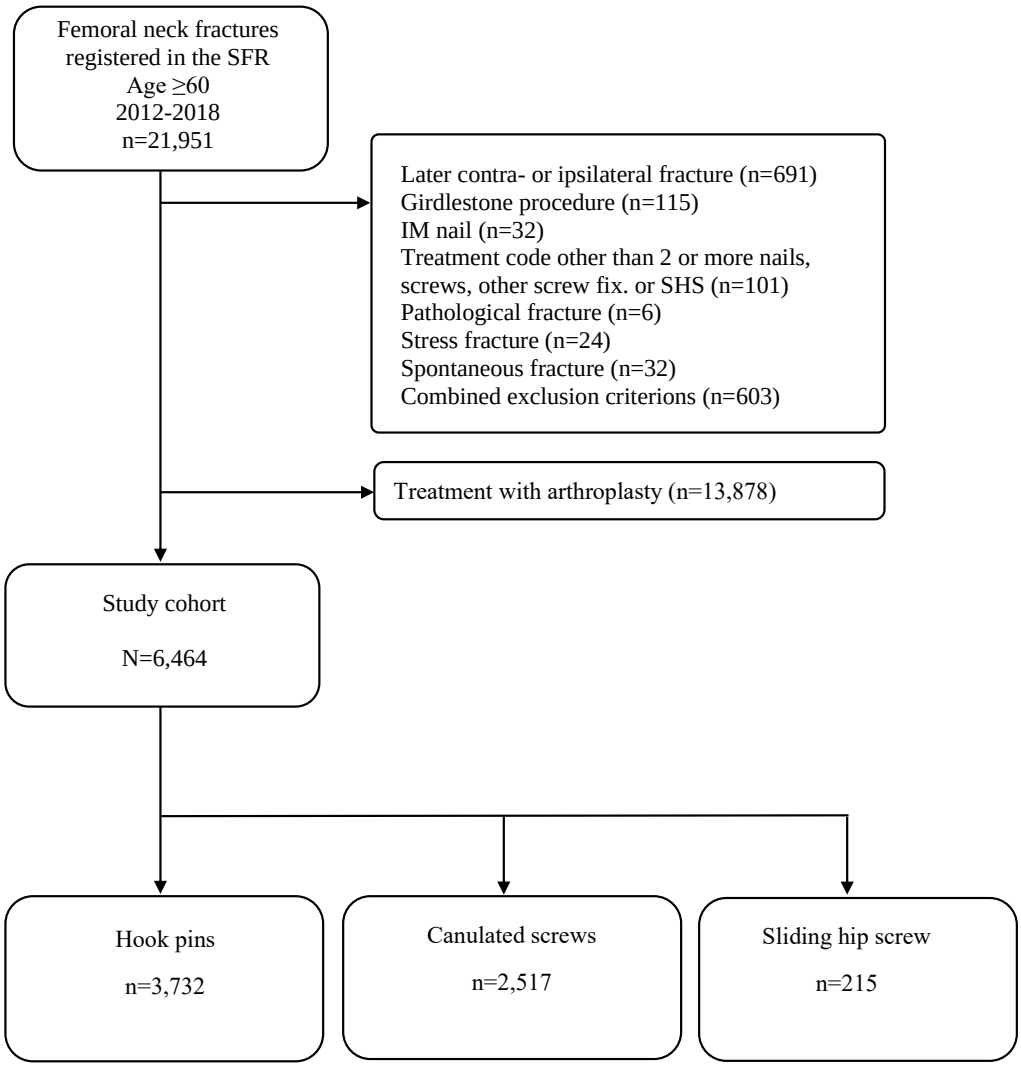

Figure 1. Flowchart of included and excluded participants.

	uFNF n=5201			dFNF n=1271		
	HP n=3014	CCS n=2047	SHS n=140	HP n=721	CCS n=474	SHS n=76
Age (SD)	80.5 (8.9)	80.6 (8.9)	81.2 (9.6)	79.0 (11)	78.0 (11)	77.1 (11)
Female (%)	2046 (68)	1416 (69)	73 (52)	393 (55)	252 (54)	39 (52)
Low energy (%)	2898 (98)	1909 (98)	129 (98)	669 (97)	434 (96)	70 (93)
2 parallel implants (%)	2917 (97)	1995 (98)	0	672 (94)	444 (95)	0
> 2 parallel implants (%)	97 (3)	32 (2)	0	46 (6)	18 (4)	0
Other screw fixation (%)	0	18 (1)	0	0	7 (2)	0

Table 1. Patient characteristics

	Hook pins	Canulated screws	Sliding hip screw
Hazard ratio (95% CI)	ref.	1.0 (0.9-1.2)	1.2 (0.8-1.8)

Table 2. Crude hazard for conversion to arthroplasty based on implant choice

	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 3. Adjusted hazard for conversion to arthroplasty

	nFNF	**p**	**dFNF**	**p**
HP	ref		ref	
CCS	1.03 (0.86-1.24)	0.73	1.03 (0.77-1.37)	0.84
SHS	1.17 (0.68-2.01)	0.57	1.06 (0.62-1.81)	0.84
Age	1.00 (0.99-1.01)	0.67	0.98 (0.96-0.99)	< 0.001
Female sex	1.60 (1.28-2.00)	<0.001	1.26 (0.96-1.67)	0.10
Surgeon exp.	1.06 (0.89-1.28)	0.50	1.20 (0.90-1.60)	0.22

Table 4. Subgroup analysis and adjusted hazard ratios for conversion to arthroplasty

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On femoral neck fractures in the elderly

Johan Lagergren, born 1978 in Alingsås, studied medicine at Umeå University and graduated in 2008. After internship in Uddevalla and Trollhättan, he started his orthopedic specialist training in 2010. As a specialist, he has mainly focused on trauma orthopedics. He is currently working at Alingsås Lasarett, Alingsås.

This thesis project on femoral neck fractures in patients over 60 began in 2017. Although this injury has been the subject of many studies, this thesis aims to add clinically relevant knowledge, in particular for "young old" patients. Results from the first and second papers have been presented at both national and international orthopedic meetings, such as EFORT in Lisbon 2019, and 2022.

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