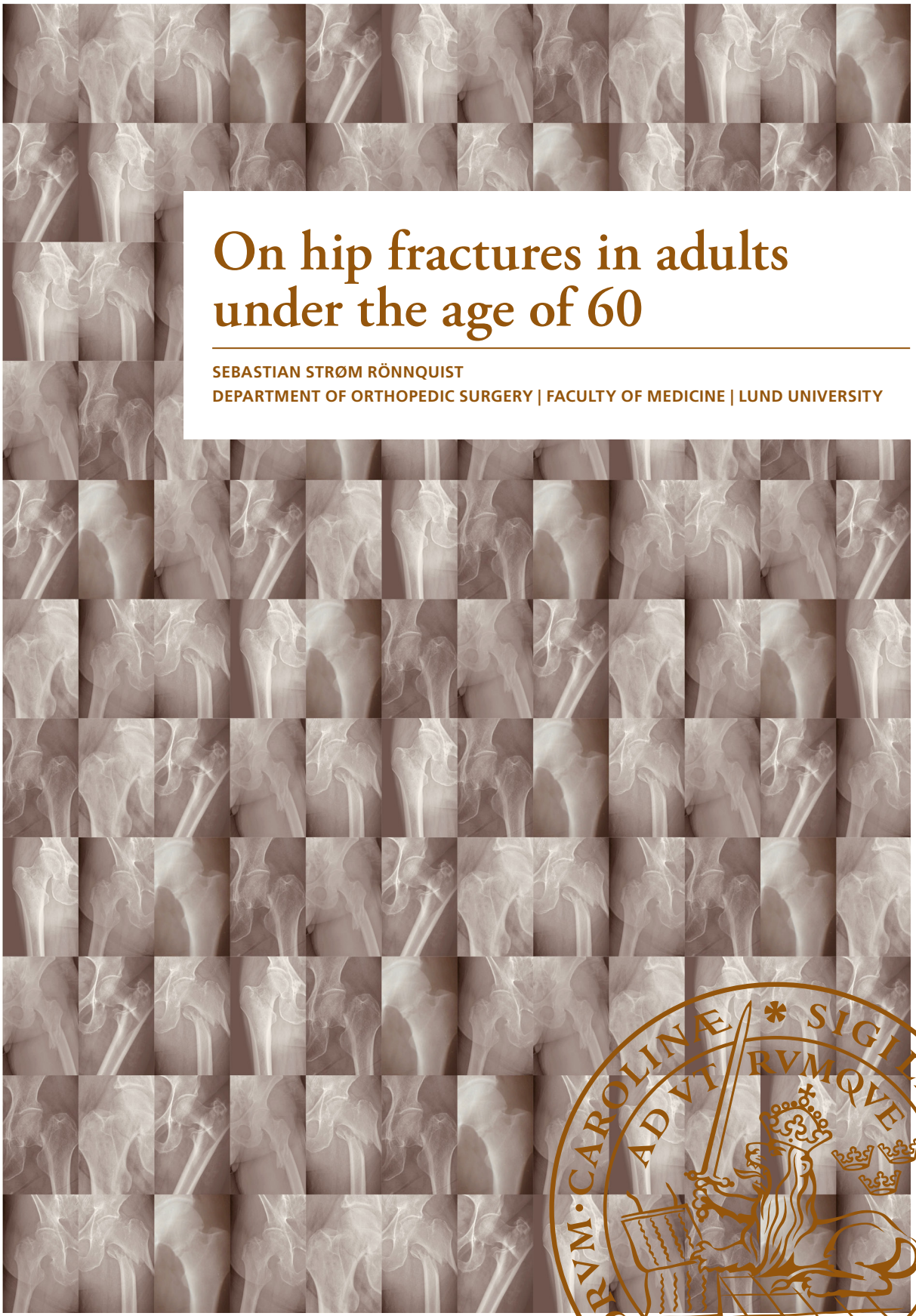
On hip fractures in adults under the age of 60

Strøm Rönnquist, Sebastian

2022

Document Version:
Publisher's PDF, also known as Version of record



On hip fractures in adults under the age of 60

SEBASTIAN STRØM RÖNNQUIST
DEPARTMENT OF ORTHOPEDIC SURGERY | FACULTY OF MEDICINE | LUND UNIVERSITY

On hip fractures in adults under the age of 60

On hip fractures in adults under the age of 60

Sebastian Strøm Rönnquist

LUND UNIVERSITY

DOCTORAL DISSERTATION

by due permission of the Faculty of Medicine, Lund University, Sweden.
To be defended at Föreläsningssalen, Ortopediska kliniken, SUS Malmö
September 16th 2022, at 9 AM.

Faculty opponent
Cathrine Marie Lofthus MD, PhD
Oslo, Norway

Organization LUND UNIVERSITY Department of Orthopaedics Clinical sciences, Malmö	**Document name** Doctoral dissertation **Date of issue** 2022-09-16
Author: Sebastian Strøm Rönnquist	Sponsoring organization

Title and subtitle
On hip fractures in adults under the age of 60

Abstract

Introduction The understanding of patients under the age of 60 with hip fractures have been influenced by preconceptions that fractures are due to high-energy trauma and the risk of osteoporosis is low. The patients' perspectives have seldomly been presented and the surgical results were insufficiently described. This thesis project was developed in response to the relative lack of research on this patient group.

Methods In a prospective, multicenter, mixed general population-based cohort study, Paper I collected detailed information on the injury, demographics, epidemiology, lifestyle factors, comorbidity and general health, and DXA was performed at the time of the fracture. Paper II described the fracture classification, and analyzed whether trauma mechanism and osteoporosis determined the fracture pattern. In a qualitative interview study, Paper III illuminated the lived experience of recovery after a hip fracture. Paper IV analyzed national register data to describe the rate of conversion to secondary arthroplasty after internal fixation of displaced and undisplaced femoral neck fractures.

Results Adults under the age of 60 constituted approximately 5% of the total hip fracture population. More than half of the fractures occurred in men and most were aged 50-59. Two thirds of the fractures were displaced or unstable and intracapsular fractures were most common. Two thirds suffered their fractures after low-energy trauma, two thirds had previous disease(s), and half had a previous fracture. On DXA, we found a high prevalence of osteopenia (57%) and osteoporosis (31%). Trauma mechanism and bone mineral density did not determine different hip fracture patterns. The recovery after a hip fracture was a protracted process with lingering pain, functional, and psychosocial challenges and support of rehabilitation was inadequate. After initial internal fixation, a secondary arthroplasty was performed in 25% of displaced and 8% of undisplaced femoral neck fractures at five years.

Interpretation Existing preconceptions should be traded for a nuanced understanding of patients under the age of 60 with hip fractures. A thorough health investigation and DXA assessment is warranted in all patients, regardless of age and trauma mechanism. A long term follow up is justified considering lingering challenges in recovery and the risk of a need for conversion to secondary arthroplasty after internal fixation of femoral neck fractures. Rehabilitation should be diversified and meet the demands of younger patients suffering hip fractures.

Key words
Hip fracture, young and middle-age, epidemiology, DXA, osteoporosis, lived experience, register cohort

Classification system and/or index terms (if any)

Supplementary bibliographical information Lund University, Faculty of Medicine Doctoral Dissertation Series 2022:115	**Language** English
ISSN and key title 1652-8220	**ISBN** 978-91-8021-276-2
Recipient's notes	**Number of pages** 82 Price
	Security classification

Signature  Date 2022-08-10

On hip fractures in adults under the age of 60

Sebastian Strøm Rönnquist

LUND
UNIVERSITY

AO 31-B1 & B3: Lutnick E, Kang J, Freccero DM. Surgical Treatment of Femoral Neck Fractures: A Brief Review. Geriatrics. 2020 Jun;5(2):22.

AO 31-B2: Wang Q, Gu X hua, Li X, Wu J hong, Ju Y feng, Huang W jie, et al. Management of Low-Energy Basicervical Proximal Femoral Fractures by Proximal Femoral Nail Anti-Rotation. Orthopaedic Surgery. 2019;11(6):1173–9.

AO 31-A1, 31-A2 & 31-A3: Lu Y, Uppal HS. Hip Fractures: Relevant Anatomy, Classification, and Biomechanics of Fracture and Fixation. Geriatr Orthop Surg Rehabil. 2019 Jan 1;10: 1–10.

AO 32-A1: Delasotta LA, Hanflik A, Bicking G, Mannella WJ. Hyperbaric Oxygen for Osteomyelitis in a Compromised Host. The Open Orthopaedics Journal [Internet]. 2013 May 3 [cited 2022 Jun 13];7(1).

Author photo: Julie Strøm Rönnquist.

Faculty of Medicine, Institution for Clinical Sciences Malmö.
Department of Orthopedic Surgery.

ISBN 978-91-8021-276-2
ISSN 1652-8220

Printed in Sweden by Media-Tryck, Lund University
Lund 2022

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

MADE IN SWEDEN

Till min familj
varande och fordom

”For hjertet er livet enkelt: det slår så lenge det kan.”
Karl Ove Knausgård, Min kamp

Table of Contents

Abstract

The understanding of patients under the age of 60 with hip fractures have been influenced by preconceptions that fractures are due to high-energy trauma and the risk of osteoporosis is low. The patients' perspectives have seldomly been presented and the surgical results were insufficiently described. This thesis project was developed in response to the relative lack of research on this patient group.

In a prospective, multicenter, mixed general population-based cohort study, Paper I collected detailed information on the injury, demographics, epidemiology, lifestyle factors, comorbidity and general health, and DXA was performed at the time of the fracture. Paper II described the fracture classification, and analyzed whether trauma mechanism and osteoporosis determined the fracture pattern. In a qualitative interview study, Paper III illuminated the lived experience of recovery after a hip fracture. Paper IV analyzed national register data to describe the rate of conversion to secondary arthroplasty after internal fixation of displaced and undisplaced femoral neck fractures.

Adults under the age of 60 constituted approximately 5% of the total hip fracture population. More than half of the fractures occurred in men and most were aged 50-59. Two thirds of the fractures were displaced or unstable and intracapsular fractures were most common. Two thirds suffered their fractures after low-energy trauma, two thirds had previous disease(s), and half had a previous fracture. On DXA, we found a high prevalence of osteopenia (57%) and osteoporosis (31%). Trauma mechanism and bone mineral density did not explain different hip fracture patterns. The recovery after a hip fracture was a protracted process with lingering pain, functional, and psychosocial challenges and support of rehabilitation was inadequate. After initial internal fixation, a secondary arthroplasty was performed in 25% of displaced and 8% of undisplaced femoral neck fractures at five years.

Existing preconceptions should be traded for a nuanced understanding of patients under the age of 60 with hip fractures. A thorough health investigation and DXA assessment is warranted in all patients, regardless of age and trauma mechanism. A long term follow up is justified considering lingering challenges in recovery and the risk of a need for conversion to secondary arthroplasty after internal fixation of femoral neck fractures. Rehabilitation should be diversified and meet the demands of younger patients suffering hip fractures.

Svensk sammanfattning

Höftfraktur är välstuderat bland äldre, medan litteraturen om de yngre patienterna har varit sparsam. Den generella uppfattningen av yngre patienter med höftfraktur har influerats av förutfattade meningar; att yngre bryter höften på grund av högenergetiskt trauma, missbruk, eller för att de är multisjuka – inte på grund av osteoporos (benskörhet). Det råder också en uppfattning om att vilken typ av höftfraktur en patient får styrs av traumamekanismen, ju högre energi i skademomentet desto värre – mer felställd eller instabil – fraktur. Ännu mindre har skrivits om de yngre patienternas egna upplever att drabbas av en höftfraktur och även resultaten efter operation för collumfrakturer (lårbenshalsbrott) var bristfälligt beskrivna. För att komplettera kunskapen om yngre individer som drabbas av höftfrakturer utvecklades doktorandprojektet, med målet att svara på de övergripande frågorna:

- Vem är det som bryter höften i yngre ålder?
- Vad avgör frakturmönstret?
- Hur påverkas livet och hur upplever patienterna återhämtningen efter en höftfraktur?
- Hur är det kirurgiska resultatet hos yngre patienter?

Delarbete I och II utgår från forskningsprojektet HöftFraktur hos vuxna Under 60 år (HFU-60). HFU-60 är en kohortstudie baserad på den allmänna befolkningen från fyra ortopediska kliniker i Sverige och Danmark, där patienter under 60 år med höftfraktur har bjudits in att delta i studien. Avsikten med HFU-60 studien var att analysera demografi, epidemiologi, förekomst av osteoporos, frakturbehandling och resultaten efter höftfraktur för unga patienter.

Delarbete I undersökte vilka patienterna är som drabbas av höftfraktur i yngre ålder; vi analyserade detaljerad information om skademekanismen bakom höftfrakturen, demografi, epidemiologi, livsstilsfaktorer, samsjuklighet och generell hälsa. Dessutom mättes bentätheten med DXA kort tid efter frakturen. Delarbete II beskrev frakturtyperna stringent enligt AO/OTAs frakturklassifikation och undersökte om det fanns ett samband mellan typ av höftfraktur, traumamekanism och osteoporos. Delarbete III var en kvalitativ intervjustudie, som baserades på en subgrupp av HFU-60 patienterna, där patienternas egna upplevelser av att bryta höften belystes.

Delarbete IV analyserade nationella registerdata från Svenska Frakturregistret och Svenska Ledprotesregistret för att beskriva frekvensen av omoperation med höftprotes i de fall när osteosyntes (spikning/skruvning) av collumfrakturer misslyckades.

Vi fann att vuxna under 60 år utgjorde cirka 5% av den totala höftfrakturpopulationen. Mer än hälften av frakturerna skedde hos män och de flesta patienter var i åldern 50–59 år. Två tredjedelar av frakturerna var felställda eller instabila och höftfrakturer innanför ledkapseln var vanligare än dem utanför ledkapseln. Två tredjedelar ådrog sig frakturen vid lågenergitrauma, två tredjedelar hade tidigare sjukdom(ar), och hälften hade haft en tidigare fraktur. Vid bentäthetsmätning fann vi en hög förekomst av osteopeni (delvis sänkt benmassa) (57%) och osteoporos (31%), men osteoporos och traumamekanism avgjorde inte frakturmönstret. Att återhämta sig efter en höftfraktur var en långsam process som innehöll kvardröjande smärta, funktionella och psykosociala svårigheter och stödet i rehabiliteringen var bristfälligt. Efter osteosyntes av collumfrakturer utfördes omoperation med höftprotes hos 25% av dem med felställda frakturer och 8% av dem med icke felställda frakturer.

Förutfattade meningar bör ersättas av en nyanserad förståelse av vilka de yngre patienterna med höftfraktur är. En grundlig hälsoundersökning samt bentäthetsmätning är befogat för alla patienter, oavsett ålder och traumamekanism. Långtidsuppföljning är motiverad; särskilt med tanke på långvariga svårigheter i återhämtningen efter en höftfraktur i kombination med risken för både tidiga och sena komplikationer efter osteosyntes av collumfrakturer, vilket kan kräva omoperation med höftprotes. Rehabiliteringen efter höftfrakturer bör individualiseras och möta kraven även från yngre patienter.

List of papers

I. Frailty and osteoporosis in patients with hip fractures under the age of 60 – a prospective cohort of 218 individuals.
Sebastian Strøm Rönnquist, Bjarke Viberg, Morten Tange Kristensen, Henrik Palm, Jens-Erik Bech Jensen, Carsten Fladmose Madsen, Kristina E Åkesson, Søren Overgaard, Cecilia Rogmark.
Osteoporosis International. 2022 May 1;33(5):1037–55.

II. Trauma mechanism and bone mineral density did not impact hip fracture type – a multicenter cohort of patients under 60 years of age.
Sebastian Strøm Rönnquist, Bjarke Viberg, Morten Tange Kristensen, Henrik Palm, Jens-Erik Bech Jensen, Carsten Fladmose Madsen, Kristina E Åkesson, Søren Overgaard, Cecilia Rogmark.
Manuscript 2022.

III. Lingering challenges in everyday life for younger patients with hip fractures – a qualitative study of the lived experience during the first three years.
Sebastian Strøm Rönnquist, Hilda K Svensson, Charlotte Myhre Jensen, Søren Overgaard, Cecilia Rogmark.
Manuscript 2022.

IV. Rate of conversion to secondary arthroplasty after femoral neck fractures in 796 younger patients treated with internal fixation: a Swedish national register-based study.
Sebastian Strøm Rönnquist, Johan Lagergren, Bjarke Viberg, Michael Möller, Cecilia Rogmark.
Acta Orthopaedica. 2022 Jun 14;93:547–53.

Abbreviations

AO	Arbeitgemeinschaft für Osteosynthesefragen / AO Foundation
AP	Antero-posterior
ASA	American Society of Anesthesiologists
BHW-PA	Board of Health and Welfare physical activity questions
BMD	Bone mineral density
CI	Confidence interval
DXA	Dual energy x-ray absorptiometry
FNF	Femoral neck fracture
FRAX®	Fracture Risk Assessment Tool
HFU-60	Hip Fractures in adults Under 60 years of age
ICD-10	International Classification of Diseases, tenth revision
IF	Internal fixation
NHANES III	Third National Health and Nutrition Examination Survey
SAR	Swedish Arthroplasty Register
SFR	Swedish Fracture Register
WHO	World Health Organization
UN	United Nations

Thesis at a glance

Paper	Questions and study design	Main results	Conclusion	Perspective
I	Who fractures their hip in younger age? Prospective, multicenter, cohort study, n=218.	Most of the fractures occurred in men (58%), in patients aged 50-59 years (68%), and after low-energy trauma (68%). 1/3 of the patients had no disease, 1/3 had 1 disease, and 1/3 had multiple comorbidities. Half of the patients had a previous fracture. Smoking (42%), alcohol (29%), and drug use (8%) were more common than in the general population. Vitamin D was low in half of the patients. On DXA investigation, the prevalence of osteopenia (57%) and osteoporosis (31%) were high compared to reference population data.	This was a heterogeneous group with a high degree of frailty and numerous risk factors for fractures. The prevalence of osteopenia and osteoporosis was high.	Younger patients with hip fractures should be thoroughly investigated, including DXA investigation.
II	What causes the fracture pattern? Prospective, multicenter, cohort study, n=218.	Femoral neck fractures constituted 58% (2/3 were displaced), pertrochanteric fractures 34% (2/3 were unstable), basicervical (5%), and subtrochanteric (4%), i.e., intracapsular fractures (63%) were more common than extracapsular. Another concurrent fracture was seen in 7 patients. Analyses on the associations between fracture type, trauma mechanism, and DXA result did not reach statistical significance, though clinically important findings were seen.	Most fractures were unstable/ displaced and the anatomical location was mainly intracapsular. Most fractures resulted from low-energy trauma. Trauma mechanism and BMD did not impact hip fracture type.	The high prevalence of low BMD calls for awareness of the risk of osteoporosis associated with hip fractures regardless of age and trauma type.

Paper	Questions and Study design	Main results	Conclusion	Perspective
III	How is life affected after a hip fracture? Qualitative interview study, n=19.	Lingering pain and feelings of weakness, disability and physical inability were expressed by participants. The provided care and rehabilitation were perceived as adapted to elderly patients, not to the needs of younger individuals.	The lived experience of sustaining a hip fracture in patients under 60 years includes challenges in everyday life, even years after the injury.	Other pathways of care and rehabilitation, and improved information, are suggested to meet diverse demands of all patients with hip fractures.
IV	What is the surgical outcome in younger patients? National register study, n=796.	Most fractures occurred in men (59%), in patients aged 50-59 years (63%), and after low-energy trauma (77%). Secondary arthroplasty was performed in 108 patients. Coversion rates for dFNF at 1, 2, and 5 years were: 1y: 9% (95% CI 6–12), 2y: 17% (CI 13–21), 5y: 25% (CI 20–30). For uFNF, conversion rates were: 1y: 3% (CI 1–5), 2y: 5% (CI 3–8), 5y: 8% (CI 5–11). Age 50-59 had an increased risk of conversion for uFNF compared to patients aged <50. Mortality rate for patients 50-59 years were 4% (CI 2-6) at 1 year, and 16% (CI 11-20) at 5 years.	Higher rate of conversion for dFNF compared to uFNF during follow-up, at 5 years 25% vs. 8%. Mortality rates were markedly higher for patients aged 50-59, but did not differ between sex or fracture types.	Surgeons and patients should be aware of the risk of conversion to arthroplasty at the time of initial fracture treatment.

DXA: Dual energy x-ray absorptiometry
BMD: Bone mineral density
dFNF: displaced femoral neck fracture
uFNF: undisplaced femoral neck fracture

Preface

This thesis project was developed in 2014, in response to the scarcity of literature regarding younger patients with hip fractures, especially in comparison to the elderly population, which has been well studied in this regard.

To understand multiple aspects of the phenomenon of hip fractures in adults under the age of 60, a prospective, multicenter, mixed general population-based cohort study called the Hip Fractures in adults under 60 years of age (HFU-60) was designed and initiated. The intention was to provide information on the demography, epidemiology, prevalence of osteoporosis, treatment, and outcomes after hip fracture. In this thesis, Paper I and Paper II come from the HFU-60 study and aim to answer these questions: who fractures their hip at younger ages, and what determines the fracture pattern?

As a sub-study of the HFU-60, the qualitative interview study InterHFU was undertaken using a subset of individuals from the cohort. The rationale behind this qualitative study was to illuminate the patients' experiences of suffering a hip fracture, with a focus on these questions: how is life affected after a hip fracture, and how do patients experience the recovery? The outcomes of this study were explicitly patient-centered, thanks to the study design of Paper III.

To expand the generalizability of the results, in Paper IV, data was retrieved from two national registers, the Swedish Fracture Register and the Swedish Arthroplasty Register. This provided a large cohort that enabled analysis of reoperation with arthroplasty after initial treatment with internal fixation of femoral neck fractures. This provided new and pertinent information on the surgical outcomes in this age group.

This has been an evolving journey, looking forward during the years of working on this project, but also looking back at the works of prior orthopedic surgeons such as Speed, Leadbetter, Garden, and Johansson in Sweden, who all provided essential knowledge on hip fractures beginning almost a century ago (1–4). Alas, you gentlemen of previous generations, even though our understanding of hip fractures has deepened, the femoral neck fracture is still unsolved.

Copenhagen, August 2022

Introduction

A life-breaking event

A hip fracture has been described as a life-breaking event, one that not only breaks a bone but also leaves existential and social cracks (5). Research on older patients with hip fractures makes clear the risks of subsequent functional deficit, persistent pain, fear of falling, and decreased health-related quality of life (6–8). Regarding younger patients, there has been a lack of knowledge about their perspectives (9). Furthermore, orthopedic surgeons tend to have preconceived notions about the characteristics of young and middle-aged patients with hip fractures.

Common preconceptions are that younger patients suffer hip fractures due to high-energy trauma or alcohol/substance use disorder, but not due to osteoporosis (10,11). This perception is underpinned by surgically-oriented studies from trauma centers and low-income countries. The few existing studies suggesting that young and middle-aged patients with hip fractures may have osteopenia and osteoporosis regardless of trauma mechanism were directed to readers interested in bone health (12–15). In addition, these studies were based only on risk factors for osteoporosis or dual-energy x-ray absorptiometry (DXA) years after the fracture – not at the time of the fracture. These shortcomings indicate a need for studies on a population-based cohort with evaluation for osteoporosis by DXA investigation at the time of the fracture.

Another common notion is that hip fracture type and degree of displacement is associated with trauma mechanism, i.e., that a higher trauma energy would lead to a displaced or more unstable fracture type. However, this has not been shown in previous reports. Poorer bone quality has previously been proposed as a reason for a shift toward more unstable fractures in older patients, as the distribution of fracture type differs compared to younger patients (16). Clearly, a better understanding of hip fractures and the possible etiology behind different fracture patterns is needed.

To illuminate younger patients' perspectives, how could their lived experience and path of recovery after sustaining a hip fracture be studied?

Who is younger?

Age and the understanding of who is younger or older is relative. There is no consensus in the literature on the dividing line distinguishing younger from older patients with hip fractures; ages between 40 and 70 years have been used in studies (17,18). Multiple studies have, however, used age 60 as a cut-off between younger and older patients (19–27).

The World Health Organization (WHO) and the United Nations (UN) collaborated in developing the United Nations Decade of Healthy Ageing (2021–2030), focusing on healthy ageing and improving the lives of older people, defined as an age above 60 (28,29).

In the HFU-60 study, 60 years of age was defined as the upper age limit, which coincides with treatment guidelines at the department of origin of the study, where age 60 has been used as a divide in deciding between arthroplasty or internal fixation for displaced FNFs.

Individuals aged under 60 are hence regarded as younger in this thesis and referred to as young, younger, young and middle-aged, or non-elderly.

Epidemiology

Hip fractures are most often suffered by an elderly individual, but 2–11% of hip fractures affect young and middle-aged patients (30,31). From the Swedish Fracture Register (SFR), the total number of adult hip fractures in 2021 was 13,936, and fractures in individuals aged 18–59 years accounted for 616 (4%) (32). In a study on hip fractures in women under age 65, age 45 was found to be the first significant increase in age-related incidence, and most fractures are found in the eldest group of younger patients (12).

Hip fractures in the elderly population are often explained as an expression of comorbidities or frailty in combination with reduced bone quality. However, although fracture risk was higher with a lower bone mineral density (BMD), in a large analysis of self-reported fractures, only one-fourth of hip fractures occurred in individuals with osteoporosis; most fractures occurred in the osteopenic range with T-scores of -1 to -2.5 (33).

From the SFR year report 2020 (16), the fracture type distribution by age visualizes a change in fracture type with higher age, where displaced femoral neck fractures and multifragmentary pertrochanteric fractures are more common at higher ages (Figure 1).

Figure 1 Hip fracture type distribution according to age group

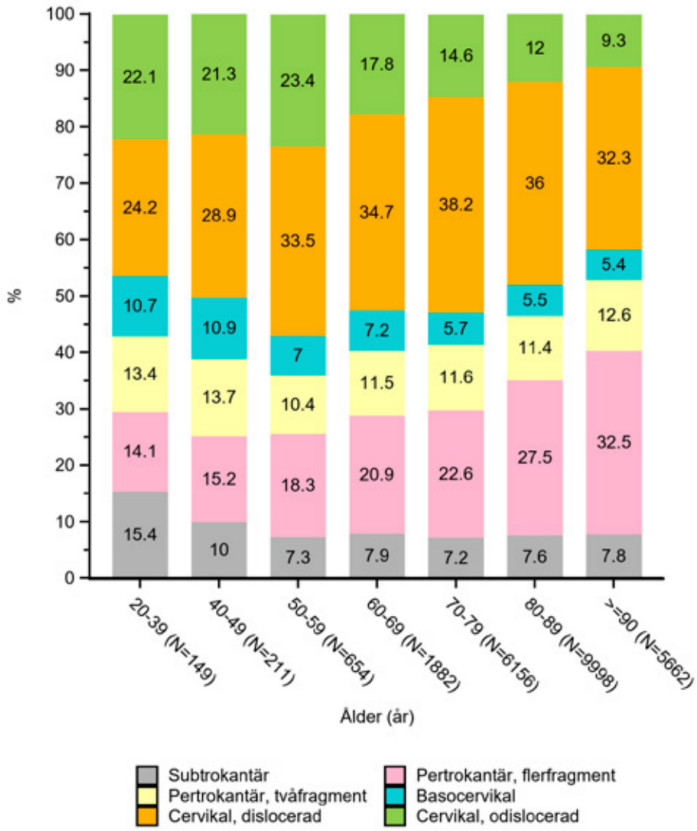


Figure 1 The distribution of hip fracture types changes with higher age. Displaced femoral neck fractures and multifragmentary pertrochanteric fractures are more common in higher ages. Figure from the SFR annual report 2020 (16). Fracture types in English – subtrokantär: subtrochanteric – pertrokantär, flerfragment: pertrochanteric, multifragment – pertrokantär, tvåfragment: pertrochanteric, two fragments – basocervikal: basicervical – cervikal, dislocerad: femoral neck fracture, displaced – cervikal, odislocerad: femoral neck fracture, undisplaced.

The injury

Some hip fractures occur spontaneously, but most fractures occur because of trauma. In the reporting of orthopedic fracture research, a distinction between low-energy and high-energy trauma is often made, and one would expect there to be universal definitions of these terms. However, there is only consensus regarding low-energy trauma, which is defined as a same-level fall from standing height or less (34). High-energy trauma can refer to traumatic events, like high-speed traffic accidents or falls from a considerable height, e.g. >3m or more (13,30,35,36), but

definitions vary. In younger patients, high-energy trauma has previously been proposed as the main reason for hip fractures (24,35,36).

In the HFU-60 study, low-energy trauma was defined as a same-level fall from a standing or sitting position, and all other trauma was defined as “not low-energy trauma”, thereby avoiding the need to enumerate specific higher-energy trauma mechanisms.

Hip fracture classification

A hip fracture is a fracture of the proximal part of the femur, but typically excluding fractures of the femoral head itself. Hip fractures can be categorized according to their anatomical location on the femur, but other systems of classification based on fracture morphology, degree of displacement, and sometimes etiology are often used.

Anatomical description

Anatomically, hip fractures can be divided into intracapsular and extracapsular fractures depending on the fracture’s location in relation to the hip joint capsule, which extends to the intertrochanteric line, as seen on plain antero-posterior (AP) radiographs. Fractures lateral to the intertrochanteric line are considered extracapsular, and consist of the sub-types pertrochanteric and subtrochanteric hip fractures. Intracapsular fractures are found medial to the intertrochanteric line and consist of femoral neck fractures (FNFs). One classification system based on the anatomical location of the fracture is the WHO International Classification of Diseases, tenth revision (ICD-10). According to ICD-10, hip fractures are classified as S72.0x (where x is 0 or 1 for closed or open fractures, respectively) for femoral neck fractures, S72.1x for pertrochanteric fractures, and S72.2x for subtrochanteric fractures (37).

AO/OTA classification

Arbeitgemeinschaft für Osteosynthesefragen (AO), currently the AO Foundation, was begun by a group of Swiss surgeons in 1958 to improve treatment of fractures (38). The work included classifying fractures, which in 1996 led to the publication of a Fracture and Dislocation Classification Compendium, a collaboration between AO and the Orthopaedic Trauma Association (OTA), most recently revised in 2018 (39). In the Swedish Fracture Register (SFR), from which data was collected for Paper IV, fractures are classified according to the 2007 revision (40). Hip fractures are classified according to their anatomical location as well as fracture morphology.

Figure 2 AO/OTA classification of hip fractures in the Swedish Fracture Register

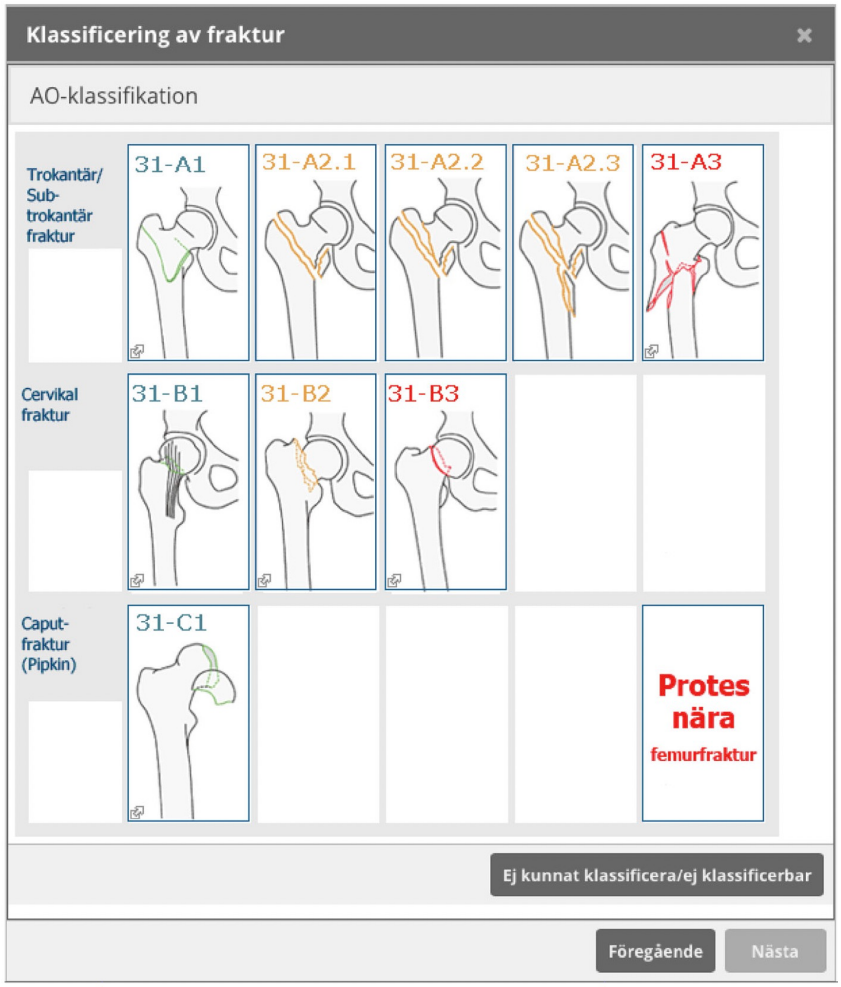


Figure 2 AO/OTA classification of hip fractures in the Swedish Fracture Register. Figure from Sundkvist et al. (41).

Garden's classification

R.S. Garden presented a classification of FNFs, based on the displacement seen on AP radiographs (3). In Garden's classification, FNFs are classified into four types – stage I–IV – but due to high inter-observer variation, it has been reduced to two categories: undisplaced (Garden 1–2) and displaced (Garden 3–4), which is commonly used clinically (42).

Description based on etiology

Hip fractures have also been described according to one of the main etiologies, i.e., osteoporosis. The Fracture Risk Assessment Tool (FRAX®), used to calculate the 10-year probability of fractures based on risk factors, defines hip fractures as a major osteoporotic fracture (together with fractures of the spine, forearm, and shoulder) (43). The FRAX® is intended for use in patients above 40 years of age, and fracture risk cannot be accurately calculated for younger patients.

Treatment

The prognosis in terms of pain, functional outcome, and mortality for a patient with a hip fracture left untreated is poor. In the days when hip fractures in adults were treated with plaster casts, the importance of reduction and firm fixation was emphasized by Leadbetter (2), but he considered aftercare to be most important in hip fracture treatment to preserve life. Today, treatment is generally surgical, with the goal to allow early mobilization, and aftercare remains important.

Regarding the choice of the specific operative treatment, decisions are based on fracture type, degree of displacement, and the patient's age, ideally biological rather than chronological. Principally, the choice of surgical treatment of hip fractures is binary, internal fixation (IF), or joint replacement by arthroplasty.

The surgical outcome after IF of displaced FNFs in older patients is well described. That understanding has led to a change in primary treatment to arthroplasty, due to unacceptably high rates of reoperations (44,45). In younger patients, IF is recommended for these fractures, thereby sparing the native joint (25). However, the rate of conversion to secondary arthroplasty has been insufficiently described. One population-based cohort study reported a conversion rate of 14% but did not distinguish fracture displacement (46), and a smaller case series presented a conversion rate of 22% for displaced fractures (22). More comprehensive results of surgical treatment, based on a large cohort with precise fracture classification, are needed.

In Scandinavia, the treatment for undisplaced FNFs in all ages is currently internal fixation, but in other countries the use of arthroplasty is increasing. Therefore, randomized trials are underway in Scandinavia and the UK to investigate if arthroplasty is a better treatment option for elderly patients (47–49).

Extracapsular fractures are mainly treated by IF, using either sliding hip screw devices or intramedullary nails; nails are usually preferred for unstable pertrochanteric and subtrochanteric fractures (25).

The Swedish Fracture Register

The SFR was begun in 2011 as a national quality register; it prospectively collects data on injury and fracture type according to AO/OTA classification, operative and non-operative fracture treatments, and reoperations – all recorded to the register by the treating physician. Patients answer questionnaires regarding functional performance pre-fracture and one year after the fracture. The coverage for hip fractures in the SFR increased from 18% to 86% during the study period for Paper IV (2012–2018), due to an increased number of hospitals participating in the register (50,51). By 2021, coverage was 100%; all orthopedic departments in Sweden report to the register, which recorded 645,000 fractures at the end of 2021. The completeness was validated and found to be 55% for femoral fractures in 2018, rising to 84% in 2020 (52,53). A validation study found the accuracy of classification by orthopedic surgeons of femoral fractures in SFR to be substantial for AO/OTA group and almost perfect for AO/OTA type (54).

The Swedish Arthroplasty Register

Begun in 1975, the Swedish Knee Arthroplasty Register was the first national quality register in Sweden; it was followed by the Swedish Hip Arthroplasty Register in 1979. The two registers are now united into one national quality register for hip and knee replacement surgery, the Swedish Arthroplasty Register (SAR). The SAR prospectively registers patient data, procedure-related information, and patient-reported outcome measures. Knee replacements are beyond the scope of this thesis and will not be covered further. References to arthroplasty in the thesis indicate arthroplasty of the hip. Regarding hip arthroplasty, all departments performing hip replacements in Sweden report to the SAR, i.e., a coverage of 100%. The completeness for the years of Paper IV (2012–2019) was approximately 98% for total hip arthroplasty (THA), 96% for hemiarthroplasty (HA), and 92% for revisions of THA and HA (55).

Using unique individual personal identification numbers, patients can be followed accurately in and across the registers. Both registers are notified from the population register (the Swedish Tax Agency) in the case of any deaths, and date of death is registered.

Aims

Overall aim

The thesis project aimed to deepen the understanding of hip fractures in younger patients. Research questions were as follows:

- Who fractures their hip at younger ages?
- What determines the fracture pattern?
- How is life affected after a hip fracture, and how do patients experience their recovery?
- What is the surgical outcome in younger patients?

Specific aims

Paper I: To describe the characteristics of a cohort of patients under age 60 with hip fractures, focusing on risk factors for fractures and osteoporosis and analyze BMD at the time of the hip fracture in relation to the general population.

Paper II: To describe the fracture classification in a cohort of patients under age 60 with hip fractures and analyze associations between trauma mechanism, BMD, and fracture type.

Paper III: To illuminate the lived experiences of and the path of recovery for adults sustaining a hip fracture before age 60.

Paper IV: To determine the rate of conversion to arthroplasty from IF due to undisplaced and displaced FNFs in patients under age 60 and to descriptively analyze mortality and the relationship between conversion rate and sex, age, trauma mechanism, and surgeon's experience.

Methods

HFU-60: Paper I and II

Study design

The HFU-60 study is a prospective, multicenter, mixed general population-based cohort study of adult patients under age 60 with hip fractures. The overarching aim of the study is to describe the epidemiology, fracture treatment, and clinical and functional results as well as patient-reported outcomes.

Paper I presents the primary baseline report from the HFU-60 study, providing detailed information on patient and injury characteristics; it describes the demography and epidemiology of hip fractures in young and middle-aged patients, lifestyle factors, comorbidity and general health, and results of DXA investigation at the time of the fracture. The latter feature was analyzed in relation to previous population-based samples. Paper II describes the fracture classifications in the cohort and analyzes associations between trauma mechanism, BMD, and fracture type. Further studies based on the HFU-60 project have been undertaken, and results will be published separately.

Setting

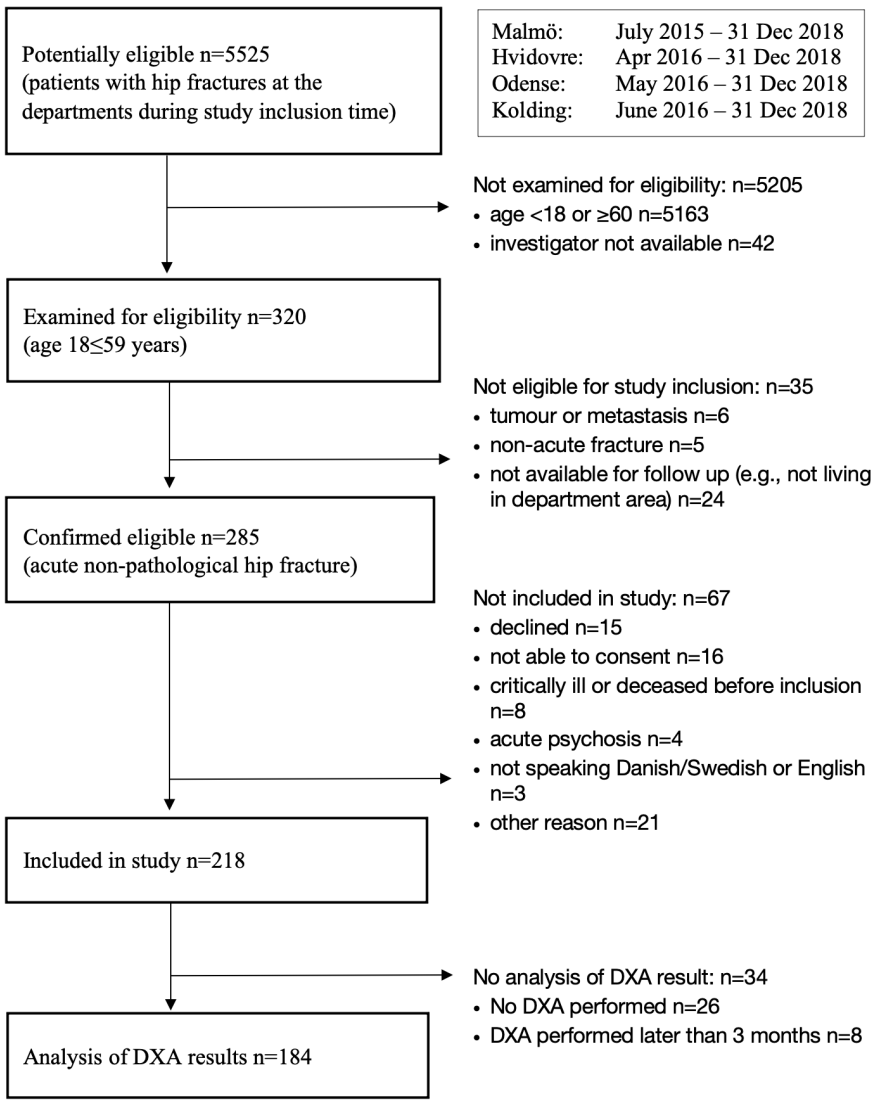
Patients were included at four departments of orthopedics and traumatology in Southern Scandinavia: Skåne University Hospital Malmö in Sweden and, in Denmark, Hvidovre University Hospital, Odense University Hospital, and Lillebaelt University Hospital Kolding. The participating departments belong to public hospitals serving both urban and rural areas; they are responsible for all fracture treatment in their catchment areas, thus the cohort represents all types of trauma and patient profiles. Public healthcare is provided in both Denmark and Sweden; it is free in Denmark and available at low cost in Sweden.

Participants

Patients aged 18 to 59 years presenting with a hip fracture to any of the participating departments were examined for eligibility, regardless of medical, functional, and

cognitive status prior to the fracture. Patients with pathological fractures (i.e., tumor or metastasis), non-acute fractures (i.e., older than four weeks), or not residing in the catchment area were excluded from study participation. Existence of other concurrent injuries was not a reason for exclusion. Of the confirmed eligible patients, 67 were excluded from the HFU-60 cohort; these patients did not consent to participate or were unable to consent due to their medical condition (i.e., they were critically ill, transferred to other departments, or in an acute psychosis) or because they did not speak Swedish, Danish, or English.

Figure 3 Flow chart of inclusion and DXA analysis in HFU-60



Data collection

In HFU-60, multiple variables were collected; recorded variables used in Paper I and II are specified and defined in Appendix Table 5 in the appended Paper I. Data were retrieved via review of medical records and patient interviews, physical activity assessments and functional tests, patient questionnaires on alcohol and drug use, laboratory assessment, and BMD investigation.

The injury was classified according to trauma mechanism, in HFU-60 as either low- or not low-energy trauma and in Paper IV following the registrations in the SFR as low- or high-energy trauma. Low-energy trauma was defined as same-level falls in both HFU-60 and the SFR. Significantly high levels of energy, e.g., falls from heights or traffic accidents, were considered high-energy trauma in the SFR. In HFU-60, the term "not low-energy trauma" was used for trauma other than same-level falls.

In Paper I, the fracture classification was simplified to either intra- or extracapsular, whereas in Paper II, the full fracture classification recorded in the HFU-60 study was used. This meant that the fractures were classified by orthopedic surgeons according to a predefined protocol fitted to the 2007 revision of the AO/OTA Fracture and Dislocation Classification Compendium (40). Fractures were classified as follows (3,40):

- undisplaced femoral neck (Garden 1-2, AO 31-B1)
- displaced femoral neck (Garden 3-4, AO 31-B3)
- basicervical (AO 31-B2)
- stable pertrochanteric (AO 31-A1 + A2.1)
- unstable pertrochanteric (AO 31-A2.2-3 + A3)
- subtrochanteric (AO 32 until 3cm below lower border of lesser trochanter)

Statistics

Data collected at the local departments was stored securely online using Research Electronic Data Capture (projectredcap.org). Data curation and analysis was performed using IBM SPSS version 26. Continuous variables were assessed for normality and presented as either mean (SD) or median (IQR) depending on normal distribution. Associations between categorical variables were analyzed by chi-square tests, and T-test was used to compare means; a p-value of <0.05 was considered statistically significant.

InterHFU: Paper III

Study design

InterHFU was a qualitative study on a subset of the HFU-60 cohort from Skåne University Hospital Malmö and Odense University Hospital, using a phenomenological hermeneutic method following Lindseth and Norberg (56): a method of text analysis or text interpretation consisting of naïve reading and understanding, structural analysis, and comprehensive understanding.

Participants

Individuals included in the HFU-60 cohort from Malmö or Odense were also eligible for participation in InterHFU, provided they fulfilled the inclusion criteria: speaking Swedish or Danish, ability to individually partake in the interview, minimum six months' time since the hip fracture, and New Mobility Score ≥3 pre-fracture (57). Of these, 30 participants were purposively sampled and invited, and 19 agreed to participate.

Data collection

Participants were interviewed by two experienced qualitative researchers; data collection continued until no new aspects of experiences were presented. Interviews were initiated with an open-ended question: "Could you tell me about when you sustained your hip fracture and how you have experienced the time after as well as your recovery?" An interview guide with follow-up questions was used if needed, with the intention to keep the interviewee within the focus of the study.

Recorded data was transcribed, and triangulation was performed through comparisons by a bilingual author, evaluating whether the collection of the two national datasets were similarly conducted.

Analysis

Naïve reading involved multiple readings of the text as openly as possible, to grasp the meaning behind the words rather than what was literally stated. The findings from both datasets echoed each other, enabling a joint analysis. In the structural analysis, the text was further studied; units of meaning and units of significance were identified, and themes emerged. Comprehensive understanding involved critical reflection in relation to relevant literature, where the apparent themes were discussed to gain an understanding of the participants' experiences.

National register study: Paper IV

Study design

Paper IV was a longitudinal cohort study based on two Swedish national registers, with analyses of prospectively collected data from the SFR and the SAR. For information on the register setting, please refer to the introduction.

Participants

From the SFR, patients with undisplaced and displaced FNFs treated with parallel pins/screws or sliding hip screw devices during 2012–2018 were included. Other fracture types and spontaneous, pathological, and stress fractures were excluded, as were fractures treated with arthroplasty, intramedullary nail, other types of plate fixation, or non-surgically. In the SAR, secondary arthroplasties were identified by cross-referencing the registers. The unique individual personal identification number carried by all Swedish inhabitants enabled a reliable match between registers, regarding both secondary surgeries and death.

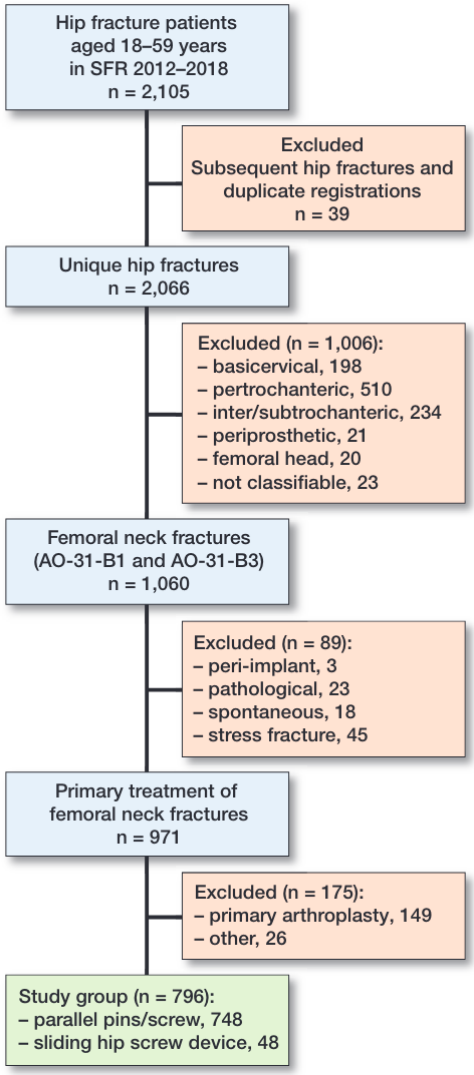
Data collection

Basic epidemiological variables (i.e., sex, age, and trauma mechanism categorized as either low- or high-energy trauma) were collected from the SFR, together with data on the primary fracture treatment (i.e., type of IF and surgeon's experience defined as performed by either a resident or a specialist). From the SAR, data on conversions to arthroplasty were collected and analyzed together with mortality data.

Statistics

Observations were grouped by fracture type (undisplaced or displaced FNF), sex, and age <50 or 50–59. Continuous variables were presented as mean or median, depending on normality, and associations between categorical variables were analyzed using the chi-square test. The rate of conversion was determined as cumulative reoperation rate with 95% confidence interval (CI) at one, two, and five years after the fracture by Kaplan-Meier analysis, which was also used to determine mortality rate. Previously described risk factors for secondary arthroplasty (female sex, higher age, high-energy trauma mechanism, and resident surgeon) (58–61) were analyzed using a Cox proportional hazard regression model. Analysis was performed in IBM SPSS version 26 and R version 4.0.2; a p-value of <0.05 was considered statistically significant.

Figure 4 Flow chart of inclusion in Paper IV



Ethical considerations

The studies included in the thesis (Paper I–IV) were conducted in accordance with the Helsinki Declaration. The HFU-60 study was registered at ClinicalTrials.gov (NCT03848195). Papers I, II, and III were approved by the ethical review boards in Sweden (Regionala etikprövningsnämnden Lund [dnr: 2015/28]) and Denmark (the Regional Health Service and University Research Ethics Committee and the Danish Data Agency [S-20150137]). Participants provided informed consent prior to study enrollment.

Paper IV was approved by the Swedish national ethical review board (Etikprövningsnämnden: Dnr 2019-05024), and data were pseudonymized before extraction from the registers and subsequent analysis.

Data supporting the findings of the studies may be made available upon reasonable request to the corresponding author. The authors have no conflicts of interest with relevance to any of the studies to declare. Funding for the studies was provided by grants from the Greta and Johan Kock Foundation, A. Påhlsson Foundation, H Järnhardt Foundation, Skåne University Hospital Research Fund, the Research and Development Council of Region Skåne, the Swedish Research Council funding for clinical research in medicine, and *Region Syddanmarks forskningsfond* from the Region of Southern Denmark. None of the funders had influence on the scientific work.

Main results

Characteristics of younger patients with hip fractures

Demographics and anthropometrics

From both the HFU-60 (Papers I–II) and the national register study (Paper IV), it was found that the proportion of men incurring hip fractures (58% and 59%, respectively) was larger than women. Approximately two-thirds of the fractures occurred in patients aged 50–59 years, and 83% of the patients in the HFU-60 study were aged 45–59 years. Figure 5 shows a larger proportion of the fractures in higher ages.

Figure 5 Age distribution of hip fractures in patients under 60 years in Paper I and II and Paper IV.

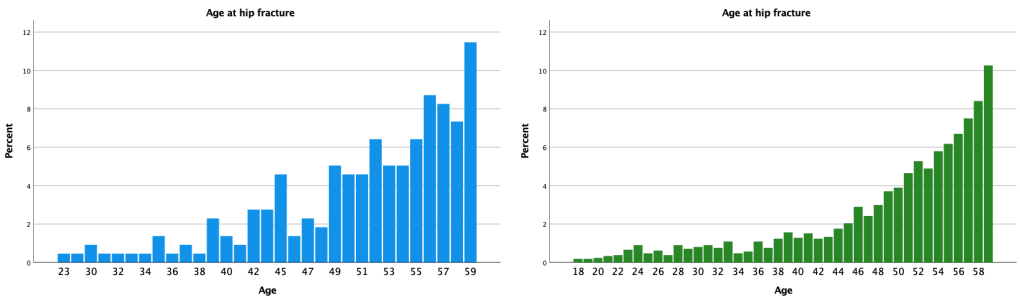


Figure 5 Age distribution of hip fractures in patients under age 60 in the HFU-60 cohort (Paper I and II, left in blue) and in the SFR cohort 2012-2018 (Paper IV, right in green).

In HFU-60, women had a higher median age than men, and women were significantly overrepresented in the oldest age group; 52% of the women were aged 50–59 versus 35% of the men (p=0.009). A little more than half of the patients lived with another adult, 37% lived alone, and 5% (8% of the men) inhabited an institution (Table 1 in Paper I). Body Mass Index (BMI) was normal in half of the patients, but

women were overrepresented in the underweight as well in the obese categories (p=0.023).

Lifestyle factors

Almost all patients (92%) in the HFU-60 study reported no specific dietary preferences; vegetarians and vegans constituted 3%, as did those on a diabetes diet (Table 2 in Paper I). Less than half of the patients (41%) achieved a score of ≥11 on the Board of Health and Welfare physical activity questions (BHW-PA) (that is, were physically active corresponding to the WHO-recommended minimum activity level of 150 minutes per week). Smoking was reported by 42% of the cohort, and 16% reported previous smoking (i.e., quit more than two years ago). Validated questionnaires on alcohol (AUDIT) and drug use (DUDIT) were answered by 89% and 87% of the patients, respectively. Hazardous or harmful alcohol use was found in 25% of the women and 31% of the men. On DUDIT, 5% of the women and 10% of the men reported signs of drug-related problems.

Medical history

We found that a third of the patients were healthy, a third had one previous disease, and a third had multiple comorbidities (Table 3 in Paper I). In 144 patients (66%), 313 diseases were found. A larger proportion of women than men were found with any previous disease(s), 71% and 62%, respectively (p=0.025). Diseases that were considered associated with increased risk of hip fracture after literature review and expert discussion (Appendix Table 6 in Paper I) were found in 105 patients (48%); neurological disease, diabetes, psychiatric disease and disability, osteoporosis, and chronic obstructive pulmonary disease were the five most common, accounting for 59% of the diseases potentially associated with hip fracture.

Patients were classified according to the American Society of Anesthesiologists (ASA), and two-thirds were categorized as ASA I-II, i.e., with no or mild systemic disease. The remaining third of the patients were ASA III-IV, with six patients considered ASA IV.

Almost half of the cohort (47%) had incurred a previous fracture in adult life, and 5% had a previous hip fracture. A family history of fragility fractures was reported by almost a fifth of the patients, but an equal fraction could not say whether fragility fractures were present in or absent from the family history.

Previous medication

Medical charts were reviewed, and patients were asked about use of medication during the five years leading up to the hip fracture; 135 patients (62%) had used any

medication regularly. Of these, 70 patients presented 130 pharmacological treatments potentially associated with increased fracture risk (Appendix Table 7 in Paper I). The three most common treatments used (accounting for 40%) were as follows: proton pump inhibitors, selective serotonin reuptake inhibitors, and opioids.

Blood sample results

Pre- and post-operative blood samples were analyzed (Appendix Table 8 in Paper I) adjunctive to the operation, on mean 1.4 (SD 1.1) days before and two (2.4) days after surgery. In the pre-operative samples, CRP and leucocytes were above reference in 30% and 75% of the cases, respectively; hemoglobin was below reference in 37% of the samples. Post-operatively, results below reference in more than a quarter of the samples were seen for sex hormones (85% low estradiol in women, 60% low testosterone in men), vitamin D (52%), albumin (45%), and calcium (29%).

The injury

Most fractures were due to low-energy trauma, accounting for 68% of all fracture types in the HFU-60 and 77% of the FNFs in Paper IV. In Paper I, we found that low-energy traumas were more common in women (78%) than in men (61%) (p=0.007).

Fracture types were classified according to AO/OTA in Paper II and Paper IV. All hip fracture types were included in Paper II, while only FNFs were included in paper IV (Table 1).

Table 1 Fracture classification in HFU-60 according to AO/OTA.
Fractures were classified by orthopedic surgeons according to the 2007 revision of the AO/OTA classification, where basicervical fractures are considered intracapslar and unstable (40).

Fracture types	n (%)
Undisplaced femoral neck, AO 31-B1	46 (21)
Displaced femoral neck, AO 31-B3	80 (37)
Basicervical, AO 31-B2	11 (5)
Stable pertrochanteric, AO 31-A1 + A2.1	28 (13)
Unstable pertrochanteric, AO 31-A2.2-3 + A3	45 (21)
Subtrochanteric, AO 32	8 (4)

In the HFU-60 cohort, intracapsular fractures (63%) were more common than extracapsular, and two-thirds of the fractures were displaced or unstable. Other concurrent fractures were seen in seven patients (five low-energy trauma, two not low-energy trauma), involving the spine, ribs, the contralateral lower extremity, or the upper extremities.

DXA results

DXA investigation was performed within three months of the hip fracture in 184 patients; 85% were performed within the first post-operative month. The median time to DXA investigation was five days (IQR 3-24). T-score at the lumbar spine, femoral neck, or total hip were osteoporotic (< -2.5) in 31% of the patients, osteopenic (-1 to -2.5) in 57%, and normal T-scores (> -1) were found in 12% (Table 4 in Paper I). Results were similar for women and men, with insignificant differences between low-energy and not low-energy trauma, although a tendency of marginally better results on DXA investigation was seen after not low-energy trauma.

Figure 6 Comparison of mean T-scores, HFU-60 vs. NHANES III

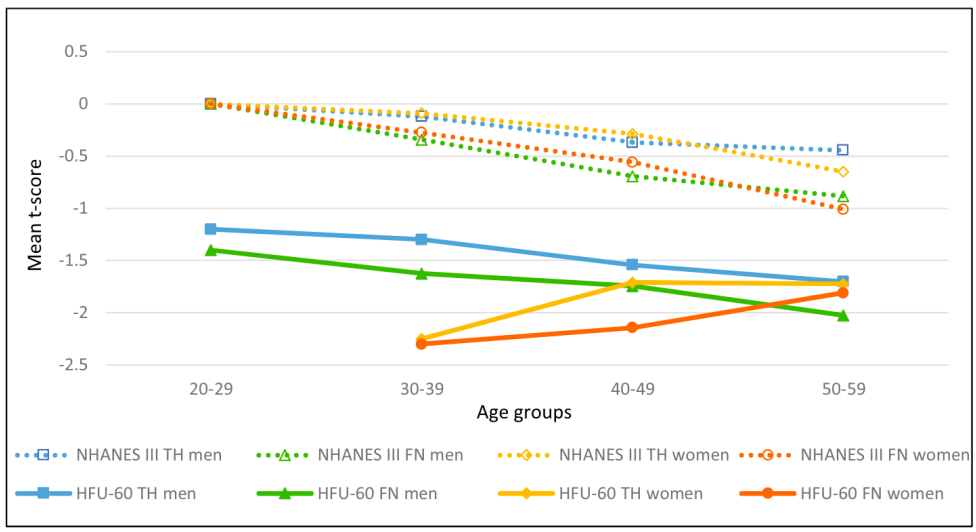


Figure 6 Comparison of mean T-score by age group, HFU-60 vs. NHANES III. Multiple line chart of HFU-60 mean T-scores for women and men compared to NHANES III mean T-scores calculated from BMD data (62). TH total hip, FN femoral neck. NHANES III mean BMD data for age groups were converted to T-scores using the formula: T-score = (measured BMD – young adult mean BMD) / young adult population SD (63). Mean T-scores for HFU-60 were significantly lower than for NHANES III regarding both TH and FN for men (p = < .001), TH for women (p = 0.02), and FN for women (p = 0.03). Figure 2 in Paper I.

Findings were compared with data from the Third National Health and Nutrition Examination Survey (NHANES III), an American general population-based sample,

and mean T-scores were significantly lower for HFU-60 women and men of all age groups (Figure 6). HFU-60 patients' mean T-scores were all osteopenic (-1 to -2.5), whereas NHANES III mean T-scores were normal (>-1) for all age groups.

Fracture classification and association with trauma mechanism and BMD

Most hip fractures in the HFU-60 cohort were of the femoral neck (58%), and two-thirds were displaced FNFs. Pertrochanteric fractures were seen in one-third, and two-thirds of these were unstable. A small proportion of the fractures was basicervical (5%) and subtrochanteric (4%).

Figure 7 Hip fracture classification divided by trauma mechanism

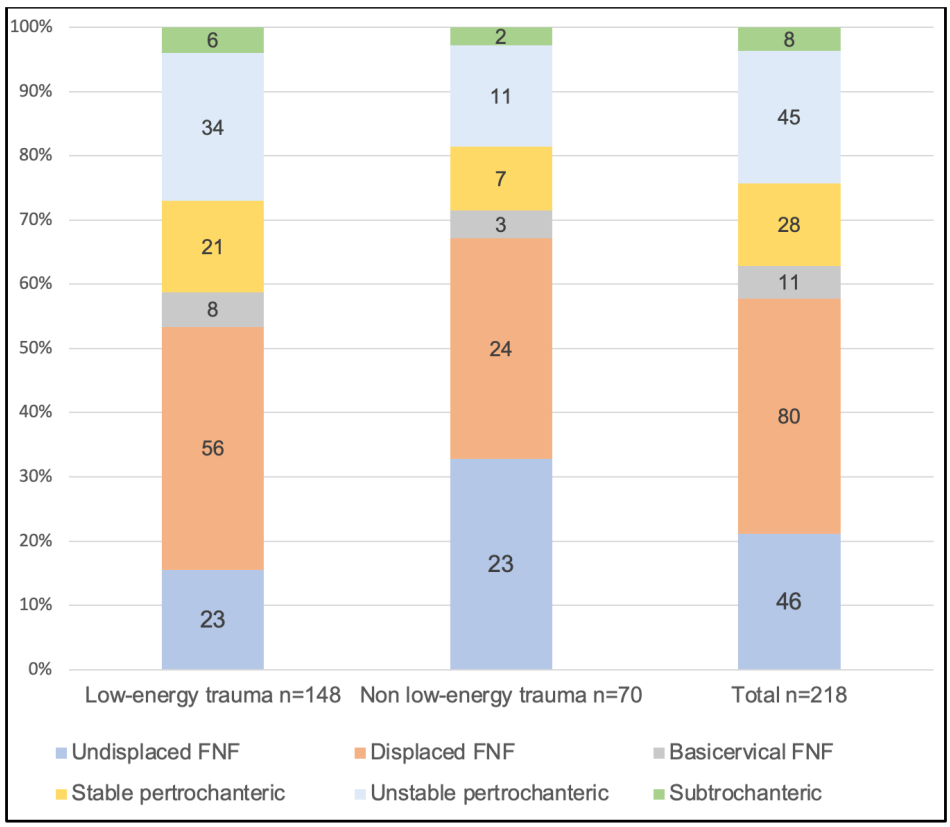


Figure 7 Hip fracture classification distribution fractioned by percentage, and divided by trauma mechanism. Numbers in fractions are frequencies. FNF: femoral neck fracture. Hip fractures classified according to AO/OTA classifications (40): undisplaced FNF 31-B1; displaced FNF 31-B3; basicervical FNF 31-B2; stable pertrochanteric 31-A1 & 31-A2.1; unstable pertrochanteric 31-A2.2-3 & 31-A3; subtrochanteric AO 32. Figure 2 in Paper II.

Analysis from Paper II on the associations between fracture classification, trauma mechanism, BMD, and a combination of trauma mechanism and BMD did not differ significantly statistically, but clinically important results were found.

A not low-energy trauma fracture was more often intracapsular (71%) than extracapsular (29%) compared to fractures after low-energy trauma, in which a more even distribution was seen – 59% and 41% respectively (p=0.07, Table 2 in Paper II). An unstable or displaced fracture was most common in the cohort (66%) and seen more often following low-energy trauma (70%) than after not low-energy trauma (57%), (p=0.06, Table 3 in Paper II).

A normal T-score on DXA was associated with an insignificant tendency towards a lower rate of unstable or displaced fractures, compared to osteoporotic and osteopenic T-scores (Table 3 in Paper II).

Analyses of the combination of trauma mechanism and osteoporotic DXA results showed that osteoporosis was common in both trauma mechanisms, with a higher rate of osteoporosis in low-energy trauma (36%) than not low-energy trauma (22%) (p=0.05). Similar results were found regarding fracture stability and anatomic location (i.e., intra- or extracapsular) in relation to trauma mechanism in combination with osteoporosis.

The lived experience of recovery after hip fracture

In Paper III, interviews were undertaken with 13 women and six men at 0.7 to 3.5 years after sustaining a hip fracture. Patients were aged 32 to 59 years at the time of the hip fracture and presented a variety of characteristics (Table 2 in Paper III). From interviews with participants and through further analysis, the themes presented in Table 2 emerged.

Interviews with young and middle-aged individuals who had suffered hip fractures revealed lingering challenges in everyday life, present years after the fracture. Challenges existed in several dimensions, both corporeal hip-specific and globally psychosocial, affecting the humor and spirit as well as behavior in social settings.

Table 2 Emerged themes, including exemplar quotes from participant interviews

Themes	Examples of quotes
Growing old overnight	“We are all different, you cannot give me the same instructions as an eighty-year-old.”
A person lacking capability	"Feeling tired all the time because I do not get the sleep I need because of the pain"
Inconsistent emotions and subsequent consequences	“A low energy trauma hip fracture is an old peoples’ disease – so why me?”
Total standstill in midlife	“My neighbor could walk nicely one month after the operation. I am now one YEAR after the operation and I still have problems even though I am younger. This is embarrassing!”
Defy despair	“I want to be exactly the same as before the operation but then I understand, I do not have that strength in the leg because it has taken quite a lot of damage. But I want to return to who I was before. I have so many beautiful shoes to use, ones with really high heels. They have been my motivation to get better (laughs), because I decided I will use them again (laughs).”
Returning to normal	“I think it has taken a long time to get back to normal. And, well, I am not quite sure that I actually am fully back to normal… But now is maybe the new normal.”

Pain

Most participants explicitly described experiencing pain from the fractured hip at the time of the interview, with varying intensity and incidence – for some daily, and for others more seldom. Hip pain or a combination of pain from the hip and groin, the back, and radiating pain in the leg was reported by participants. The pain was described as a constant reminder of the fracture, affecting the present but also the future by anticipation of further pain.

Functional impact

Physical limitations following the hip fracture were omnipresent, rendering ordinary activities difficult through pain, limping, stiffness, and loss of physical strength and leg function. Doubt regarding the body’s capability and fear of falling led participants to live more cautiously, in anticipation of falls or fear of aggravating symptoms of the hip fracture. Participants living alone were forced to ask for help with ordinary chores, which for some created an unpleasant duality where they felt incapable and diminished, yet thankful for the help. Furthermore, the limitations led to reduced work capacity for some, with prolonged sick-leave or reassignment to other tasks, which also could mean a reduced income.

Psychological impact

Strong emotions were experienced by the participants; a sense of growing old overnight arose when suffering the fracture, and most struggled to believe in a future with full recovery. Having different personae were reported: an overly positive façade expressing confidence in front of others, and another feeling depressed and hopeless when alone. Feelings of sadness and entrapment, self-imposed isolation in combination with external exclusion, and fear of falling preoccupied the latter persona. In an escalation of negative feelings, frustration and anger grew towards those feelings of weakness, helplessness, and dependence. Furthermore, many struggled with an unanswerable question of why they broke their hip – "why did this happen to me?"

Social impact

Negative impacts of the fracture were also present in social contexts, for example, through fear of falling. Participants not only hesitated in familiar situations, in which expectations of others might involve risks of falling or worsening of hip symptoms, but also avoided unfamiliar situations, leading to a more limited life compared to that before the fracture. The social impact included managing the reactions and expectations of others; participants reported that people around them often failed to appreciate the severity of their symptoms and limitations, which in turn generated feelings of shame from the perception that they were overreacting. On the other hand, support from family and maintaining social networks were described as important parts of the path to recovery.

Recovery

Information on the injury, treatment, and prognosis, as well as physical rehabilitation, was provided at the hospital ward after the hip fracture surgery, often while participants were under the influence of analgesics, making it difficult for some to remember information and instructions later during the recovery process. Many described the initiation of the recovery process following the hip fracture as following a standard protocol adapted to elderly patients and as mechanical and oblivious to specific rehabilitation needs. Participants described feeling abandoned after discharge, left alone to seek further support through municipal care or private caregivers. Individually targeted rehabilitation and continuous support of needs were identified as important factors in the recovery process, but most participants described a lack of it.

Conversion to secondary arthroplasty after IF in FNFs

In Paper IV, the rate of conversion to secondary arthroplasty was analyzed in 796 patients under age 60 with undisplaced and displaced FNFs that were initially treated with IF. The cohort with FNFs was defined, and patients were identified from the SFR. Patients were aged 20 to 59 years, 59% were men, and 77% of the fractures were due to low-energy trauma.

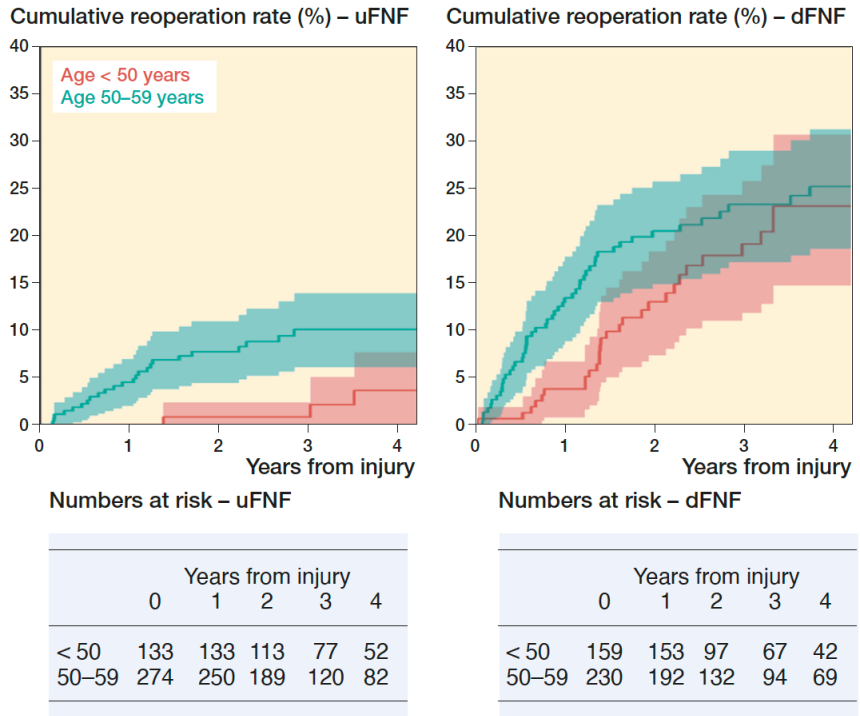
Included fractures were undisplaced (n=407) or displaced (n=389); most were treated with parallel pins/screws (n=748), and only a small part of the cohort (6%) was treated with sliding hip screw devices (n=48). From the SAR, 108 secondary arthroplasties (106 THA, 2 HA) were identified, 28 after undisplaced and 80 after displaced fractures.

In a Kaplan-Meier implant survival analysis, the conversion rates for undisplaced and displaced fractures were identified up to five years after the fracture (Figure 8). The conversion rates were significantly higher at all time points for displaced fractures, both for patients aged <50 years and those aged 50–59 (Table 2b in Paper IV).

The rate of conversion for undisplaced FNFs was 3% (95%CI 1-5) at one year, 5% (CI 3-8) at two years, and 8% (CI 5-11) at five years. For displaced FNFs, the 1, 2, and 5-years conversion rates were 9% (CI 6-12), 17% (CI 13-21), and 25% (CI 20-30), respectively.

In a Cox proportional hazards regression model of risk factors for conversion, age 50–59 had a hazard ratio of 5.2 (95%CI 1.4-20), compared with age <50 in the group with undisplaced FNFs. At five years, a conversion rate of 10% (CI 6-14) was seen in patients with undisplaced fractures aged 50–59 years, compared to 4% (CI 0-8) in patients <50 years. Neither female sex, high-energy trauma, nor resident surgeon could be identified as risk factors (Table 3 in Paper IV).

Figure 8 Conversion rates in undisplaced and displaced FNFs by age <50 and 50-59 years.



Numbers at risk – uFNF

	Years from injury				
	0	1	2	3	4
< 50	133	133	113	77	52
50–59	274	250	189	120	82

Numbers at risk – dFNF

	Years from injury				
	0	1	2	3	4
< 50	159	153	97	67	42
50–59	230	192	132	94	69

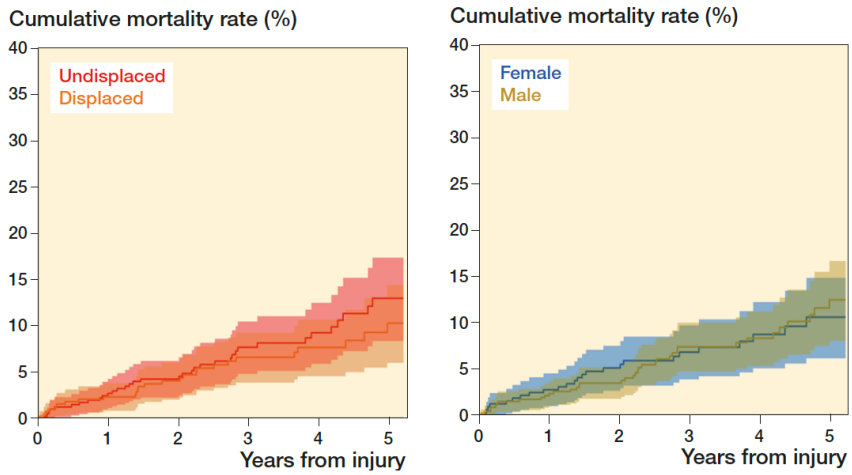
Figure 8 Conversion rates showed as cumulative reoperation rate with 95% confidence intervals presented by fracture type and age classification. uFNF: undisplaced femoral neck fracture, dFNF: displaced femoral neck fracture. Figure 2 from Paper IV.

Mortality in younger patients after hip fracture

In Paper IV, mortality rates were analyzed through Kaplan-Meier analysis. At one year and five years post-fracture, mortality rates were similar between undisplaced and displaced fractures as well as between women and men (Figure 9).

Patients aged 50–59 years had a significantly higher mortality rate compared to patients aged <50. The 1- and 5-year cumulative mortality rates for patients aged <50 years were 0% and 5% (CI 2-7); for patients aged 50–59, it was 4% (CI 2-6) at one year and 16% (CI 11-20) at five years.

Figure 9 Mortality rates by fracture type and sex



Numbers at risk

	Years from injury					
	0	1	2	3	4	5
uFNF	407	395	349	212	149	80
dFNF	389	380	284	215	146	86

Numbers at risk

	Years from injury					
	0	1	2	3	4	5
Female	326	316	245	183	119	69
Male	470	459	358	244	176	97

Figure 9 The cumulative mortality rates by fracture type and sex showed similar mortality rates between undisplaced and displaced fractures, as well as between women and men. Figure 3 and 4 in Paper IV.

Discussion

Demographic and physical characteristics of subjects

Young and middle-aged patients with hip fractures formed a heterogenous group, where multiple risk factors for fractures and low bone mass were common. Previous assumptions and preconceptions regarding younger patients do not seem to be valid; most patients are not “addicts”, multimorbid, or incurring their fracture through high-energy trauma mechanisms. Indeed, the opposite was true for most patients. We also found a high prevalence of osteopenia and osteoporosis on DXA investigation at the time of the fracture.

Patients aged under 60 constituted circa 5% of the total hip fracture population. Since every twentieth patient presenting with a hip fracture can be expected to be young, all orthopedic surgeons will probably meet and treat these patients. In both the HFU-60 and the SFR cohorts, hip fractures became more common with increasing age (Figure 5). This is also consistent with a large Danish register report where 90% of hip fractures in patients under 65 were found in the ages 40–65 (64). Hence, a hip fracture in the third or fourth decade of life is quite uncommon, approximately accounting for fewer than one in a hundred of all patients with hip fractures.

In younger individuals, hip fractures were more common in men, in contrast to hip fractures among the elderly, an observation that has been previously reported (13,15,35,36). In the HFU-60 cohort, two-thirds of the men were aged below 50, compared to half of the women. The explanation for the difference in age distribution between women and men is probably multifactorial, resulting in young men being at higher risk of hip fractures than young women. Men reported heavier smoking, more alcohol and drug use, and more fractures were seen in men after not low-energy traumas, suggesting a more risk-exposed behavior in men. Nevertheless, proportionally more women than men had a history of previous fractures and comorbidities.

Regarding lifestyle factors, the HFU-60 cohort presented worse characteristics compared to the general population in Sweden and Denmark. Physical activity level was found to be lower than the WHO-recommended 150 min/week in more than half of the cohort; in Sweden and Denmark, around 70% of the general population are physically active ≥150 min/week (65–67). Smoking was two-and-a-half to four

times as common, harmful alcohol use was almost twice as common in men and more than twice as common in women, and signs of drug-related problems were three times higher than in the general population (68–72). Previous studies of younger patients with hip fractures show varying degrees of smoking and alcohol use but support our findings of higher prevalence than in the general population (12–14,18,23,30,73).

The medical history of the cohort indicates a high degree of frailty in younger patients with hip fractures, and their biological age can be considered more advanced than their chronological age. Two-thirds of the patients in the HFU-60 cohort had no previous disease or only mild systemic disease, i.e., ASA I-II. One-third was classified ASA III-IV with multiple comorbidities, carrying 78% of the disease burden, yet only 3% of the cohort were ASA IV. In previous studies on younger patients with hip fractures, comorbidity has been reported in 9 to 55%, suggesting a variance in the composition of the study populations (14,17,35,74–77). Diseases associated with increased risk of hip fractures were seen in almost half of the cohort, and one-half had also incurred a previous fracture in adult life, suggesting increased risk of hip fractures.

The blood sample results may also reflect frailty and a predisposal for poor bone health and fractures in the cohort. Pathologically low values for vitamin D, albumin, and calcium were common, and most had low sex hormones. However, testosterone and estradiol were analyzed post-operatively after opioids were administered, which may have negatively affected the results (78).

DXA investigation at the time of the hip fracture revealed a high prevalence of osteopenia and osteoporosis in the HFU-60 cohort; only 12% had a normal T-score. Somewhat surprisingly, no normal DXA results were found in patients younger than age 40. Compared to the American population-based NHANES III cohort used as a reference database, the mean T-scores were lower for all age groups in both women and men from the HFU-60 cohort. Our found rates of osteopenia (57%) and osteoporosis (31%) were also much higher than in local population-based samples from Scandinavia – Malmö in Sweden and Tromsø in Norway – which presented rates of osteopenia of 5–9% and of osteoporosis of 0–5% (79,80). Rates of osteopenia and osteoporosis similar to ours were also presented by Al-Ani et al. (18) in their smaller cohort of somewhat older patients with hip fractures from Stockholm, Sweden.

From our findings and the comparisons, it seems reasonable to expect an inferior bone quality in almost all patients under the age of 60 with hip fractures. Furthermore, since we could not identify any particular subgroup with no or only low risk of low BMD, all young and middle-aged patients with hip fractures should be considered at risk and should be investigated accordingly and treated when indicated (81). One could argue that the diagnosis of osteoporosis is a categorical variable, whereas a diminished bone quality is reflected perhaps more correctly by

a continuous decrease in T-score. Hence, the group without osteoporosis also contains individuals with lower-than-normal bone quality, but not low enough to be categorized as osteoporotic. As previously mentioned, it has been reported that most fractures, including hip fractures, occur in individuals with osteopenia, not osteoporosis (33). The treatment of osteopenia and osteoporosis is beyond the aim of this thesis; but only briefly mentioned, the cut-off T-score value for treatment and fracture prophylaxis of low bone quality has been discussed, and former guidelines from the National Osteoporosis Foundation also recommended treatment in the osteopenic range for T-scores < -2 (33).

Impact of trauma mechanism and BMD on hip fracture type

Fracture classification in the HFU-60 cohort found intracapsular fractures to be most common (63%), a finding comparable to previous studies, which reported a distribution of approximately three to two between intra- and extracapsular fractures (17,26,36,82). The distribution of the specific fracture types among the intracapsular fractures was comparable to previous reports (36,41). Regarding extracapsular fractures, the proportions of subtrochanteric fractures were higher than ours in previous studies (26,36,82). These studies did not, however, report fractures using AO/OTA classification, making strict comparisons difficult, and thus our findings can be considered sufficiently representative.

The injury leading to the hip fracture was typically a low-energy trauma, i.e., a same-level fall. In the HFU-60 cohort (Paper I & II), two-thirds of the trauma mechanisms were classified as low-energy trauma, as were almost four-fifths in the SFR cohort (Paper IV). A possible explanation for the larger proportion of low-energy trauma in Paper IV might lie in the alternative definition of trauma mechanism in the SFR, whereas in HFU-60, trauma mechanisms other than same-level falls were categorized as not low-energy. This might have led to a classification of intermediate trauma mechanisms as low-energy if they fitted that definition better than the definition of high-energy trauma. Hence, the proportion of low-energy fractures is plausibly more correct based on the HFU-60 cohort. On the other hand, high-energy trauma cannot be distinguished in the HFU-60 cohort but is available from Paper IV.

The inconsequence in the classification of trauma mechanism may be explained by the lack of a uniform definition of what high-energy trauma actually is; although the term often include high-speed traffic accidents and falls from a height (13,30,35,36). Similar criteria can also be used to triage patients to care at designated trauma centers; for example, the Swedish National Trauma Alert criteria specifies car accident >50km/h without seatbelts and falls >5m (83). The fracturing of a bone in

these instances might not be unexpected, as the trauma energy probably exceeds the force required to break even a healthy bone. A definition of an intermediate trauma mechanism, which might be energetic enough to break a healthy bone but not necessarily accompanied by multiple injuries in other organ systems, might be appropriate in future fracture reporting to differentiate trauma mechanisms. However well-defined the criteria, it may still be challenging to correctly grade the energy of the trauma mechanism retrospectively and define when the fracture actually occurred, which has been stated before (81).

In Paper II, no significant associations between trauma mechanism and fracture types could be seen. There was a trend of not low-energy trauma leading to intracapsular fractures more often. Also, low-energy traumas tended to produce unstable or displaced fractures more often than not low-energy trauma. In Paper IV however, the opposite was seen, and high-energy trauma led to displaced FNFs significantly more often. That a trauma mechanism with lower energy would more often produce unstable or displaced fractures may seem counterintuitive and challenges common preconceptions, but this observation suggests that factors beyond the trauma mechanism are implicated in the creation of different fracture patterns.

Experimental biomechanical studies simulating a sideways fall onto the greater trochanter of a cadaver human femur have suggested that fractures of the proximal femur begin with compression of the superolateral cortex of the femoral neck, leading to both intra- and extracapsular fractures (84,85). Similar findings were presented in a clinical study on actual femoral neck fractures in patients treated with arthroplasty, analyzing the fracture site in the resected proximal part of the femur (86). In experimental simulation of fractures, the load was continuously increased until a fracture occurred. The load required to create a fracture varied more than three-fold between the femora used in the biomechanical analyses (84,85). The superolateral femoral neck was found to be the origin of the fractures both in osteoporotic bone as well as in bone with higher T-scores (85).

This suggests that varying properties between the bones require different levels of trauma to fracture them, but the origin of the fractures seems to be the same regardless of degree of trauma and BMD. However, this does not fully explain the reason for different fracture types, especially not where the cranial cortex of the femoral neck is not engaged, e.g., transverse pertrochanteric or subtrochanteric fractures. Another experimental study found that intracapsular fractures were more common at lower failure loads, whereas pertrochanteric and subtrochanteric fractures were more common in femora that required higher loads to break (87). This indicates that intracapsular fractures should be more common than extracapsular fractures after low-energy trauma mechanisms. However, this does not necessarily imply that extracapsular fractures should be more common after higher energy trauma mechanisms, since a low-energy trauma might be enough to break the hip of a weaker bone – as most of our cohort presented with – resulting in

an intracapsular fracture after a not low-energy trauma mechanism, which was also often seen in our cohort.

Inferior bone quality may partly explain a more severe fracture pattern, and in Paper II we found a somewhat lower rate of unstable or displaced fractures in those with normal bone quality compared to osteopenic and osteoporotic bone. Still, BMD was not significantly associated with fracture type, and inferior bone quality did not by itself explain an unstable or displaced fracture pattern. Neither were different fracture patterns explained by a combination of osteoporosis and trauma mechanism alone. It is probable that other factors of biomechanics and bone properties are also involved in producing different fracture patterns: for instance, the proportion of cancellous to cortical bone, the microarchitecture of the bone, or the skeleton's elasticity.

Lingering challenges and a call for diversified support of recovery

The patient's perspective – challenges after surgery

A hip fracture in young individuals is a sudden, traumatic event that profoundly impacts the individual through many aspects of life. Participants in our qualitative study (Paper III) provided a variety of examples of a hip fracture's negative effects and protracted challenges to everyday life. Through this explicitly patient-centered report, a nuanced picture of the patients' experiences was presented.

The younger patients reported a feeling of growing old overnight, partly due to the type of fracture they suffered but mainly because of the way they were treated by healthcare staff. Care and rehabilitation were described as mechanical and standardized according to the needs of elderly patients, without involving the individual patient in the planning and execution.

Participants reported pain, fear of falling, and negative psychological effects from the hip fracture which damaged integrity, self-worth, and pride. Negative social implications and stories of life being brought to a standstill were common. Economic implications from decreased work ability were also present. The previous description of a hip fracture in the elderly as a life-breaking event seems valid also for younger patients, with negative impact in multiple dimensions of life, which is supported by previous reports (35,9,88–91).

Support from family and social networks, understanding employers, and hope and belief in improvement promoted recovery according to the participants. The need for social support seems as important to our younger participants as it is to elderly

individuals, as demonstrated in previous reports (92). However, younger patients described the outside world as struggling to understand the magnitude of limitations and lingering symptoms after a hip fracture, which supports previous findings (88).

According to our participants, there is a lack of individually targeted rehabilitation directed at specific needs relevant for younger individuals. Some patients received individualized rehabilitation, and they described it as greatly contributing towards recovery. Correspondingly, a previous report on hip fractures in patients of all ages stated that only a third found their rehabilitation adequate (93). These results suggest that there is room for improvement in the rehabilitation after hip fractures for all ages.

In the reporting of outcomes after hip fractures, a shift from surgeon-based evaluation to patient-centered assessment has been proposed (11,94). In Paper III, explicitly patient-centered outcomes were reported through the participants' lived experiences. In future evaluations of hip fracture outcomes, it may be of value to add an assessment of psychosocial consequences, as this was accentuated by our participants, and implications were present years after the hip fracture.

In supporting patients when they recover after hip fractures, one should bear in mind that not all individuals reach a full return to the pre-injury state of function and mobility, and that psychosocial consequences affect patients years after the injury (6,11,88,93,95). It is important for future studies to identify those who do and do not recover fully, to better understand what can be expected after a hip fracture.

As surgeons, our job is often considered complete when the patient leaves the operating room and we are satisfied with our work. For the patient who receives surgery for a hip fracture, however, the work has only just begun, and they are often left alone with this burden. It is important for surgeons to inform patients of the lengthy rehabilitation process and the risk of long-term implications after suffering a hip fracture. This information might help to adjust expectations, thus making the patients' burden easier to carry or at least to accept. The addition of diversified rehabilitation tailored to the individual could lessen the burden and result in an improved recovery process. Healthcare services should be able to provide suitable support in recovery for all patients, not merely offer standard geriatric hip fracture rehabilitation.

Could primary treatment of FNFs be better?

The surgeon's perspective – challenges prior to surgery

> Fracture of the neck of the femur continues to be regarded as "the unsolved fracture", but its claim to this distinction becomes increasingly insecure. Since the introduction of the Smith-Petersen nail in 1931, unrelenting endeavours have been made to solve this problem […] The overall picture is one of some confusion but two elementary points of universal agreement are seen to emerge: reduction must be perfect; and fixation must be secure. – *R. S. Garden, 1961* (3).

Since Garden's publication, most elderly patients with displaced FNFs are now treated with primary arthroplasty because the complication rate and the rate of conversion to secondary arthroplasty after IF was deemed to be unacceptably high (44,45,96). Current studies are focusing on whether primary arthroplasty might be a better solution even for undisplaced FNF in the elderly (e.g., the ongoing HipSTHeR study in Sweden, SENSE in Denmark, and FRUITI in the UK), as failures of IF and subsequent conversion to arthroplasty also occur after undisplaced fractures (47–49,97).

In younger patients, arthroplasty has not been considered a universally attractive alternative. Concerns are expressed that the limited longevity of the implant compared to the patient's expected remaining survival would require revision of the arthroplasty (98). Sparing the native femoral head has also been considered beneficial; thus, IF has been the recommended treatment of FNFs in younger patients (25). Different methods to achieve secure fixation are used internationally. In Sweden, two parallel pins or screws are almost uniformly used. The use of three or even four parallel implants is seen in other countries, but there is little evidence that adding extra screws will reduce the risk of complications (59).

Although research on femoral neck fractures has continued to increase since Garden's publication in 1961, it seems that these endeavors have not been sufficient; this fracture is still unsolved (1). Displaced FNFs in younger patients continue to pose a problem, as not all patients heal their fracture uneventfully after IF. As stated by Speed (1) on the treatment of femoral neck fractures, "although the results obtained today show improvement … there is no guarantee of 100% cure.". That is why this fracture remains unsolved and also where the surgeon's problem presents itself.

The challenge for the treating surgeon lies in pre-operative decision-making, specifically in the selection of the proper treatment for the individual patient; unlike comorbidities and fracture displacement, the surgeon can control this challenge. In Paper IV, we found that most patients heal their fractures after IF of both

undisplaced and displaced FNFs and do not require conversion to arthroplasty. For undisplaced FNFs, our findings confirmed IF as the gold-standard treatment: one in 12 patients underwent conversion to arthroplasty within five years. However, results for displaced FNFs were markedly poorer, where one in four patients treated initially with IF were converted to arthroplasty. Our results are comparable to the few earlier studies on younger patients (22,46).

For some patients, a primary arthroplasty has been proposed as advantageous; previous reports have suggested that alcohol abuse, renal or respiratory disease, osteoarthritis, inflammatory arthritis, and symptomatic hip dysplasia are reasons to choose arthroplasty as a primary treatment of an FNF (11,22). The criteria for patient-selection for either IF or arthroplasty for younger patients without these specified traits are unclear, why the choice of treatment could be arduous. Factors predicting failure of IF have previously been reported in elderly patients; posterior tilt of the femoral neck >20 degrees and anterior tilt >10 degrees in Garden I-II FNFs (99,100), as well as the degree of displacement and fracture comminution (101). In Paper IV, we were not able to perform all the same analyses, since the SFR does not include data on these factors apart from displacement in the form of fracture classification. We found that displaced FNFs had a higher rate of conversion to secondary arthroplasty, suggesting that factors predicting failure of IF in the elderly also might be valid in younger patients. It has previously been shown that time to surgery exceeding 24 hours was associated with a higher failure rate in displaced FNFs treated with IF (22).

Another factor to consider is the longevity of the respective implants. The risk of conversion from IF to arthroplasty should be weighed against the risk of subsequent revisions when choosing arthroplasty as the primary treatment. In a recent register report on survival of THA for all indications, Nugent et al. (98) found a 10-year rate of revision of less than 10% in patients aged 45–60 – much lower than our 25% conversion rate at five years. The lifetime rate of revision was found to be as high as 28% – similar to our conversion rate. However, conversion rates can be expected to increase after even five years post-fracture; a rise in conversion rate from 10% to 14% between five and 10 years in both undisplaced and displaced FNFs was reported by Stockton et al. (46). If a similar increase were true for the displaced FNFs in our register cohort, the 10-year conversion rate would be 35%, somewhat higher than the lifetime revision rate presented by Nugent et al. (98).

The comparison is not fully appropriate, since the results presented by Nugent et al. (98) were for THA performed for all indications. From previous research, it is known that the results regarding implant survival after an arthroplasty due to a hip fracture are somewhat worse than for arthroplasties performed for other reasons (102). Therefore, we could expect the lifetime rate of revision of arthroplasties performed due to FNFs to be higher than 28% presented by Nugent et al. (98). An interesting question would be how the lifetime revision rate of a primary fracture arthroplasty compares to the lifetime conversion rate after initial IF of FNFs, i.e.,

the lifetime risk of major secondary surgery after either primary treatment of a displaced FNF.

From studies on older patients, we know that secondary arthroplasties after initial IF are associated with inferior results regarding revision rate, hip function, and health-related quality-of-life compared to primary fracture arthroplasty (103,104). It has also been shown that patients treated with initial IF of their FNF, in which the native femoral head was spared, did not reach better functional results than those treated with a primary arthroplasty (44,45,105). Consequently, the results speak in favor of arthroplasty as primary treatment of displaced FNFs in the older population, but this has not yet been proven in young and middle-aged patients.

In contrast to the elderly who suffer hip fractures, more younger patients can expect a long survival after their hip fracture. Therefore, long-term results are of interest, which may potentially impact the choice of implant at the initial fracture surgery. An interesting analysis would be a long-term comparison between the first revision of a primary fracture arthroplasty and the secondary arthroplasty after initial failed IF, i.e., a comparison of the results of the secondary surgeries after either primary treatment of displaced FNFs. One could assume – at least in a Swedish setting – that a cohort of patients under 60 years treated primarily with arthroplasty were selected to such treatment for specific reasons, and not representative for most younger patients with FNFs. This may call for a randomized trial with long-term follow-up comparing IF and arthroplasty, similar to the Norwegian trial on patients aged 55-70 years, which recommended THA as primary treatment (106).

Although initial arthroplasty may be the best solution for some patients with an inherently higher risk of fixation failure, most younger patients actually do heal their displaced FNFs; in Paper IV, three in four were not converted to arthroplasty within five years. This speaks in favor of IF as the primary treatment for most young and middle-aged patients, although both surgeons and patients should have realistic expectations and be aware of the risk of complications requiring a secondary arthroplasty during the years following a fracture of the femoral neck.

Higher mortality after hip fracture

The mortality found in Paper IV for young and middle-aged patients with FNFs was similar between undisplaced and displaced fractures, suggesting that the fracture type itself does not pose an increased threat to life. Although one might have expected some characteristics or properties to predispose for a certain fracture type and that this would have had an impact on mortality, no such differences could be identified.

Mortality rates were – somewhat surprisingly –similar between women and men. In the elderly, men have a higher risk of dying after suffering a hip fracture (107). In Paper I, younger women were found to have more comorbidities, which may partly explain why the difference in mortality vanished in our young cohort.

As expected, older patients in the cohort (aged 50–59 years) had an increased mortality rate both at one and five years compared to patients under 50. When comparing the mortality for patients aged 50–59 to mortality rates for the general Swedish population of the same ages for the years of the study, the one-year mortality rate of 4% is 10-fold higher, and the five-year mortality rate of 16% is noticeable (108,109). This suggests that although mortality rates are not as high as among the elderly patients, suffering a hip fracture poses an increased threat to life even in younger patients. They may also resemble older patients biologically, although their chronological age is lower.

Limitations and strengths

Considering the evidence pyramid, one could always aspire for higher evidence levels of the studies one conduct. But, both with our research questions and practical issues in mind, we chose the current designs. In particular regarding the outcome after different surgical methods or rehabilitation strategies, randomized trials are preferrable. Such comparative studies will be a natural second step to improve the care chain for young individuals with hip fractures, but initially we need more information about who these patients are and how they fracture and recover. Thus, descriptive cohort studies and a qualitative study became our choice of study designs.

From an international point-of-view, our results may not be generalizable to more than high-income countries with a publicly financed healthcare. Still, we think our underlying message is important, that a patient group should not be looked upon and treated based on preconceived notions. Clinically useful facts must be investigated, and the patients' experience should be sought. A corresponding cohort of young patients in low- and middle-income countries or in a commercialized healthcare setting would most certainly stand forward with other characteristics.

The typical features of Scandinavian healthcare have on the other hand generated some of the strengths of the project. Individuals are admitted to acute orthopaedic care, rehabilitation and follow-up regardless of their socioeconomic status. The participating departments care for all fracture cases in their catchment areas, serving both urban and rural areas. Patients are easily traced via their unique personal identification number, meaning fewer cases with missing data and solid information about mortality. Also, the national quality registers on which Paper IV is based on

rely on a long history of register development with the use of personal identity numbers, enabling dependable longitudinal data within and across registers.

The privacy legislation forbids a drop-out analysis of eligible individuals not included in the HFU-60 study; thus, we cannot estimate any possible selection bias. However, three-quarters of the eligible patients were included in this mixed general population-based cohort and we consider the study population to be representative of the heterogeneous group of younger individuals incurring hip fractures. Although our study is one of the largest compared to other clinical studies on corresponding ages, the sample size may limit the statistical power of some of our findings.

The exclusion of some late DXA investigations from the analyses might introduce a selection bias, but DXA performed at the time of the fracture was considered more accurate in the description of the pre-fracture condition. The characteristics of the excluded patients were associated with low BMD as well, with higher median age and ASA-class, a lower proportion of normal BMI, and a higher rate of low-energy trauma compared to patients included in the analyses of DXA results. Hence, the prevalence of osteopenia and osteoporosis in the cohort was probably not overestimated through the exclusion, but might be underestimated.

The participants in Paper III were purposively sampled from the larger HFU-60 cohort; hence, the results cannot be extrapolated to all individuals. Nevertheless, the participants represent a wide variety of characteristics, and our findings are valid as a testimony of experiences of recovery after hip fractures that are important to patients.

In Paper IV, the rate of conversion may have been affected by the treatment with primary arthroplasty of some patients in the age group 50–59, which theoretically reduced the number of FNFs at risk of conversion to arthroplasty. Furthermore, it possibly led to an underestimation of the conversion rate, assuming that these patients were identified as having a higher risk of fixation failure. From an international perspective, the lack of data on whether open reductions were performed and the almost exclusive use of two parallel implants may limit the study. However, there is little evidence that adding extra implants reduces the risk of failure, and open reduction has not been proved to have any clear benefits (11,59,110). Indeed, other outcomes than reoperation are valuable, and patient-reported outcomes are preferable. Nevertheless, conversion to arthroplasty was considered a marker of major hip complications and this outcome was chosen due to the national coverage of the SAR and its high completeness, leading to dependable findings. Our result reflects the everyday practice in non-selected patients and surgeons, rendering generalizability.

Conclusions

Patients under the age of 60 form a heterogenous group. A wide range of different characteristics were seen in demographics, lifestyle factors, previous fractures, and medical history and medications. Some patients showed signs of vitality and health, yet primarily we found a high degree of frailty. Furthermore, risk factors for fractures and osteoporosis were ubiquitous.

On DXA investigation at the time of the fracture, only one in eight had a normal T-score. The prevalence of osteopenia and osteoporosis was high compared to general population-based reference samples, regardless of age and trauma mechanism.

Low-energy trauma was the main trauma mechanism in patients under the age of 60. Most hip fractures were unstable or displaced, and the anatomical location was mainly intracapsular.

Trauma mechanism and BMD did not alone nor in combination sufficiently explain the reasons for different hip fracture patterns.

The lived experience of sustaining a hip fracture includes challenges in everyday life for patients under the age of 60, even years after the fracture. According to the patients, the care and rehabilitation were not adapted to their needs.

Although most patients heal their femoral neck fracture after internal fixation, one in twelve with undisplaced fractures and one in four with displaced fractures needed conversion to a secondary arthroplasty within five years.

Mortality after a hip fracture was higher than in the general population, suggesting that the underlying frailty associated with hip fractures pose a threat to life even in patients under the age of 60.

Clinical perspectives

Regarding patients under the age of 60 with hip fractures, existing preconceptions do not seem valid and should be traded for a nuanced understanding of who these patients are.

A thorough health investigation is warranted given the high degree of frailty and comorbidity in combination with a high prevalence of risk factors for fractures and low bone quality.

Bone quality should be assessed by DXA investigation of all patients with hip fractures, including the youngest patients and regardless of trauma mechanism.

A need for improved information and diversified support in recovery was requested by patients. Healthcare services should be equipped to provide this support.

Both surgeons and patients need to be aware of the risk of complications leading to secondary arthroplasty after internal fixation of femoral neck fractures. This is important in order to inform patients and to plan the follow-up scheme in younger individuals with hip fractures.

Long-term follow-up is justified after hip fractures in patients under the age of 60, primarily concerning a protracted recovery process. In addition, internal fixation of femoral neck fractures carries a risk of early and late developing complications that may require secondary surgery.

Future research in the HFU-60 study

Ongoing, in manuscript:

- Physical activity in young hip fracture patients is associated with health-related quality of life and strength; results from the HFU-60 multicenter study.
  Anna Gaki Lindestrand, Sebastian Strøm Rönnquist, Bjarke Viberg, Søren Overgaard, Henrik Palm, Cecilia Rogmark, Morten Tange Kristensen.

- How to spot osteonecrosis of the femoral head after internal fixation of femoral neck fractures in younger patients, with implants in situ. The value of MARS MRI versus conventional x-ray.
  Mikael Kindt, Maria L Jönsson, Trine Torfing, Sebastian Strøm Rönnquist, Bjarke Viberg, Søren Overgaard, Cecilia Rogmark.

- Alcohol and drug use in patients younger than 60 years with hip fracture, measured by validated instruments and the clinical eye.
  Sara Svanholm, Sebastian Strøm Rönnquist, Åsa Magnusson, Bjarke Viberg, Carsten Fladmose Madsen, Morten Tange Kristensen, Henrik Palm, Søren Overgaard, Cecilia Rogmark.

Planned papers:

- Outcome after hip fracture in adults under the age of 60 – clinical, functional and patient reported results.

- Risk factors for failure after hip fracture treatment in adults under age 60.

- Long term outcome after hip fracture in adults under the age of 60.

Acknowledgements

Many deserve acknowledgement; I could not have done it without you. Thank you.

Cecilia Rogmark – main supervisor, guide, and beacon. Thank you for showing me what research can be; full of hard work, fun, and excitement.

Kristina Åkesson – co-supervisor. Thank you for sharing tips and tricks from your vast experience.

The co-authors in the HFU-60 project – Bjarke, Morten, Henrik, Jens-Erik, Carsten, Kristina, Søren, Cecilia. It has been a long time coming. Thank you for your engagement, encouragement, and sharing your knowledge.

The co-authors in InterHFU – Hilda, Charlotte, Søren, Cecilia. Thank you for the good work together, and for giving me a chance to learn something new.

The co-authors in the register study – Johan, Bjarke, Michael, Cecilia. Thank you for the odd-hours commitment and exchange of ideas, you are quicker than most.

All patients in the HFU-60 study, for your valuable participation.

Marika Bergman, for the administrative support.

Felix Narin, for constant drive and performing functional tests and follow-up in Malmö.

All the staff at the wards and outpatient clinics working hard to treat our patients.

The DXA-units at the participating centers, for your support and in welcoming me and the phantom when visiting on our traveling circus.

All colleagues who contribute to the registers, it is truly a treasure that you gather.

My colleagues at Skåne University Hospital in Malmö and Lund and at Odense University Hospital, thank you for your support and good spirits.

My mother, sister, and late father for the loving support and constant encouragement in early endeavors. For teaching me to be me, and somehow also introducing patience, grit, and resilience, which have been needed in this work.

My wonderful wife Julie and our fantastic children – Eskil, Folke, and Gry – you amaze me! Team familjen!

References

1. Speed K. The unsolved fracture. Surg Gynecol Obst. 1935;60:341–52.

2. Leadbetter GW. A Treatment for Fracture of the Neck of the Femur: Clin Orthop. 2002 Jun;399:4–8.

3. Garden RS. Low-angle fixation in fractures of the femoral neck. J Bone Joint Surg Br. 1961 Nov 1;43-B(4):647–63.

4. Johansson S. On the Operative Treatment of Medial Fractures of the Neck of the Femur. Acta Orthop Scand. 1932 Jan 1;3(3–4):362–92.

5. Zidén L, Wenestam CG, Hansson-Scherman M. A life-breaking event: early experiences of the consequences of a hip fracture for elderly people. Clin Rehabil. 2008 Sep 1;22(9):801–11.

6. Bertram M, Norman R, Kemp L, Vos T. Review of the long-term disability associated with hip fractures. Inj Prev. 2011 Dec 1;17(6):365–70.

7. Jellesmark A, Herling SF, Egerod I, Beyer N. Fear of falling and changed functional ability following hip fracture among community-dwelling elderly people: an explanatory sequential mixed method study. Disabil Rehabil. 2012 Dec 1;34(25):2124–31.

8. Sale JEM, Frankel L, Thielke S, Funnell L. Pain and fracture-related limitations persist 6 months after a fragility fracture. Rheumatol Int. 2017 Aug 1;37(8):1317–22.

9. Janes G, Serrant L, Sque M. Silent slips, trips and broken hips in the under 60s: A review of the literature. Int J Orthop Trauma Nurs. 2018 Aug 1;30:23–30.

10. Cheng K, Montgomery S, Housley S, Wheelwright E. Clinical Risk Factors for Hip Fracture in Young Adults Under 50 Years Old. Eur J Trauma Emerg Surg. 2009 Feb;35(1):40–2.

11. Rogmark C, Kristensen MT, Viberg B, Rönnquist SS, Overgaard S, Palm H. Hip fractures in the non-elderly—Who, why and whither? Injury. 2018 Aug;49(8):1445–50.

12. Karantana A, Boulton C, Bouliotis G, Shu KS, Scammell BE, Moran CG. Epidemiology and outcome of fracture of the hip in women aged 65 years and under: a cohort study. J Bone Jt Surg Br. May;93:658–64.

13. Lofthus CM, Osnes EK, Meyer HE, Kristiansen IS, Nordsletten L, Falch JA. Young patients with hip fracture: a population-based study of bone mass and risk factors for osteoporosis. Osteoporos Int. 2006;17:1666–72.

14. Al-Ani AN, Neander G, Samuelsson B, Blomfeldt R, Ekstrom W, Hedstrom M. Risk factors for osteoporosis are common in young and middle-aged patients with femoral neck fractures regardless of trauma mechanism. Acta Orthop. 2013 Feb;84:54–9.

15. Boden SD, Labropoulos P, Saunders R. Hip fractures in young patients: Is this early osteoporosis? Calcif Tissue Int. 1990 Feb;46(2):65–72.

16. Svenska Frakturregistret - årsrapport 2020 [Internet]. [cited 2022 Mar 9]. Available from: https://registercentrum.blob.core.windows.net/sfr/r/VGR_SFR_-rsrapport-2020-SE-DIGITAL-uppslag-B1xBpRe6q_.pdf

17. Lin JC, Wu CC, Lo C, Liang WM, Cheng CF, Wang CB, et al. Mortality and complications of hip fracture in young adults: a nationwide population-based cohort study. BMC Musculoskelet Disord. 2014 Oct 31;15:362.

18. Al-Ani AN, Cederholm T, Sääf M, Neander G, Blomfeldt R, Ekström W, et al. Low bone mineral density and fat-free mass in younger patients with a femoral neck fracture. Eur J Clin Invest. 2015;45(8):800–6.

19. Jain R, Koo M, Kreder HJ, Schemitsch EH, Davey JR, Mahomed NN. Comparison of early and delayed fixation of subcapital hip fractures in patients sixty years of age or less. J Bone Jt Surg Am. 2002 Sep;84-A:1605–12.

20. Farooq MA, Orkazai SH, Okusanya O, Devitt AT. Intracapsular fractures of the femoral neck in younger patients. Ir J Med Sci. 2005 Dec;174:42–5.

21. Huang HK, Su YP, Chen CM, Chiu FY, Liu CL. Displaced femoral neck fractures in young adults treated with closed reduction and internal fixation. Orthopedics. 2010 Dec;33(12):873–873.

22. Duckworth AD, Bennet SJ, Aderinto J, Keating JF. Fixation of intracapsular fractures of the femoral neck in young patients: risk factors for failure. J Bone Jt Surg Br. 2011 Jun;93:811–6.

23. Razik F, Alexopoulos AS, El-Osta B, Connolly MJ, Brown A, Hassan S, et al. Time to internal fixation of femoral neck fractures in patients under sixty years--does this matter in the development of osteonecrosis of femoral

head? Int Orthop. 2012 Oct;36:2127–32.

24. Gupta M, Arya RK, Kumar S, Jain VK, Sinha S, Naik AK. Comparative study of multiple cancellous screws versus sliding hip screws in femoral neck fractures of young adults. Chin J Traumatol Zhonghua Chuang Shang Za Zhi. 2016 Aug 1;19(4):209–12.

25. Bhandari M, Swiontkowski M. Management of Acute Hip Fracture. N Engl J Med. 2017 Nov 23;377(21):2053–62.

26. Keohane D, Al Azawi L, Downey C, Quinlan JF. Assessing outcomes in hip fracture patients under the age of 60. Ir J Med Sci. 2022 Feb;191(1):233–8.

27. Fernandez MA, Achten J, Parsons N, Griffin XL, Png ME, Gould J, et al. Cemented or Uncemented Hemiarthroplasty for Intracapsular Hip Fracture. N Engl J Med. 2022 Feb 10;386(6):521–30.

28. Ageing and health [Internet]. [cited 2021 Nov 16]. Available from: https://www.who.int/news-room/fact-sheets/detail/ageing-and-health

29. Decade of Healthy Ageing (2021-2030) [Internet]. [cited 2022 Mar 1]. Available from: https://www.who.int/initiatives/decade-of-healthy-ageing

30. Wang MT, Yao SH, Wong P, Trinh A, Ebeling PR, Tran T, et al. Hip fractures in young adults: a retrospective cross-sectional study of characteristics, injury mechanism, risk factors, complications and follow-up. Arch Osteoporos. 2017 Dec;12:46.

31. Pasoto SG, Yoshihara LA, Maeda LC, Bernik MM, Lotufo PA, Bonfa E, et al. Osteoporotic hip fractures in non-elderly patients: relevance of associated co-morbidities. Rheumatol Int. 2012 Oct;32:3149–53.

32. Frakturklassfördelning · Svenska Frakturregistret [Internet]. [cited 2022 Mar 29]. Available from: https://sfr.registercentrum.se/statistik/frakturklassfoerdelning/p/Hkzqgu9D7

33. Siris ES, Chen YT, Abbott TA, Barrett-Connor E, Miller PD, Wehren LE, et al. Bone Mineral Density Thresholds for Pharmacological Intervention to Prevent Fractures. Arch Intern Med. 2004 May 24;164(10):1108–12.

34. Osteoporosis: assessing the risk of fragility fracture | Guidance | NICE [Internet]. NICE; [cited 2022 May 31]. Available from: https://www.nice.org.uk/guidance/cg146/chapter/Introduction#ftn.footnote_3

35. Swiontkowski MF, Winquist RA, Hansen ST. Fractures of the femoral neck in patients between the ages of twelve and forty-nine years. J Bone Jt

Surg Am. 1984 Jul;66:837–46.

36. Robinson CM, Court-Brown CM, McQueen MM, Christie J. Hip fractures in adults younger than 50 years of age. Epidemiology and results. Clin Orthop Relat Res. 1995 Mar;238–46.

37. World Health Organization. ICD-10 Version:2019 [Internet]. [cited 2021 Dec 16]. Available from: https://icd.who.int/browse10/2019/en#/S70-S79

38. AO Trauma Who we are [Internet]. [cited 2022 Feb 1]. Available from: https://aotrauma.aofoundation.org/about/who-we-are

39. Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and Dislocation Classification Compendium-2018. J Orthop Trauma. 2018 Jan;32 Suppl 1:S1–170.

40. Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, et al. Fracture and Dislocation Classification Compendium - 2007: Orthopaedic Trauma Association Classification, Database and Outcomes Committee. J Orthop Trauma. 2007 Dec;21(10):S1.

41. Sundkvist J, Brüggeman A, Sayed-Noor A, Möller M, Wolf O, Mukka S. Epidemiology, classification, treatment, and mortality of adult femoral neck and basicervical fractures: an observational study of 40,049 fractures from the Swedish Fracture Register. J Orthop Surg. 2021 Dec;16(1):561.

42. Frandsen PA, Andersen E, Madsen F, Skjødt T. Garden's classification of femoral neck fractures. An assessment of inter-observer variation. J Bone Joint Surg Br. 1988 Aug;70(4):588–90.

43. FRAX - Fracture Risk Assessment Tool [Internet]. [cited 2022 Mar 29]. Available from: https://www.sheffield.ac.uk/FRAX/index.aspx

44. Leonardsson O, Sernbo I, Carlsson å., Åkesson K, Rogmark C. Long-term follow-up of replacement compared with internal fixation for displaced femoral neck fractures. J Bone Joint Surg Br. 2010 Mar 1;92-B(3):406–12.

45. Chammout GK, Mukka SS, Carlsson T, Neander GF, Helge Stark AW, Skoldenberg OG. Total Hip Replacement Versus Open Reduction and Internal Fixation of Displaced Femoral Neck Fractures: A Randomized Long-Term Follow-up Study. J Bone Jt Surg - Am Vol. 2012 Nov;94(21):1921–8.

46. Stockton DJ, O'Hara LM, O'Hara NN, Lefaivre KA, O'Brien PJ, Slobogean GP. High rate of reoperation and conversion to total hip arthroplasty after internal fixation of young femoral neck fractures: a population-based study of 796 patients. Acta Orthop. 2019 Jan 2;90(1):21–5.

47. Wolf O, Sjöholm P, Hailer NP, Möller M, Mukka S. Study

protocol: HipSTHeR - a register-based randomised controlled trial – hip screws or (total) hip replacement for undisplaced femoral neck fractures in older patients. BMC Geriatr. 2020 Jan 21;20(1):19.

48. Viberg B, Kold S, Brink O, Larsen MS, Hare KB, Palm H. Is arthroplaSty bEtter than interNal fixation for undiSplaced femoral nEck fracture? A national pragmatic RCT: the SENSE trial. BMJ Open. 2020 Oct 1;10(10):e038442.

49. World Hip Trauma Evaluation - FRUITI: Fix or Replace Undisplaced Intracapsular fractures Trial of Interventions - NIHR Funding and Awards [Internet]. [cited 2022 Aug 3]. Available from: https://fundingawards.nihr.ac.uk/award/NIHR128399

50. Lagergren J, Möller M, Rogmark C. Displaced femoral neck fractures in patients 60-69 years old – treatment and patient reported outcomes in a register cohort. Injury. 2020 Nov 1;51(11):2652–7.

51. SFR Årsrapport 2018 [Internet]. [cited 2022 Mar 22]. Available from: https://registercentrum.blob.core.windows.net/sfr/r/sfr_2018_web-SJxxQsru4H.pdf

52. Bergdahl C, Nilsson F, Wennergren D, Ekholm C, Möller M. Completeness in the Swedish Fracture Register and the Swedish National Patient Register: An Assessment of Humeral Fracture Registrations. Clin Epidemiol. 2021 May 21;13:325–33.

53. Täckningsgradsanalys · Svenska Frakturregistret [Internet]. [cited 2022 Jan 28]. Available from: https://sfr.registercentrum.se/om-registret/taeckningsgradsanalys/p/HJedFyVyE

54. Knutsson SB, Wennergren D, Bojan A, Ekelund J, Möller M. Femoral fracture classification in the Swedish Fracture Register – a validity study. BMC Musculoskelet Disord. 2019 May 8;20(1):197.

55. W-Dahl A, Kärrholm J, Rogmark C, Nauclér E, Nåtman J, Bülow E, et al. Årsrapport 2021 Svenska Ledprotesregistret [Internet]. Svenska Ledprotesregistret; 2021 [cited 2022 Jan 28] p. 25475202 byte. Available from: http://refdocs.registercentrum.se/10.18158/SyZ333H5F

56. Lindseth A, Norberg A. A phenomenological hermeneutical method for researching lived experience. Scand J Caring Sci. 2004;18(2):145–53.

57. Parker MJ, Palmer CR. A new mobility score for predicting mortality after hip fracture. J Bone Joint Surg Br. 1993 Sep;75(5):797–8.

58. Swart E, Roulette P, Leas D, Bozic KJ, Karunakar M. ORIF or Arthroplasty for Displaced Femoral Neck Fractures in Patients Younger Than 65

Years Old: An Economic Decision Analysis. J Bone Joint Surg Am. 2017 Jan 4;99(1):65–75.

59. Nyholm AM, Palm H, Sandholdt H, Troelsen A, Gromov K, Danish Fracture Database Collaborators. Osteosynthesis with Parallel Implants in the Treatment of Femoral Neck Fractures: Minimal Effect of Implant Position on Risk of Reoperation. J Bone Joint Surg Am. 2018 Oct 3;100(19):1682–90.

60. Kanthasamy S, To K, Webb JI, Elbashir M, Parker MJ. Timing of surgery for internal fixation of intracapsular hip fractures and complications at 1 year; a 32 year clinical study of 2,366 patients at a single center. Injury. 2022 Feb;53(2):584–9.

61. Authen AL, Dybvik E, Furnes O, Gjertsen JE. Surgeon's experience level and risk of reoperation after hip fracture surgery: an observational study on 30,945 patients in the Norwegian Hip Fracture Register 2011–2015. Acta Orthop. 2018 Oct;89(5):496.

62. Looker AC, Wahner HW, Dunn WL, Calvo MS, Harris TB, Heyse SP, et al. Updated Data on Proximal Femur Bone Mineral Levels of US Adults. Osteoporos Int. 1998 Aug 1;8(5):468–90.

63. Blake GM, Fogelman I. The role of DXA bone density scans in the diagnosis and treatment of osteoporosis. Postgrad Med J. 2007 Aug;83(982):509–17.

64. Omari A, Madsen CM, Lauritzen JB, Jørgensen HL, Vojdeman FJ. Comorbidity and mortality after hip fracture in nineteen thousand six hundred and eighty two patients aged eighteen to sixty five years in Denmark from 1996 to 2012. Int Orthop [Internet]. 2019 Mar 23 [cited 2019 Sep 20]; Available from: http://link.springer.com/10.1007/s00264-019-04323-z

65. World Health Organization. WHO guidelines on physical activity and sedentary behaviour [Internet]. 2020 [cited 2021 Jan 31]. Available from: https://apps.who.int/iris/handle/10665/336656

66. SWEDEN Physical Activity Factsheet-WHO Europe [Internet]. [cited 2021 Jan 31]. Available from: https://www.euro.who.int/__data/assets/pdf_file/0009/288126/SWEDEN-Physical-Activity-Factsheet.pdf

67. Denmark - Physical activity factsheet – WHO/Europe [Internet]. [cited 2021 Feb 2]. Available from: https://www.euro.who.int/en/health-topics/disease-prevention/physical-activity/data-and-statistics/physical-activity-fact-sheets/physical-activity-country-factsheets/denmark

68. Sundhedsstyrelsen. Danskernes sundhed - Den Nationale

Sundhedsprofil 2013 [Internet]. 2014 [cited 2021 Jan 19]. Available from: https://www.sst.dk/-/media/Udgivelser/2014/Den-nationale-sundhedsprofil-2013/Danskernes-sundhed,-d-,-Den-nationale-sundhedsprofil-2013.ashx

69. Färre röker, fler snusar [Internet]. Statistiska Centralbyrån. [cited 2021 Jan 19]. Available from: http://www.scb.se/hitta-statistik/artiklar/2018/farre-roker-fler-snusar/

70. Bergman H. Alcohol use among Swedes and a psychometric evaluation of the Alcohol Use Disorders Identification Test. Alcohol Alcohol. 2002 May 1;37(3):245–51.

71. Beich A, Gannik D, Saelan H, Thorsen T. Screening and brief intervention targeting risky drinkers in Danish general practice--a pragmatic controlled trial. Alcohol Alcohol Oxf Oxfs. 2007 Dec;42(6):593–603.

72. Berman AH, Bergman H, Palmstierna T, Schlyter F. Evaluation of the Drug Use Disorders Identification Test (DUDIT) in Criminal Justice and Detoxification Settings and in a Swedish Population Sample. Eur Addict Res. 2005;11(1):22–31.

73. Zetterberg CH, Irstam L, Andersson GB. Femoral neck fractures in young adults. Acta Orthop Scand. 1982 Jun;53:427–35.

74. Samuel AM, Russo GS, Lukasiewicz AM, Webb ML, Bohl DD, Basques BA, et al. Surgical Treatment of Femoral Neck Fractures After 24 Hours in Patients Between the Ages of 18 and 49 Is Associated With Poor Inpatient Outcomes: An Analysis of 1361 Patients in the National Trauma Data Bank. J Orthop Trauma. 2016 Feb;30:89–94.

75. Stearns AT, Jaberoo MC, Ashraf R, Wheelwright EF, Maclean AD. Displaced intracapuslar hip fractures in the working age alcohol-abusing patient. Scott Med J. 2009 Feb;54:16–20.

76. Verettas DA, Galanis B, Kazakos K, Hatziyiannakis A, Kotsios E. Fractures of the proximal part of the femur in patients under 50 years of age. Injury. 2002 Jan;33:41–5.

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

78. O'Rourke TK, Wosnitzer MS. Opioid-Induced Androgen Deficiency (OPIAD): Diagnosis, Management, and Literature Review. Curr Urol Rep. 2016 Oct;17(10):76.

79. Callréus M, McGuigan F, Akesson K. Country-specific young adult

dual-energy X-ray absorptiometry reference data are warranted for T-score calculations in women: data from the peak-25 cohort. J Clin Densitom Off J Int Soc Clin Densitom. 2014 Mar;17(1):129–35.

80. Emaus N, Omsland TK, Ahmed LA, Grimnes G, Sneve M, Berntsen GK. Bone mineral density at the hip in Norwegian women and men—prevalence of osteoporosis depends on chosen references: the Tromsø Study. Eur J Epidemiol. 2009 Jun 1;24(6):321–8.

81. Cummings SR, Eastell R. Stop (mis)classifying fractures as high- or low-trauma or as fragility fractures. Osteoporos Int. 2020 Jun;31(6):1023–4.

82. Thoors O, Mellner C, Hedström M. Good clinical outcome for the majority of younger patients with hip fractures: a Swedish nationwide study on 905 patients younger than 50 years of age. Acta Orthop. 2021 Jan 22;1–5.

83. Landstingens Ömsesidiga Försäkringsbolag. Nationella traumalarmskriterier 2017 - Säker traumavård. :16.

84. Grassi L, Kok J, Gustafsson A, Zheng Y, Väänänen SP, Jurvelin JS, et al. Elucidating failure mechanisms in human femurs during a fall to the side using bilateral digital image correlation. J Biomech. 2020 Jun 9;106:109826.

85. de Bakker PM, Manske SL, Ebacher V, Oxland TR, Cripton PA, Guy P. During sideways falls proximal femur fractures initiate in the superolateral cortex: Evidence from high-speed video of simulated fractures. J Biomech. 2009 Aug 25;42(12):1917–25.

86. Tang T, Cripton PA, Guy P, McKay HA, Wang R. Clinical hip fracture is accompanied by compression induced failure in the superior cortex of the femoral neck. Bone. 2018 Mar 1;108:121–31.

87. Pulkkinen P, Eckstein F, Lochmüller EM, Kuhn V, Jämsä T. Association of Geometric Factors and Failure Load Level With the Distribution of Cervical vs. Trochanteric Hip Fractures. J Bone Miner Res. 2006;21(6):895–901.

88. Janes G. Silent slips trips and broken hips: the recovery experiences of young adults following an isolated fracture of the proximal femur. PhD thesis, University of Wolverhampton. [Internet]. 2016 [cited 2021 Nov 2]. Available from: https://wlv.openrepository.com/handle/2436/618587

89. Holt G, Smith R, Duncan K, Hutchison JD, Gregori A. Epidemiology and outcome after hip fracture in the under 65s—Evidence from the Scottish Hip Fracture Audit. Injury. 2008 Oct 1;39(10):1175–81.

90. Zidén L, Frandin K, Kreuter M. Home rehabilitation after hip fracture. A randomized controlled study on balance confidence, physical function and everyday activities. Clin Rehabil. 2008 Dec 1;22(12):1019–33.

91. Jensen CM, Smith AC, Overgaard S, Wiil UK, Clemensen J. “If only had I known”: a qualitative study investigating a treatment of patients with a hip fracture with short time stay in hospital. Int J Qual Stud Health Well-Being. 2017 Apr 3;12(1):1307061.

92. Beer N, Riffat A, Volkmer B, Wyatt D, Lambe K, Sheehan KJ. Patient perspectives of recovery after hip fracture: a systematic review and qualitative synthesis. Disabil Rehabil. 2021 Aug 24;0(0):1–16.

93. Hansson S, Rolfson O, Åkesson K, Nemes S, Leonardsson O, Rogmark C. Complications and patient-reported outcome after hip fracture. A consecutive annual cohort study of 664 patients. Injury. 2015 Nov 1;46(11):2206–11.

94. Sprague S, Slobogean GP, Scott T, Chahal M, Bhandari M. Young femoral neck fractures: Are we measuring outcomes that matter? Injury. 2015 Mar 1;46(3):507–14.

95. Ekegren CL, Edwards ER, Page R, Hau R, de Steiger R, Bucknill A, et al. Twelve-month mortality and functional outcomes in hip fracture patients under 65 years of age. Injury. 2016 Oct 1;47(10):2182–8.

96. Johansson T. Internal fixation compared with total hip replacement for displaced femoral neck fractures: a minimum fifteen-year follow-up study of a previously reported randomized trial. J Bone Joint Surg Am. 2014 Mar 19;96(6):e46.

97. Lagergren J, Mukka S, Wolf O, Nauclér E, Möller M, Rogmark C. Conversion to arthroplasty after fixation of undisplaced femoral neck fractures. Results from a national register cohort of 5,909 individuals. Manuscript.

98. Nugent M, Young SW, Frampton CM, Hooper GJ. The lifetime risk of revision following total hip arthroplasty. Bone Jt J. 2021 Mar;103-B(3):479–85.

99. Palm H, Gosvig K, Krasheninnikoff M, Jacobsen S, Gebuhr P. A new measurement for posterior tilt predicts reoperation in undisplaced femoral neck fractures: 113 consecutive patients treated by internal fixation and followed for 1 year. Acta Orthop. 2009 Jun;80(3):303–7.

100. Sjöholm P, Otten V, Wolf O, Gordon M, Karsten G, Sköldenberg O, et al. Posterior and anterior tilt increases the risk of failure after internal fixation of Garden I and II femoral neck fracture. Acta Orthop. 2019 Dec;90(6):537–41.

101. Alho A, Benterud JG, Rønningen H, Høiseth A. Prediction of disturbed healing in femoral neck fracture: Radiographic analysis of 149 cases. Acta Orthop Scand. 1992 Jan;63(6):639–44.

102. Leonardsson O, Rogmark C, Kärrholm J, Akesson K, Garellick G. Outcome after primary and secondary replacement for subcapital fracture of the hip in 10 264 patients. J Bone Joint Surg Br. 2009 May;91(5):595–600.

103. Frihagen F, Madsen JE, Aksnes E, Bakken HN, Maehlum T, Walløe A, et al. Comparison of re-operation rates following primary and secondary hemiarthroplasty of the hip. Injury. 2007 Jul;38(7):815–9.

104. Blomfeldt R, Törnkvist H, Ponzer S, Söderqvist A, Tidermark J. Displaced femoral neck fracture: comparison of primary total hip replacement with secondary replacement after failed internal fixation: A 2-year follow-up of 84 patients. Acta Orthop. 2006 Jan 1;77(4):638–43.

105. Støen RØ, Lofthus CM, Nordsletten L, Madsen JE, Frihagen F. Randomized trial of hemiarthroplasty versus internal fixation for femoral neck fractures: no differences at 6 years. Clin Orthop. 2014 Jan;472(1):360–7.

106. Bartels S, Kristensen TB, Gjertsen JE, Frihagen F, Rogmark C, Dolatowski FC, et al. Total Hip Arthroplasty Leads to Better Results After Low-Energy Displaced Femoral Neck Fracture in Patients Aged 55 to 70 Years: A Randomized Controlled Multicenter Trial Comparing Internal Fixation and Total Hip Arthroplasty - PubMed. 2022(104):1341–51.

107. Meyer AC, Ek S, Drefahl S, Ahlbom A, Hedström M, Modig K. Trends in Hip Fracture Incidence, Recurrence, and Survival by Education and Comorbidity: A Swedish Register-based Study. Epidemiol Camb Mass. 2021 May;32(3):425–33.

108. Statistiska centralbyrån. Ettårig livslängdstabell för hela riket efter kön och ålder. År 1960 - 2020 [Internet]. Statistikdatabasen. [cited 2022 Feb 3]. Available from: http://www.statistikdatabasen.scb.se/pxweb/sv/ssd/START__BE__BE0101__BE0101I/LivslangdEttariga/

109. Bergh C, Möller M, Ekelund J, Brisby H. 30-day and 1-year mortality after skeletal fractures: a register study of 295,713 fractures at different locations. Acta Orthop. 2021 Nov 2;92(6):739–45.

110. Patterson JT, Ishii K, Tornetta PI, Leighton RK, Friess DM, Jones CB, et al. Open Reduction Is Associated With Greater Hazard of Early Reoperation After Internal Fixation of Displaced Femoral Neck Fractures in Adults 18–65 Years. J Orthop Trauma. 2020 Jun;34(6):294–301.

Appendix

Paper I: Frailty and osteoporosis in patients with hip fractures under the age of 60 – a prospective cohort of 218 individuals

Paper II: Trauma mechanism and bone mineral density did not impact hip fracture type – a multicenter cohort of patients under 60 years of age

Paper III: Lingering challenges in everyday life for younger patients with hip fractures – a qualitative study of the lived experience during the first three years

Paper IV: Rate of conversion to secondary arthroplasty after femoral neck fractures in 796 younger patients treated with internal fixation: a Swedish national register-based study

Printed by Media-Tryck, Lund 2022 NORDIC SWAN ECOLABEL 3041 0903

On hip fractures in adults under the age of 60

Sebastian Strøm Rönnquist, born in 1982, studied medicine at Umeå University and graduated in 2011. After an internship in Copenhagen and receiving his license to practice medicine, he commenced specialist training in orthopedic surgery at Skåne University Hospital Malmö/Lund. As a specialist in orthopedic surgery since 2018, he works clinically in pediatric orthopedics.

This thesis project on hip fractures in adults under the age of 60 began in 2014. Parts of the work have previously been presented at orthopedic meetings; nationally in Sweden and Denmark and internationally at EFORT in Barcelona in 2018, Lisbon in 2022, and at AAOS in Las Vegas in 2019.

LUND UNIVERSITY

FACULTY OF MEDICINE

Department of Orthopedic Surgery
Institution for Clinical Sciences Malmö

Lund University, Faculty of Medicine
Doctoral Dissertation Series 2022:115
ISBN 978-91-8021-276-2
ISSN 1652-8220