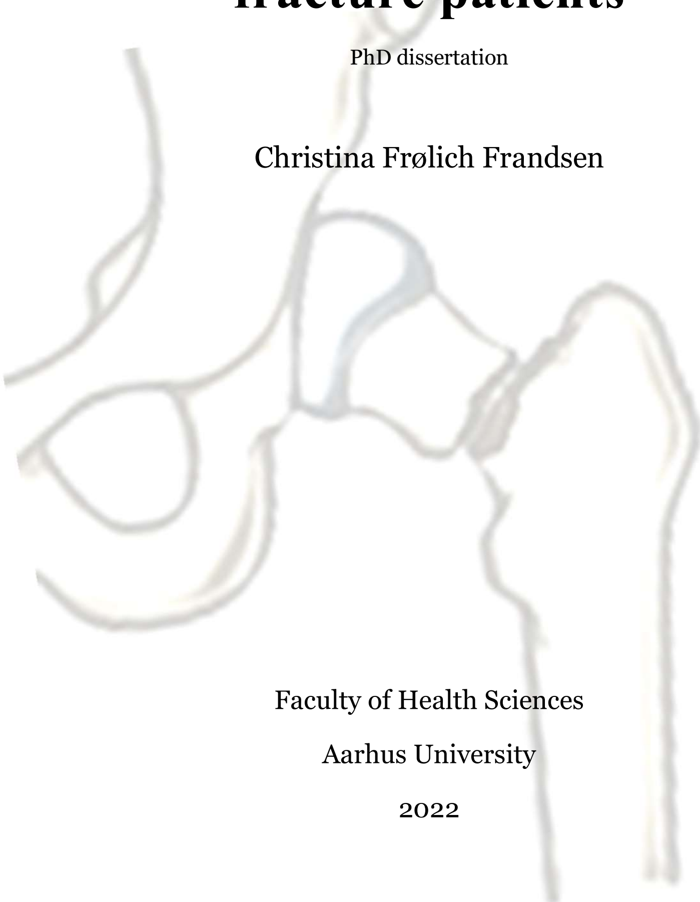
Optimization of care among hip fracture patients

PhD dissertation

Christina Frølich Frandsen



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Preface

This PhD dissertation is based on original studies completed during my enrollment as a PhD student at the University Clinic for Hand, Hip and Knee Surgery from 2017 to 2022. The studies will be referred to in the dissertation by their roman numeral (I-V):

Study I: Frandsen CF, Glassou EN, Stilling M, Hansen TB. Poor adherence to guidelines in treatment of fragile and cognitively impaired patients with hip fracture: a descriptive study of 2,804 patients.
Acta Orthop. 2021 Oct;92(5):544-50.
doi: 10.1080/17453674.2021.1925430. Epub 2021 May 12.

Study II: Frandsen CF, Glassou EN, Stilling M, Hansen TB. Malnutrition, poor function and comorbidities predict mortality up to one year after hip fracture – a cohort study of 2,800 patients.
Eur Geriatr Med. 2021 Dec 2.
doi: 10.1007/s41999-021-00598-x. Epub ahead of print. PMID: 34854063.

Study III: Frandsen CF, Stilling M, Glassou EN, Pedersen ABL, Hansen TB. Active clinical issues at discharge predict readmission within 30 days and one year following hip fracture surgery.
Eur Geriatr Med. Submitted December 2021.

Study IV: Frandsen CF, Stilling M, Glassou EN, Hansen TB. Intramedullary nail versus dynamic hip screw with stabilising trochanteric plate in treatment of unstable intertrochanteric fractures.
Arch Orthop Trauma Surg. Submitted January 2022.

Study V: Frandsen CF, Stilling M, Glassou EN, Hansen TB. The majority of community-dwelling hip fracture patients return to independent living with a minor increase in care needs – A prospective cohort study.
Arch Orthop Trauma Surg. Submitted February 2022.

Financial disclosure: The studies were financed primarily by the University Clinic for Hand, Hip and Knee Surgery. Grants were received from Aarhus University and from the Regional Hospital West Jutland’s Research Foundation.
The authors have no competing interests to declare that are relevant to the contents of this dissertation.

Abbreviations

AF = Attributable fraction

ACI = Active clinical issues

ASA = American Society of Anesthesiologists

AT/OTA = Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association

BMI = Body Mass Index

CAS = Cumulated Ambulation Score

CI = Confidence interval

CPR = Civil Personal Register

DHS = Dynamic hip screw

ER = Emergency room

EQ-5D = European Quality of Life-5 Dimensions

FNF = Femoral neck fracture

FRA = Fall risk assessment

HR = Hazard ratio

IMN = Intramedullary nail

IQR = Interquartile range

LMWH = Low-molecular weight heparin

LOS = Length of stay

NMS = New Mobility Score

OHS = Oxford Hip Score

OR = Odds ratio

PROM = Patient-reported outcome measure

RCT = Randomized controlled trial

RR = Relative risk ratio

SD = Standard deviation

SF-12 = 12-Item Short Form

SFG-36 = 36-Item Short Form

THA = Total hip arthroplasty

TSP = Trochanteric stabilizing plate

TUG = Timed-up-and-go test

Acknowledgments

It has been a great privilege to prepare this dissertation in cooperation with such enthusiastic and experienced people. I could not have made this work myself, and I am deeply indebted to those who made it possible.

During medical school, I was fortunate enough to meet *Torben Bæk Hansen*. Our encounter quickly triggered both clinical and research activities at the Department of Orthopedics Regional Hospital West Jutland; activities that would soon evolve into this PhD project, in which he has served as my main supervisor. *Torben Bæk Hansen*, thank you for your never-failing trust in me, for sharing your extensive knowledge, and for guiding me on the way to becoming an independent researcher. Without your faith in me and the financial support from the University Clinic for Hand, Hip, and Knee Surgery, I would not have had the privilege to pursue this opportunity.

I need to express my gratitude to *Maiken Stilling* for introducing me to the field of research, for valuable support and feedback to launch this PhD project, and for your constructive comments throughout.

To *Eva Glassou*, a warm thank you for your guidance in the unknown fields of epidemiology and biostatistics and for your treasured feedback.

This PhD project stands, in large, on the foundation laid by *Maiken Stilling* and *Henrik Palm* when they launched the Hip Fracture Databases. However, this would merely have been an idea had it not been for the nurses and therapists at the Department of Orthopedics. Their daily data collection for nearly a decade has been invaluable. Thank you all.

Furthermore, I want to express my gratitude to *Anne Dorte Riedel* for your shoulders to lean on when things got rough, for your considerable help with the database, and for sharing life lessons. To *Charlotte Stilling,* you have been a great help with practical matters and irreplaceable in relation to patient follow-up.

To *Anne-Birgitte Langsted Pedersen*, thank you for sharing your extensive knowledge of geriatric medicine, thereby providing valuable insights into this frail patient group.

When COVID-19 swept across the world impacting everything, this PhD was also affected. Therefore, I have a special thank you to *Janne Bach Pedersen* for making Studies III and IV possible and for your incredible patience with me.
Also, I express my gratitude to the Department of Geriatrics at Aarhus University Hospital, especially *Catherine Hauerslev Foss* and *Merete Gregersen,* for welcoming me with open arms when my research stay abroad was canceled. Thank you for your unique insights and feedback.

Finally, my sincerest gratitude to my loving family and friends for all the times when we were together and my mind was elsewhere engaged, and you put up with it. I am grateful also to my mother and father for teaching me that with hard work and determination, no dream is too big to realize. A special thank you to my beloved husband *Lean* and our children, *Isack, Toke,* and *Kaare,* for letting me pursue my dream. Thank you for your patience, support, and encouragement; I would not have made it to the finish line without your support.

Christina Frølich Frandsen 2022

Table of contents

English summary

Patients sustaining a hip fracture face an increased mortality and readmission risk, often accompanied by functional decline that may lead to long-term institutionalization. Whereas most patients with hip fractures are frail, several subgroups exist. They range from healthy and active older patients living independently to comorbid and bedridden nursing home residents. Because of this heterogeneity, future treatment of hip fractures may aim to be related more to the patient than to the diagnosis. To achieve this, more information about patients at risk is required. Therefore, the overall aim of this dissertation was to investigate which hip fracture patients are at risk of poor outcomes and to identify targets for interventions. Furthermore, the dissertation aimed to assess the treatment currently provided. Such knowledge may help target future interventions and may thus potentially serve to improve the prognosis following a hip fracture.

Study I examined the overall adherence to seven best-practice indicators. Adherence was low, with only a third meeting the requirements of all seven indicators. The most dependent patients characterized by cognitive impairment, comorbidities, or low functional levels had a significantly lower adherence than the remaining patients. Among the individual indicators, not achieving preoperative pain management, thromboprophylaxis, postoperative mobilization, and blood transfusions were associated with an increased mortality. None of the indicators were associated with readmission risk.

Studies II, III, and V investigated risk factors for poor outcomes. Unsurprisingly, the most dependent patients carried the highest risk in all three studies. Even so, the studies established some modifiable risk factors that may potentially be targeted for interventions. In Study II, increased mortality was found for comorbid and malnourished patients, and patients operated on more than 36 hours after their admission or mobilized more than 24 hours after their surgery. In Study III, the most interesting results were that while delaying surgery for more than 36 hours increased readmission, no differences were found between patients delayed due to

medical issues and organizational reasons. Furthermore, we investigated the impact of active clinical issues at discharge and found them to predict readmissions, especially medical readmissions. In Study V, mobilizing patients to standing within 24 hours from surgery was associated with achieving independence at discharge, which, in turn, was associated with return to independent living at 12 months.

Study IV compared intramedullary nails (IMN) to dynamic hip screws with trochanteric stabilizing plate in the treatment of unstable intertrochanteric fractures. Only minor differences were found, with increased blood loss and fewer patients mobilized within 24 hours in the IMN group. However, no differences were found regarding regaining prefracture function and patient-reported outcomes at one year, or reoperation rates within three years.

In conclusion, the most dependent patients carried a higher risk of obtaining a poorer outcome, and providing the best possible treatment was more challenging for this group than for other groups. Dividing patients into subgroups will be essential in future studies to investigate which treatment steps are more important for each particular subgroup and how to provide them. Such studies providing treatments that are more closely tailored to the individual patient may be key to achieving better outcomes. One place to start based on the results presented in this dissertation may be to focus on hospital-related variables such as time to surgery, postoperative mobilization, and discharge planning including active clinical issues.

Dansk resumé

Efter et hoftebrud vil patienter have øget dødelighed og genindlæggelsesrisiko, ofte ledsaget af nedsat funktionsevne, der kan medføre behov for flytning til et plejehjem. De fleste patienter med hoftebrud er skrøbelige, men der ses flere undergrupper af patienter. Disse undergrupper spænder fra raske og aktive ældre patienter, der bor i eget hjem, til multisyge, sengeliggende plejehjemsbeboere. Med sådan en spredning kan alle patienter ikke behandles ens, og vi må stile efter en behandling, som tager udgangspunkt i patienten frem for diagnosen. Det overordnede formål med denne afhandling var at undersøge, hvilke hoftefrakturpatienter, der er i risiko for dårlige resultater og at vurdere den behandling, der aktuelt ydes. Med denne viden kan vi målrette interventionerne og forbedre prognosen efter et hoftebrud.

Studie I undersøgte den overordnede overensstemmelse med syv indikatorer, der reflekterede de gældende retningslinjer. Kun en tredjedel af patienterne opfyldte alle syv indikatorer. De skrøbeligste patienter med kognitiv svækkelse, komorbiditet eller lav funktionsevne havde lavere grad af overensstemmelse. Patienter, der ikke fik præoperativ smertebehandling, tromboseprofylakse, postoperativ mobilisering og blodtransfusioner, var i risiko for øget dødelighed. Ingen af indikatorerne var associeret med øget genindlæggelsesrisiko.

Studierne II, III og V undersøgte risikofaktorer for dårlige resultater. Ikke overraskende havde de skrøbeligste patienter den højeste risiko for øget dødelighed, genindlæggelser og flytning til plejehjem. Nogle modificerbare risikofaktorer blev identificeret i studierne. De kan danne grundlag for fremtidige interventioner. I Studie II blev der fundet øget dødelighed for komorbide og underernærede patienter, patienter opereret mere end 36 timer efter indlæggelse samt patienter mobiliseret mere end 24 timer efter deres operation. Studie III viste, at mens udsættelse af operationen i mere end 36 timer var forbundet med en øget genindlæggelsesrisiko, var der ikke forskel mellem patienter, som var forsinkede på grund af henholdsvis medicinske problemstillinger og organisatoriske årsager. Desuden viste studiet, at abnorme vitalparametre ved udskrivelsen var associeret med

genindlæggelser, især medicinske genindlæggelser. I Studie V fandt vi en association mellem mobilisering af patienter inden for 24 timer fra operationen og funktionel uafhængighed ved udskrivelsen. Funktionel uafhængighed var associeret med fortsat at bo i eget hjem efter 12 måneder.

Studie IV sammenlignede intramedullære søm (IMN) med glideskruer med trochanterskjold i behandlingen af ustabile ekstrakapsulære frakturer. Der blev kun fundet mindre forskelle mellem de to implantater, hvor IMN-gruppen havde øget blodtab og færre mobiliserede patienter inden for 24 timer. Der blev ikke fundet forskelle med hensyn til genvinding af funktionsniveau og patientrapporterede resultater efter et år eller med hensyn til reoperationsraten inden for tre år.

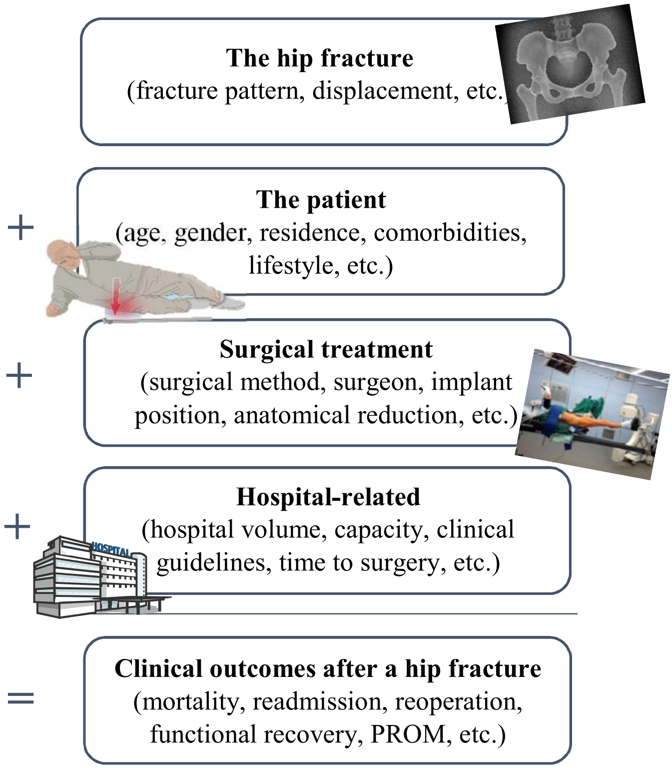
Studierne fandt, at de skrøbeligste patienter er i størst risiko for dårlige resultater efter et hoftebrud. Samtidig er det også i denne gruppe sværere at følge de evidensbaserede retningslinjer. Skræddersyede behandlingsforløb kan udvikles ved at inddele patienter i undergrupper i fremtidige studier og herefter undersøge hvilke trin i retningslinjerne, der har størst betydning for resultatet og beskrive, hvordan trinene opfyldes. Dette kan være en af nøglerne til at forbedre prognosen efter et hoftebrud. Baseret på resultaterne fra de beskrevne studier kunne et udgangspunkt være at fokusere på hospitalsrelaterede variabler såsom tid til operation, postoperativ mobilisering og udskrivelsesplanlægning inklusive abnorme vitalparametre.

1. Introduction

Hip fracture is a common injury, particularly in older people and are typically associated with low-energy falls among osteoporotic patients. Hip fracture is a leading cause of trauma-related mortality in older people, and approx. half of surviving patients never return to their prefracture functional level [1, 2]. Besides serious individual consequences, hip fractures are also associated with substantial socioeconomic costs [3]. Unfortunately, predictions see the number of hip fractures worldwide increasing from 1.6 million in 2000 to 4.5-6.5 million by 2050 [4]. However, the age-standardized incidence rates for hip fracture in Denmark have been decreasing, and the latest national audit found an incidence rate for people above 65 years of 56.5 /10.000 person years [5]. The age-standardized incidence rates for hip fractures vary worldwide with the highest rates being recorded in the Nordic countries, Europe, and North America, whereas Africa has the lowest rate [3, 6].

The high mortality rate, frequent readmissions, reoperations, and diminished quality of life and functional level have all prompted several studies exploring how the clinical outcomes following a hip fracture may be improved. Treatments and outcomes vary greatly despite extensive research into hip fractures with multiple clinical guidelines and national audits having been developed in the past decades [3, 7–10]. To improve outcomes following hip fracture, one must appreciate the complexity of this fragile patient group and understand how various factors interact. Sackett et al. proposed an algorithm for the determinants of outcomes, and a modified version regarding hip fractures is presented in Figure 1.1 [11]. The figure emphasizes that we cannot single out individual factors. Instead, we need to focus on the overall picture. To translate this more specifically into the context of the present dissertation, many variables regarding fracture, patient, treatment, and hospital were investigated for association with clinical outcomes following hip fracture surgery.

Figure 1.1. *Determinants of clinical outcomes following hip fracture surgery (modified from Sacket et al. (11))*



PROM = Patient-reported outcome measures

1.1 Hip fracture

Hip fracture occurs mainly in older people due to a combination of a lower bone mineral density and an increased tendency to fall. Hip fractures are diagnosed based on clinical findings and x-rays. A hip fracture is defined as a fracture from the edge of the femoral head to five cm below the minor trochanter. Generally, hip fractures are divided into two main groups based on the fracture pattern: intracapsular and extracapsular. Intracapsular fractures, or femoral neck fractures, are located above the insertion of the hip joint capsule, whereas extracapsular fractures are located below the insertion. Additionally, extracapsular fractures are divided into intertrochanteric and subtrochanteric fractures (Figure 1.2).

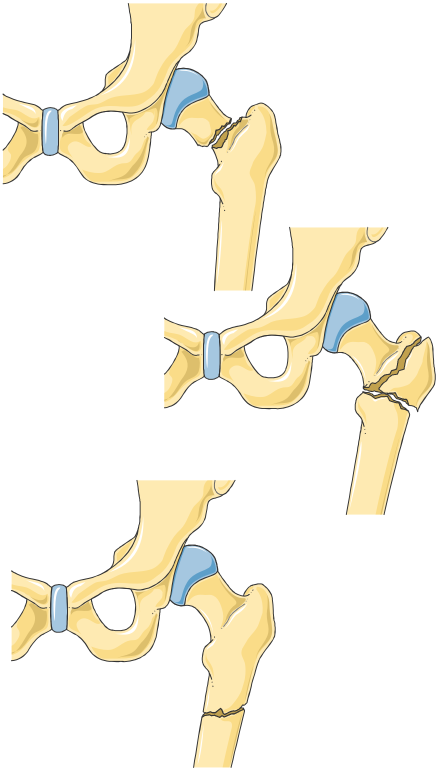


Figure 1.2 *Types of hip fracture. From the top: intracapsular fracture and extracapsular fractures; intertrochanteric fracture and subtrochanteric fracture.*

Multiple classification systems are used throughout the literature. Some of the most well-known classification systems are the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classification system with or without subgroups [12, 13]. Additionally, the Garden classification system with two or four groups is used for intracapsular fractures and the Evans classification system for intertrochanteric fractures. Each system has limitations regarding intra- and intertester reliability [14–18]. However, classification systems have their merits in enabling clinicians to choose the best surgical method for the fracture pattern based on current research. To reach conclusions based on a wide range of studies, researchers must use similar classification systems.

1.2 The patient

As hip fractures have a considerable impact on the patients' lives, a large body of research has evolved that focuses on identifying people at risk of sustaining a hip fracture to prevent such fractures. The pathogenesis of hip fracture is multifactorial. However, some established risk factors of sustaining a hip fracture include higher age, male sex, underweight, osteoporosis, prior fractures, fall tendency, and lifestyle factors such as smoking and increased alcohol consumption [19–21]. To prevent hip fractures, various preventive measures have been investigated including fall prevention, exercises, pharmacological measures to treat osteoporosis, and hip protectors. Unfortunately, findings are inconsistent [22, 23]. Many risk factors associated with an increased risk of sustaining a hip fracture are also associated with poor clinical outcomes [24–26].

1.3 Surgical treatment of hip fracture

The majority of hip fractures are surgically treated in an effort to restore normal anatomy, relieve pain, and facilitate early mobilization. The surgical treatment of hip fractures has developed considerably in recent decades; and various implants have been developed: extramedullary, intramedullary, and prostheses (Figure 1.3). A large part of the decision basis for implant use is based on the fracture pattern. In general, it can be said that intracapsular fractures are typically treated with screws or prostheses; extracapsular fractures with intramedullary nails (IMNs) or screws [9, 10].

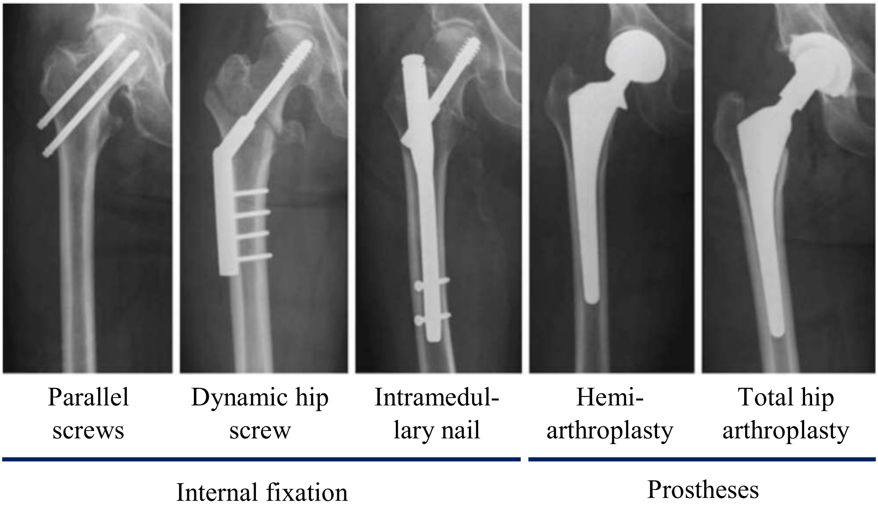


Figure 1.3 *X-rays of implants used in the treatment of hip fractures* [27].

Whereas most non-displaced intracapsular fractures are treated with screws, displaced intracapsular fractures may disrupt the blood supply to the femoral head as the arteries run through the femoral neck. This disruption may lead to avascular necrosis of the femoral head, causing pain and requiring reoperation. This is one of the reason why displaced intracapsular fractures are treated with prostheses. When considering a prosthesis for a hip fracture, the choice stands between total hip arthroplasty (THA) or hemiarthroplasty. The superiority of THA versus hemiarthroplasty is a matter of continued debate, with some favoring THA owing to reports about better functional outcomes and quality of life, whereas others prefer hemiarthroplasty in the elderly owing to the less invasive surgery and more limited surgical stress in combination with equal functional outcomes and a lower dislocation risk [28–32].

Furthermore, the surgeon needs to decide if the arthroplasty will be cemented or not. Cementation has been linked to increased operation time, higher blood loss, and a higher incidence of pulmonary embolism than uncemented prostheses [33, 34]. Similar results have been reported for both groups with respect to functional outcome, pain, quality of life, and long-term mortality [32, 33, 35, 36]. However, uncemented prostheses have an increased reoperation rate, especially due to periprosthetic fractures [32, 33, 35, 37, 38].

Internal fixation is the primary surgical method for extracapsular fractures, primarily dynamic hip screw (DHS) and IMN. The decision generally relies more on the specific fracture pattern than on patient characteristics [39]. Unstable intertrochanteric fractures in particular pose a challenge as fractures of the lateral wall and greater trochanter diminish the support, thereby carrying a heightened risk that the fracture may collapse. Therefore, the issue of which implant is optimal remains unresolved. IMN has been linked with a shorter operation time, better functional recovery, and shorter length of stay (LOS). Results, however, are conflicting [40–44].

An increasing focus exists on the fact that not only the fracture pattern should determine the surgical method but also age, functional level, comorbidities, and hip-related issues such as bone quality and previous osteoarthritis. Such considerations may impact the success of each method. Hence, the continuous development of new implants requires continuous research to provide clear evidence for orthopedic surgeons and to establish which implants are more suited for different fracture patterns and patients.

1.4 Hospital-related variables

The care of hip fracture patients relies on close multidisciplinary collaboration aiming to return the patients to their prefracture functional level and reduce complications. Hence, guidelines have been developed with recommendations regarding multiple treatment steps, e.g., pain management, time to surgery, rehabilitation, and prevention of future hip fractures [9, 10]. To monitor the quality of the treatment performed, national audits have been developed in various countries to reflect key recommendations in the guidelines [5, 8, 45–47]. Most national audits rely largely on process performance measures. Whereas some studies have found process performance measures to be associated with outcomes following hip fracture surgery, they do have limitations [48, 49]. In some instances, process performance measures may only describe if patients have been assessed for the process performance measure but provide no information about the actual treatment given based on the assessment.

Furthermore, the audits rely solely on the data provided by each hospital, e.g., in Germany only approximately 5% of hip fracture patients were reported to the national audit in 2018 [8]. Additionally, national audits have been reported to contain inaccuracies that studies need to take into consideration [50–53].

Previous studies into the adherence to various guidelines have reported considerable variation, with 0-88% of patients receiving treatment strictly following the studied guideline’s indicators [54–57]. However, the studies included different indicators, and the number of indicators ranged from 1 to 22. Unsurprisingly, adherence was typically lower in studies with more indicators. Some commonly used indicators are presented in more detail below.

Time to surgery is generally defined as the time from admission to surgery – also known as surgical delay. Countries have set different timelines as their goal, with 24, 36, or 48 hours being the most typical [9, 10]. Time to surgery has primarily been investigated in association with mortality with multiple studies finding increased time to surgery to be associated with increased mortality and complications [1, 58–60]. Time to surgery is interesting for the patient but is also relevant when determining how hospitals are organized and where resources need to be allocated.

Orthogeriatric assessment or integrated care is available in an increasing number of countries and has been incorporated as an indicator in some national audits [46, 61]. The design of the orthogeriatric input varies. In some models, geriatricians are involved upon request, whereas other hospitals have developed integrated orthogeriatric care with shared patient care [62]. Some studies indicate better outcomes with integrated orthogeriatric care than with upon-request care [63, 64]. Besides being better equipped to handle medical issues in this frail patient group, orthogeriatric care has also been shown to improve overall guideline adherence [65]. Furthermore, orthogeriatric care has shown improvements in outcomes with lower mortality and better mobility up to one year after surgery [63–67]. Other more indirect indicators aiming to ensure that medical aspects of this frail patient group are taken into account include, e.g., hemoglobin assessment, fluid balance, cognitive status, and prefracture medication.

Surgical guidelines were found to be easily implemented and may reduce the risk of reoperations without increasing cost, despite different algorithms being implemented in the studies [39, 57, 68, 69]. As mentioned previously, no total agreement exists as to which implants should be used for specific fracture patterns. Hence, hospitals will have minor differences in their implemented algorithm.
Prevention of complications, such as delirium, pressure ulcers, infections, and embolism, and measures to prevent future fractures, by preventing falls and ensuring osteoporosis treatment, are implemented in most national guidelines. The mentioned factors are focus points as they are known to increase the risk of readmissions and mortality following a hip fracture [23, 70–77].
Early postoperative mobilization may help prevent some of the complications outlined above and have a positive impact on patients' functional outcomes and mortality [78, 79]. Mobilizing patients on the first postoperative day has also been incorporated into national guidelines and audits, mirroring its importance [5, 9, 61].

The factors mentioned above are just some of the factors involved in the treatment of hip fracture patients; and they exemplify the complexity of hip fractures and illustrate the multidisciplinary nature of care required to improve outcomes.

1.5 Clinical outcomes

The overall goal of hip fracture treatment is to allow the patient to return to their prefracture life by mobilizing them quickly and preventing complications. However, patients with hip fractures form a fragile group, and the result of treatment is measured by several different clinical outcomes. The below section outlines some of the most common outcomes reported in the literature along with known risk factors and gaps in the literature.

1.5.1 Mortality

Mortality, whether in-hospital, three-day, 30-day, or one-year, is frequently used as an outcome measure. Mortality is easily reported and compared across patient groups and studies; and it is the ultimate outcome. Hip fracture patients experience an increased mortality rate, especially in the short term. However, studies have found excess mortality up to 20 years after sustaining a hip fracture [80, 81]. In particular, comorbidities have previously been shown to affect the risk of excess mortality, which may be reflected in the typical causes of death; pneumonia and cardiovascular disease [80, 82–84]. In addition to comorbidities, several other, generally accepted, risk factors for increased mortality exist: higher age, male sex, cognitive impairment, prefracture nursing home residence, and low prefracture functional level. However, these risk factors are primarily static and not targets for interventions. This does not mean that they are irrelevant as patients with hip fractures are a heterogeneous group; indeed, these static risk factors may potentially help clinicians identify patients at high risk of poor outcomes. In the literature, targetable risk factors for increased mortality include low Body Mass Index (BMI), malnutrition, anemia, functional recovery, and time to surgery. However, most of these risk factors have been studied in small populations or with conflicting results [25, 26, 79, 85–88].

1.5.2 Readmission

Readmissions occur in approximately 10% of hip fracture patients within 30 days of discharge and are associated with increased mortality [24, 70, 89–92]. The leading cause for readmission is reported to be medical issues, especially infections, such as pneumonia, or cardiovascular diseases [70, 89, 90, 92]. Readmissions have been used to measure the quality of care provided by hospitals, and the US and UK have used non-payment policies or fines to reduce readmissions [93]. However, studies have suggested that readmission is a poor measure of treatment quality because readmission, like mortality, is often closely related to comorbidities [24, 94]. Whereas some risk factors are similar to those known for mortality, inconsistencies remain with respect to the association of many risk factors with readmission [24, 95]. Differences between healthcare systems seen worldwide may explain some of these inconsistencies. In countries with free all-access healthcare, people may be more likely to seek health professionals earlier than in payment-based healthcare systems. Likewise, differences in the primary sector and the tolerance for admission differ significantly. Furthermore, significant variations exist in the LOS between countries. LOS is around one week in the Nordic countries, whereas other countries have LOS that are two or three times longer [6, 8]. Patients readmitted on day ten for a deep vein thrombosis in Denmark may not have been readmitted in Germany as the patient would not yet have been discharged after their hip fracture.

In order to prevent readmissions, multiple interventions have been implemented, but only a few have been found to be effective, e.g., discharge planning [96–98]. Discharge planning has also been incorporated into the national guideline in England [99]. However, consensus is lacking as to what qualifies as readiness for discharge, and many patients do not feel ready when discharged [100, 101]. This raises the concern of premature discharge being aggravated by a shortening of LOS. Galvin et al. proposed that readiness for discharge may be evaluated by physical stability (e.g., stable vital signs, adequate nutrition, pain control, and functional abilities), adequate support by staff and family, psychological ability, and adequate information and knowledge about, e.g., whom to call, the plan after discharge, and how to care for themselves [100]. Even though this is a general model, factors such as instability in vital signs, malnutrition, and functional recovery have been linked to readmission following a hip fracture [87, 102–104].

1.5.3 Reoperation

Reoperation following hip fracture is typically a result of complications to the primary surgery, e.g., dislocation, pain, non-union, or aseptic loosening. Patients are typically divided into groups according to the fracture pattern in the literature when reoperation is used as a clinical outcome.

Reoperation following intracapsular fractures treated with screws or prostheses has been investigated extensively in older patients [105–108]. Recent decades have seen a growing use of prostheses because they carry a lower reoperation risk and ensure better functional outcome than internal fixation [105, 106, 109, 110]. THA has been reported to carry a higher reoperation risk than hemiarthroplasty, primarily owing to more dislocations [29, 111]. However, dual mobility cups have been developed to reduce dislocation rates in THA with promising results [112, 113]. Screws are still used in non-displaced intracapsular fractures to preserve the native hip, especially among patients below 70 years of age. However, prostheses performed due to failure of internal fixation are associated with an increased risk of complications, and both hip function and quality of life may be inferior compared with those achieved by a primary prosthesis [114, 115].

Extracapsular fractures have been less extensively studied. Most studies have reported on the use of DHS for stable intertrochanteric fractures and IMNs for unstable and subtrochanteric fractures [39, 42, 116]. DHSs have also been used to treat unstable fractures, with some studies reporting reoperation rates that are in line with those observed for IMN; others have found an increased risk, mainly due to medialization of the femur, due to lack of lateral wall support [44, 117–119]. However, IMNs are reported to have an increased fracture risk during surgery and fractures below the implant postoperatively [120]. Multiple implants have been developed to address the high reoperation risk in unstable intertrochanteric fractures in recent decades. One such implant is the trochanteric stabilizing plate (TSP) that attaches to the DHS to reduce medialization of the femur and gives lateral support [121, 122]. Some studies have found DHS with TSP (DHS w/TSP) to be superior in the treatment of unstable intertrochanteric fractures [122, 123]. In contrast, others find IMN to be the preferred choice of treatment [40, 41, 124].

In addition to surgical method, correct implant placement and anatomical reduction of the fracture is vital to reduce the risk of reoperation [125–128]. Some of this may come with more experience. Thus, some studies have found better outcomes with more experienced surgeons [129–131]. Even so, Okike et al. found no relation between the surgeons' experience and mortality, complications, or readmission [132].

1.5.4 Functional recovery

The WHO has made the 2020s the decade of healthy aging, focusing on maintaining function [26]. A large part of the surviving hip fracture patients experience a decline in their functional level with increased use of walking aids and increased care needs that may result in institutionalization [2, 6, 133]. Long-term institutionalization is a massive transition for the patient with a hip fracture, and being institutionalized decreases older people's quality of life [134]. Up to 36.5% of patients move out of their own homes within one year of their hip fracture [2, 133, 135]. One of the main reasons for being institutionalized is a deterioration in the patient's physical state. Loss of function and decreasing ability to perform daily activities are common after having sustained a hip fracture. As most of functional recovery occurs within the first year after the hip fracture, most patients institutionalized due to their hip fracture suffer this transition within the first year [136, 137]. Higher age, multiple comorbidities, low prefracture functional level, and cognitive impairment have all been linked to increased risk of moving to a nursing home [133, 138].

The setup in place to ensure functional recovery following a hip fracture varies greatly. Some countries have a longer LOS including more in-hospital rehabilitation. In other countries, rehabilitation will primarily take place in rehabilitation facilities or in the municipality, as is the case in Denmark [139]. Short-term functional recovery has been found to predict long-term function, and deterioration in patients' functional abilities impacts their ability to care for themselves while increasing mortality and readmissions [87, 140].
To measure functional outcomes, multiple measurements have been used with some being validated in hip fracture populations such as the Timed-

up-and-go (TUG) test, the New Mobility Score (NMS), and the Cumulated Ambulation Score (CAS). [141–145].
The TUG test measures the time in seconds it takes a patient to rise from a standardized chair, walk three meters, return to the chair, and sit down with or without walking aids [146]. The TUG is a reliable outcome measure that has been demonstrated to predict functional outcomes after a hip fracture [143, 147].

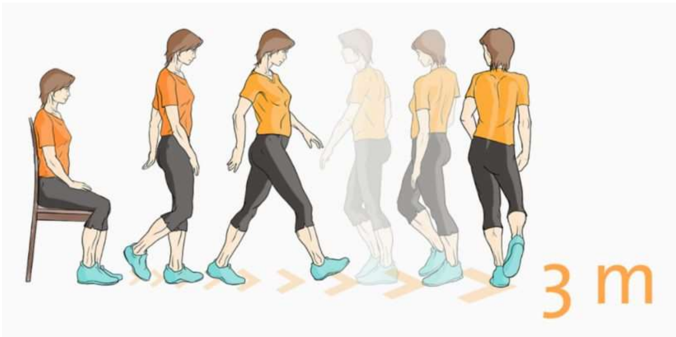


Figure 1.4 *TUG test* [148].

The NMS is a hip-fracture-specific questionnaire consisting of three functional activities concerning walking ability in different contexts (indoor, outdoor, and shopping) (the NMS questionnaire is provided in the appendix, Table 14). It has been shown to predict outcomes following hip fracture surgery [141, 142, 149]. A score is given to each activity (0-3 points), and scores are then combined to provide a final score between zero and nine, where nine is independent with no aid in all three activities, and zero means that the patient cannot carry out any of the activities. A cut-off point of six has previously been used to predict mortality and functional outcomes following hip fracture surgery [142, 149].
The CAS is a reliable outcome measure that evaluates a patient's ability to get in and out of bed, sit down and stand up, and walk with or without a walking aid [144, 150]. The scores for each task (0-2 points) are combined to provide a total score between zero and six, where six implies independence in all three tasks and zero indicates the inability to perform any of the tasks despite assistance (the CAS is provided in the appendix, Table 15). Studies have demonstrated that the CAS is a valid predictor of

functional recovery in patients with hip fractures [87, 144]. However, no consensus exists on which measure should be used to evaluate functional outcomes. This means that comparisons between the studies are made more difficult, and consensus on how to optimize functional recovery therefore does not exist.

1.5.5 Patient-reported outcome measures

Recent years have seen an increase in the use of patient-reported outcome measures (PROMs) and more patient-centered care sparked, in general, by a growing recognition of the importance of the patient's experience. Patients' quality of life declines following a hip fracture; from an initial postfracture level that is equal to or worse than death before it increase to one that rarely fully reaches prefracture level [151–154]. Factors associated with a risk of experiencing considerable deterioration in quality of life include female sex, multiple comorbidities, a low prefracture functional level, malnutrition, or postoperative complications [154]. PROMs have also been linked to different surgical methods and techniques [35, 153, 155]. Different questionnaires have been utilized to investigate the quality of life after a hip fracture, such as the 12-item short-form (SF-12), the 36-item short-form (SF-36), the European Quality of Life-5 Dimensions (EQ-5D), and the Oxford Hip Score (OHS) [35, 113, 151, 154–157]. The common denominator for most of these validated questionnaires is their focus on the patient's general health, physical function (such as walking and self-care), mental status, social life, and pain [158–161].

Whereas PROMs or quality of life questionnaires may be difficult to implement in register-based research, they may be an important addition to the clinical outcome generally used as such measures provide more than a quantitative measure of life after a hip fracture.

1.3 Literature search

A review of selected relevant background literature for this dissertation was conducted based on systematic and unsystematic searches from January 2017 to January 2022. PubMed and EMBASE were searched for studies using the Medical Subject Headings (MeSH) and non-MeSH terms: “Hip fracture” in combination with various terms depending on the exposure and outcome investigated. The terms were “mortality” OR “readmission” OR “reoperation” OR “complications” OR “functional outcome” OR “functional recovery”, “adherence” OR “compliance” OR “guidelines” OR “care pathways”, “orthogeriatric”, “surgical delay” OR “time to surgery”, “dynamic hip screw” OR “trochanteric stabilizing plate” OR “intramedullary nail” OR cephalomedullary nail”, “early mobilization”, “Active clinical issues” OR “vital signs”.

I supplemented the searches by reviewing the reference lists of relevant retrieved full-text papers. Furthermore, the annual reports from national audits conducted in multiple countries were reviewed.

2. Aims and hypotheses

The outcome following a hip fracture has consequences for patients, including increased mortality and diminished function. Furthermore, hip fractures are associated with substantial economic costs for society, warranting the continuous improvement of the evidence base used to guide clinical guidelines. The overall aim of this dissertation was to add to existing knowledge about which hip fracture patients are at risk of poor outcomes and to assess the treatment currently provided. With increased knowledge about these aspects, we may potentially introduce targeted interventions thereby improving the prognosis following a hip fracture.

The individual studies had the following specific aims:

Study I

Aim: To assess the adherence to seven best-practice indicators to evaluate the treatment provided and clarify whether particular patient groups are at risk of a significantly lower adherence at our institution.
Hypothesis: Adherence will increase during the study period owing to a sustained focus, and enhanced adherence is associated with a lower mortality rate and fewer readmissions.

Study II

Aim: To explore the association between 30-day and one-year mortality following hip fracture surgery and multiple risk factors, including modifiable risk factors, to increase our knowledge about patients at risk.
Hypothesis: One or more modifiable risk factors may be identified.

Study III

Aim: To identify risk factors contributing to all-cause readmission in general and readmission due to medical causes in particular within 30 days and one year after hip fracture surgery. Furthermore, to investigate the impact of surgical delay for medical causes and active clinical issues (ACIs) on 30-day readmission.
Hypothesis: Medical issues resulting in a delay in surgery and ACIs at the time of discharge are associated with an increased risk of readmission within 30 days.

Study IV

Aim: To compare IMN and DHS w/TSP in the treatment of unstable intertrochanteric fractures.

Hypothesis: IMN and DHS w/TSP do not differ significantly with respect to the chosen clinical outcomes.

Study V

Aim: To describe risk factors for being functionally dependent at discharge and for subsequent failure to return to independent living 12 months after hip fracture surgery.

Hypothesis: Being functionally dependent at discharge impacts the ability to return to independent living.

3. Methods

3.1 Study design and study population

All five studies were observational cohort studies based on prospectively collected data.

Patients were included from 2011 through 2017. They were all treated at our institution in line with a well-defined hip fracture guideline introduced in January 2011. As from the introduction of the guideline, all patients admitted with a hip fracture were prospectively included in the Holstebro Hip Fracture Database. The database was established to monitor the treatment and outcomes of patients with a hip fracture at our institution. Data were gathered prospectively by trained nurses, physiotherapists, and doctors; and data collectors were continuously trained in reporting to the database, minimizing variation in reporting during the study period.

The exclusion criteria for all the studies were periprosthetic fractures, pathological fractures, conservatively treated fractures, or patients operated at a different hospital. Furthermore, 11 patients had no information regarding their hip fracture and were therefore excluded. For patients suffering a fracture of both hips during the study period, only the first surgery was included in the studies (for details, see Figure 3.1). All of the injuries were the result of low-energy trauma.

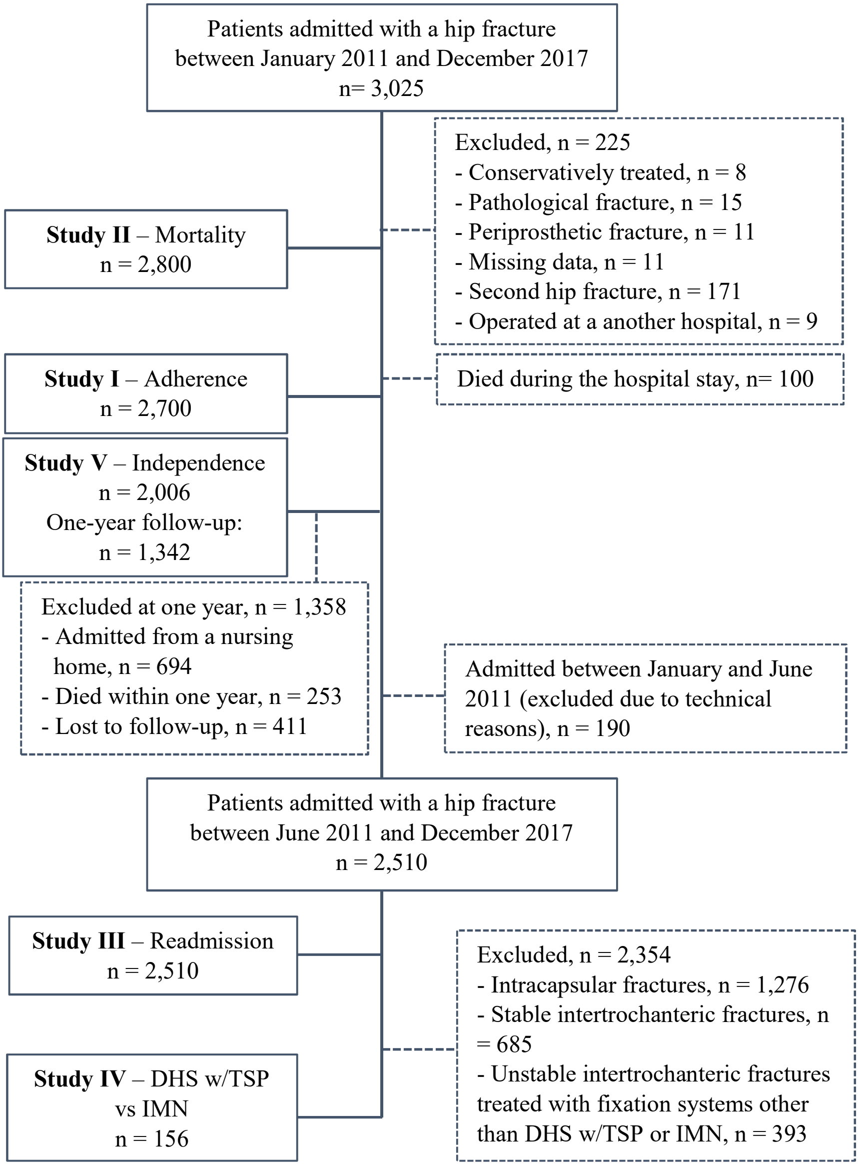


Figure 3.1 *The inclusion process for all five studies included in this dissertation.*

3.2 Data sources

The primary data source for this dissertation was the Holstebro Hip Fracture Database. Data reported to the database included age, sex, weight, height, the American Society of Anesthesiologists (ASA) score, residence, cognitive function, smoking status at admission, weekly alcohol consumption, prefracture use of walking aid, prefracture functional level, and vital signs at admission. During the hospital stay, nurses reported data regarding biochemistry, blood transfusions, pre- and postoperative pain management, medication at admission (anticoagulation and antihypertensive medication), vital signs at admission, and antibiotics administered during the hospital stay. Nurses performed a fall risk assessment (FRA) based on an eight-question questionnaire (appendix, Figure 10.1). Doctors classified fracture patterns, documented operation date and time, the surgical method, and anesthesia technique. Physiotherapists documented all mobilization sessions during the hospital stay, including timing and duration. Physiotherapists evaluated the CAS prefracture, at day one to three postoperatively, and at discharge; and they documented with which walking aids patients were discharged. Finally, nurses registered vital signs at discharge, the discharge date, and destination.

3.2.1 In-hospital variables

The variables were categorized as follows:

BMI, derived from the patients' height and weight, was categorized based on the World Health Organization into underweight (< 18.5 kg/cm^2), normal weight (18.5-25 kg/cm^2), and obese (> 25 kg/cm^2) [162]. Height was primarily patient-reported, whereas weight was obtained from weighing the patients. The ASA score was obtained from the anesthesiology report and dichotomized into ASA 1-2 and ASA 3-5. Patients were divided into cognitively fit or cognitively impaired based on previous diagnoses of dementia or similar. Alcohol consumption was dichotomized into below or above seven units per week. Walking aids both at admission and discharge were none, walking stick, walker, walking frame, and no walking ability. The prefracture functional level was based on the NMS and dichotomized into a low (1-5 points) and a high functional level (6-9 points). Vital signs included heart rate, blood pressure, temperature, and oxygen saturation.

Biochemistry included pre- and postoperative hemoglobin with a lower limit at 10 g/dl, preoperative albumin with a lower limit at 35 g/dl, creatinine with an upper limit at 100 µmol/l, and 25-hydroxy-vitamin D with a lower limit at 50 µmol/l [163]. Preoperative pain management was a fascia lata block or oral pain management with opioids and paracetamol if a block was contraindicated. Postoperatively, patients received oral pain management alone or combined with an epidural catheter in the initial three days. Anticoagulation or antihypertensive medication at admission was registered. Antibiotics given in addition to the perioperative antibiotics were documented along with the reasoning. The FRA was based on a questionnaire regarding previous falls, dizziness, medication, nightly urination, visual impairment, cognitive status, and previous stroke, with patients scoring between 0 and 8 points. The questionnaire was based on clinical experience and other FRA tools available at the time, e.g., the Johns Hopkins FRA tool [164, 165]. Patients were divided based on clinical experience into a low-risk group (0–1 point), a medium-risk group (2–6 points), and a high-risk group (7–8 points). Fracture patterns were classified based on preoperative x-rays. The classification systems varied between the studies. For Study I, fractures were classified using the Garden classification system for intracapsular fractures and the Evans classification for intertrochanteric fractures [15, 166, 167]. For Studies II, III, and V, fracture patterns were categorized as either intracapsular or extracapsular [168–170]. The AO/OTA classification was used for Study IV, which only included unstable intertrochanteric fractures (Figure 3.2) [171]. AO/OTA classifies intertrochanteric fractures into three groups: 31A1 are simple fractures, 31A2 are multifragmentary fractures, and 31A3 are reverse obliquity fractures; subgroups 31A2.2-3 and 31A3.1-3 were considered unstable [12].

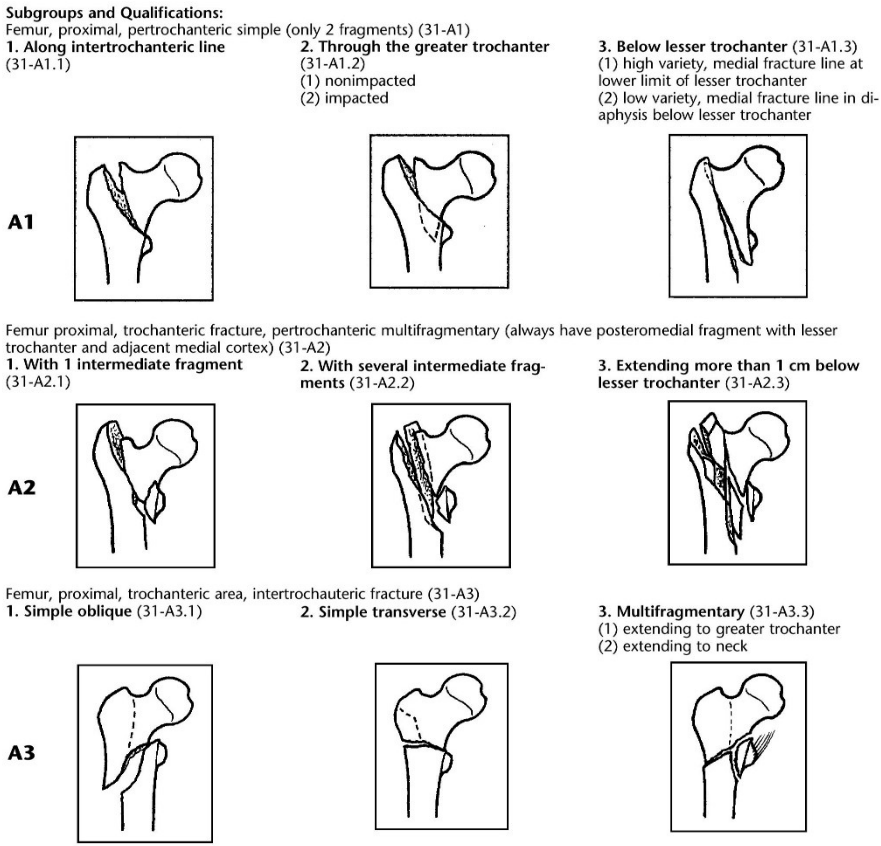


Figure 3.2 *The AO/OTA fracture classification system for intertrochanteric fractures* [12].

All fractures were surgically managed according to the local guideline based on recommendations from the Danish Orthopedic Society [9, 167]. The fracture pattern primarily dictated the surgical method. However, for intercapsular fractures, the patient’s age was also a determining factor (see Figure 3.3). For displaced intracapsular fractures, THAs were the standard surgical method for patients above 70 years. For patients between 60 and 70 years, displaced intracapsular fractures could be treated with parallel screws, DHSs, or THAs based on the surgeon’s assessment. Internal fixation was used if the fracture could be anatomically reduced in patients without severe comorbidities or severely impaired functional level. Internal fixation was the standard surgical method for patients under 60 years regardless of fracture displacement. The surgical method was THA instead of internal fixation for non-displaced intracapsular fractures with a posterior tilt exceeding 20 degrees. THAs were all dual mobility arthroplasties. For intertrochanteric fractures, the DHS was the standard surgical method. However, IMNs or DHSs w/TSP were used for unstable fractures. Usually, a four-hole plate DHS was used; however, in fractures with subtrochanteric extension, a six- or eight-hole plate was used. IMNs could be with or without a cerclage depending on the fracture pattern. Hemiarthroplasty and external fixation was not used at our institution.

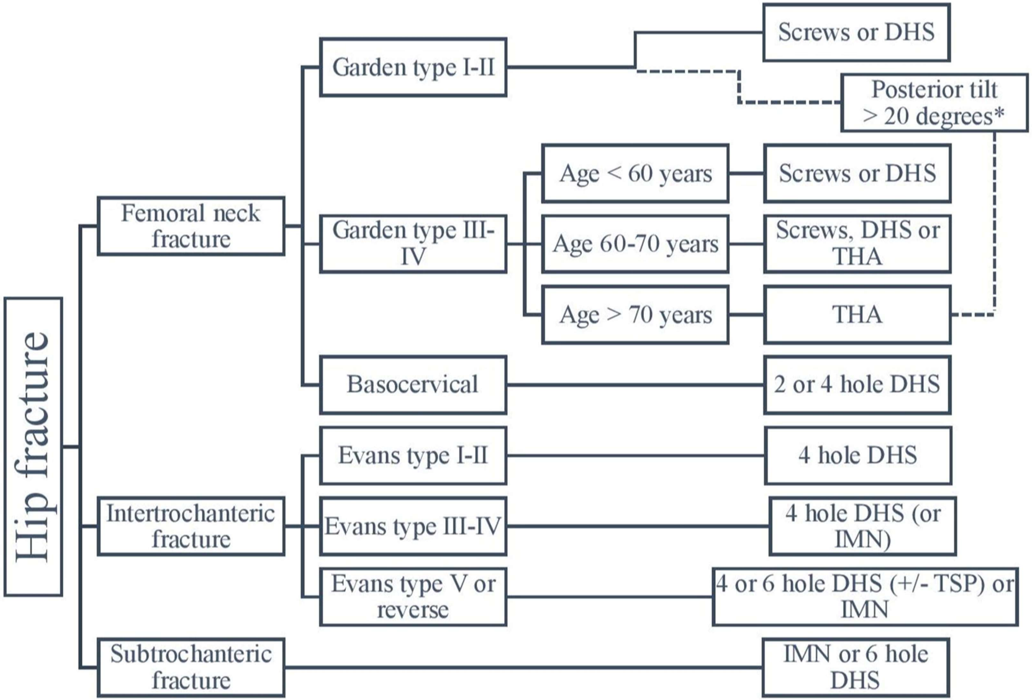


Figure 3.3 *Guideline for surgical method based on fracture pattern and patient age*
**Posterior tilt > 20 degrees in the lateral view of Garden I-II fractures resulted in the recommended method changing to a total hip arthroplasty (THA). DHS = Dynamic hip screw, TSP = Trochanteric stabilizing plate, and IMN = Intramedullary nail.*
Figure from Study I [167].

Physiotherapists documented the initial postoperative mobilization, including whether the patient was mobilized to standing and, if relevant, the reasoning for not being mobilized to standing. First-time mobilization was checked in the electronic patient records and divided into mobilized to standing within 24 hours of surgery, not mobilized within 24 hours despite indication, and no indication for mobilization (e.g., patients without prefracture standing abilities, who had been admitted to, e.g., ICU, or complex fractures making mobilization impossible). Prior to discharge, patients performed a TUG test with a physiotherapist who also assessed the CAS.

Time to surgery was calculated from the admission and divided into less than 24 hours, between 24 and 36 hours, and more than 36 hours from admission based on national guidelines [9, 172]. LOS was calculated from the admission to the emergency room (ER) to discharge or transfer to another hospital.

3.2.2 Follow-up variables

Contact was attempted to all surviving patients by a trained nurse one year after surgery by telephone. A standardized questionnaire was completed with the patient, relatives, or caregivers, and the respondent was documented. Patients were asked about changes in living arrangements, pain, NMS, osteoporotic treatment, rehabilitation, care needs, and self-evaluated walking ability, health status, and social life. Patients were categorized as having changed their living arrangements if they had moved from independent living to either protective living or nursing home at one year as a result of their hip fracture. Patients were asked to grade their pain level at rest and during walking into none, mild, moderate, severe, or worst imaginable pain. Their ability to perform the three activities of the NMS was noted, and a score was calculated. The care needs at one year were compared with their prefracture care needs. Patients were asked to evaluate their walking ability, general health, and social life compared with their prefracture counterparts and grade them as worse, the same, or better.

Table 1. An overview of the variables used in the studies. Variables used in each study are indicated with a +, and a – indicates that the variable was not used in the study.

Variables	Study I Adherence n = 2,700	Study II Mortality n = 2,800	Study III Readmission n = 2,510	Study IV IMN vs. DHS w/TSP n = 156	Study V Functional recovery n = 2,006
Hip fracture					
Fracture pattern	+	+	+	+	+
Patient-related variables					
Age	+	+	+	+	+
Sex	+	+	+	+	+
Residence	+	+	+	+	+
Smoking	-	+	+	-	+
Alcohol consumption	-	+	+	-	+
BMI[1]	-	+	+	+	+
Prefracture NMS[2]	+	+	+	+	+
Prefracture walking aid	+	-	-	-	-
Visual impairment	-	-	-	-	+
ASA[3] score	+	+	+	+	+
Hemoglobin	-	+	+	-	+
Albumin	-	+	+	-	+
Creatinine	-	+	+	-	-
25-hydroxy vitamin D	-	-	-	-	+
Cognitive status	+	+	+	+	+
Fall risk assessment	-	+	-	-	-
Anticoagulation therapy	-	-	+	+	-
Antihypertensive therapy	-	-	+	-	-

Surgical treatment					
Surgical method	-	+	+	+	+
Anesthesia	-	+	-	-	+
Hospital-related variables					
Postoperative mobilization	-	+	+	-	+
Time to surgery	-	+	+	-	+
Active clinical issues	-	-	+	-	-
Additional antibiotics	-	-	+	-	-
Discharge CAS[4]	-	-	-	-	+
Discharge TUG[5]	-	-	-	-	+
LOS[6]	-	-	-	-	+
Postoperative pain management	-	-	-	-	+
Readmission within 1 year	-	-	-	-	+

[1] Body Mass Index
[2] New Mobility Score
[3] American Society of Anesthesiologists
[4] Cumulated Ambulation Score
[5] Timed up and go
[6] Length of stay

3.2.3 Outcome variables

All Danish citizens are given a unique ten-digit Civil Personal Register (CPR) number at birth, allowing linkage between databases. Due to the covid-19 pandemic, it was not possible to obtain data from the National Patient Register during the course of this PhD work. To obtain data regarding date of death, readmissions, and reoperation, the Central Denmark Region's local medical servers were used. However, the servers comprise data only from June 2011 and onwards, and 190 patients admitted between from January to June 2011 were excluded in Studies III and IV (Figure 3.1) [168, 171].

To obtain data regarding readmissions and reoperations, an algorithm was created. Patients registered with a surgical code relevant to a hip fracture (KNFJ0-99, KNFB0-99, or KNFG0-99) were extracted from the servers and matched to the Holstebro Hip Fracture Database using their CPR number. Data were extracted regarding date of death, any readmission, and any reoperations.

The date of death is updated daily, ensuring near-complete follow-up. Data for unplanned readmissions, including visits to the ER without further hospitalization, were obtained regarding date, time, and diagnosis code for the readmission. The cause of readmission was checked in the electronic patient records.

For reoperations, data on date, diagnosis, and surgical code were obtained. These data were checked in the electronic patient records and side-matched to the fractured hip.

The algorithm was also used to validate the Holstebro Hip Fracture Database's inclusion process.

3.3 Outcomes

3.3.1 Study I

Typically, patients were admitted to the ER where they were assessed by an orthopedic surgeon. Patients were administered a peripheral nerve block or an epidural catheter to relieve pain. Following the diagnosis of a hip fracture, surgery was performed as soon as possible, ideally within 24 h of admission. Antibiotics were given upon initiation of surgery. On the first postoperative day, thromboprophylaxis treatment with low-molecular-weight heparin (LMWH) was initiated. All patients received daily individual physiotherapy, which was initiated on the first postoperative day on weekdays and weekends alike.

The primary outcome was adherence to seven best-practice indicators defined *a priori*. The indicators mirroring the treatment of hip fracture patients were chosen based on review of national and international recommendations, national audits, and previous literature [10, 54, 172, 173].

The seven best-practice indicators were:

1. Preoperative block - either epidural or peripheral nerve block prior to surgery.
2. Time to surgery – less than 24 or 36 hours from admission.
3. Perioperative use of antibiotics.
4. Surgical method – based on the fracture pattern and patient age (Figure 3.2).
5. Thromboprophylaxis - LMWH for at least seven days with the first injection being administered six to eight hours after surgery.
6. Postoperative mobilization to standing within 24 hours of surgery.
7. Blood transfusions if postoperative hemoglobin was below 10 g/dl.

The electronic patient records were reviewed for data regarding perioperative antibiotics, thromboprophylaxis, and postoperative mobilization. Data on preoperative pain management, time to surgery, surgical method, and blood transfusions were obtained from the Holstebro

Hip Fracture Database. The electronic patient records were screened for predefined contraindications for the indicators not complied with.

Secondary outcomes were the association between adherence and readmission, and mortality and adherence in different patient groups. The groups were divided based on; age, sex, ASA score, residence, cognitive status, fracture pattern, prefracture functional level, and use of walking aids.

3.3.2 Study II

The outcome for Study II was 30-day and one-year mortality from the date of admission.

3.3.3 Study III

The primary outcome for Study III was first-time readmission within 30 days and one year. Secondary analyses were conducted regarding 1) risk factors for medical readmissions within 30 days and one year. 2) The association between medical issues delaying surgery and readmission within 30 days. 3) The impact of ACIs at discharge on readmissions for medical causes within 30 days. A follow-up period of 30 days was chosen for both 2) and 3), as medical issues delaying surgery and ACIs are likely acute conditions, hence affecting short-term outcomes. Each readmission cause was classified as unrelated to the hip fracture or directly related to the hip fracture. Unrelated causes were divided into medical, trauma, surgical (e.g., general surgery, urology), unrelated orthopedic (e.g., osteoarthritis in another joint), and other causes (e.g., psychiatric, poisoning, eye surgery). Medical causes for readmission were further subdivided into medical infectious or non-infectious causes, with medical infections including, e.g., sepsis, urinary tract infections, and pneumonia. Causes related to the hip fracture were divided into THA dislocation, hip infection, reoperation or revision of the fractured hip, and other causes directly related to the fracture (e.g., pain, rehabilitation).

If time to surgery exceeded 24 hours, the reason for delaying surgery was checked in the electronic patient records and divided into medical issues, anticoagulation therapy, organizational reasons, and other reasons. Medical issues delaying surgery included, e.g., rhabdomyolysis treatment, cardiovascular diseases, e.g., arrhythmia and acute myocardial infarction, and pre-operative infections. Organizational reasons for surgical delay covered, e.g., capacity issues, lack of operative rooms, or surgeons. Other reasons for delaying surgery included fractures more than five days old and awaiting consent from patients or family members, this group was not included in the analysis.

ACIs were assessed at admission and discharge based on vital signs and extra antibiotics administered during the hospital stay. ACIs were present if the vital signs met any criteria displayed in Figure 3.4. The choice of vital signs and dividing values was primarily based upon previously published studies [102, 103, 174]. However, < 36.0°C was added to reflect that some patients become hypothermic when infected. Furthermore, a criterion regarding extra antibiotics during the hospital stay, beyond those given perioperatively, was added as this would indicate complications during the acute hospital stay.

Active clinical issues:

Heart rate >100 /min
Systolic blood pressure < 90 mmHg
Diastolic blood pressure < 60 mmHg
Temperature < 36.0 °C or ≥ 37.8 °C
Oxygen saturation < 90%
Extra antibiotics[a]

Figure 3.4 *Definition of active clinical issues.*
[a] *In addition to perioperative surgical prophylaxis.*
Figure modified from Study III [168].

3.3.4 Study IV

In Study IV, the primary outcome was reoperation within three years. Data regarding reoperations were obtained from the local server and checked in the electronic patient records as outlined above. Secondary outcomes included the following in-hospital measures; postoperative mobilization and blood transfusions. As the need for blood transfusions is highly dependent on hemoglobin at admission, it may not accurately assess the blood loss [175]. Therefore, the total blood loss was calculated. The calculations were based on hemoglobin levels at admission and after surgery, and the estimated blood volume (based on Nadler's formula) [176–178]. The calculated loss of hemoglobin was based on the assumptions that the blood volume would be the same on admission and after surgery, and that any blood transfusion given has the same number of cells [179].

Additional secondary outcomes at one year were derived from the one-year telephone interview. The outcomes were whether the patient had regained their prefracture NMS, the level of hip pain during walking, and PROM. PROM included self-evaluation regarding walking ability, social life, and general health.

3.3.5 Study V

The primary outcome was failure to remain in the patient's own home one year after their hip fracture. The secondary outcome was independence at discharge measured by the CAS and a TUG test at discharge. The total CAS score was dichotomized into whether the patient regained complete independence (CAS = 6) or not (CAS score ≤ 5) [87]. A cut-off point of 20 seconds was chosen for the TUG test to indicate independence, based on previous research [113, 146, 180].

3.4 Statistics

The study population was described according to the distribution of patient characteristics, tabulating the number and percentage of patients for each characteristic. Tests were two-sided, and results were considered statistically significant at a p-value < 0.05. However, 95% confidence intervals (95% CI) are presented if possible. The statistical computations were performed using the STATA statistical software (Stata/IC 17.1, StataCorp, College Station, TX, USA).
The normal distribution of data was checked visually using a QQ-plot. Continuous variables were compared using Student's t-test, reporting

means and standard deviations (SD). Non-normally distributed variables were compared using the Mann-Whitney U and reporting medians with interquartile range (IQR). Categorical variables were compared using Pearson's chi-squared test and Fisher's exact test depending on the number of events in the groups.

A sample size calculation was performed for the mortality study, and based on an estimated one-year mortality rate of 20% and assuming 60% of the admitted patients would have an ASA score of three or above [181]. A sample size of 118 patients was needed to detect a 15% difference in one-year mortality (power 0.80, significance limit 0.05).

3.4.1 Study I

An all-or-none test was performed to clarify adherence to all seven best-practice indicators. Furthermore, the number of best-practice indicators achieved for each patient was calculated and presented. Patients were excluded from the all-or-none test if they had a valid contraindication or missing data on any of the seven best-practice indicators. However, in the analyses for each indicator, the patient was excluded for that indicator only but remained in the analysis for the other indicators. However, the analyses for indicator three (perioperative antibiotics) and five (thromboprophylaxis) were executed differently. For perioperative antibiotics, the only valid contraindication was if the patient was already in a relevant antibiotic treatment regimen at the time of surgery. These patients were labeled 'correctly treated' in the analysis corrected for contraindications. For thromboprophylaxis, patients who were given their first injection of LMWH prior to six hours or later than eight hours after surgery were labeled 'correctly treated' if they had also received LMWH for seven days. This was chosen as recent studies have shown that the timing of thromboprophylaxis is not as crucial as previously presumed [182, 183].

The association between adherence overall and for the individual indicators on mortality and readmission was investigated using logistic regression adjusted for age and sex.

The chi-squared test was used to assess between-patient-group differences in adherence.

3.4.2 Study II

As mortality was treated as a binary outcome, dead or alive at 30 days and one year, logistic regression analysis was used to investigate which variables were associated with increased mortality. The dependent variable was mortality in the analysis. The independent variables are presented in Table 1. A univariable model was created for 30-day and one-year mortality for each independent variable. Adjustment for confounders was performed by multivariable logistic regression in three models with increasing numbers of confounders. The selection of confounders in each model was based on clinical experience and the existing literature. Model one was adjusted for age, gender, and residence; model two was additionally adjusted for ASA score, cognitive impairment, and BMI; and model three was adjusted for all the independent variables.

3.4.3 Study III

Risk factors for readmission were analyzed as time-to-event data, with death as a competing risk using the pseudo-value approach [184, 185]. We accounted for the impact of abnormalities in the same vital sign at both admission and discharge on the risk estimates. The following variables were selected for adjustment in the multivariable analysis: age, sex, residence, ASA score, cognitive status, and NMS. All estimates were presented as relative risk ratios (RR) with 95% CI. Differences in patient characteristics between groups were analyzed using the chi-squared test. The attributable fraction (AF) of readmission due to medical issues delaying surgery and ACIs was calculated. AF was defined as the proportion of the outcome that could be averted if the risk factor was eliminated [186, 187].

3.4.4 Study IV

Student's t-test was used for normally distributed variables and the Mann-Whitney U test was used for non-normally distributed variables. For categorical variables, we evaluated between-group differences using the chi-squared test or Fisher's exact test depending on the number of events.

3.4.5 Study V

Variables associated with dependency at discharge and failure to return to independent living were investigated using logistic regression analysis. A univariable model was created with the dependent variables; CAS = 6 and TUG < 20 seconds for short-term functional recovery and failure to return to independent living at 12 months. The independent variables are presented in Table 1. The CAS and the TUG were also used as independent variables in the analysis for failure to return to independent living. Multivariable logistic regression was conducted adjusting for age, gender, ASA score, cognitive function, pre-fracture functional level, postoperative mobilization, and fracture pattern reporting odds ratio (OR) with 95% CI.

3.5 Ethics

The protocols for the studies were reviewed by the Central Denmark Region Committee on Biomedical Research Ethics, and no ethical approval or written consent was required under Danish law. The studies were registered with the Central Denmark Region and the Danish Data Protection Agency (record number 1-16-02-177-11 and 2007-58-0010, respectively).

The authors have no competing interests to declare that are relevant to the contents of this dissertation.

4. Main results

The main findings from Studies I-V are presented in the following sections. A more detailed description of the results is available in appendices I-V [167–171].

The inclusion process was validated by checking the Central Denmark Region's servers, and 46 patients (1.6%) were identified as having been treated for a hip fracture in the study period without being included in the database. Among these, 22 patients (49%) were operated by our department but remained admitted at, e.g., an internal medical or neurology department. Available baseline characteristics were extracted from electronic patient records for all patients who were not included and are summarized in Table 2. Patients who were not included had higher ASA scores than patients included in the study population. There was no significant year in which patients were more unlikely to be included ($p = 0.24$).

Table 2. Baseline characteristics for patients not included in the Holstebro Hip Fracture Database but surgically treated for a hip fracture (n = 45).

Variables	Number (percentages)	p-value*
Age (median (IQR))	77 (23)	
Sex		
Female	28 (62%)	0.58
Male	17 (38%)	
ASA score		
ASA score 1-2	12 (29%)	< 0.001
ASA score ≥ 3	29 (61%)	
Fracture pattern		
Intracapsular fracture	23 (51%)	0.78
Extracapsular fracture	22 (49%)	
Surgical method		
Internal fixation	30 (67%)	< 0.001
THA	13 (29%)	
Girdlestone resection arthroplasty	2 (4%)	
Died within one year	19 (41%)	0.26
Readmission within one year	16 (36%)	0.69
Reoperation within three years	6 (13%)	0.31

* Compared with the included study population
ASA = American Society of Anesthesiologists
THA = Total hip arthroplasty

Conservatively treated patients included in the database (n = 8) were older (median 83.5 years (IQR: 37)) and more frequently of male sex (43%). We had no information regarding ASA score, but 57% had no ACIs at admission, 43% had one ACI, and none had two or more.

Patients who died during their acute hospital stay (n = 100) were older (median: 85 years range: 41 years), more frequently of male sex (48%), nursing home residents (38%), with an ASA score of three or above (72%), and cognitively impaired (28%). At admission, 56 patients had no ACIs, 16 had one ACI, and 18 had two or more ACIs, which was higher than the corresponding values for those who survived.

4.1 Demographics

Baseline demographics for the study population are listed in Table 3.

Table 3. Baseline characteristics for the patients included in Studies I-V.

Variable	**Total, n (%)**
Total	2,800 (100%)
Hip fracture	
Fracture pattern	
Intracapsular	1,486 (53%)
Extracapsular	1,307 (47%)
Patient-related variables	
Age (median (range))	81.6 (31.2-104.9))
Gender	
Female	1,852 (66%)
Male	948 (34%)
Prefracture residence	
Independent living	2,062 (74%)
Nursing home	734 (26%)
Smoking status at admission	
Non-smoker	2,072 (74%)
Smoker	585 (21%)
Alcohol consumption	
< 7 units a week	2,565 (92%)
≥ 7 units a week	53 (2%)
BMI	
< 20 kg/m^2	522 (19%)
20-30 kg/m^2	2,006 (72%)
> 30 kg/m^2	210 (8%)
ASA score	
ASA 1-2	1,538 (55%)
ASA 3-5	1,195 (43%)
Cognitive status	
Cognitive impairment	551 (20%)
Cognitive fit	2,231 (80%)
Prefracture NMS	
Low functional level	1,071 (38%)
High functional level	1,604 (57%)
Surgical treatment	
Surgical method	
Internal fixation	1,810 (65%)
Total hip arthroplasty	972 (35%)
Hospital-related variables	
Mobilized to standing within 24 hours from surgery	
Yes	2,185 (78%)
No	341 (12%)
No indication for mobilization	148 (5%)
Time from admission to surgery	
< 24 hours	2,004 (72%)
24-36 hours	381 (14%)
> 36 hours	339 (12%)

ASA = American Society of Anesthesiologists
BMI = Body Mass Index
NMS = New Mobility Score, 0-5 point = low functional level and 6-9 points = high functional level.

The surgical method changed during the study period, as illustrated in Figure 4.1. An increase in uncemented THA was seen for intracapsular fractures, especially from 2012 to 2013. Similarly, an increase was observed in IMN for intertrochanteric fractures from 2016 to 2017.

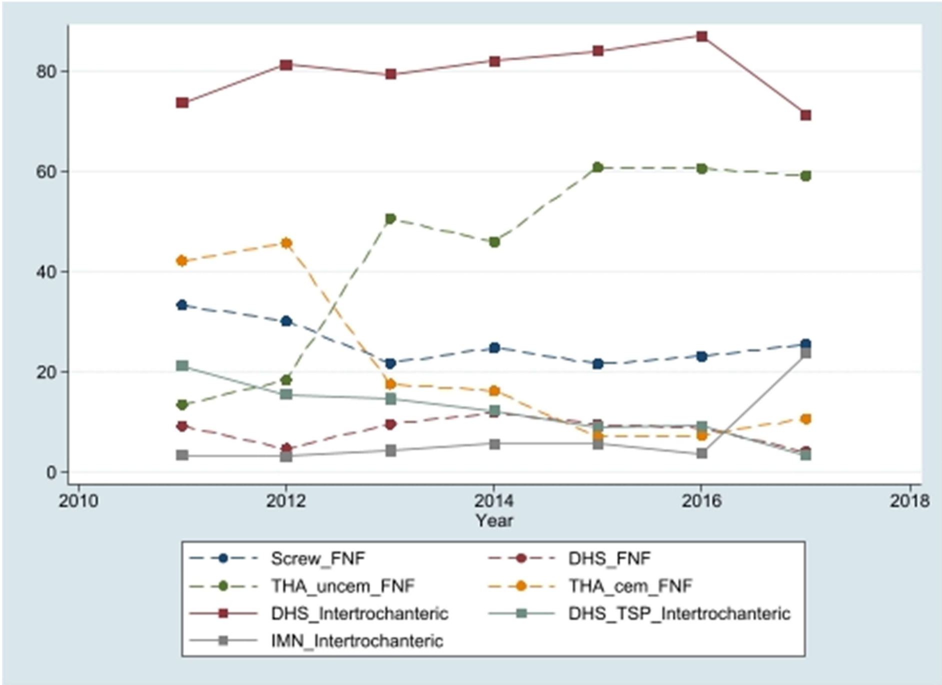


Figure 4.1 *Displaying the different surgical methods employed for intracapsular fractures in dashed lines and intertrochanteric fractures in solid lines for each year of the study period.*

cem = Cemented
DHS = Dynamic hip screw
FNF = Femoral neck fracture
THA = Total hip arthroplasty
TSP = Trochanteric stabilizing plate
uncem = Uncemented

4.2 Study I

The percentage of patients receiving all seven best-practice indicators was 17%, which increased to 32% after considering contraindications. The improvement was mainly due to indicator five, thromboprophylaxis, increasing from 56% to 86% (Table 4). Indicators three and four, perioperative antibiotics, and surgical method according to the guideline had the highest adherence after considering contraindications.

Table 4. Observed adherence before and after contraindications were considered for each of the seven best-practice indicators and all-or-none adherence to all seven best-practice indicators, listed as numbers (%).

	Adherence	Corrected for contraindications
1. Preoperative nerve block	1,550 (58%) *n = 2,696*	1,550 (61%) *n = 2,549*
2. Time to surgery		
Less than 24 hours	1,991 (74%) *n = 2,689*	1,991 (83%) *n = 2,393*
Less than 36 hours	2,342 (87%) *n = 2,690*	2,342 (94%) *n = 2,481*
3. Perioperative antibiotics	2,544 (96%) *n = 2,662*	2,574 (97%) *n = 2,662*
4. Surgical method	2,397 (89%) *n = 2,693*	2,397 (92%) *n = 2,603*
5. Thromboprophylaxis	1,515 (56%) *n = 2,688*	2,213 (86%) *n = 2,582*
6. Postoperative mobilization	2,200 (85%) *n = 2,577*	2,200 (88%) *n = 2,498*
7. Blood transfusions	600 (86%) *n = 694*	600 (90%) *n = 665*
All-or-none	445 (18%) *n = 2,535*	645 (32%) *n = 2,027*

Modified table from Study I [167].

Adhering to all seven best-practice indicators was not associated with a statistically significant decrease in mortality or readmission within 30 days (RR 0.69; 95% CI 0.45-1.05; RR 0.86; 95% CI 0.67-1.11, respectively) or one year (RR 0.89; 95%CI 0.73-1.08; RR 0.87; 95%CI 0.87-1.12, respectively). The same applied for the association of the individual indicators with risk of readmission. Increased mortality within 30 days was associated with not complying with indicators one and seven, preoperative nerve block (RR 0.67; 95% CI 0.47-0.95), and blood transfusions (RR 0.40; 95% CI 0.18-0.89). Furthermore, not complying with indicators five and six, thromboprophylaxis (30 days: RR 0.63; 95% CI 0.41-0.95; one year: RR 0.73; 95% CI 0.59-0.90) and postoperative mobilization (30 days: RR 0.55; 95% CI 0.36-0.84; one year: RR 0.61; 95% CI 0.50-0.75) was associated with an increased mortality within 30 days and one year. Patients receiving six indicators constituted 49%. Patients at risk of complying with less than seven indicators were nursing home residents, cognitively impaired patients, patients with a low pre-fracture functional level, and patients with high comorbidity (ASA $\geq$ 3) (Table 5).

Statistically significant differences were observed in overall adherence in the individual years of the study period ($p < 0.001$). A U-shaped adherence was found with increasing adherence until 2015 and then declining in 2016 and 2017. Adherence to preoperative block declined during each of the seven years, and adherence to blood transfusions dropped in 2016 and 2017.

Table 5. Chi-squared test for no difference in adherence based on the characteristics of the study population presented as number (%).

Characteristics	Total (%)	All or no adherence: Compliance	All or no adherence: No compliance	p-value
Age *(n = 2,027)*				
< 75 years	128 (6.2%)	198 (34%)	377 (66%)	0.282
75-84 years	259 (12.6%)	220 (31%)	496 (69%)	
≥ 85 years	1,666 (81.2%)	227 (31%)	509 (69%)	
Sex *(n = 2,027)*				
Female	1,490 (72.7%)	438 (32%)	924 (68%)	0.640
Male	559 (27.3%)	207(31%)	458 (69%)	
ASA *(n = 1,990)*				
ASA 1-2	193 (9.6%)	418 (34%)	796 (66%)	**0.002**
ASA 3-5	1,032 (51.2%)	215 (28%)	561 (72%)	
Residence *(n = 2,026)*				
Independent	1,550 (75.5%)	513 (33%)	1,021 (67%)	**0.006**
Institution	502 (24.5%)	132 (27%)	360 (73%)	
Cognitive status *(n = 2,018)*				
Cognitive fit	1,665 (81.5%)	547 (33%)	1,106 (67%)	**0.012**
Cognitive impairment	377 (18.5%)	96 (26%)	269 (74%)	
Fracture pattern *(n = 2,026)*				
Intracapsular	315 (15.4%)	345 (32%)	719 (68%)	0.668
Extracapsular	709 (34.6%)	300 (31%)	661 (69%)	
Prefracture NMS *(n = 1,953)*				
Low NMS	990 (50.1%)	197 (27%)	545 (73%)	**< 0.001**
High NMS	986 (49.9%)	432 (36%)	779 (64%)	
Prefracture walking aids *(n = 1,901)*				
Independently	789 (41.4%)	292 (37.0%)	497 (63.0%)	**0.016**
Assisted walking	1,080 (56.7%)	331 (30.7%)	749 (69.3%)	
No walking ability	36 (1.9%)	12 (33.3%)	24 (66.7%)	

ASA = American Society of Anesthesiologists

NMS = New Mobility Score, 0-5 point = low functional level and 6-9 points = high functional level

Modified table from Study I [167].

4.3 Study II

The overall mortality rate was 9% at 30 days and 24% at one year. For the risk of death within 30 days, the adjusted OR in model three increased approximately two-fold for patients aged above 75 years, male sex, nursing home residence, BMI below 20 kg/m^2, hypoalbuminemia (< 35 g/dl), high creatinine (≥ 100 µmol/l), cognitive impairment, low prefracture functional level, postoperative mobilization exceeding 24 hours from surgery, and no indication for mobilization (Table 6). In addition to the risk factors mentioned above for 30 days mortality, one-year mortality was associated with an ASA score of three or above, medium risk in the FRA, and time to surgery exceeding 36 hours (Table 6).

Table 6. Adjusted[a] odds ratio (OR) for potential risk factors for increased 30-day and one-year mortality following a hip fracture, shown with OR with 95% confidence intervals (CI) (n = 2,800). Only statistically significant results are presented.

	Mortality within	
Variable	**30 days**	**One year**
Total	263 (9%)	659 (24%)
Patient-related variables		
Age (ref. < 75 years)		
75-84 years	**1.96 (1.03-3.72)**	**1.97 (1.34-2.91)**
≥ 85 years	**2.97 (1.58-5.58)**	**3.49 (2.36-5.16)**
Sex (ref. female)		
Male	**1.65 (1.14-2.40)**	**1.92 (1.47-2.50)**
Prefracture residence (ref. independent living)		
Nursing home	**1.97 (1.32-2.94)**	**1.97 (1.48-2.62)**
BMI (ref. 20-30 kg/m^2)		
< 20 kg/m^2	**1.90 (1.27-2.82)**	**1.90 (1.42-2.53)**
> 30 kg/m^2	1.02 (0.47-2.21)	0.76 (0.44-1.32)
Prefracture NMS (ref. high functional level)		
Low NMS	**1.93 (1.26-2.93)**	**2.14 (1.64-2.80)**
ASA score (ref. ASA 1-2)		
ASA ≥ 3	1.20 (0.84-1.71)	**1.57 (1.22-2.00)**
Albumin (ref. ≥ 35 g/dl)		
< 35 g/dl	**2.09 (1.47-2.98)**	**2.21 (1.71-2.88)**
Creatinine (ref. < 100 μmol/l)		
≥ 100 μmol/l	**2.49 (1.74-3.58)**	**1.54 (1.18-2.02)**
Cognitive status (ref. cognitively fit)		
Cognitive impairment	**1.80 (1.21-2.68)**	**1.60 (1.19-2.16)**
Fall risk assessment (ref. low risk)		
Medium risk	1.73 (0.85-3.51)	**1.61 (1.08-2.42)**
High risk	3.00 (0.62-14.43)	0.92 (0.24-3.53)
Hospital-related variables		
Postoperative mobilization to standing (ref. < 24 hours)		
> 24 hours	**1.90 (1.24-2.90)**	**1.72 (1.24-2.39)**
No indication for mobilization	**3.86 (2.27-6.55)**	**2.22 (1.39-3.55)**
Time from admission to surgery (ref. < 24 hours)		
24-36 hours	0.80 (0.48-1.32)	1.07 (0.76-1.51)
> 36 hours	1.07 (0.66-1.74)	**1.74 (1.24-2.43)**

[a] Adjusted for age group, gender, residence, smoking, alcohol consumption, BMI group, ASA score, hemoglobin, albumin, creatinine, known dementia, fall risk assessment, NMS, postoperative mobilization, fracture pattern, surgical method, anesthesia, and time to surgery.
ASA = American Society of Anesthesiologists
BMI = Body Mass Index
NMS = New Mobility Score
Table modified from Study II [170].

4.4 Study III

A total of 362 patients were readmitted within 30 days and 987 patients within one year of discharge, resulting in an overall readmission rate of 14% and 39%, respectively. The cause of readmission within 30 days was medical in 62% of cases, primarily medical infections (58%), and a new trauma in 13% of cases. The most frequent cause related to the hip fracture was dislocation of a THA (8%). For one-year readmissions, the cause was medical in 53%, with medical infections comprising 38%, whereas new trauma accounted for 19% of all readmissions. Reoperations and revisions of the fractured hip were the most frequent causes related to the hip fracture, accounting for 13% of readmissions. Patients readmitted within 30 days were more likely to die within the first year ($p < 0.01$).

Medical issues delaying surgery by more than 24 hours were not found to increase the risk of readmission compared with delaying surgery for organizational reasons or due to use of anticoagulation therapy. Patients with medical issues delaying surgery were typically older, nursing home residents, and had an ASA score of three or above ($p < 0.05$).

Table 7. Multivariable risk ratios (RRs) with 95% confidence intervals (CI) for readmission for all causes and medical causes within 30 days and one year, n = 2,510. Adjusted for age, gender, residence, ASA score, cognitive status, and NMS. Only statistically significant risk factors are presented.

	Readmitted			
	For all causes		For medical causes	
	Within 30 days	Within one year	Within 30 days	Within one year
Hip fracture				
Fracture pattern (ref. intracapsular fracture)				
Extracapsular fracture	0.90 (0.69-1.16)	1.02 (0.92-1.13)	1.15 (0.81-1.64)	**1.20 (1.03-1.40)**
Patient-related variables				
Age (ref. < 75 years)				
75-84 years	1.29 (0.93-1.81)	1.09 (0.95-1.24)	**1.96 (1.18-3.23)**	**1.35 (1.10-1.67)**
≥ 85 years	1.38 (0.98-1.94)	**1.17 (1.01-1.36)**	**1.84 (1.07-3.16)**	1.27 (0.99-1.63)
Sex (ref. female)				
Male	1.13 (0.89-1.46)	**1.14 (1.02-1.27)**	**1.56 (1.14-2.14)**	**1.38 (1.18-1.62)**
Residence (ref. independent living)				
Nursing home	0.89 (0.62-1.28)	**0.75 (0.63-0.87)**	0.87 (0.53-1.43)	**0.72 (0.57-0.90)**
Smoking status at admission (ref. non-smoker)				
Smoker	0.99 (0.74-1.32)	**1.18 (1.05-1.33)**	0.61 (0.37-1.01)	1.04 (0.85-1.25)
BMI (ref. 18.5-25 kg/m^2)				
< 18.5 kg/m^2	**1.44 (1.05-1.98)**	**1.17 (1.00-1.37)**	**1.62 (1.03-2.56)**	**1.30 (1.03-1.64)**
> 25 kg/m^2	1.01 (0.75-1.35)	1.01 (0.90-1.13)	0.94 (0.62-1.43)	0.95 (0.80-1.13)
NMS (ref. low prefracture functional level)				
High prefracture functional level	**0.60 (0.45-0.81)**	0.88 (0.78-1.01)	**0.53 (0.36-0.78)**	**0.77 (0.63-0.93)**
ASA score (ref. ASA score 1-2)				
ASA score ≥ 3	**1.41 (1.11-1.79)**	**1.43 (1.27-1.61)**	**1.52 (1.08-2.14)**	**1.57 (1.30-1.88)**

Preoperative hemoglobin (ref. ≥10 g/dl)				
< 10 g/dl	1.15 (0.69-1.91)	1.21 (0.97-1.50)	1.33 (0.70-2.52)	**1.36 (1.01-1.83)**
Postoperative hemoglobin (ref. ≥10 g/dl)				
< 10 g/dl	**1.35 (1.02-1.77)**	1.08 (0.97-1.21)	**1.55 (1.10-2.19)**	**1.19 (1.00-1.40)**
Albumin (ref. ≥ 35 g/l)				
< 35 g/l	1.11 (0.84-1.48)	**1.24 (1.10-1.39)**	1.24 (0.83-1.87)	**1.47 (1.24-1.74)**
Creatinine (ref. < 100 µmol/l)				
≥ 100 µmol/l	1.31 (0.98-1.75)	**1.24 (1.10-1.39)**	**1.76 (1.22-2.52)**	**1.51 (1.27-1.80)**
Surgical treatment				
Surgical method (ref. internal fixation)				
THA	**1.33 (1.01-1.76)**	0.92 (0.82-1.03)	1.06 (0.71-1.59)	**0.84 (0.70-0.99)**
Girdlestone resection arthroplasty	**2.46 (1.07-5.66)**	**1.69 (1.04-2.76)**	1.99 (0.52-7.68)	1.49 (0.61-3.65)
Hospital-related variables				
Time from admission to surgery (ref. < 24 hours)				
24-36 hours	1.05 (0.74-1.48)	1.01 (0.86-1.18)	0.98 (0.59-1.64)	1.11 (0.89-1.39)
> 36 hours	**1.38 (1.02-1.87)**	1.11 (0.96-1.29)	1.37 (0.86-2.17)	**1.24 (1.01-1.53)**
Active clinical issues at discharge[a] (ref. 0)				
1	1.18 (0.92-1.53)	1.11 (0.99-1.24)	**1.50 (1.02-2.19)**	1.18 (0.99-1.40)
≥ 2	**1.50 (1.08-2.10)**	**1.17 (1.00-1.37)**	**2.32 (1.30-4.13)**	**1.44 (1.15-1.80)**

[a] Based on vital signs at discharge and additional antibiotics during the primary hospital stay.
ASA = American Society of Anesthesiologists
BMI = Body Mass Index
NMS = New Mobility Score
Modified Table from Study III [168].

ACIs were associated with readmission within 30 days for both medical and medical infectious causes (Table 8). The combined ACI score seemed to predict readmission better than the individual ACIs, especially for medical causes. The AF suggested that ACIs attributed with 46% (28-59%) of medical readmissions, especially among patients between 75-84 years and of male sex. For readmission for all causes, the AF was 34% (18-47%).

Patients with ACIs were more likely to be older, nursing home residents, have a high ASA score, be cognitively impaired, and have a low prefracture functional level ($p < 0.05$).

Accounting for abnormalities at admission and discharge in the same vital sign did not significantly change the risk of readmission. The proportion of patients with the same abnormality in vital signs present at admission and at discharge ranged from < 1% for systolic blood pressure < 90 mmHg to 2% for heart rate ≥ 100/min.

Table 8. Associations between active clinical issues (ACIs) at discharge and readmission for medical causes and infectious causes within 30 days. Results presented as RR (95% CI)[a] for the combined ACIs and the individual ACI (n = 2,413).

	Readmission for medical causes	**Readmission for medical infections**
Active clinical issues (ref. 0)		
1	**1.50 (1.02-2.21)**	**2.73 (1.30-5.75)**
≥ 2	**2.32 (1.30-4.16)**	**6.69 (1.82-24.64)**
Individual active clinical issue:		
Heart rate > 100 /min	1.15 (0.65-2.03)	1.58 (0.76-3.26)
Systolic blood pressure < 90 mmHg	2.42 (0.56-10.47)	**4.09 (1.10-15.20)**
Diastolic blood pressure < 60 mmHg	**1.95 (1.20-3.16)**	**2.98 (1.46-6.07)**
Temperature < 36.0 or > 37.8 degrees	1.55 (0.84-2.84)	**2.25 (1.06-4.78)**
Oxygen saturation < 90%	1.25 (0.71-2.20)	2.07 (0.63-6.76)
Additional antibiotics	1.40 (0.99-1.97)	**1.81 (1.01-3.25)**

[a] Risk ratio with 95% confidence intervals adjusted for age, gender, residence, ASA score, cognitive function, and NMS.

Modified table from Study III [168].

4.5 Study IV

A total of 107 females and 49 males were included in the study (Figure 3.1). The two groups were similar with respect to baseline characteristics except for a tendency towards an increased use of IMN among men and patients living independently, and a statistically significantly higher use of IMN for AT/OTA31.3 fractures (Table 9). LOS was similar between the groups with a median LOS of six days and an IQR of four days for both groups ($p = 0.86$).

Table 9. Baseline characteristics of the study population of patients treated with dynamic hip screw with trochanteric stabilizing plate (DHS w/TSP), intramedullary nail (IMN), and in total, presented as numbers (%).

Variable	DHS w/TSP	IMN	Total	p-value
Total	102 (65)	54 (35)	156 (100)	
Age				
< 70 years	17 (17)	10 (19)	27 (17)	0.62
70-84 years	39 (38)	24 (44)	63 (40)	
85 years	46 (45)	20 (37)	66 (42)	
Sex				
Female	75 (74)	32 (59)	107 (69)	0.07
Male	27 (26)	22 (41)	49 (31)	
Pre-fracture residence				
Independent living	70 (69)	44 (81)	114 (73)	0.09
Nursing home	32 (31)	10 (19)	42 (27)	
BMI				
< 18.5 kg/m^2	14 (14)	4 (7)	18 (12)	0.49
18.5-25 kg/m^2	51 (50)	29 (54)	80 (51)	
> 25 kg/m^2	36 (35)	21 (39)	57 (37)	
Fracture pattern				
AT/OTA A31.2	72 (71)	24 (44)	96 (62)	**< 0.01**
AT/OTA A31.3	30 (29)	30 (56)	60 (38)	
ASA score				
ASA 1-2	54 (54)	28 (53)	82 (54)	0.89
ASA ≥ 3	46 (46)	25 (47)	71 (46)	
Cognitive status				
Cognitively fit	75 (75)	40 (75)	115 (75)	0.95
Cognitively impaired	25 (25)	13 (25)	38 (25)	
Anticoagulation therapy				
No	60 (59)	26 (48)	86 (55)	0.18
Yes	41 (41)	28 (52)	69 (45)	
Prefracture NMS				
Low functional level	39 (41)	18 (33)	57 (38)	0.38
High functional level	57 (59)	36 (67)	93 (62)	

AT/OTA = Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association
BMI = Body Mass Index
ASA = American Society of Anesthesiologists
NMS = New Mobility Score, 0-5 point = low functional level. 6-9 points = high functional level
Modified table from Study IV [171].

A total of 19 patients (12%) were reoperated within three years, with eight patients being reoperated for mechanical failure and two for hip infections. The median operative time was 75 minutes for DHS w/TSP and 82 minutes for IMN, but the difference was statistically insignificant ($p = 0.16$). The IMN group was more likely to experience a higher total blood loss ($p < 0.01$); however, no difference was observed in the number of patients receiving blood transfusions during the hospital stay ($p = 0.73$). Among the 156 patients, seven (4%) had no indication for postoperative mobilization and were excluded from the analysis. Among the remaining 149 patients, 120 (81%) were mobilized within 24 hours postoperatively. The DHS w/TSP group was more likely to be mobilized to standing within 24 hours from surgery than patients treated with IMN ($p = 0.02$).

At one year, 36 patients had died (ten patients in the IMN group and 26 in the DHS w/TSP group, $p = 0.33$). Telephone contact was attempted but was unsuccessful in 33 patients with a statistically significantly increased risk that patients from the DHS w/TSP group did not complete the interview ($p < 0.01$). Hence, the follow-up interview was conducted with 87 (56%) patients one year after surgery. Patients treated with IMN reported less pain, whereas walking compared with the DHS w/TSP group ($p = 0.04$) and a tendency towards a better self-evaluated walking ability were found ($p = 0.09$). However, no differences were found for regaining NMS and PROM (Table 10).

Table 10. Outcomes for patients treated with dynamic hip screw with trochanteric stabilizing plate (DHS w/TSP) or intramedullary nail (IMN), presented as numbers (%).

Variable	DHS w/TSP	IMN	p-value
Total	102 (65)	54 (35)	
Operation time (min)			
Median (IQR)	75 (53)	82 (38)	0.16
Postoperative mobilization			
Not mobilized within 24 hours	14 (14)	15 (31)	**0.02**
Mobilized within 24 hours	86 (86)	34 (69)	
Blood transfusion			
Yes	69 (68)	35 (65)	0.73
No	33 (32)	19 (35)	
Total blood loss (ml)			
Median (IQR)	722 (562)	885 (562)	**< 0.01**
Function one year after surgery (NMS)			
Did not regain prefracture function	28 (61)	23 (59)	0.86
Regained prefracture function	18 (39)	16 (41)	
Pain level during walking one year after surgery			
No pain	22 (47)	29 (76)	**0.04**
Mild pain	10 (21)	5 (13)	
Moderate pain	8 (17)	3 (8)	
Sever pain	7 (15)	1 (3)	
Walking ability one year after surgery			
Deterioration compared with prefracture ability	27 (69)	17 (50)	0.09
No deterioration compared with prefracture ability	12 (31)	17 (50)	
PROM			
Worse than before fracture	27 (73)	20 (63)	0.35
The same as before fracture	10 (27)	12 (37)	
Reoperation within three years			
All causes	14 (14)	5 (9)	0.61
Mechanical failure	6 (6)	2 (4)	0.71
Infections	1 (1)	1 (2)	1.00

IQR = interquartile range

NMS = New Mobility Score

PROM = Patient-reported outcome measures

Modified table from Study IV [171].

4.6 Study V

Only patients admitted from their own homes were included in Study V. A total of 2,006 patients comprised the study population for investigating independence at discharge (Figure 3.1). Within the first year, 253 patients died (13%), and 411 patients were lost to follow-up (23%), leaving 1,342 patients for analysis of risk factors for failure to return to independent living (Figure 3.1).

Two measures were used that indicated independence at discharge, CAS = 6 and TUG test < 20 seconds. At discharge, 613 patients were independent measured by CAS = 6, and the median CAS was 4 (IQR: 3). Multiple risk factors were identified for dependency at discharge (CAS ≤ 5) after adjusting for confounders and are presented in Table 11.

In all, 398 (20%) patients completed the TUG test at discharge, and only 84 (21%) patients performed the test in less than 20 seconds, indicating independence at discharge. Patients treated with THA were more likely to complete the TUG test and more likely to do so in less than 20 seconds ($p < 0.001$). Extracapsular fracture and postoperative anemia were associated with increased odds of completing the TUG test > 20 seconds at discharge (Table 11).

Table 11. Risk factors for dependency at discharge predicted by CAS ≤ 5 and TUG > 20 seconds adjusted age, sex, ASA score, cognitive status, prefracture NMS, postoperative mobilization, and fracture pattern. OR with 95% confidence intervals. Only statistically significant risk factors are presented.

Variables	**CAS (n = 2,006)**	**TUG (n = 398)**
Hip fracture		
Fracture pattern (ref. intracapsular fracture)		
Extracapsular fracture	**3.10 (2.45-3.93)**	**2.47 (1.26-4.86)**
Patient-related variables		
Age (ref. < 75 years)		
75-84 years	**2.09 (1.61-2.71)**	1.56 (0.85-2.87)
≥ 85 years	**4.39 (3.20-6.03)**	0.87 (0.39-1.94)
BMI (ref. 18.5-25 kg/m^2)		
< 18.5 kg/m^2	0.89 (0.59-1.35)	0.83 (0.33-2.08)
> 25 kg/m^2	**1.29 (1.00-1.66)**	0.78 (0.44-1.39)
Prefracture NMS (ref. NMS ≥ 6 points)		
NMS ≤ 5 points	**4.34 (3.03-6.21)**	0.79 (0.27-2.30)
ASA score (ref. ASA 1-2)		
ASA ≥ 3	**2.22 (1.71-2.90)**	1.35 (0.67-2.74)
Cognitive status (ref. cognitive fit)		
Cognitive impairment	**6.34 (2.67-15.04)**	0.51 (0.09-3.03)
Postoperative hemoglobin (ref. ≥ 10 g/dl)		
< 10 g/dl	1.25 (0.92-1.70)	**3.16 (1.04-9.57)**
Albumin (ref. ≥ 35 g/l)		
< 35 g/l	**1.94 (1.38-2.71)**	0.92 (0.40-2.10)
Surgical treatment		
Surgical method (ref. internal fixation)		
THA	**1.86 (1.35-2.57)**	1.64 (0.89-3.03)
Hospital-related variables		
Postoperative mobilization (ref. < 24 hours)		
> 24 hours from surgery	**1.88 (1.12-3.15)**	1.47 (0.30-7.20)
Anesthesia technique (ref. spinal anesthesia)		
General anesthesia	**1.35 (1.07-1.71)**	1.09 (0.64-1.87)
LOS (per day)	**1.12 (1.06-1.18)**	1.12 (0.96-1.32)

CAS = Cumulated Ambulation Score
TUG = Timed-up and go
BMI = Body Mass Index
NMS = New Mobility Score
ASA = American Society of Anesthesiologists
THA = Total hip arthroplasty
LOS = Length of stay
Table modified from Study V [169].

The one-year telephone interview was completed with 77% of the surviving patients, and an interview was conducted with the patient in 83% of the cases. Failure to return to independent living was reported by 136 (10%) patients. An association was identified for the following risk factors; older age, extracapsular fracture, cognitive impairment, low prefracture NMS, and being dependent at discharge (CAS ≤ 5) (Table 12).

Increased care needs were reported by 26% of patients at one year, whereas 71% reported the same level as before their hip fracture. Regaining prefracture NMS at one year was reported by 667 (50%) patients, whereas 600 (45%) patients experienced a decline in their NMS, and 75 (5%) patients either had no information on their prefracture NMS or one-year NMS.

Table 12. Odds ratio (OR) for failure to return to independent living at one year adjusted for age, sex, ASA score, cognitive status, prefracture NMS, and fracture pattern, n = 1,342. Displayed with 95% confidence intervals (CI). Only statistically significant risk factors are presented.

Variables	**Multivariate analysis OR (95% CI)**
Hip fracture	
Fracture pattern (ref. intracapsular fracture)	
Extracapsular fracture	**1.65 (1.12-2.42)**
Patient-related variables	
Age (ref. < 75 years)	
75-84 years	**1.83 (1.11-3.02)**
≥ 85 years	**2.25 (1.32-3.85)**
Prefracture NMS (ref. NMS ≥ 6 points)	
NMS ≤ 5 points	**2.50 (1.65-3.80)**
Cognitive status (ref. cognitive fit)	
Cognitive impairment	**4.48 (2.54-7.91)**
Hospital-related factors	
TUG test at discharge (ref. < 20 seconds)	
> 20 seconds	0.51 (0.13-1.95)
CAS at discharge (ref. CAS = 6)	
CAS ≤ 5	**1.86 (1.06-3.26)**

NMS = New Mobility Score
TUG = Timed-up and go
CAS = Cumulated Ambulation Score
Table modified from Study V [169].

5. Discussion

In the following sections, the results of the five studies are compared with the existing literature, and the limitations of the studies are presented. The discussion section is followed by a conclusion presenting the results in a clinical and research perspective.

5.1 Key findings

In overview, this dissertation has highlighted the complexity of treating hip fractures. This complexity is mirrored in a low total adherence to the seven best-practice indicators, a multitude of factors affecting adherence, but also the clinical outcomes following hip fracture surgery. Unsurprisingly, the frailest patients with higher age, multiple comorbidities, low prefracture functional level, nursing home residence, and cognitive impairment are at risk of a poorer clinical outcome and also of receiving suboptimal care. Although attention to these risk factors may help focus resources on patients who are at risk, they are largely unmodifiable. However, we also detected modifiable factors that may guide clinicians while treating specific patient groups and thereby serve to improve the prognosis following hip fracture surgery and optimize resource allocation within this field. These factors include, among others, malnutrition, time to surgery, postoperative mobilization, and ACIs. The multiple variables associated with the clinical outcomes following hip fracture surgery in this dissertation are summarized in Table 13.

This dissertation also compares IMN and DHS w/TSP in the treatment of unstable intertrochanteric fractures. The three main findings of Study IV were, firstly, that patients treated with IMN were more likely to have a higher total blood loss and longer time to mobilization than patients treated with DHS w/TSP [171]; secondly, that patients treated with DHS w/TSP reported more hip pain while walking one year after surgery; thirdly, that the overall reoperation rate at three years was 12% and similar for the two groups.

Table 13. Overview of the results from the five studies in this dissertation (+ = a statistically significant association found, % = no statistically significant association found, - = not investigated).

	Study I Adherence	Study II Mortality (30-d / 1-y)	Study III Readmission (30d / 1y)	Study IV IMN vs. DHS-TSP	Study V Function (discharge*/1y)
Hip fracture					
Fracture pattern	%	% / %	% / %	+	+ / +
Patient-related variables					
Age	%	+ / +	% / +	%	+ / +
Sex	%	+ / +	% / +	%	% / %
Residence	+	+ / +	% / +	%	- / -
Smoking	-	% / %	% / +	-	% / %
Alcohol consumption	-	% / %	% / %	-	% / %
BMI	-	+ / +	+ / +	%	+ / %
Prefracture NMS	+	+ / +	+ / %	%	+ / +
Prefracture walking aid	+	- / -	- / -	-	- / -
Visual impairment	-	- / -	- / -	-	% / %
ASA score	+	% / +	+ / +	%	+ / %
Hemoglobin	-	% / %	% / %	-	% / %
Albumin	-	+ / +	% / +	-	+ / %
Creatinine	-	+ / +	% / +	-	- / -
25-hydroxy vitamin D	-	- / -	- / -	-	% / %
Cognitive status	+	+ / +	% / %	%	+ / +
Fall risk assessment	-	% / +	- / -	-	- / -
Anticoagulation therapy	-	- / -	% / %	%	- / -
Antihypertensive therapy	-	- / -	% / %	-	- / -
Surgical treatment					
Surgical method	-	% / %	+ / %	(%)	+ / %
Anesthesia technique	-	% / %	- / -	-	+ / %

Hospital-related variables					
Discharge CAS	-	- / -	- / -	-	- / +
Discharge TUG	-	- / -	- / -	-	- / %
Postoperative mobilization	-	+ / +	% / %	(+)	+ / %
Time to surgery	-	% / +	+ / %	-	% / %
Active clinical issues	-	- / -	+ / +	-	- / -
Length of stay	-	- / -	- / -	-	+ / %
Postoperative pain management	-	- / -	- / -	-	% / %
Readmission within one year	-	(+)	- / -	-	- / %
Preoperative pain management	61%	+ / %	% / %	- / -	- / -
Surgical delay (< 24 hours)	83%	% / %	% / %	- / -	- / -
Preoperative antibiotics	97%	% / %	% / %	- / -	- / -
Surgical method	92%	% / %	% / %	- / -	- / -
Thromboprophylaxis	86%	+ / +	% / %	- / -	- / -
Postoperative mobilization	88%	+ / +	% / %	- / -	- / -
Blood transfusion	90%	+ / %	% / %	- / -	- / -
Overall adherence	32%	% / %	% / %	- / -	- / -

* Independence at discharge (CAS = 6).
BMI = Body Mass Index
NMS = New Mobility Score
ASA = American Society of Anesthesiologists
CAS = Cumulated Ambulation Score
TUG = Timed up and go

5.2 Comparison to the literature

Hip fracture treatment is complex and a range of factors may directly affect the outcome or interact with other factors. One example is age, which directly affects mortality and increases the risk of having multiple comorbidities and low bone quality. Comorbidities may affect mortality and increase the risk of readmission and entail poorer functional recovery. Bone quality may affect the risk of reoperation, which will affect functional recovery and the level of pain that the patient experiences, and thereby negatively affect the patient's quality of life. This is just one illustrative example of the complexity associated with hip fractures.

Risk factors in the studies comprising this dissertation are shown in relation to the outcomes and each other in Figure 5.1. The figure does not give an entirely comprehensive picture, but it illustrates how many interactions are present at the same time. With so many possible interactions and confounding variables, altering one factor may have a more limited impact than expected, because many other factors will also affect the particular factor or outcome investigated. Furthermore, we need to consider the difference between clinical and statistical differences to avoid allocating a significant amount of resources to factors producing little clinical effect. Last but not least, we must be aware that association is not the same as causality.

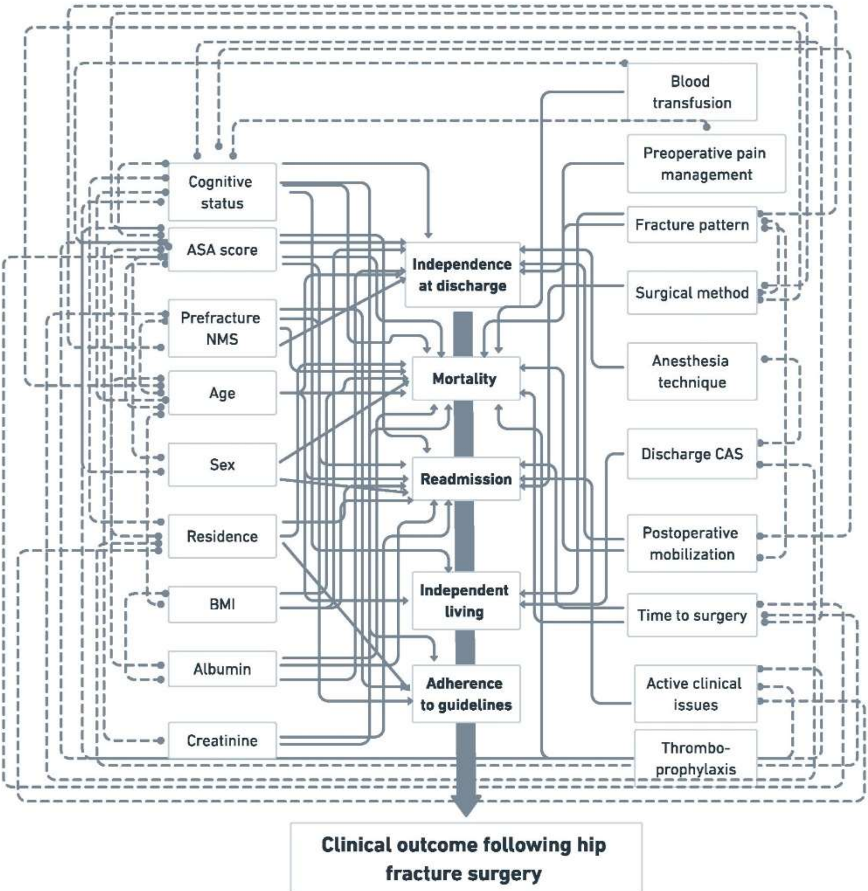


Figure 5.1 *Overview of the variables investigated in Studies I-III and V and their association with clinical outcomes and their association with each other.*
ASA = American Society of Anesthesiologists
BMI = Body Mass Index
NMS = New Mobility Score

5.2.1 Hip fracture

In some studies, the fracture pattern is linked to different clinical outcomes, including increased mortality [25, 188–190]. However, the results are conflicting, with some researchers reporting increased mortality among patients with intracapsular fractures, whereas others find this outcome for patients with extracapsular fractures. Study II found no association between fracture pattern and mortality. This is in line with results reported in other studies [91, 170, 191, 192]. It seems unlikely that the way a bone breaks increases or decreases your risk of dying. However, the inconsistency in reported results may be explained by factors that either affect the type of fracture that a patient experiences or factors that vary based on the fracture pattern. This is supported by research having found that patients suffering extracapsular fractures are older, more cognitively impaired, and have lower prefracture functional levels [193]. All of these factors increase postoperative mortality. Furthermore, extracapsular fractures have been shown to be associated with increased blood loss, which may also increase mortality [194]. Conversely, studies have shown that intracapsular fractures are associated with a longer time to surgery, which increases the immobilization time, which, in turn, has been linked to increased mortality and complications [58, 195].

Most studies report no association between readmission and fracture pattern, except for surgical complications where intracapsular fractures increase the risk of readmission [90, 91, 196, 197]. However, in Study III, an association between extracapsular fractures and readmission for medical causes was found [168]. As for mortality, this association may be explained by these patients being frailer than patients experiencing an intracapsular fracture, despite adjustment for such factors [193]. Additionally, patients with extracapsular fractures may experience more pain resulting in poorer rehabilitation that may cause immobilization and complications such as pneumonia [198]. This was supported by Study V, where an extracapsular fracture pattern was associated with an increased risk of being dependent at discharge and failure to return to independent living [169].

5.2.2 Patient-related variables

Higher age, male sex, nursing home residence, and cognitive impairment are generally associated with poorer clinical outcomes [24–26, 91, 198]. This was confirmed in Studies II, III, and V [168–170]. Similar results were found for poor prefracture function and comorbidities; in this dissertation measured using the NMS and the ASA score, respectively. These factors are not modifiable after the hip fracture. However, the association of these factors with poorer clinical outcome emphasizes the importance of maintaining function and optimizing the health of older people [199].

Another focus point in older community-dwelling people is the frequency of malnutrition. Malnutrition reportedly affects around 2% in the healthy part of the population, whereas over half of hip fracture patients are malnourished or at risk of malnourishment at admission [200–202]. While malnutrition has not been as thoroughly investigated as the other patient-related variables listed above, it does seem to impact clinical outcomes, especially mortality [163, 192, 200, 203]. We used low BMI and hypoalbuminemia to measure malnutrition in this dissertation based on the literature [168–170, 204, 205]. These factors were associated with increased mortality, with hypoalbuminemia having one of the highest ORs. This observation is in line with the findings by Uriz-Otano et al. [170, 192]. Furthermore, we found low BMI and hypoalbuminemia to be associated with readmission [168]. Even though the literature has generally reported increased mortality among malnourished hip fracture patients, the consensus is not that unambiguous regarding readmission and function [104, 163, 203, 206–208]. Whereas some have reported an association with readmission, as was the case in Study III, others have found no such association [91, 104, 200, 206]. Low BMI and hypoalbuminemia may indicate diminished physiological resources to tolerate the surgical stress and recovery following a hip fracture. These factors may also indicate comorbidities such as malignancies, explaining the increased mortality and readmission in this group of patients. However, some have found a BMI >30 kg/m^2 to be associated with increased mortality and readmissions [25, 209]. In Study V, we found an association between dependency at discharge and BMI > 25 kg/m^2, whereas BMI < 18.5 kg/m^2 was not associated with dependency or failure to return to independent living [169]. The association between malnutrition and functional outcomes following hip fracture surgery is inconsistent [26, 137, 200]. However, the assessment of malnourishment differs between studies, which could potentially explain the variations. This, along with methodological weakness, are limitations to the studies conducted regarding interventions targeting nutrition in hip fracture patients [201, 210]. However, it seems plausible that nutrition impacts function as it has been shown to prevent the onset of sarcopenia [202].

Hip fractures patients often experience an overlap of issues related to their health and function, which may affect the treatment given [58, 211–213]. In line with these results, Study I demonstrated that patients living in nursing homes with poor prefracture function, high ASA score, or cognitive impairment are at risk of suboptimal treatment [167]. However, previous studies have all focused on single aspects of treatment like time to surgery, surgical method, or rehabilitation. One exception to this is Schrøder et al. [213] who investigated the adherence to the Danish Multidisciplinary Hip Fracture Registry's process measures and found a similar adherence frequency as we did in Study I. Furthermore, they found that comorbid patients were at risk of adhering to fewer process measures than none-comorbid patients [213].

5.2.3 Surgical treatment

With respect to surgical method, we found an association between treatment with THA and 30-day readmission and dependency at discharge. Others have found an increased readmission rate among patients receiving prosthetic treatment due to early surgical complications such as dislocation [93, 197]. This correlates with our findings in Study III, as THA was associated with 30-day readmission for any cause, whereas the association disappeared for readmission within one year [168]. Furthermore, no association was observed for 30-day readmission for medical causes, and even a reduced risk of readmission was observed for medical causes within one year. However, to reduce the risk of dislocation, all patients in the study population were treated with dual-mobility THA, which has shown a lower dislocation risk, which is an even more significant risk in hip fracture patients than in osteoarthritis patients [112]. Another factor that may

contribute to the dislocation rate is surgical approach. Despite some studies indicating increased dislocation rates with the posterior approach, all surgeons used this approach at our institution [111, 214]. However, some studies have found a similar dislocation rate between the posterior and lateral approaches, with less pain and increased PROM with the posterior approach [155, 215]. The importance of the approach and the effect of the use of dual mobility THA on dislocations rates among hip fracture patients are still under investigation.
In Study V, patients treated with THA had an increased risk of being dependent at discharge [169]. However, patients' movements during the CAS assessment may have been limited due to a three-month movement restriction following THA surgery. The restrictions included hip flexion > 90 degrees, hip adduction > 0 degrees, and hip internal rotation > 0 degrees. In support of this hypothesis, more patients were able to complete the TUG test, which may indicate a better walking ability at discharge.

When investigating the impact of anesthesia technique on clinical outcomes following hip fracture surgery, we found no association with increased mortality, but spinal anesthesia was associated with independence at discharge [169, 170]. Studies have found spinal anesthesia to be associated with lower in-hospital mortality, fewer complications, and fewer readmissions [95, 216, 217]. However, selection bias may be in play as to which patients receive spinal or general anesthesia, e.g., patients in anticoagulation therapy are more likely to receive general anesthesia. Despite most studies aiming to adjust for confounders, residual confounding cannot be ruled out that could potentially explain these findings. A randomized controlled trial found no significant difference between spinal and general anesthesia for 60-day functional outcome and mortality [218].

5.2.4 Hospital-related variables

Hospital-related variables may be the most apparent place to start when attempting to improve clinical outcomes as most of these variables are modifiable. To evaluate discharge functional level, we used CAS, because CAS has been validated to predict clinical outcomes in hip fracture patients and in multiple languages [144, 219–222]. Whereas its simplicity underpins intertester reliability and feasibility, using CAS also comes with inherent limitations such as a ceiling effect and a rough division of patients. Therefore, Ferriero et al. recommended using the three-day CAS instead. Indeed, Pedersen et al. found the NMS to be a better predictor for survival, maintaining residence status, and being independent in walking at four months [219, 223]. In line with this, low prefracture NMS was in Study II, III, and V associated with increased mortality, readmission, dependence at discharge (CAS ≤ 5), and with failure to return to independent living; for the latter, with a higher OR than the CAS [168–170]. Nevertheless, we found a median CAS of four, which is in line CAS values reported in other studies [140, 145, 169]. CAS has also been shown to predict several clinical outcomes following hip fracture surgery, including mortality, readmission, and complications [87, 144, 150]. It seems plausible that early ambulation and functional outcomes may have implications for such outcomes. Therefore, we should strive to obtain more knowledge of which factors affect CAS to improve these outcomes. The results in Study V confirm those of other studies, showing an association between CAS and age, residence, ASA score, prefracture NMS, and postoperative mobilization [140, 169, 224].

Postoperative mobilization is another hospital-related variable that is often used as a process performance measure in national audits [5, 46, 61]. Early postoperative mobilization has been shown to improve clinical outcomes and is modifiable. Seys et al. conducted a Delphi study and found that 93% of the expert committee evaluated postoperative mobilization to be of high importance in treating hip fractures [54]. Delaying postoperative mobilization has been associated with complications such as pneumonia and delirium [225, 226]. Such complications may partly explain why delaying postoperative mobilization increases in-hospital mortality and 30-day mortality, and decreases functional recovery [49, 78, 79, 227]. These findings were similar to those reported in Studies II and V, with increased mortality and dependency at discharge among patients not mobilized within 24 hours [169, 170].

With an increased risk of delirium and pneumonia, an increased risk of readmission seems plausible. However, after adjusting for confounders, we found no association between postoperative mobilization and readmission in Study III [168]. Before adjusting, a 69% increased risk of being readmitted for medical causes, e.g., pneumonia, was recorded. We adjusted for age, gender, residence, ASA score, cognitive status, and prefracture NMS. These are all factors that impact the chance of early mobilization and may dilute any increased risk by postponing mobilization [213, 227, 228]. The number of patients receiving early postoperative mobilization differs between countries, indicating an optimization potential, and postoperative mobilization should be a focal point in the future for hip fracture research and in the clinical setting [7].

In recent decades, time to surgery has been a factor of interest, and ever shorter timelines have been introduced. To adhere to such increasingly demanding timelines, hospitals need to allocate resources, which often means that resources are redirected from other patients or surgeries. To justify such reallocation, earlier surgery has to improve clinical outcomes for patients. Multiple factors impact time to surgery, including patient-related, fracture-related, and hospital-related factors [229, 230].
When discussing the implications from time to surgery, aspects to consider are who can be safely delayed and why surgery is delayed. Özturk et al. and Hongisto et al. both explored comorbidities in relation to delaying surgery but found contradictory results [1, 58, 59]. Özturk et al. found that delaying surgery for the healthiest patient by more than 24 hours increased their 30 days mortality, whereas Hongisto et al. found that delaying the most comorbid patients by more than 12 hours increased their mortality [58, 59]. Some of the explanations for this discrepancy may lie in the very reasoning for delaying the surgery, as suggested by Lizaur-Utrilla et al. [60]. They suggested that delays to optimize patients' comorbidities do not increase mortality, whereas delays due to organizational issues do increase mortality. In Studies II and III, more than 36 hours from admission to surgery was associated with increased one-year mortality along with an increased risk of 30-day readmission for all causes and one-year readmissions for medical causes [168, 170]. We did not investigate the reasons for delaying surgery and the association with mortality in Study II. However, in Study III, we investigated the reasons for delaying surgery and found no increased risk for medical readmissions if surgery was postponed

to optimize medical issues compared with delays due to organizational issues.
Another factor to consider is the time from fracture to admission. This will vary among patients, and it seems logical to suggest that it may be just as dangerous to be lying on the floor after a fall as lying in a hospital bed awaiting surgery. Leer-Salversen et al. divided time to surgery into time from fracture to surgery (total time) and time from admission to surgery [231]. They found a mean time from fracture to admission of 6.2 hours. However, for some patients, the time gap was more than 24 hours. Increased one-year mortality and in-hospital complication rates were found for patients with a total time to surgery exceeding 48 hours. Our results do not support lowering surgery time beyond the current 24 hours, as it seems that little is gained by doing so. Instead, research may further explore which patients are most impacted by awaiting surgery and by time spent immobilized.

We investigated the association of ACIs with readmission following hip fracture surgery [102]. However, others have examined ACIs in other patient groups with conflicting results [103, 174, 232, 233]. We found ≥ 2 ACIs to be associated with an increased risk of 30-day and one-year readmission for both all causes and medical causes [168]. In Study III, ACIs were primarily based on abnormalities in vital signs. Whereas ACIs may reflect acute conditions, they may also signify a more chronic state in patient comorbidities. However, it seems sensible that newly developed ACIs increase the risk of readmission, and in Study III, most patients discharged with an ACI developed it during the hospital stay. ACIs developed during the hospital stay may indicate deterioration in the patient's health. Nevertheless, most studies into ACIs have not considered this aspect, which may explain the diversity in results [102, 174, 232, 233]. It should be clarified that while Study III showed an attributable fraction of 46% for ACIs, this needs to be interpreted with caution as Gabayan et al. found ≥ 2 ACIs to have a sensitivity of 0.014 and a specificity of 0.995 for readmissions within seven days [168, 232]. They investigated ER patients and readmission within seven days, but future studies in hip fractures patients should also include these measures in their results.
By paying attention to ACIs at discharge, clinicians may prevent premature

discharge or initiate close post-discharge follow-up with the primary physician or a geriatric team. Such measures have been found to prevent readmission following a hip fracture [96, 234].

Adhering to an evidence-base treatment guideline is always the goal. However, everybody involved in the treatment of hip fracture patients knowns that achieving 100% evidence-based treatment is not always possible. Although contraindications were considered, only a third of all patients complied with all seven best-practice indicators in Study I. However, half of the patients complied with six indicators [167]. Similarly, the literature reports that adherence to guidelines is not convincing [54–57]. These results underpin the difficulties related to providing a standard treatment package to a heterogeneous patient group. Studies have identified patients at risk of lower adherence to guidelines similar to the ones identified in Study I [211–213]. Given the considerable diversity among hip fracture patients, future studies may focus on more tailor-made treatment plans based on fracture pattern, comorbidity, cognitive status, and prefracture functional level to ensure the best possible treatment for the individual patient.

5.2.5 IMN versus DHS w/TSP

The optimal treatment choice for unstable intertrochanteric fractures is an issue of ongoing debate because intertrochanteric fractures are associated with high reoperation rates. Multiple surgical methods have been investigated. However, DHS alone, hemiarthroplasty, and proximal femoral locked plate have been shown to be inferior to IMN or DHS w/TSP [116, 123, 235]. Most reviews recommend IMN as the treatment choice for unstable intertrochanteric fractures owing to better performance, lower failure rates, and lower blood loss [42, 43, 116]. However, DHSs w/TSP are typically not included because only few studies have compared it to IMNs [40, 41, 119, 122, 124, 236]. DHSs w/TSP are typically used in unstable intertrochanteric fractures to ensure lateral support [237]. In 2018, the AO Trauma and Orthopedic Trauma Association reviewed their fracture classification to streamline it with other major systems [13]. The former 2007 edition included a subgroup termed AO/OTA31-A2.1, which is not incorporated in the 2018 version [12, 13]. This is important, as involvement of the lateral wall is only a specific criterion in the AO/OTA31-A3 fractures in the 2007 edition [12]. However, perioperative fracture of the lateral cortical buttress is significantly more common in AO/OTA31-A2.2 and -A2.3 fractures than in AO/OTA31-A2.1 fractures [118]. In the 2018 edition, the thickness of the lateral wall is a criterion in the AO/OTA31-A2 subgroup, and, in the future, researchers need to be aware of which edition is used when comparing results.

In Study IV, we found that the total blood loss was higher in patients treated with IMN than patients treated with DHS w/TSP [171]. This may be due to the fact that patients with AO/OTA31-3 fractures were more likely to receive IMN, and these complex fractures may bleed more. The increased blood loss did not translate into an increased need for blood transfusions, which is similar to the findings reported in the review by Selim et al. [238]. Regarding operation time, we found a statistically insignificant shorter operation time in the group treated with DHS w/TSH [171]. Whereas most authors have found shorter operation times when using IMNs, Fu et al. likewise found that DHS w/TSP had shorter operation time [40, 41, 236, 238]. For most of the studies, the difference falls in the 10-20 minute range, which may be due to surgeon's experience and may be of limited clinical relevance.
An important clinical outcome when choosing a surgical method is the functional outcome. Study IV demonstrated slower postoperative mobilization in the IMN group than in the DHS w/TSP group [171]. Even so, no difference was observed in terms of regaining prefracture functional level at one year. Moreover, despite less pain while walking in the IMN group, the remaining PROMs were similar between the two groups at one year. Whereas some studies have reported more weight-bearing restrictions in patients treated with DHS w/TSP, most studies have found no long-term differences in function [40, 41, 119, 236]. The primary outcome in Study IV was reoperation within three years, which is a longer follow-up than in most previously conducted studies [171]. No differences were found, which is in line with previous reports [40, 41]. However, higher reoperation rates in patients treated with DHS w/TSP have been found in other studies [119, 124]. Whereas Tucker et al. did not report radiological measures, Müller et al. found poorer placement of the DHS w/TSP than IMN. This may play an

important role as studies have shown that implant placement is important in reoperation following internal fixation [127, 128, 239]. Unfortunately, we had no information on implant placement and fracture reduction. Regardless, more research is needed to explore if there are clinically significant differences between IMN and DHS w/TSP in treating unstable intertrochanteric fractures.

5.3 Methodological considerations

When considering the results, one must also assess the study's internal validity to evaluate if they are valid or may be due to systematic errors. As the design of the five conducted studies is similar, the considerations regarding internal validity are discussed collectively.

5.3.1 Selection bias

Selection bias is a skewed inclusion of patients causing the association to differ between those eligible for inclusion and those included, e.g., if the outcome affects the participation or selection of patients. The inclusion process of the hip fracture database ensured minimal selection bias as all patients were included consecutively regardless of age, comorbidity, cognitive status, and prefracture functional level. Cognitively impaired patients, in particular, have previously been excluded from hip fracture studies [240]. However, recent years have seen a steady rise in the inclusion of this patient group in research. Furthermore, Indeed, the inclusion process in our database was validated, revealing that more than 98% of all patients admitted with a hip fracture were included.

Cohort studies such as ours carry a risk of loss to follow-up, which may be a substantial source of selection bias. As most of our results were based on register data, we had almost complete follow-up. We estimate the selection bias to be minimal. Study IV and V partially relied on a telephone interview for a one-year follow-up [169, 171]. In Study V, a more significant loss to follow-up was seen in the DHS w/TSP group, which may have skewed the results towards better one-year results for the DHS w/TSP group, assuming that patients with poorer health status, cognitive impairment, and nursing home residents are more unlikely to participate in the follow-up interview. However, this factor does not affect the in-hospital results or the three-year reoperation rate.

5.3.2 Information bias

Information bias is the systematic misclassification of either exposure or outcome. Misclassification may depend on other variables (differential misclassification) or may not depend on such variables (non-differential misclassification).

Study III and IV relied on data regarding readmission and reoperation from the Central Denmark Region's medical servers [168, 171]. This meant that patients admitted or reoperated outside the region would have been misclassified as not having been readmitted or reoperated in the studies. However, the tax-funded free-of-charge Danish healthcare system will prompt that the majority of patients are treated in their local hospital, reducing such misclassification. Whereas mortality has a nearly complete follow-up, we have no exact data on the completeness of readmissions and reoperations [241]. Some underreporting is possible, but we have no reason to suspect that reporting differed between exposure or outcome. Another potential misclassification in such registers is reliance on diagnosis and surgical codes [241]. Therefore, all causes for readmissions and reoperations were checked in the electronic patient records to minimize any such misclassification.

The study design reduces the risk of misclassification owing to its consecutive, prospective collection of data independently of the research questions, and any misclassification will therefore most likely be non-differential. A non-differential misclassification would, with the binary outcomes, yield a bias towards the null hypothesis [242].

5.3.3 Confounding

Confounding is always a potential limitation in observational studies. However, its impact may be reduced by the study's design or statistical method. A confounding variable is a variable that impacts the association by affecting both the exposure and the outcome without being an intermediate step in the pathway between exposure and outcome (Figure 5.2) [242]. Such factors are known as mediators. If mediators are introduced in the statistical analyses, they may dilute any true association. However, it can be challenging to distinguish confounders from mediators in complex situations such as hip fracture research. To further complicate the situation, competing exposures may also impact the outcome or the effect that an exposure has on the outcome.

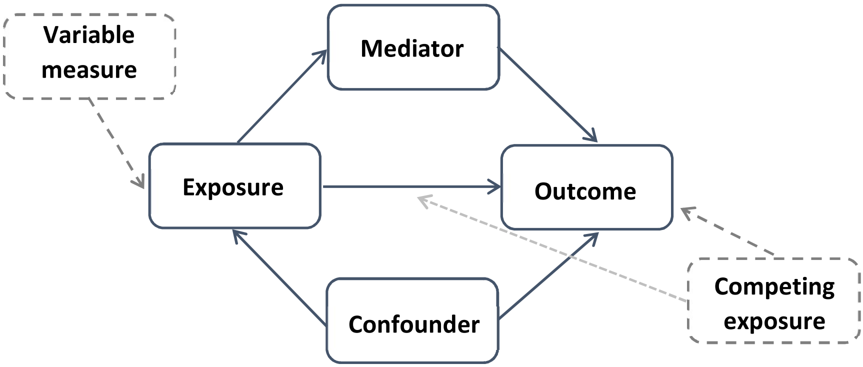


Figure 5.2 *Illustration of the concept of confounders and mediators in relation to exposure and outcome along with some additional factors.*

Studies I, II, III, and V handled confounding variables through the statistical analyses by adjusting for potential confounders defined *a priori* [167–170]. There were too few events in Study IV to adjust for confounders [171]. We conducted a standard multivariable logistic regression for most studies; but in Study II, we did so using three models [170]. This method was chosen instead of the more routinely used forward or backward stepwise selection based on the significance level in a univariable model. Statisticians have recommended that one generally refrains from these stepwise methods as they remove the importance of the clinical knowledge regarding the variables [243, 244]. Instead, we decided to implement our knowledge in the selection of confounders. Thus, in model three, we included all risk factors in the adjustment based on Olusegun et al. 2015, who stated "… researchers should retain a variable, even if it has near zero correlation with the response variable but have a significant correlation with other predictor variables. Further, other benefits accrue from including such a variable in multiple regression model(s). Including such a variable will eliminate the danger of rejecting a true hypothesis as false" [243]. In Study II, BMI and creatinine showed an increase in OR in model three. This may be explained by other variables affecting how much BMI and creatinine predict mortality. However, we recognize that it introduces a risk of over-adjustment, especially of the more complex risk factors such as ASA score, where mediators might be included in the model and explain that high ASA score was not associated with 30-day mortality in model three. Although multiple adjustments were made, residual confounding may remain, such as marital status, cohabitation, socioeconomic status, and individual comorbidities.

In Study IV, the surgeon decided on the surgical method, which may lead to confounding by indication [171]. Surgeons may have more experience using one type of implant and that may affect the choice of surgical procedure, including operation time and implant position. However, based on previous studies, we do not suspect the implant positioning to be systematically different between the two groups [40, 122]. This would have screwed the association towards the null hypothesis and have blurred any true association.

Another factor to consider is the measures used to evaluate the exposure and outcome (Figure 5.2). Whereas outcomes like mortality are either-or, outcomes like PROMs and functional outcomes may be measured in many ways. The most optimal measurements are validated among hip fracture patients, reproducible, and easily implemented in the clinic. Our PROM was not a validated questionnaire, which is a limitation. The NMS and the CAS were the choices of measures for functional outcomes, and both are validated in hip fracture patients and in multiple countries, as described previously [141, 144, 145]. However, they are both relatively simple measures, making for a relatively rough division of patients. This limits the detectability of changes in such a score following any intervention. The same applies to the ASA score used for comorbidities.

5.3.4 Causality

Causality is a problem in many hip fracture studies, including ours, as the studies are performed mainly as cohort or register studies. One such example is studies finding an increased risk of dying or being institutionalized following internal fixation. It seems unlikely that the implant causes a considerable increase in these factors; hence, the association observed is more likely due to confounding or selection bias when choosing the surgical method [119, 245]. Studies II and III found that exceeding 36 hours from admission to surgery was associated with increased mortality and readmission for medical causes within one year [168, 170]. Whereas delaying surgery may increase the short-term risk, other factors are probably in play here. Patients may suffer from comorbidities that delay their surgery and increase their risk of dying or being readmitted within one year, which in turn increases the long-term risk more than the actual delay. The same applies in Study V where a longer LOS was associated with a higher risk of dependency at discharge [169]. This is probably an instance of reverse causality. Healthy and more active patients will be more prone to reach independence more easily and quickly and hence be discharged faster than will less healthy and active patients. Only RCTs can determine causality, and RCTs are generally more difficult to conduct, especially in an acute situation with frail older patients such as hip fracture patients. However, a need exists for larger RCTs among hip fracture patients as this design will also take residual confounding into account.

5.3.5 Statistical considerations

The majority of the statistical methods utilized in the studies are well-described in the literature, but some may need further elaboration.

In Study III, time-to-event data were handled using the pseudo-value approach rather than the more well-known Cox regression [168]. The Cox regression model produces hazard ratios (HRs) that may be difficult to interpret even for researchers and likely more so for clinicians [246]. Whereas the HR cannot be directly translated into a relative risk, the pseudo-value approach makes multivariable analyses of time-to-event data possible on the absolute and the relative scale [184]. This gives the advantages of results are more easily interpreted, and conclusions may be more precise in conveying the results to the public.

For most of the studies, we had a relatively large study population, which would reduce any random variation that could cause false results. However, Study IV was a smaller study with 152 patients [171]. Therefore, the number of events was equally small, giving rise to some considerations: Firstly, it was not possible to make a multivariable logistic regression. The implication of this is that variables such as fracture pattern may not be included as confounders. Secondly, the risk of a type II error occurring increases with a small study population, which may cause the null hypothesis to be wrongfully accepted.

5.3.6 Generalizability

Patients were included with very little selection, yielding a study population similar to that expected in the general population. When compared with the national audit, the study population is similar in all comparable aspects, such as age, sex, residence, fracture pattern, and BMI [5]. However, when adopting a global outlook, limitations apply to the generalizability of the studies. The patient characteristics differ slightly between countries, e.g., ethnicity, where the majority of the Danish population is Caucasian. However, healthcare-related differences probably have a greater impact. Accessibility of healthcare may impact whether a patient is readmitted, treated in primary healthcare, or seeks medical advice at all. Furthermore, the LOS differs significantly between countries and is affected by a multitude of variables apart from patient characteristics, e.g., time to surgery, rehabilitation in the homes, and availability of out-patient treatments [6, 8]. The same considerations apply to time to surgery, which depends on national guidelines, hospital capacity, and patient-related variables [195]. Therefore, different LOS and time to surgery than ours may impact our findings and the applicability of these in other countries.

6. Conclusions

The studies included in this dissertation have provided new information about the prognosis following hip fracture surgery and have confirmed some previously found results.

6.1 Study I

Overall adherence was low and only a third of patients complied with all seven best-practice indicators. However, half of the patients complied with six indicators. The most dependent patients with cognitive impairment, comorbidities, or low functional levels had a lower adherence. Among the individual indicators, not achieving preoperative pain management, thromboprophylaxis, postoperative mobilization, and blood transfusions were associated with increased mortality. None of the indicators were associated with readmission risk. This study showed that achieving 100% adherence to guidelines is difficult in such heterogeneous patient groups. Furthermore, a large patient subgroup was identified in need of an enhanced treatment focus and additional resources to achieve higher adherence to improve their clinical outcome.

6.2 Study II

Risk factors for mortality following hip fracture surgery have been investigated in multiple studies, but we added to the existing knowledge by focusing on a number of modifiable risk factors. Non-modifiable risk factors associated with increased mortality included higher age, male sex, nursing home residence, and cognitive impairment. In addition, we found comorbidities (expressed as ASA score ≥ 3 and creatinine $> 100\mu mol/l$), malnutrition (low BMI and hypoalbuminemia), and failure to achieve postoperative mobilization within 24 hours to be associated with increased short and long-term mortality. These are potentially modifiable factors; however, the effect of any optimization interventions warrants further research.

6.3 Study III

Risk factors for readmission following hip fracture surgery have been investigated in multiple studies. However, we sought to deepen the understanding. In addition to risk factors associated with 30-day and one-year readmission, we explored medical readmissions separately. We also studied two sparsely investigated factors; the impact of the reasons for delaying surgery and ACIs on readmission risk. Whereas the readmission risk was increased if time to surgery exceeded 36 hours, we found no increased risk if medical issues caused the delay compared with organizational reasons. For ACIs, we found that patients discharged with two or more ACIs were at a higher risk of readmission for any reason. Furthermore, for readmissions for medical causes, even being discharged with one ACI increased the risk. Resolving ACIs before discharge may reduce readmissions following hip fracture surgery.

6.4 Study IV

In the treatment of unstable intertrochanteric fractures, the lack of structural support poses a challenge to surgical treatment. We compared two surgical methods, IMN and DHS w/TSP, that are well known but rarely compared regarding in-hospital and one-year outcomes, and three-year reoperation rate. We found only minor differences between the two implants. The IMN group had a more significant total blood loss during the hospital stay and was not mobilized within 24 hours to the same degree as the DHS w/TSP group was. However, these differences did not lead to increased blood transfusions or fewer patients regaining their prefracture function at one year. At one year, the only significant difference was increased pain while walking in the DHS w/TSP group. The reoperation rate was similar between the two groups.

6.5 Study V

The diminished functional level seen after hip fractures may lead to institutionalization, but we need more information to determine exactly which patients are at risk and to establish if the functional level at discharge impacts the risk of being institutionalized. Most of the risk factors were static for both outcomes, especially higher age, low prefracture functional level, and cognitive impairment increasing the risk. However, mobilizing patients to standing within 24 hours from hip fracture surgery was associated with achieving independence at discharge, as measured by CAS = 6; which, in turn, was associated with return to independent living at 12 months. Patients who are institutionalized following hip fracture surgery are typically frailer than those who do return to their homes. However, the majority of the patients who are admitted from their own homes remain in their own homes with a minor increase in care needs.

7. Perspectives and future research

Clinical outcomes for hip fracture patients are discouraging; they include high mortality rates, decline in functional level, and loss of independence [2, 6]. Understanding the complexity inherent to the treatment of hip fractures is key in optimizing patient care and clinical outcomes. Unsurprisingly, we found that the frailest patients carry the highest risk of poorer clinical outcomes and of receiving suboptimal treatment. As most patient characteristics are not modifiable after the hip fracture, a shift in focus is needed. Some focus points in the treatment of hip fractures for the clinic and future research may be derived from this dissertation.

Whereas the studies included fracture pattern, patient-related variables, surgical treatment, and hospital-related variables, the perspectives outlined in this section will focus mainly on hospital-related variables. Although patient-related variables may help clinicians focus on patients at risk, they are generally static at the time of the hip fracture and, therefore, not targetable for interventions. However, a few are, at least to some extent, modifiable, including BMI, biochemical measures, and ASA score. Nutritional interventions have received more focus recently, with malnutrition being linked to unfavorable outcomes [247–249]. However, reviews have highlighted the limitations in the methodology in most nutritional intervention studies [210, 250]. Therefore, clear recommendations to improve the nutritional status are lacking. Nutritional education and supplements may help improve clinical outcomes such as readmissions and functional recovery, but larger trials with a clear methodology are warranted.

The studies showed that postoperative mobilization was associated with a decreased mortality and with independence at discharge [169, 170]. The national adherence to postoperative mobilization within 24 hours is low in some countries, and some patient groups, such as comorbid or cognitively impaired patients, are harder to mobilize [213, 251]. Whereas some studies have shown promising results in rehabilitation for the cognitively impaired, consensus on this point is lacking [252]. A greater focus on the importance of early postoperative mobilization in the clinic is needed. Furthermore, studies characterizing patients who are not mobilized and clarifying the

reasons why, along with intervention studies, are warranted to establish the best method to mobilize patients with hip fractures.
The same may apply for time to surgery. Whereas nearly 90% of patients are operated within 36 hours in Denmark, other countries have a far longer time to surgery. Both of these hospital-related variables require allocation of resources, and in countries that already have a high degree of adherence to, e.g., time to surgery, allocating more resources towards other variables may be more beneficial than increasing the goals for fulfillment.

The implication of ACIs on the clinical outcomes following hip fracture surgery is sparsely investigated, but the available research points towards ACIs at discharge being associated with poorer outcomes [102, 168]. More studies to confirm these findings are warranted. Additional to studies regarding ACIs predicting mortality and readmission, interventional studies using ACIs to identify patients in need of tailor-made discharge planning may be interesting. This may help prevent premature discharge and design post-discharge protocols with follow-up visits to reduce mortality and readmissions.

Hip fractures are a major healthcare issue that requires continued studies allowing us to determine the best preventive, interventional, and post-discharge protocols to maximize outcomes and limit complications. However, decades of research indicate that there may never be a gold standard treatment plan suitable for all hip fracture patients. This dissertation builds upon these many researchers' hard work aiming to add new knowledge to the discussion. However, for some patients, we, as clinicians, may also need to recognize that a hip fracture may be the symptom of deterioration in health. Readmissions and mortality may not be preventable in these patients, and the future for hip fracture treatment may call for more tailor-made treatment protocols that ensure the best possible outcome for the individual patient.

8. References

1. Glassou EN, Kjørholt KKE, Hansen TB, Pedersen AB (2019) Delay in surgery, risk of hospital-treated infections and the prognostic impact of comorbidity in hip fracture patients. A Danish nationwide cohort. Clin Epidemiol 11:383–395. https://doi.org/10.2147/CLEP.S200454

2. Dyer SM, Crotty M, Fairhall N, et al (2016) A critical review of the long-term disability outcomes following hip fracture. BMC Geriatr 16:158. https://doi.org/10.1186/s12877-016-0332-0

3. Veronese N, Maggi S (2018) Epidemiology and social costs of hip fracture. Injury 49:. https://doi.org/10.1016/j.injury.2018.04.015

4. Cooper C, Cole Z, Holroyd C, et al (2011) Secular trends in the incidence of hip and other osteoporotic fractures. Osteoporos Int 22:1277–1288. https://doi.org/10.1007/s00198-011-1601-6.Secular

5. Danish Health Authority (2021) The Danish Multidisciplinary Hip Fracture Registry - annual report 2020

6. Rapp K, Büchele G, Dreinhöfer K, et al (2019) Epidemiology of hip fractures: Systematic literature review of German data and an overview of the international literature. Z Gerontol Geriatr 52:10–16. https://doi.org/10.1007/s00391-018-1382-z

7. Johansen A, Golding D, Brent L, et al (2019) Using national hip fracture registries and audit databases to develop an international perspective. Injury 48:2174–2179. https://doi.org/10.1016/j.injury.2017.08.001

8. Werner M, Macke C, Gogol M, et al (2021) Differences in hip fracture care in Europe: a systematic review of recent annual reports of hip fracture registries. Eur J Trauma Emerg Surg. https://doi.org/10.1007/s00068-021-01797-8

9. Jensen CM, Mainz H, Lamm M, et al (2008) Reference programme for treatment of patients with proximal femur fractures. Dansk Sygeplejeråd, Danske Fysioterapeuter Dansk Ortopædisk Selsk 1–128

10. NICE (2017) National Institute for Health and Clinical Excellence (NICE) (2012) Management of hip fractures in adults

11. Sackett DL, Haynes RB, Tugwell P, Guyatt GH (1992) Introduction: How to review your own performance. In: Clinical Epidemiology: A Basic Science for Clinical Medicine, 2nd ed. Little, Brown and Company, pp 191–305

12. Marsh JL, Slongo TF, Agel J, et al (2007) Fracture and Dislocation Classification Compendium - 2007: Orthopaedic Trauma Association Classification, Database and Outcomes Committee - Femur. J Orthop Trauma 21:31–42

13. Wilber JH, Ricci WM, Kellam JF, et al (2018) Fracture and Dislocation Classification Compendium—2018. J Orthop Trauma 32:. https://doi.org/10.1097/BOT.0000000000001063

14. Pervez H, Parker MJ, Pryor GA, et al (2002) Classification of trochanteric fracture of the proximal femur: a study of the reliability of current systems. Injury 33:713–715

15. Kazley JM, Banerjee S, Abousayed MM, Rosenbaum AJ (2018) Classifications in brief: Garden classification of femoral neck fractures. Clin Orthop Relat Res 476:441–445. https://doi.org/10.1007/s11999.0000000000000066

16. Masionis P, Uvarovas V, Mazarevičius G, et al (2019) The reliability of a Garden, AO and simple II stage classifications for intracapsular hip fractures. Orthop Traumatol Surg Res 105:29–33. https://doi.org/10.1016/j.otsr.2018.11.007

17. Yin B, He Y, Wang D, Zhou J (2021) Classification of femur trochanteric fracture: Evaluating the reliability of Tang classification. Injury 52:1500–1505. https://doi.org/10.1016/j.injury.2020.11.031

18. Masters J, Metcalfe D, Achten J, et al (2019) Interpreting and reporting fracture classification and operation type in hip fracture: Implications for research studies and routine national audits. Bone Jt J 101-B:1292–1299. https://doi.org/10.1302/0301-620X.101B10.BJJ-2019-0213.R1

19. Remily EA, Mohamed NS, Wilkie WA, et al (2020) Hip Fracture Trends in America between 2009 and 2016. Geriatr Orthop Surg Rehabil 11:1–10. https://doi.org/10.1177/2151459320929581

20. Mortensen SJ, Beeram I, Florance J, et al (2021) Modifiable lifestyle factors associated with fragility hip fracture: a systematic review and meta-analysis. J Bone Miner Metab 39:893–902. https://doi.org/10.1007/s00774-021-01230-5

21. Abey-Nesbit R, Schluter PJ, Wilkinson T, et al (2019) Risk factors for hip fracture in New Zealand older adults seeking home care services: A national population cross-sectional study. BMC Geriatr 19:1–13. https://doi.org/10.1186/s12877-019-1107-1

22. Papaioannou A, Santesso N, Morin SN, et al (2015) Recommendations for preventing fracture in long-term care. CMAJ 187:1135–1144. https://doi.org/10.1503/cmaj.141331

23. El-Khoury F, Cassou B, Charles M-A, Dargent-Molina P (2013) The effect of fall prevention exercise programmes on fall induced injuries in community dwelling older adults: systematic review and meta-analysis of randomised controlled trials. BMJ 347:f6234. https://doi.org/10.1136/bmj.f6234

24. Ali AM, Gibbons CER (2017) Predictors of 30-day hospital readmission after hip fracture: a systematic review. Injury 48:243–252. https://doi.org/10.1016/j.injury.2017.01.005

25. Smith T, Pelpola K, Ball M, et al (2014) Pre-operative indicators for mortality following hip fracture surgery: a systematic review and meta-analysis. Age Ageing 43:464–471. https://doi.org/https://doi.org/10.1093/ageing/afu065

26. Xu BY, Yan S, Low LL, et al (2019) Predictors of poor functional outcomes and mortality in patients with hip fracture: a systematic review. BMC Musculoskelet Disord 20:568. https://doi.org/10.1186/s12891-019-2950-0

27. Falaschi P, Marsh DR (2017) Orthogeriatrics. Springer Nature

28. Hansson S, Nemes S, Kärrholm J, Rogmark C (2017) Reduced risk

of reoperation after treatment of femoral neck fractures with total hip arthroplasty: A matched pair analysis. Acta Orthop 88:500–504. https://doi.org/10.1080/17453674.2017.1348095

29. Hansson S, Bülow E, Garland A, et al (2020) More hip complications after total hip arthroplasty than after hemi-arthroplasty as hip fracture treatment: analysis of 5,815 matched pairs in the Swedish Hip Arthroplasty Register. Acta Orthop 91:133–138. https://doi.org/10.1080/17453674.2019.1690339

30. Ravi B, Pincus D, Khan H, et al (2019) Comparing Complications and Costs of Total Hip Arthroplasty and Hemiarthroplasty for Femoral Neck Fractures. J Bone Jt Surg 101:572–579. https://doi.org/http://dx.doi.org/10.2106/JBJS.18.00539

31. Leonardsson O, Rolfson O, Hommel A, Akesson K (2013) Patient-Reported Outcome After Displaced Femoral Neck Fracture. J Bone Jt Surg 95:1693–1699. https://doi.org/http://dx.doi.org/10.2106/JBJS.L.00836

32. Rogmark C, Leonardsson O (2016) Hip arthroplasty for the treatment of displaced fractures of the femoral neck in elderly patients. Bone Jt J 98B:291–297. https://doi.org/10.1302/0301-620X.98B3.36515

33. Li N, Zhong L, Wang C, et al (2020) Cemented versus uncemented hemi-arthroplasty for femoral neck fractures in elderly patients: A systematic review and meta-analysis of randomized controlled trials. Med (United States) 99:1–10. https://doi.org/10.1097/MD.0000000000019039

34. Talsnes O, Vinje T, Gjertsen JE, et al (2013) Perioperative mortality in hip fracture patients treated with cemented and uncemented hemiprosthesis: A register study of 11,210 patients. Int Orthop 37:1135–1140. https://doi.org/10.1007/s00264-013-1851-3

35. Kristensen TB, Dybvik E, Kristoffersen M, et al (2020) Cemented or uncemented hemiarthroplasty for femoral neck fracture? Data from the Norwegian Hip Fracture Register. Clin Orthop Relat Res

478:90–100. https://doi.org/10.1097/CORR.0000000000000826

36. Barenius B, Inngul C, Alagic Z, Enocson A (2018) A randomized controlled trial of cemented versus cementless arthroplasty in patients with a displaced femoral neck fracture. Bone Jt J 100B:1087–1093. https://doi.org/10.1302/0301-620X.100B8.BJJ-2017-1593.R1

37. Viberg B, Overgaard S, Lauritsen J, Ovesen O (2013) Lower reoperation rate for cemented hemiarthroplasty than for uncemented hemiarthroplasty and internal fixation following femoral neck fracture: 12- to 19-year follow-up of patients aged 75 years or more. Acta Orthop 84:254–259. https://doi.org/10.3109/17453674.2013.792033

38. Duijnisveld BJ, Koenraadt KLM, van Steenbergen LN, Bolder SBT (2020) Mortality and revision rate of cemented and uncemented hemiarthroplasty after hip fracture: an analysis of the Dutch Arthroplasty Register (LROI). Acta Orthop 91:408–413. https://doi.org/10.1080/17453674.2020.1752522

39. Palm H, Krasheninnikoff M, Holck K, et al (2012) A new algorithm for hip fracture surgery. Reoperation rate reduced from 18 % to 12 % in 2,000 consecutive patients followed for 1 year. Acta Orthop 83:26–30. https://doi.org/10.3109/17453674.2011.652887

40. Nuber S, Schönweiss T, Rüter A (2003) Stabilisierung von instabilen trochantären mehrfragmentfrakturen. Vergleich zwischen PFN und DHS mit trochanterabstützplatte. Unfallchirurg 106:39–47. https://doi.org/10.1007/s00113-002-0476-6

41. Klinger HM, Baums MH, Eckert M, Neugebauer R (2005) Eine vergleichende untersuchung der versorgung instabiler per- und intertrochantärer femurfrakturen mittels DHS-osteosynthese unter verwendung der trochanterabstützplatte und dem proximalen femurnagel (PFN). Zentralbl Chir 130:301–306. https://doi.org/10.1055/s-2005-836784

42. Yu X, Wang H, Duan X, et al (2018) Intramedullary versus extramedullary internal fixation for unstable intertrochanteric

fracture, a meta-analysis. Acta Orthop Traumatol Turc 52:299–307. https://doi.org/10.1016/j.aott.2018.02.009

43. Li A, Zhang W, Wang J, et al (2017) Intramedullary and extramedullary fixations for the treatment of unstable femoral intertrochanteric fractures: a meta-analysis of prospective randomized controlled trials. Int Orthop 403–413. https://doi.org/10.1007/s00264-016-3308-y

44. Matre K, Vinje T, Havelin LI, et al (2013) TRIGEN INTERTAN Intramedullary Nail Versus Sliding Hip Screw - A Prospective, Randomized Multicenter Study on Pain, Function, and Complications in 684 Patients with an Intertrochanteric or Subtrochanteric Fracture and One Year of Follow-up. J Bone Jt Surg Am 95:200–208

45. Royal College of Physicians (2019) The National Hip Fracture Database. https://www.nhfd.co.uk/. Accessed 17 Aug 2020

46. Australian & New Zealand Hip Fracture Registry (2019) Annual report 2019

47. Sweden's National Quality Register (2018) Annual report 2018

48. Sarimo S, Pajulammi H, Jämsen E (2020) Process-related predictors of readmissions and mortality following hip fracture surgery: a population-based analysis. Eur Geriatr Med 11:613–622. https://doi.org/10.1007/s41999-020-00307-0

49. Kristensen PK, Thillemann TM, Søballe K, Johnsen SP (2016) Are process performance measures associated with clinical outcomes among patients with hip fractures? A population-based cohort study. Int J Qual Heal Care 28:698–708. https://doi.org/10.1093/intqhc/mzw093

50. Hughes AJ, Hennessy O, Brennan L, et al (2019) How accurate is the data provided to the Irish hip fracture database? Ir J Med Sci 188:13–18

51. Cundall-Curry D, Lawrence JE, Fountain DM, Gooding CR (2016) Data errors in the National Hip Fracture Database. bone Jt J 98-

B:1406–1409. https://doi.org/10.1302/0301-620X.98B10.37089

52. Lawrence JE, Cundall-Curry D, Stewart ME, et al (2019) The use of an electronic health record system reduces errors in the National Hip Fracture Database. Age Ageing 48:285–290. https://doi.org/10.1093/ageing/afy177

53. Kristensen PK, Röck ND, Christensen HC, Pedersen AB (2020) The danish multidisciplinary hip fracture registry 13-year results from a population-based cohort of hip fracture patients. Clin Epidemiol 12:9–21. https://doi.org/10.2147/CLEP.S231578

54. Seys D, Sermon A, Sermeus W, et al (2018) Recommended care received by geriatric hip fracture patients: where are we now and where are we heading? Arch Orthop Trauma Surg 138:1077–1087. https://doi.org/10.1007/s00402-018-2939-4

55. Oakley B, Nightingale J, Moran CG, Moppett IK (2017) Does achieving the best practice tariff improve outcomes in hip fracture patients? An observational cohort study. BMJ Open 7:. https://doi.org/10.1136/bmjopen-2016-014190

56. Farrow L, Hall A, Wood AD, et al (2018) Quality of Care in Hip Fracture Patients: The relationsship between adherence to National standards and improved outcomes. J Bone Jt Surg Am 100:751–757. https://doi.org/10.2106/JBJS.17.00884

57. Flikweert ER, Diercks RL, Izaks GJ, et al (2019) Strict adherence to evidence-based protocol in choice of implants and surgical technique leads to fewer hip fracture reoperations. PLoS One 14:1–9

58. Öztürk B, Johnsen SP, Röck ND, et al (2019) Impact of comorbidity on the association between surgery delay and mortality in hip fracture patients: A Danish nationwide cohort study. Injury 50:424–431. https://doi.org/10.1016/j.injury.2018.12.032

59. Hongisto MT, Nuotio MS, Luukkaala T, et al (2019) Delay to Surgery of Less Than 12 Hours Is Associated With Improved Short- and Long-Term Survival in Moderate- to High-Risk Hip

Fracture Patients. Geriatr Orthop Surg Rehabil 10:215145931985314. https://doi.org/10.1177/2151459319853142

60. Lizaur-Utrilla A, Gonzalez-Navarro B, Vizcaya-Moreno MF, et al (2019) Reasons for delaying surgery following hip fractures and its impact on one year mortality. Int Orthop 43:441–448. https://doi.org/10.1007/s00264-018-3936-5

61. Royal College of Physicians (2019) National Hip Fracture Database (NHFD) annual report 2019

62. Ranhoff AH, Saltvedt I, Frihagen F, et al (2019) Interdisciplinary care of hip fractures. Orthogeriatric models, alternative models, interdisciplinary teamwork. Best Pract Res Clin Rheumatol 33:205–226. https://doi.org/10.1016/j.berh.2019.03.015

63. Baroni M, Serra R, Boccardi V, et al (2019) The orthogeriatric comanagement improves clinical outcomes of hip fracture in older adults. Osteoporos Int 30:907–916

64. Middleton M, Wan B, Assuncao R da (2017) Improving hip fracture outcomes with integrated orthogeriatric care: a comparison between two accepted orthogeriatric models. Age Ageing 46:465–470. https://doi.org/10.1093/ageing/afw232

65. Kristensen PK, Thillemann TM, Søballe K, Johnsen SP (2016) Can improved quality of care explain the success of orthogeriatric units? A population-based cohort study. Age Ageing 45:66–71. https://doi.org/10.1093/ageing/afv155

66. Taraldsen K, Thingstad P, Sletvold O, et al (2015) The long-term effect of being treated in a geriatric ward compared to an orthopaedic ward on six measures of free-living physical behavior 4 and 12 months after a hip fracture - a randomised controlled trial. BMC Geriatr 1–8. https://doi.org/10.1186/s12877-015-0153-6

67. Thingstad P, Taraldsen K, Saltvedt I, et al (2016) The long-term effect of comprehensive geriatric care on gait after hip fracture: the Trondheim Hip Fracture Trial - a randomised controlled trial. Osteoporos Int 27:933–942. https://doi.org/10.1007/s00198-015-3313-9

68. Ban I, Palm H, Birkelund L, et al (2014) Implementing, Adapting, and Validating an Evidence-Based Algorithm for Hip Fracture Surgery. J Orthop Trauma 28:21–26. https://doi.org/10.1097/BOT.0b013e3182a4aa6

69. Egol KA, Marcano AI, Tejwani NC, et al (2012) Can the use of an evidence-based algorithm for the treatment of intertrochanteric fractures of the hip maintain quality at a reduced cost ? Bone Jt J 96-B:1192–1197. https://doi.org/10.1302/0301-620X.96B9.34153

70. Kates SL, Behrend C, Mendelson DA, et al (2015) Hospital readmission after hip fracture. Arch Orthop Trauma Surg 135:329–337. https://doi.org/10.1007/s00402-014-2141-2

71. Mosk CA, Mus M, Vroemen JP, et al (2017) Dementia and delirium , the outcomes in elderly hip fracture patients. Clin Interv Aging 10:421–430

72. Flikweert ER, Wendt KW, Diercks RL, et al (2018) Complications after hip fracture surgery: are they preventable? Eur J Trauma Emerg Surg 44:573–580. https://doi.org/10.1007/s00068-017-0826-2

73. Hsu C, Chen H, Chen H, et al (2021) A national study on long-term osteoporosis therapy and risk of recurrent fractures in patients with hip fracture. Arch Gerontol Geriatr 88:104021. https://doi.org/10.1016/j.archger.2020.104021

74. Dobre R, Niculescu DA, Petca R-C, et al (2021) Adherence to Anti-Osteoporotic Treatment and Clinical Implications after Hip Fracture: A Systematic Review. J Pers Med 11:. https://doi.org/https://doi.org/10.3390/jpm11050341

75. Wing A, Ho H, Wong SH (2020) Osteoporosis and Sarcopenia Second hip fracture in Hong Kong - Incidence, demographics, and mortality. Osteoporos Sarcopenia 6:71–74. https://doi.org/10.1016/j.afos.2020.05.004

76. Trevisan C, Bedogni M, Pavan S, et al (2020) The impact of second hip fracture on rehospitalization and mortality in older adults. Arch Gerontol Geriatr 90:104175.

https://doi.org/10.1016/j.archger.2020.104175

77. Joeris A, Blauth M, Goldhahn J, et al (2017) Expert Consensus on Predictive Parameters for the Occurrence of a Fall and a Contralateral Hip Fracture 1 and 3 Years After Hip Fracture: A Delphi Survey. Geriatr Orthop Surg Rehabil 8:94–98. https://doi.org/10.1177/2151458516687811

78. Siu AL, Penrod JD, Boockvar KS, et al (2006) Early Ambulation After Hip Fracture: Effects on Function and Mortality. Arch Intern Med 166:766–771. https://doi.org/10.1001/archinte.166.7.766

79. Ferris H, Brent L, Coughlan T (2020) Early mobilisation reduces the risk of in-hospital mortality following hip fracture. Eur Geriatr Med 11:527–533. https://doi.org/10.1007/s41999-020-00317-y

80. Friesendorff M Von, Mcguigan FE, Wizert A, Rogmark C (2016) Hip fracture, mortality risk, and cause of death over two decades. Osteoporos Int 27:2945–2953. https://doi.org/10.1007/s00198-016-3616-5

81. Katsoulis M, Benetou V, Karapetyan T, et al (2017) Excess mortality after hip fracture in elderly persons from Europe and the USA: the CHANCES project. J Intern Med 281:300–310. https://doi.org/10.1111/joim.12586

82. Chang W, Lv H, Feng C, et al (2018) Preventable risk factors of mortality after hip fracture surgery: Systematic review and meta-analysis. Int J Surg 52:320–328. https://doi.org/10.1016/j.ijsu.2018.02.061

83. Cher EWL, Allen JC, Howe T Sen, Koh JSB (2019) Comorbidity as the dominant predictor of mortality after hip fracture surgeries. Osteoporos Int 30:2477–2483. https://doi.org/10.1007/s00198-019-05139-8

84. Rohold CK, Lauritzen JB, Jørgensen HL (2021) Causes of death among 93.637 hip fracture patients– data based on the Danish National Registry of causes of death. Eur J Trauma Emerg Surg. https://doi.org/10.1007/s00068-021-01791-0

85. Sheehan KJ, Sobolev B, Chudyk A, et al (2016) Patient and system factors of mortality after hip fracture: a scoping review. BMC Musculoskelet Disord 17:. https://doi.org/10.1186/s12891-016-1018-7

86. Ryan G, Nowak L, Melo L, et al (2020) Anemia at Presentation Predicts Acute Mortality and Need for Readmission Following Geriatric Hip Fracture. JBJS Open Access. https://doi.org/http://dx.doi.org/10.2106/JBJS.OA.20.00048

87. Kristensen MT, Öztürk B, Röck ND, et al (2019) Regaining pre-fracture basic mobility status after hip fracture and association with post-discharge mortality and readmission - a nationwide register study in Denmark. Age Ageing 48:278–284. https://doi.org/10.1093/ageing/afy185

88. Meng D, Bai X, Wu H, et al (2019) Patient and Perioperative Factors Influencing the Functional Outcomes and Mortality in Elderly Hip Fractures. J Investig Surg 0:1–8. https://doi.org/10.1080/08941939.2019.1625985

89. Ingstad F, Solberg LB, Nordsletten L, et al (2021) Vitamin D status and complications, readmissions, and mortality after hip fracture. Osteoporos Int 32:873–881. https://doi.org/10.1007/s00198-020-05739-9

90. Lizaur-Utrilla A, Serna-Berna R, Lopez-Prats FA, Gil-Guillen V (2015) Early rehospitalization after hip fracture in elderly patients: risk factors and prognosis. Arch Orthop Trauma Surg 135:1663–1667. https://doi.org/10.1007/s00402-015-2328-1

91. Sofu H, Üçpunar H, Çamurcu Y, et al (2017) Predictive factors for early hospital readmission and 1-year mortality in elder patients following surgical treatment of a hip fracture. Ulus Travma Acil Cerrahi Derg 23:245–250. https://doi.org/10.5505/tjtes.2016.84404

92. Rutenberg TF, Rutenberg R, Vitenberg M, et al (2020) Prediction of readmissions in the first post-operative year following hip fracture surgery. Eur J Trauma Emerg Surg 46:939–946. https://doi.org/10.1007/s00068-018-0997-5

93. Heyes GJ, Tucker A, Marley D, Foster A (2015) Predictors for Readmission up to 1 Year Following Hip Fracture. Arch Trauma Res 4:. https://doi.org/10.5812/atr.4(2)2015.27123

94. Härstedt M, Rogmark C, Sutton R, et al (2015) Impact of comorbidity on 6-month hospital readmission and mortality after hip fracture surgery. Injury 46:713–718. https://doi.org/10.1016/j.injury.2014.12.024

95. Mathew SA, Gane E, Heesch KC, McPhail SM (2016) Risk factors for hospital re-presentation among older adults following fragility fractures: A systematic review and meta-analysis. BMC Med 14:1–20. https://doi.org/10.1186/s12916-016-0671-x

96. Sutton EL, Kearney RS (2021) What works? Interventions to reduce readmission after hip fracture: A rapid review of systematic reviews. Injury 52:1851–1860. https://doi.org/10.1016/j.injury.2021.04.049

97. Conroy T, Heuzenroeder L, Feo R (2020) In-hospital interventions for reducing readmissions to acute care for adults aged 65 and over: An umbrella review. Int J Qual Heal Care 32:414–430. https://doi.org/10.1093/intqhc/mzaa064

98. Holst L, Peter P, Catherine B, et al (2018) Avoidable readmissions seem to be reduced by early follow - up visits for geriatric patients discharged from hospital. Eur Geriatr Med 9:613–621. https://doi.org/10.1007/s41999-018-0078-7

99. NHS England (2021) Hospital Discharge and Community Support: Policy and Operating Mode

100. Galvin EC, Wills T, Coffey A (2017) Readiness for hospital discharge: A concept analysis. J Adv Nurs 73:2547–2557. https://doi.org/10.1111/jan.13324

101. Mabire C, Bachnick S, Ausserhofer D, Simon M (2019) Patient readiness for hospital discharge and its relationship to discharge preparation and structural factors: A cross-sectional study. Int J Nurs Stud 90:13–20. https://doi.org/10.1016/j.ijnurstu.2018.09.016

102. Halm EA, Magaziner J, Hannan EL, et al (2003) Frequency and impact of active clinical issues and new impairments on hospital discharge in patients with hip fracture. Arch Intern Med 163:107–112. https://doi.org/10.1097/00006416-200307000-00017

103. Nguyen OK, Makam AN, Clark C, et al (2017) Vital Signs Are Still Vital: Instability on Discharge and the Risk of Post-Discharge Adverse Outcomes. J Gen Intern Med 32:42–48. https://doi.org/10.1007/s11606-016-3826-8

104. Chung AS, Hustedt JW, Walker R, et al (2018) Increasing severity of malnutrition is associated with poorer 30-day outcomes in patients undergoing hip fracture surgery. J Orthop Trauma 32:155–160. https://doi.org/10.1097/BOT.0000000000001081

105. Deng J, Wang G, Li J, et al (2021) A systematic review and meta-analysis comparing arthroplasty and internal fixation in the treatment of elderly displaced femoral neck fractures. OTA Int Open Access J Orthop Trauma 4:e087. https://doi.org/10.1097/oi9.0000000000000087

106. Bartels S, Gjertsen JE, Frihagen F, et al (2018) High failure rate after internal fixation and beneficial outcome after arthroplasty in treatment of displaced femoral neck fractures in patients between 55 and 70 years: An observational study of 2,713 patients reported to the Norwegian Hip Fracture Regis. Acta Orthop 89:53–58. https://doi.org/10.1080/17453674.2017.1376514

107. Rogmark C, Johnell O (2006) Primary arthroplasty is better than internal fixation of displaced femoral neck fractures: A meta-analysis of 14 randomized studies with 2,289 patients. Acta Orthop 77:359–367. https://doi.org/10.1080/17453670610046262

108. Gjertsen JE, Vinje T, Engesæter LB, et al (2010) Internal screw fixation compared with bipolar hemiarthroplasty for treatment of displaced femoral neck fractures in elderly patients. J Bone Jt Surg - Ser A 92:619–628. https://doi.org/10.2106/JBJS.H.01750

109. Wahlsten LR, Palm H, Gislason GH, Brorson S (2021) Sex differences in incidence rate, and temporal changes in surgical management and adverse events after hip fracture surgery in

Denmark 1997–2017: a register-based study of 153,058 hip fracture patients. Acta Orthop 92:424–430. https://doi.org/10.1080/17453674.2021.1923256

110. Stockton DJ, O'Hara LM, O'Hara NN, et al (2019) 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 90:21–25. https://doi.org/10.1080/17453674.2018.1558380

111. Moerman S, Mathijssen NMC, Tuinebreijer WE, et al (2018) Hemiarthroplasty and total hip arthroplasty in 30,830 patients with hip fractures: data from the Dutch Arthroplasty Register on revision and risk factors for revision. Acta Orthop 89:509–514. https://doi.org/10.1080/17453674.2018.1499069

112. Jobory A, Kärrholm J, Overgaard S, et al (2019) Reduced Revision Risk for Dual-Mobility Cup in Total Hip Replacement Due to Hip Fracture A Matched-Pair Analysis of 9,040 Cases from the Nordic Arthroplasty Register Association (NARA). J Bone Jt Surg 101:1278–1285

113. Tabori-Jensen S, Hansen TB, Bøvling S, et al (2018) Good function and high patient satisfaction at mean 2.8 years after dual mobility THA following femoral neck fracture: a cross-sectional study of 124 patients. Clin Interv Aging 13:615–621

114. Blomfeldt R, Törnkvist H, Ponzer S, et al (2006) Displaced femoral neck fractur : comparison of primary total hip replacement with secondary replacement after failed internal fixation: A 2-year follow-up of 84 patients. Acta Orthop 77:638–643. https://doi.org/10.1080/17453670610012728

115. Frihagen F, Madsen JE, Aksnes E, et al (2007) Comparison of re-operation rates following primary and secondary hemiarthroplasty of the hip. Injury 38:815–819. https://doi.org/10.1016/j.injury.2006.09.020

116. Socci AR, Casemyr NE, Leslie MP, Baumgaertner MR (2017) Implant options for the treatment of intertrochanteric fractures of the hip - rationale, evidence, and recommendations. Bone Jt J 99-

B:128–133. https://doi.org/10.1302/0301-620X.99B1.BJJ-2016-0134.R1

117. Parker MJ (2017) Sliding hip screw versus intramedullary nail for trochanteric hip fractures; a randomised trial of 1000 patients with presentation of results related to fracture stability. Injury 48:2762–2767. https://doi.org/10.1016/j.injury.2017.10.029

118. Palm H, Jacobsen S, Sonne-Holm S, Gebuhr P (2007) Integrity of the lateral femoral wall in intertrochanteric hip fractures: An important predictor of a reoperation. J Bone Jt Surg 89:470–475. https://doi.org/10.2106/00004623-200711000-00039

119. Tucker A, Donnelly KJ, Rowan C, et al (2018) Is the Best Plate a Nail? A Review of 3230 Unstable Intertrochanteric Fractures of the Proximal Femur. J Orthop Trauma 32:53–60. https://doi.org/10.1097/BOT.0000000000001038

120. Parker MJ, Handoll HHG (2010) Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults. Cochrane Database Syst Rev 2010:. https://doi.org/10.1002/14651858.CD000093.pub5.

121. Babst R, Renner N, Biedermann M, et al (1998) Clinical results using the trochanter stabilizing plate (TSP): The modular extension of the dynamic hip screw (DHS) for internal fixation of selected unstable intertrochanteric fractures. J Orthop Trauma 12:392–399

122. Madsen JE, Næss L, Aune AK, et al (1998) Dynamic Hip Screw with Trochanteric Stabilizing Plate in the Treatment of Unstable Proximal Femoral Fractures: A Comparative Study with the Gamma Nail and Compression Hip Screw. J Orthop Trauma 12:241–248. https://doi.org/10.1097/00005131-199805000-00005

123. Selim A, Beder FK, Algeaidy IT, et al (2020) Management of unstable pertrochanteric fractures, evaluation of forgotten treatment options. SICOT-J 6:

124. Müller F, Doblinger M, Kottmann T, Füchtmeier B (2020) PFNA and DHS for AO/OTA 31-A2 fractures: radiographic

measurements, morbidity and mortality. Eur J Trauma Emerg Surg 46:947–953. https://doi.org/10.1007/s00068-019-01251-w

125. Gregersen M, Krogshede A, Brink O, Damsgaard EM (2015) Prediction of Reoperation of Femoral Neck Fractures Treated With Cannulated Screws in Elderly Patients. Geriatr Orthop Surg Rehabil 6:322–327. https://doi.org/10.1177/2151458515614369

126. Nyholm AM, Palm H, Sandholdt H, et al (2020) Risk of reoperation within 12 months following osteosynthesis of a displaced femoral neck fracture is linked mainly to initial fracture displacement while risk of death may be linked to bone quality: a cohort study from Danish Fracture Database. Acta Orthop 91:1–75. https://doi.org/10.1080/17453674.2019.1698503

127. Bojan AJ, Beimel C, Taglang G, et al (2013) Critical factors in cut-out complication after gamma nail treatment of proximal femoral fractures. BMC Musculoskelet Disord 14:1–9. https://doi.org/10.1186/1471-2474-14-1

128. Yamamoto N, Tomita Y, Noda T, et al (2021) Reduction quality and nail fixation ratio as bone-implant stability factors associated with reoperation for trochanteric fractures. Injury 52:1813–1818. https://doi.org/10.1016/j.injury.2021.04.048

129. Authen AL, Dybvik E, Furnes O, Gjertsen JE (2018) 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 89:496–502. https://doi.org/10.1080/17453674.2018.1481588

130. Nyholm AM, Gromov K, Palm H, et al (2015) Time to Surgery Is Associated with Thirty-Day and Ninety-Day Mortality After Proximal Femoral Fracture. J Bone Jt Surg 97:1333–1339. https://doi.org/http://dx.doi.org/10.2106/JBJS.O.00029

131. Palm H, Jacobsen S, Krasheninnikoff M, et al (2007) Influence of surgeon's experience and supervision on re-operation rate after hip fracture surgery. Injury 38:775–779. https://doi.org/10.1016/j.injury.2006.07.043

132. Okike K, Chan PH, Paxton EW (2017) Effect of surgeon and hospital volume on morbidity and mortality after hip fracture. J Bone Jt Surg - Am Vol 99:1547–1553. https://doi.org/10.2106/JBJS.16.01133

133. Gamboa-Arango A, Duaso E, Malafarina V, et al (2020) Prognostic factors for discharge to home and residing at home 12 months after hip fracture: an Anoia hip study. Aging Clin Exp Res 32:925–933. https://doi.org/10.1007/s40520-019-01273-9

134. De Medeiros MMD, Carletti TM, Magno MB, et al (2020) Does the institutionalization influence elderly's quality of life? A systematic review and meta-analysis. BMC Geriatr 20:1–25. https://doi.org/10.1186/s12877-020-1452-0

135. Osnes EK, Lofthus CM, Meyer HE, et al (2004) Consequences of hip fracture on activities of daily life and residential needs. Osteoporos Int 15:567–574. https://doi.org/10.1007/s00198-003-1583-0

136. Magaziner J, Hawkes W, Hebel JR, et al (2000) Recovery From Hip Fracture in Eight Areas of Function. J Gerontol 55:M498–M507. https://doi.org/10.1093/gerona/55.9.M498

137. Fischer K, Trombik M, Freystätter G, et al (2019) Timeline of functional recovery after hip fracture in seniors aged 65 and older: a prospective observational analysis. Osteoporos Int 30:1371–1381. https://doi.org/10.1007/s00198-019-04944-5

138. Martinez-Reig M, Ahmad L, Duque G (2012) The Orthogeriatrics Model of Care: Systematic Review of Predictors of Institutionalization and Mortality in Post-Hip Fracture Patients and Evidence for Interventions. J Am Med Dir Assoc 13:770–777. https://doi.org/10.1016/j.jamda.2012.07.011

139. Kronborg L, Bandholm T, Kehlet H, Kristensen MT ang. (2015) Municipality-based physical rehabilitation after acute hip fracture surgery in Denmark. Dan Med J 62:A5023

140. Fitzgerald M, Blake C, Askin D, et al (2018) Mobility one week after a hip fracture - can it be predicted? Int J Orthop Trauma Nurs

29:3–9. https://doi.org/10.1016/j.ijotn.2017.11.001

141. Parker MJ, Palmer CR (1993) A NEW MOBILITY AFTER SCORE FOR PREDICTING MORTALITY. J Bone Jt Surg Br 75:797–798

142. Kristensen MT, Foss NB, Kehlet H (2007) A new mobility score for predicting mortality after hip fracture. Physi 87:24–30

143. Kristensen MT, Foss NB, Kehlet H (2007) Timed “up & go” test as a predictor of falls within 6 months after hip fracture surgery. Phys Ther 87:24–30. https://doi.org/10.1016/0308-5953(77)90120-9

144. Foss N, Kristensen M, Kehlet H (2006) Prediction of postoperative morbidity, mortality and rehabilitation in hip fracture patients: the cumulated ambulation score. Clin Rehabil 20:701–708

145. Kristensen M, Andersen L, Bech-Jensen R, et al (2009) High intertester reliability of the cumulated ambulation score for the evaluation of basic mobility in patients with hip fracture. Clin Rehabil 23:1116–1123. https://doi.org/10.1177/0269215509342330

146. Podsiadlo D, Richardson S (1991) The timed “Up & Go”: A test of basic functional mobility for frail elderly persons. JAGS 39:142–8

147. Kristensen MT, Bandholm T, Holm B, Ekdahl C (2009) Timed Up & Go Test Score in Patients With Hip Fracture Is Related to The Type of Walking Aid. Arch Phys Med Rehabil 90:1760–1765. https://doi.org/10.1016/j.apmr.2009.05.013

148. Wüest S, Masse F, Aminian K, et al (2016) Validity of inertial sensor-based Timed “Up and Go” test in individuals affected by stroke. In: J. Rehabil. Res. Dev. https://science.gaitup.com/publications/tugstroke/

149. Kristensen MT, Bandholm T, Foss NB, et al (2008) High inter-tester reliability of the new mobility score in patients with hip fracture. J Rehabil Med 589–591. https://doi.org/10.2340/16501977-0217

150. Kristensen MT, Kehlet H (2018) The basic mobility status upon acute hospital discharge is an independent risk factor for mortality up to 5 years after hip fracture surgery - Survival rates of 444 pre-fracture ambulatory patients evaluated with the Cumulated Ambulation Score. Acta Orthop 89:47–52. https://doi.org/10.1080/17453674.2017.1382038

151. Salkeld G, Cameron ID, Cumming RG, et al (2006) Quality of life related to fear of falling and hip fracture in older women: a time trade off study. BMJ 320:341–346

152. Prieto-Alhambra D, Moral-Cuesta D, Palmer A, et al (2019) The impact of hip fracture on health-related quality of life and activities of daily living: the SPARE-HIP prospective cohort study. Arch Osteoporos 14:. https://doi.org/10.1007/s11657-019-0607-0

153. Gjertsen J, Vinje T, Lie SA, et al (2008) Patient satisfaction, pain, and quality of life 4 months after displaced femoral neck fractures: A comparison of 663 fractures treated with internal fixation and 906 with bipolar hemiarthroplasty reported to the Norwegian Hip Fracture Register Patient. Acta Orthop 79:594–601. https://doi.org/10.1080/17453670810016597

154. Peeters CMM, Visser E, Ree CLP Van De, et al (2019) Quality of life after hip fracture in the elderly: A systematic literature review. Injury 47:1369–1382. https://doi.org/10.1016/j.injury.2016.04.018

155. Kristensen TB, Vinje T, Havelin LI, et al (2017) Posterior approach compared to direct lateral approach resulted in better patient-reported outcome after hemiarthroplasty for femoral neck fracture: 20,908 patients from the Norwegian Hip Fracture Register. Acta Orthop 88:29–34. https://doi.org/10.1080/17453674.2016.1250480

156. Orive M, Aguirre U, Garc S, et al (2015) Changes in health-related quality of life and activities of daily living after hip fracture because of a fall in elderly patients : a prospective cohort study. Int J Clin Pr 69:491–500. https://doi.org/10.1111/ijcp.12527

157. Kristoffersen MH, Dybvik EH, Steihaug OM, et al (2021) Patient-reported outcome measures after hip fracture in patients with

chronic cognitive impairment - Results from 34,675 patients in the Norwegian Hip Fracture register. Bone Jt Open 2:454–465. https://doi.org/10.1302/2633-1462.27.BJO-2021-0058.R1

158. The Euroqol Group (1990) EuroQol - a new facility for the measurement of health-related quality of life. Health Policy (New York) 16:199–208. https://doi.org/10.1016/0168-8510(90)90421-9

159. Laucis NC, Hays RD, Bhattacharyya T (2014) Scoring the SF-36 in orthopaedics: A brief guide. J Bone Jt Surg - Am Vol 97:1628–1634. https://doi.org/10.2106/JBJS.O.00030

160. Gandek B, Ware J, Aaronson N, et al (1998) Cross-Validation of Item Selection and Scoring for the SF-12 Health Survey in Nine Countries Results from the IQOLA Project. J Clin Epidemiol 51:1171–1178. https://doi.org/10.1016/s0895-4356(98)00109-7

161. Paulsen A, Odgaard A, Overgaard S (2012) Translation, cross-cultural adaptation and validation of the Danish version of the Oxford hip score: Assessed against generic and disease-specific questionnaires. Bone Joint Res 1:225–33. https://doi.org/10.1302/2046-3758.19.2000076

162. World Health Organization Body mass index - BMI. https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi. Accessed 9 Sep 2021

163. Laulund AS, Lauritzen JB, Duus BR, et al (2012) Routine blood tests as predictors of mortality in hip fracture patients. Injury 43:1014–1020. https://doi.org/10.1016/j.injury.2011.12.008

164. Poe SS, Cvach M, Dawson PB, et al (2007) The Johns Hopkins fall risk assessment tool: Postimplementation evaluation. J Nurs Care Qual 22:293–298. https://doi.org/10.1097/01.NCQ.0000290408.74027.39

165. Poe SS, Dawson PB, Cvach M, et al (2018) The Johns Hopkins Fall Risk Assessment Tool: A Study of Reliability and Validity. J Nurs Care Qual 33:10–19. https://doi.org/10.1097/NCQ.0000000000000301

166. Evans EM (1949) The treatment of trochanteric fractures of the femur. J Bone Jt Surg Br 31B:190–203

167. Frandsen CF, Glassou EN, Stilling M, Hansen TB (2021) Poor adherence to guidelines in treatment of fragile and cognitively impaired patients with hip fracture: a descriptive study of 2,804 patients. Acta Orthop 1–7. https://doi.org/10.1080/17453674.2021.1925430

168. Frandsen CF, Stilling M, Glassou EN, et al (2021) Active clinical issues at discharge predict readmission within 30 days and one year following hip fracture surgery. Submitt to Eur Geriatr Med December:

169. Frandsen CF, Stilling M, Glassou EN, Hansen TB (2022) The majority of community-dwelling hip fracture patients return to independent living with minor increase in care needs – A prospective cohort study. Submitt to AOTS January:

170. Frandsen CF, Glassou EN, Stilling M, Hansen TB (2021) Malnutrition, poor function and comorbidities predict mortality up to one year after hip fracture: a cohort study of 2800 patients. Eur Geriatr Med Epub ahead: https://doi.org/10.1007/s41999-021-00598-x

171. Frandsen CF, Stilling M, Glassou EN, Hansen TB (2022) Intramedullary nail versus dynamic hip screw with stabilising trochanteric plate in treatment of unstable intertrochanteric fractures. Submitt to January:

172. Danish Multidisciplinary Hip Fracture Registry (2019) Annual report 2019

173. Dansk Ortopædisk selskab (2008) Referenceprogram for Patienter med Hoftebrud (2008)

174. Robinson R, Bhattarai M, Hudali T (2019) Vital sign abnormalities on discharge do not predict 30-day readmission. Clin Med Res 17:63–71. https://doi.org/10.3121/cmr.2019.1461

175. Arshi A, Lai W, Iglesias B, et al (2021) Blood transfusion rates

and predictors following geriatric hip fracture surgery. HIP Int 31:272–279. https://doi.org/10.1177/1120700019897878

176. Good L, Peterson E, Lisander B (2003) Tranexamic acid decreases external blood loss but not hidden blood loss in total knee replacement. Br J Anaesth 90:596–599. https://doi.org/10.1093/bja/aeg111

177. Foss NB, Kehlet H (2006) Hidden blood loss after surgery for hip fracture. J Bone Jt Surg Br 88:1053–1059. https://doi.org/10.1302/0301-620X.88B8.17534

178. Nadler SB, Hidalgo JU, Bloch T (1962) Prediction of blood volume in normal human adults. Surgery 51:224–232

179. Lisander B, Ivarsson I, Jacobsson SA (1998) Intraoperative autotransfusion is associated with modest reduction of allogeneic transfusion in prosthetic hip surgery. Acta Anaesthesiol Scand 42:707–712

180. Bischoff HA, Stähelin HB, Monsch AU, et al (2003) Identifying a cut-off point for normal mobility: a comparison of the timed ‘up and go’ test in community-dwelling and institutionalised elderly women. Age Ageing 32:315–320

181. Tsang C, Boulton C, Burgon V, et al (2017) Predicting 30-day mortality after hip fracture surgery - Evaluation of the National Hip Fracture Database case-mix adjustment model. Bone Jt Res 6:550–556. https://doi.org/10.1302/2046-3758.69.BJR-2017-0020.R1

182. Liu Z, Han N, Xu H, et al (2016) Incidence of venous thromboembolism and hemorrhage related safety studies of preoperative anticoagulation therapy in hip fracture patients undergoing surgical treatment: a case-control study. BMC Musculoskelet Disord 17:1–8. https://doi.org/10.1186/s12891-016-0917-y

183. Leer-Salvesen S, Dybvik E, Engesaeter LB, et al (2018) Low-molecular-weight heparin for hip fracture patients treated with osteosynthesis: should thromboprophylaxis start before or after

surgery? An observational study of 45,913 hip fractures reported to the Norwegian Hip Fracture Register. Acta Orthop 89:615–621. https://doi.org/10.1080/17453674.2018.1519101

184. Overgaard M, Andersen PK, Parner ET (2015) Regression analysis of censored data using pseudo-observations: An update. Stata J 15:809–821. https://doi.org/10.1177/1536867x1501500313

185. Mortensen LM, Hansen CP, Overvad K, et al (2018) The Pseudo-observation analysis of time-to-event data. example from the Danish Diet, Cancer and Health Cohort illustrating assumptions, model validation and interpretation of results. Epidemiol Method 7:1–15. https://doi.org/10.1515/em-2017-0015

186. Miettinen OS (1974) Proportion of disease caused or prevented by a given exposure, trait or intervention. Am J Epidemiol 99:325–332. https://doi.org/10.1093/oxfordjournals.aje.a121617

187. Hanley JA (2001) A heuristic approach to the formulas for population attributable fraction. J Epidemiol Community Health 55:508–514. https://doi.org/10.1136/jech.55.7.508

188. Neuman MD, Silber JH, Passarella MA, Werner RM (2017) Comparing the contributions of acute and post-acute care facility characteristics to outcomes after hospitalization for hip fracture. Med Care 55:411–420. https://doi.org/10.1097/MLR.0000000000000664.Comparing

189. Björkelund K, Hommel A, Thorngren K, et al (2009) Factors at admission associated with 4 months outcome in elderly patients with hip fracture. AANA 77:49–58

190. Kannegaard PN, van der Mark S, Eiken P, Abrahamsen B (2010) Excess mortality in men compared with women following a hip fracture. National analysis of comedications, comorbidity and survival. Age Ageing 39:203–209. https://doi.org/10.1093/ageing/afp221

191. Barahona M, Barrientos C, Cavada G, et al (2020) Survival analysis after hip fracture: higher mortality than the general population and delayed surgery increases the risk at any time. HIP

Int 30:54–58. https://doi.org/10.1177/1120700020938029

192. Uriz-Otano F, Pla-Vidal J, Tiberio-López G, Malafarina V (2016) Factors associated to institutionalization and mortality over three years, in elderly people with a hip fracture - An observational study. Maturitas 89:9–15. https://doi.org/10.1016/j.maturitas.2016.04.005

193. Hershkovitz A, Rutenberg TF (2021) Are extracapsular and intracapsular hip-fracture patients two distinct rehabilitation subpopulations? Disabil Rehabil 13:1–6. https://doi.org/10.1080/09638288.2021.1919214

194. Stacey J, Bush C, DiPasquale T (2021) The hidden blood loss in proximal femur fractures is sizeable and significant. J Clin Orthop Trauma 16:239–243. https://doi.org/10.1016/j.jcot.2021.02.012

195. Sheehan KJ, Sobolev B, Villán Villán YF, Guy P (2017) Patient and system factors of time to surgery after hip fracture: A scoping review. BMJ Open 7:1–8. https://doi.org/10.1136/bmjopen-2017-016939

196. Khan MA, Hossain FS, Dashti Z, Muthukumar N (2012) Causes and predictors of early re-admission after surgery for a fracture of the hip. J Bone Jt Surg Br 94 B:690–697. https://doi.org/10.1302/0301-620X.94B5.28933

197. Yli-Kyyny TT, Sund R, Heinänen M, et al (2019) Risk factors for early readmission due to surgical complications after treatment of proximal femoral fractures – A Finnish National Database study of 68,800 patients. Injury 50:403–408. https://doi.org/10.1016/j.injury.2018.10.030

198. Sheehan KJ, Williamson L, Alexander J, et al (2018) Prognostic factors of functional outcome after hip fracture surgery: a systematic review. Age Ageing 47:661–670. https://doi.org/10.1093/ageing/afy057

199. Beaudart C, Dawson A, Shaw SC, et al (2017) Nutrition and physical activity in the prevention and treatment of sarcopenia: systematic review. Osteoporos Int. https://doi.org/10.1007/s00198-

017-3980-9

200. Koren-Hakim T, Weiss A, Hershkovitz A, et al (2012) The relationship between nutritional status of hip fracture operated elderly patients and their functioning, comorbidity and outcome. Clin Nutr 31:917–921. https://doi.org/10.1016/j.clnu.2012.03.010

201. Inoue T, Maeda K, Nagano A, et al (2020) Undernutrition, Sarcopenia, and Frailty in Fragility Hip Fracture: Advanced Strategies for Improving Clinical Outcomes. Nutrients 12:1–26. https://doi.org/https://doi.org/10.3390/nu12123743

202. Malafarina V, Uriz-otano F, Malafarina C, et al (2017) Effectiveness of nutritional supplementation on sarcopenia and recovery in hip fracture patients. A multi-centre randomized trial. Maturitas 101:42–50. https://doi.org/10.1016/j.maturitas.2017.04.010

203. Akinleye SD, Garofolo G, Culbertson MD, et al (2018) The Role of BMI in Hip Fracture Surgery. Geriatr Orthop Surg Rehabil 9:1–6. https://doi.org/10.1177/2151458517747414

204. Cross MB, Yi PH, Thomas CF, et al (2014) Evaluation of malnutrition in orthopaedic surgery. J Am Acad Orthop Surg 22:193–199. https://doi.org/10.5435/JAAOS-22-03-193

205. Bharadwaj S, Ginoya S, Tandon P, et al (2016) Malnutrition: Laboratory markers vs nutritional assessment. Gastroenterol Rep 4:272–280. https://doi.org/10.1093/gastro/gow013

206. Bohl DD, Shen MR, Hannon CP, et al (2017) Serum Albumin Predicts Survival and Postoperative Course Following Surgery for Geriatric Hip Fracture. J Bone Jt Surg Am 99:2110–2118. https://doi.org/10.2106/JBJS.16.01620

207. Daly BJO, Walsh JC, Quinlan JF, et al (2010) Serum albumin and total lymphocyte count as predictors of outcome in hip fractures. Clin Nutr 29:89–93. https://doi.org/10.1016/j.clnu.2009.07.007

208. Müller M, Gutwerk A, Greve F, et al (2020) The Association between High Body Mass Index and Early Clinical Outcomes in

Patients with Proximal Femur Fractures. J Clin Med 9:2076. https://doi.org/10.3390/jcm9072076

209. Basques BA, Bohl DD, Golinvaux NS, et al (2015) Postoperative length of stay and 30-day readmission after geriatric hip fracture: An analysis of 8434 patients. J Orthop Trauma 29:e115–e120. https://doi.org/10.1097/BOT.0000000000000222

210. Rea J, Walters K, Avgerinou C (2019) How effective is nutrition education aiming to prevent or treat malnutrition in community-dwelling older adults? A systematic review. Eur Geriatr Med 10:339–358. https://doi.org/10.1007/s41999-019-00172-6

211. Hernández AMR, Alarcón T, Menéndez-Colino R, et al (2020) Factors affecting exercise program adherence in patients with acute hip fracture and impact on one-year survival. Brazilian J Phys Ther 24:479–487. https://doi.org/10.1016/j.bjpt.2019.07.008

212. Perry DC, Metcalfe D, Griffin XL, Costa ML (2016) Inequalities in use of total hip arthroplasty for hip fracture: Population based study. BMJ 353:. https://doi.org/10.1136/bmj.i2021

213. Schrøder CK, Hjelholt TJ, Madsen M, et al (2021) Comorbidity and quality of in-hospital care for hip fracture patients. In: Danish Orthopaedic Society Congress. Copenhagen, p 53

214. Skoogh O, Tsikandylakis G, Mohaddes M, et al (2019) Contemporary posterior surgical approach in total hip replacement: still more reoperations due to dislocation compared with direct lateral approach? An observational study of the Swedish Hip Arthroplasty Register including 156,979 hips. Acta Orthop 90:411–416. https://doi.org/10.1080/17453674.2019.1610269

215. Blankstein M, Schemitsch EH, Bzovsky S, et al (2020) What Factors Increase Revision Surgery Risk When Treating Displaced Femoral Neck Fractures With Arthroplasty: A Secondary Analysis of the HEALTH Trial. J Orthop Trauma 34:S49–S54. https://doi.org/10.1097/BOT.0000000000001936

216. Fields AC, Dieterich JD, Buterbaugh K, Moucha CS (2015) Short-term complications in hip fracture surgery using spinal versus

general anaesthesia. Injury 46:719–723. https://doi.org/10.1016/j.injury.2015.02.002

217. Chen DX, Yang L, Ding L, et al (2019) Perioperative outcomes in geriatric patients undergoing hip fracture surgery with different anesthesia techniques: A systematic review and meta-analysis. Med (United States) 98:. https://doi.org/10.1097/MD.0000000000018220

218. Neuman MD, Feng R, Carson JL, et al (2021) Spinal Anesthesia or General Anesthesia for Hip Surgery in Older Adults. N Engl J Med 385:2025–2035. https://doi.org/10.1056/NEJMoa2113514

219. Ferriero G, Kristensen MT, Invernizzi M, et al (2018) Psychometric properties of the Cumulated Ambulation Score: A systematic review. Eur J Phys Rehabil Med 54:766–771. https://doi.org/10.23736/S1973-9087.18.04822-0

220. Çolak I, Mete E, Kristensen MT, Çolak TK (2020) Translation, reliability, agreement and validity of the turkish version of cumulated ambulation score in patients with hip fracture. Jt Dis Relat Surg 31:346–352. https://doi.org/10.5606/EHC.2020.75526

221. Ogawa T, Hayashi H, Kishimoto T, et al (2020) Translation, Inter-rater Reliability, Agreement, and Internal Consistency of the Japanese Version of the Cumulated Ambulation Score in Patients after Hip Fracture Surgery. Prog Rehabil Med 5:n/a. https://doi.org/10.2490/prm.20200030

222. Grana E, Verzellotti S, Grassi FA, et al (2016) Cross-cultural validation of the Italian version of the Cumulated Ambulation Score. Int J Rehabil Res 39:160–164. https://doi.org/10.1097/MRR.0000000000000165

223. Pedersen TJ, Lauritsen JM (2016) Routine functional assessment for hip fracture patients - Are there sufficient predictive properties for subgroup identification in treatment and rehabilitation? Acta Orthop 87:374–379. https://doi.org/10.1080/17453674.2016.1197534

224. Hulsbæk S, Larsen R, Troelsen A (2015) Predictors of not

regaining basic mobility after hip fracture surgery. Disabil Rehabil 37:1739–1744. https://doi.org/10.3109/09638288.2014.974836

225. Kamel HK, Iqbal MA, Mogallapu R, et al (2003) Time to Ambulation After Hip Fracture Surgery: Relation to Hospitalization Outcomes. J Gerontol 58:1042–1045. https://doi.org/https://doi.org/10.1093/gerona/58.11.M1042

226. Kenyon-Smith T, Nguyen E, Oberai T, Jarsma R (2019) Early Mobilization Post–Hip Fracture Surgery. Geriatr Orthop Surg Rehabil 10:215145931982643. https://doi.org/10.1177/2151459319826431

227. Goubar A, Martin FC, Potter C, et al (2021) The 30-day survival and recovery after hip fracture by timing of mobilization and dementia : a UK database study. Bone Joint J 103-B:1317–1324. https://doi.org/10.1302/0301-620X.103B7.BJJ-2020-2349.R1

228. Haslam-Larmer L, Donnelly C, Auais M, et al (2021) Early mobility after fragility hip fracture: a mixed methods embedded case study. BMC Geriatr 21:1–14. https://doi.org/10.1186/s12877-021-02083-3

229. Sheehan KJ, Sobolev B, Guy P (2017) Mortality by Timing of Hip Fracture Surgery - Factors and Relationships at play. J Bone Jt Surg Am 99:1–9

230. Belotti L, Bartoli S, Trombetti S, et al (2013) Factors Influencing Surgical Delay after Hip Fracture in Hospitals of Emilia Romagna Region, Italy: A Multilevel Analysis. HIP Int 23:15–21. https://doi.org/10.5301/HIP.2013.10717

231. Leer-Salvesen S, Engesæter LB, Dybvik E, et al (2019) Does time from fracture to surgery affect mortality and intraoperative medical complications for hip fracture patients? An observational study of 73 557 patients reported to the Norwegian hip fracture register. Bone Jt J 101-B:1129–1137. https://doi.org/10.1302/0301-620X.101B9.BJJ-2019-0295.R1

232. Gabayan GZ, Gould MK, Weiss RE, et al (2017) Emergency Department Vital Signs and Outcomes after Discharge. Acad

Emerg Med 24:846–854. https://doi.org/10.1111/acem.13194.Emergency

233. Pittappilly M, Sarao MS (2019) Vital signs on hospital discharge and re admission rates. QJM 112:275–279. https://doi.org/10.1093/qjmed/hcz002

234. Holst L, Merete P, Ishay G, et al (2018) Early geriatric follow-up visits to nursing home residents reduce the number of readmissions: a quasi-randomised controlled trial. Eur Geriatr Med 9:329–337. https://doi.org/10.1007/s41999-018-0045-3

235. Kumar P, Rajnish RK, Sharma S, Dhillon MS (2020) Proximal femoral nailing is superior to hemiarthroplasty in AO/OTA A2 and A3 intertrochanteric femur fractures in the elderly: a systematic literature review and meta-analysis. Int Orthop 44:623–633. https://doi.org/https://doi.org/10.1007/s00264-019-04351-9

236. Fu C-W, Chen J-Y, Liu Y-C, et al (2020) Dynamic Hip Screw with Trochanter-Stabilizing Plate Compared with Proximal Femoral Nail Antirotation as a Treatment for Unstable AO/OTA 31-A2 and 31-A3 Intertrochanteric Fractures. Biomed Res Int 2020:1–7. https://doi.org/10.1155/2020/1896935

237. Alm CE, Gjertsen JE, Basso T, et al (2021) Trochanteric stabilizing plate in the treatment of trochanteric fractures: a scoping review. Acta Orthop 92:733–738. https://doi.org/10.1080/17453674.2021.1954305

238. Selim A, Ponugoti N, Naqvi AZ, Magill H (2021) Cephalo-medullary nailing versus dynamic hip screw with trochanteric stabilisation plate for the treatment of unstable per-trochanteric hip fractures: a meta-analysis. J Orthop Surg Res 16:1–9. https://doi.org/10.1186/s13018-020-02193-5

239. Page PRJ, Field MH, Vetharajan N, et al (2020) Incidence and predictive factors of problems after fixation of trochanteric hip fractures with sliding hip screw or intramedullary devices. HIP Int September: https://doi.org/10.1177/1120700020959339

240. Mundi S, Chaudhry H, Bhandari M (2014) Systematic review on

the inclusion of patients with cognitive impairment in hip fracture trials: A missed opportunity? Can J Surg 57:141–145. https://doi.org/10.1503/cjs.023413

241. Schmidt M, Schmidt SAJ, Sandegaard JL, et al (2015) The Danish National Patient Registry: a review of content, data quality, and research potential. Clin Epidemiol 7:449–490. https://doi.org/10.2147/CLEP.S91125

242. Lash TL, VanderWeele TJ, Haneuse S, Rothman KR (2021) Modern Epidemiology, 4th editio. Wolters Kluwer

243. Michael Olusegun A (2015) Identifying the Limitation of Stepwise Selection for Variable Selection in Regression Analysis. Am J Theor Appl Stat 4:414. https://doi.org/10.11648/j.ajtas.20150405.22

244. Heinze G, Wallisch C, Dunkler D (2018) Variable selection – A review and recommendations for the practicing statistician. Biometrical J 60:431–449. https://doi.org/10.1002/bimj.201700067

245. Marks L, Pass B, Knobe M, et al (2021) Quality of life, walking ability and change of living situation after trochanteric femur fracture in geriatric patients - Comparison between sliding hip screw and cephalomedullary nails from the registry for geriatric trauma. Injury 52:1793–1800

246. Sutradhar R, Austin PC (2018) Relative rates not relative risks: addressing a widespread misinterpretation of hazard ratios. Ann Epidemiol 28:54–57. https://doi.org/10.1016/j.annepidem.2017.10.014

247. O'Leary L, Jayatilaka L, Leader R, Fountain J (2021) Poor nutritional status correlates with mortality and worse postoperative outcomes in patients with femoral neck fractures. Bone Jt J 103-B(1):164–169. https://doi.org/10.1302/0301-620X.103B1.BJJ-2020-0991.R1

248. Malafarina V, Reginster J, Cabrerizo S, Bruy O (2018) Nutritional Status and Nutritional Treatment Are Related to Outcomes and Mortality in Older Adults with Hip Fracture. Nutrients 10:1–26.

https://doi.org/10.3390/nu10050555

249. Peeters CMM, Visser E, Van De Ree CLP, et al (2016) Quality of life after hip fracture in the elderly: A systematic literature review. Injury 47:1369–1382. https://doi.org/10.1016/j.injury.2016.04.018

250. Avenell A, Smith T, Curtain J, et al (2016) Nutritional supplementation for hip fracture aftercare in older people (Review). Cochrane Database Syst Rev. https://doi.org/10.1002/14651858.CD001880.pub6.www.cochranelibrary.com

251. Johansen A, Golding D, Brent L, et al (2017) Using national hip fracture registries and audit databases to develop an international perspective. Injury 48:2174–2179. https://doi.org/10.1016/j.injury.2017.08.001

252. Smith TO, Gilbert AW, Sreekanta A, et al (2020) Enhanced rehabilitation and care models for adults with dementia following hip fracture surgery. Cochrane Database Syst Rev 2020:. https://doi.org/10.1002/14651858.CD010569.pub3

9. Appendix

Table 14. New Mobility Score (NMS). Questionnaire used when calculating the NMS (0-9 points) [141].

Mobility	No difficulty	With an aid	With the help from another person	Not at all
Able to get about the house	3	2	1	0
Able to get out of the house	3	2	1	0
Able to go shopping	3	2	1	0

Table 15. Cumulated Ambulation Score (CAS). Form for assessment of CAS, modified according to Foss et al [144].

Task	Able to perform it independently	Only able to perform it with assistance from one to two people	Unable to perform it despite assis-tance from two people
Transfer from supine-to-sitting-to-supine	2	1	0
Transfer from sitting-to-standing-to-sitting (from armchair)	2	1	0
Walking with appropriate walking aid	2	1	0

Fall risk assessment (Check the boxes below, and count the score)

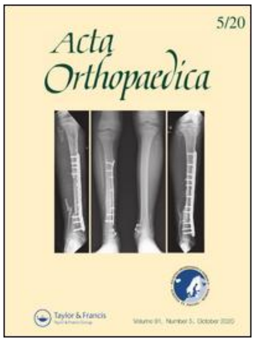
1. Has the patient previously fallen ☐ and/or
   is the patient afraid of falling ☐? Point: _________
2. Is the patient light-headed ☐ and/or unsure on his legs☐? Point: _________
3. Does the patient take anti-psychotic ☐ and/or diuretic ☐,
   antihypertensive medications ☐ or anti-arhythmical medicine ☐? Point: _________
4. Does the patient have frequent bathroom visits ☐? Point: _________
5. Does the patient have impaired vision, which affects
   everyday life ☐? Point: _________
6. Is there a suspicion of the patient being delirious ☐ / confused ☐? Point: _________
7. Is the patient cognitively impaired ☐, or is there
   a suspicion of cognitive impairment ☐? Point: _________
8. Is there a suspicion of, due to a stoke or similar
   cognitive problems, diminished mental function
   with impact on the ability to move around ☐? Point: _________

Total points (at admission): _________ (0-8 points)

***Figure 10.1** The questionnaire used during the fall risk assessment (FRA) at admission.*

10. Papers I-V

Paper I



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Poor adherence to guidelines in treatment of fragile and cognitively impaired patients with hip fracture: a descriptive study of 2,804 patients

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Poor adherence to guidelines in treatment of fragile and cognitively impaired patients with hip fracture: a descriptive study of 2,804 patients

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Background and purpose — Following a hip fracture, most patients will encounter poorer functional outcomes and an increased risk of death. Treatment-monitoring of hip fracture patients is in many countries done by national audits. However, they do not allow for a deeper understanding of treatment limitations. We performed a local evaluation study to investigate adherence to 7 best-practice indicators, and to investigate patient groups at risk of suboptimal treatment.

Patients and methods — 2,804 patients were surgically treated for a hip fracture from 2011 to 2017 at our institution. Data regarding admission, hospital stay, and discharge was prospectively collected, and adherence to the 7 best practice indicators (nerve block, surgical delay, antibiotics, implant choice, thromboprophylaxis, mobilization, and blood transfusions) was analyzed. Patient groups with lower adherence were identified.

Results — 34% of patients received all 7 best practice indicators after considering contraindications; in particular, nerve blocks and thromboprophylaxis displayed low adherence at 61% and 91% respectively. Nursing home residents and patients with cognitive impairment, multiple comorbidities, or low functional levels were at risk of having a lower adherence.

Interpretation — The most dependent patients with cognitive impairment, comorbidities, or low functional levels had lower guideline adherence. This large patient subgroup needs a higher treatment focus and more resources. Our findings are likely similar to those in other national and international institutions.

Hip fractures are a leading cause of disability and mortality among seniors worldwide, with 1-year mortality surpassing 20%. Survivors often experience diminished walking ability, reduced activities of daily living, and loss of independence (Bentler et al. 2009, Dyer et al. 2016). Recent years have seen only minimal improvements in outcomes, such as mortality, which suggest that hip fracture treatment needs improvement (Rogmark 2020). However, patients with hip fracture represent a heterogeneous and fragile patient group with multiple comorbidities, which complicates treatment.

Evidence-based treatment is fundamental to modern medicine, and previous research has demonstrated improved outcomes for patients receiving best practice indicators (Nielsen et al. 2009, Kristensen et al. 2016, Oakley et al. 2017, Farrow et al. 2018). However, most studies are based on process indicators, which give no information on the actual treatment provided; this includes national audits (Sweden's National Quality Register 2018, Danish Multidisciplinary Hip Fracture Registry 2019, Royal College of Physicians 2019, Australian & New Zealand Hip Fracture Registry 2019). To our knowledge, only a few studies have evaluated direct local adherence to guidelines for patients with hip fracture (Seys et al. 2018, Mcglynn et al. 2003, Sunol et al. 2015). Continuous monitoring through national audits and local studies might detect gaps in the treatment of patients with hip fracture and hopefully secure improvement.

We assessed the degree of adherence to 7 best practice indicators in a local evidence-based guideline for treatment of hip fractures. We expected adherence to increase during the study period as the guideline was incorporated better over time. Furthermore, the study aimed to clarify whether particular patient groups are at risk of significantly lower guideline adherence and hence suboptimal treatment at our institution.

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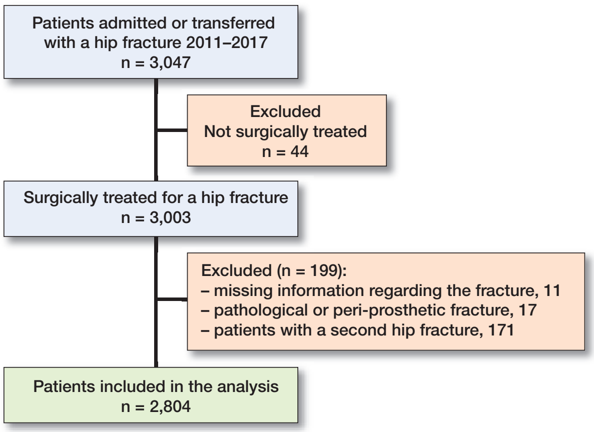

Figure 1. Patient inclusion flowchart.

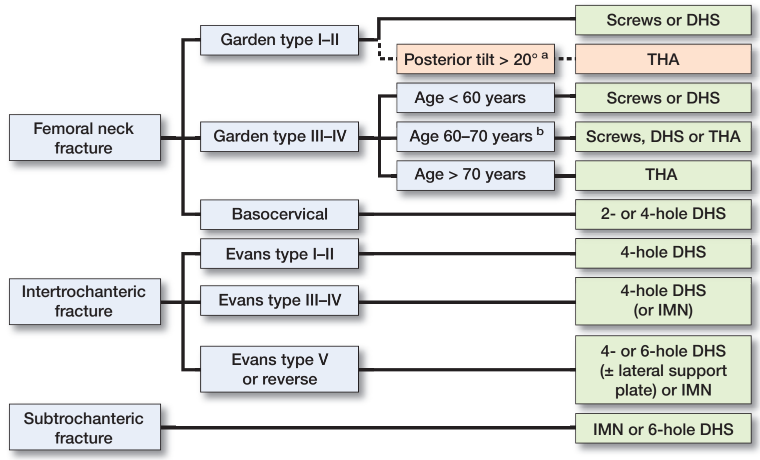

Figure 2. Protocol for implant choice based on fracture type and patient age.
[a] Posterior tilt > 20° in the lateral view of Garden I–II fractures resulted in the recommended treatment changing to a THA. However, as this was part of the adjustment after contraindications it is shown in dotted lines but included in the figure for clarification.
[b] Individual assessment of each patient's comorbidity, pre-fracture mobility, and radiograph to determine best treatment option, favoring screws or DHS in fractures that can be anatomically reduced, and patients without severe comorbidities and severely impaired pre-fracture mobility.
DHS = dynamic hip screw. IMN = intramedullary nail. THA = total hip arthroplasty.

Patients and methods

Design

The study is a retrospective analysis of prospectively collected data from a cohort of patients with hip fracture conducted at a department of orthopedic surgery.

Patients

All patients admitted to our hospital or transferred from other hospitals with a hip fracture between January 2011 and December 2017 were examined for inclusion (n = 3,047). Hip fracture was defined as a femoral neck fracture, an inter-trochanteric fracture, or a sub-trochanteric fracture. Only surgically treated patients were included. Patients with pathological hip fractures or peri-prosthetic fractures were excluded (n = 17). 11 patients with missing data at the start of the study period were also excluded. For patients who suffered a second hip fracture during the study period, only the first hip fracture was included in the analysis (n = 171). 2,804 patients were included in the study (Figure 1).

Data

All patients were treated according to a well-defined hip fracture guideline at our hospital, which was introduced in January 2011. Simultaneously with the implementation of the guideline, all patients admitted with a hip fracture were prospectively included in our Hip Fracture Database. The database was established in January 2011 to study mortality and morbidity among hip fracture patients at our institution.

During admission, patient characteristics and clinical measures were recorded by a nurse on specified forms for the Hip Fracture Database. Data included weight, height, comorbidity, residency, cognitive impairment, preoperative walking aid, and pre-fracture functional level. At discharge, nurses reported prospectively collected data to the database regarding blood samples, blood transfusions, surgery (date, time, and choice of treatment), pain management (regional block and oral analgesics), and discharge placement.

Comorbidities were assessed by ASA classification. Pre-fracture functional level was estimated using the New Mobility Score (NMS) and was dichotomized into a low pre-fracture functional level (0–5 points) and a high functional level (6–9 points) (Kristensen et al. 2005).

Retrospectively, one researcher (CFF) classified all fractures on the preoperative radiographs (anterior-posterior, lateral view, and pelvic). The radiographs were classified according to the Garden classification for femoral neck fractures and the Evans classification for inter-trochanteric fractures. Posterior tilt was measured on the lateral view for all Garden I–II fractures. No sub-classification for sub-trochanteric fractures was used.

Prior to analysis, we outlined 7 best practice indicators of particular importance in our local hip fracture guideline. National and international recommendations, national audits, and previous literature were reviewed for important indicators (Dansk Ortopædisk selskab 2008, NICE 2017, Seys et al. 2018, Danish Multidisciplinary Hip Fracture Registry 2019). Indicators were chosen to mirror the different procedural steps and diverse care groups involved in the treatment.

The 7 best practice indicators were as follows:

1. Preoperative block. Defined as the use of either epidural or peripheral nerve block prior to surgery.
2. Surgical delay. Defined as surgery within 24 or 36 hours from admission.

Table 1. Contraindications for each best practice indicator

Factor	Number (%)
1. Preoperative block (n = 1,171)	
Patient declined	155 (13)
No valid contraindications [a]	1,016 (87)
2. Surgical delay	
Within 24 hours (n = 738)	
Medical complications [b]	128 (17)
Anticoagulation treatment	97 (13)
Death	1 (0.1)
Others	36 (4.9)
No valid contraindication [a]	476 (65)
Within 36 hours (n = 376)	
Medical complications [b]	99 (26)
Anticoagulation treatment	81 (22)
Death	1 (0.3)
Others	27 (7.2)
No valid contraindication [a]	168 (45)
3. Perioperative antibiotics (n = 126)	
Irrelevant antibiotic treatment	33 (26)
No valid contraindication [a]	93 (74)
4. Implant choice (n = 349)	
Fracture characteristics	104 (30)
Patient morbidity	61 (18)
Pre-fracture mobility	9 (2.6)
Others	8 (2.3)
No valid contraindication [a]	167 (48)
5a. Thromboprophylaxis for 7 days after surgery (n = 211)	
Renal failure	3 (1.4)
Former HIT [c]	0 (0.0)
Former bleeding	10 (4.7)
Bridging	88 (42)
Others	39 (20)
No valid contraindication [a]	71 (34)
5b. Thromboprophylaxis given 6–8 h after surgery (n = 1,175)	
Given too early	223 (19)
Given too late	691 (59)
Not given the first day postoperatively	136 (12)
Others	22 (1.9)
No valid contraindication [a]	103 (8.8)
6. Postoperative mobilization (n = 464)	
No standing abilities prior to surgery	32 (6.9)
Others [d]	91 (20)
No valid contraindication [a,e]	341 (73)
7. Blood transfusions (n = 90)	
Patient declined	6 (6.7)
Asymptomatic	18 (20)
Others	7 (7.8)
No valid contraindication [a]	59 (66)

[a] Including no reasons given in the patient record or invalid contraindications given.
[b] For example, cardiac arrhythmias and strokes.
[c] Heparin-induced thrombocytopenia.
[d] For example, patient died within 24 h or was transferred to another hospital within 24 h.
[e] Including patients only mobilized to a sitting position within 24 h.

3. Perioperative use of antibiotics.
4. Implant choice. Defined from fracture type and age (Figure 2).
5. Thromboprophylaxis. Defined as injections of low-molecular-weight heparin (LMWH) for at least 7 days with the 1st injection given 6–8 hours after surgery.
6. Postoperative mobilization to standing within 24 hours of surgery.
7. Blood transfusions if postoperative hemoglobin was below 6 mmol/l.

Implant choice was based on recommendations from the Danish Orthopedic Society, and primarily dictated by the fracture type; however, especially for femoral neck fractures the patient's age was also a determining factor (Dansk Ortopædisk selskab 2008). Dual mobility total hip arthroplasties (THAs) were used as standard treatment for patients over 70 years with a Garden III and IV fracture. Internal fixation was standard care for younger patients under 60 years due to superior healing potential and to postpone possible revision of a THA in the future. Garden III–IV fractures in patients between 60 and 70 years could be treated with screws, dynamic hip screws (DHSs), or THAs, based on an assessment by the surgeon. Screws or DHSs were used for fractures that could be anatomically reduced and patients without severe comorbidities or severely impaired mobility. For inter-trochanteric fractures, the DHS has been our standard treatment choice; however, for more unstable and complex fractures, intramedullary nails (IMNs) or DHSs with lateral support plate were used, with increasing use of IMNs during the study period. Hemiarthroplasty and external fixation was not performed for hip fractures at our institution.

Data regarding perioperative antibiotics, thromboprophylaxis, and postoperative mobilization was obtained from patient records; data on preoperative pain management, surgical delay, implant choice, and blood transfusions was obtained from our Hip Fracture Database.

Patient records were screened for pre-defined contraindications for each indicator (Table 1).

To investigate whether patient characteristics affected adherence, patients were grouped based on commonly known risk factors for increased mortality and morbidity: age, sex, ASA score, residence, cognitive impairment, fracture type, pre-fracture functional level, and walking aids (Bentler et al. 2009, Smith et al. 2014).

Statistics

An all-or-none test was performed to clarify the percentages of patients receiving all 7 best practice indicators. Furthermore, adherence was calculated as the proportion of patients who achieved a given number of indicators. A chi-square test was used to assess the hypothesis of no difference in adherence between patient groups to identify groups with statistically significantly lower adherence.

In the statistical analysis, patients with a valid contraindication or missing data were excluded from the adherence analysis for that particular indicator. They remained in the analysis for the other indicators. However, analysis for indicators 3 (perioperative antibiotics) and 5 (thromboprophylaxis) were executed differently. For perioperative antibiotics, the only valid contraindication was if the patient was already in a relevant antibiotic treatment regimen at the time of surgery. These patients were labelled "correctly treated" and remained

Table 2. Characteristics of the study population at the time of hip fracture (n = 2,804). Values are observed numbers (%) unless otherwise stated

Variables	Observed values
Mean age (SD)	80 (11)
Female sex	2,029 (72)
ASA score	
ASA 1	233 (8.3)
ASA 2	1,311 (47)
ASA 3	1,090 (39)
ASA 4	102 (3.6)
ASA 5	1 (0.1)
Missing	67 (2.4)
Pre-fracture residence	
Independent living	2,064 (74)
Institutionalized	736 (26)
Missing	4 (0.1)
Cognitive function	
Cognitively impaired	552 (20)
Not cognitively impaired	2,233 (80)
Missing	19 (0.7)
Fracture type	
Garden type I and II	431 (15)
Garden type III and IV	977 (35)
Stable intertrochanteric	572 (20)
Unstable intertrochanteric	680 (24)
Subtrochanteric	57 (2.0)
Basocervical	81 (2.9)
Missing	6 (0.2)
Pre-fracture mobility [a]	
Low NMS	1,405 (50)
High NMS	1,274 (45)
Missing	125 (4.5)
Walking aids	
None	1,047 (37)
Assisted walking	1,484 (53)
No walking ability	79 (2.8)
Missing	194 (6.9)

[a] Pre-fracture mobility was assessed by New Mobility Score (NMS) with 0–5 points labelled as low and 6–9 points as high.

Table 3. Observed adherence to the guideline for each of the 7 best practice indicators and all-or-none adherence to all 7 best practice indicators, listed as total number and observed numbers (%)

Factor	Adherence to guideline	Corrected for contraindications
1. Preoperative block	2,793	2,638
	1,607 (57)	1,607 (61)
2. Surgical delay		
within 24 hours	2,786	2,524
	2,048 (74)	2,048 (81)
within 36 hours	2,787	2,579
	2,411 (87)	2,411 (93)
3. Perioperative antibiotics	2,759	2,759
	2,633 (95)	2,666 (97)
4. Implant choice	2,804	2,613
	2,446 (87)	2,446 (94)
5. Thromboprophylaxis	2,787	2,640
	1,538 (55)	2,394 (91)
6. Postoperative mobilization	2,675	2,552
	2,211 (83)	2,211 (87)
7. Blood transfusions	718	687
	628 (87)	628 (91)
All-or-none	2,629	2,028
	442 (17)	684 (34)

Table 4. Percentage of patients fulfilling 3, 4, 5, 6, or 7 best practice indicators (n = 1,946)

Number of indicators fulfilled	Observed numbers (%)
3	7 (0.4)
4	53 (2.6)
5	319 (17)
6	883 (45)
7	684 (35)

in the adherence analysis corrected for contraindications. For thromboprophylaxis, patients who were given their 1st injection of LMWH prior to 6 hours or later than 8 hours after surgery were labeled "correctly treated" if they had also received LMWH for 7 days. This was chosen as recent studies have shown that the timing of thromboprophylaxis is not as crucial as had been presumed earlier (Liu et al. 2016, Leer-Salvesen et al. 2018). Only patients with data regarding all 7 best practice indicators were included in the all-or-none test.

Data analyses were performed using STATA 16 computer software (StataCorp, College Station, TX, USA).

Ethics, funding, and potential conflicts of interest

The study was conducted in accordance with the Declaration of Helsinki and registered by the Danish Data Protection Agency (number 2007-58-0010), which stated no need for written consent according to Danish law. The study has not received any funding. None of the authors has any conflicts of interest to declare.

Results

2,804 patients were treated for a hip fracture. The mean age was 80 years, and females predominated. The majority lived independently. Almost one-fifth of the patients had cognitive impairment, and half of the population had a low pre-fracture functional level (Table 2).

Total study period

17% of patients received all 7 best practice indicators. The lowest adherence was found for preoperative block and thromboprophylaxis. The indicators with the highest degree of adherence were perioperative antibiotics and implant choice (Table 3). Overall adherence increased to 34% after considering contraindications, primarily due to increased adherence to thromboprophylaxis (Table 3). Furthermore, 65% of patients in fact fulfilled 6 or more indicators (Table 4).

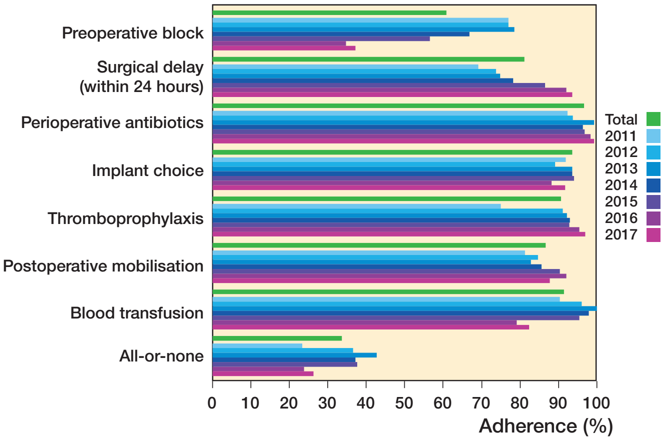

Figure 3. Adherence to the individual best practice indicators and overall adherence in percentages divided into the different years of the study period after taking contraindications into consideration.

Annual adherence

Adherence to individual best practice indicators and overall adherence for each year in the study period are displayed in Figure 3 (the data is shown after considering contraindications). Preoperative block showed a decline in adherence during the 7-year period, and blood transfusions dropped in 2016 and 2017. Both declines had an impact on overall adherence, which decreased in 2016 and 2017 to 24% and 26%, respectively. Data is also shown in Table 5 (see Supplementary data).

Adherence in subgroups

No difference in overall adherence was found when comparing adherence in patient groups in relation to age groups, sex, or fracture type. However, nursing home residents, cognitively impaired patients, patients with a low pre-fracture functional level, and patients with high comorbidity (ASA > 4) were at risk of receiving insufficient treatment (Table 6, see Supplementary data).

Discussion

Our most important finding was that only one-third of hip fracture patients at our institution fulfilled all 7 best practice indicators; however, the majority of patients received 6 or more indicators. The study also suggests lower adherence among patients with multiple comorbidities, cognitive impairment, low pre-fracture functional level, and nursing home residency. Surprisingly, adherence did not increase during the study period because of declining adherence to the indicators "preoperative pain management" and "blood transfusion" in 2016 and 2017. The decrease in adherence to preoperative pain management might be explained by a major organizational change in 2016, whereby admissions past 10 pm were performed by medical doctors rather than orthopedic surgeons or ER doctors. Medical doctors have less experience in administering regional blocks at our institution, which may cause fewer blocks to be administered. For blood transfusions, decreasing adherence over the study period might be due to the 2015 introduction of a new guideline setting lower hemoglobin limits (< 5.6 mmol/L) for transfusion (Danish Healthcare System 2015). Although the transfusion guideline was not specific for patients with hip fracture, it likely influenced the use of blood transfusions for this patient group as well.

Other local evaluation studies have similarly found suboptimal care for patients with hip fracture, some with an overall adherence of 0% (Mcglynn et al. 2003, Sunol et al. 2015, Farrow et al. 2018, Seys et al. 2018). Contrary to local evaluations, most national audits show a high level of adherence (Sweden's National Quality Register 2018, Danish Multidisciplinary Hip Fracture Registry 2019, Australian & New Zealand Hip Fracture Registry 2019). Local evaluation studies should be seen as a supplement to national audits as they can provide a deeper understanding of treatment gaps. Surgical delay may serve as a good illustrator. National audits can only give the results, whereas local studies can point to capacity issues or patient comorbidities as the reason for low adherence. This will identify what steps are needed to increase adherence. The same is true for implant choice as national audits can only give the proportion of patients receiving the different implants; they cannot determine whether the choice of implant was the right one.

In previous years, our institution has demonstrated high adherence to the national Danish audit, and similar adherence was found in the present study for matching indicators (Danish Multidisciplinary Hip Fracture Registry 2019). However, when investigating overall adherence, only one-third of patients obtained full treatment. This indicates that care for patients with hip fracture may also be suboptimal at other hospitals despite high adherence to the national audit, underlining the need for local evaluation. Nevertheless, national audits play an important role in monitoring treatment as adherence to national indicators has shown reduced mortality and readmission (Nielsen et al. 2009, Kristensen et al. 2016). Supplementing national audits with local studies in the future may inform future initiatives to improve hip fracture treatment.

For the individual best practice indicators, the most surprising results were low adherence for preoperative pain management and thromboprophylaxis. Preoperative pain management will be a future focus area because optimal pain management, especially the use of preoperative blocks, may improve recovery by reducing the use of opioids and by reducing nausea and dizziness, while helping in improving mobilization and nutrition (Guay et al. 2017). Thromboprophylaxis had low adherence before considering contraindications. Low adherence was especially due to bridging, where patients did not receive LMH for 7 days, and patients receiving the 1st injection before 6 hours or later than 8 hours after surgery. However, after the start of the study, anticoagulation therapy has changed. Previous studies have shown that the timing of the thromboprophylaxis is of less importance (Liu et al. 2016, Leer-Salvesen et al. 2018), and with the emergence of new anticoagulation strategies, bridging has become more frequent. Consequently, a revision of the guideline is required. The change in anticoagulation therapy also had an impact on the best practice indicator "surgical delay." Especially in the early stages of the study, vitamin K antagonists (VKA) and novel oral anticoagulants (NOAC) posed a challenge. Surgery was delayed when patients did not respond to vitamin K within 24 hours or due to the initial recommendation of a 24-hour pause from NOAC. However, more recent studies have demonstrated that operating regardless of anticoagulation therapy is, indeed, safe (Schuetze et al. 2019). Despite these delays, our study shows an impressive level of adherence compared with international standards, where most guidelines have a 36-or 48-hour deadline and most national audits show lower fulfilment than in this study (Sweden's National Quality Register 2018, Australian & New Zealand Hip Fracture Registry 2019, Royal College of Physicians 2019). The increased adherence is probably due to an organizational change with more experienced surgeons and operating rooms functioning outside standard working hours.

Implant choice adherence was in line with that reported in other studies (Palm et al. 2012). Most patients had valid contraindications when the guideline was not followed. Contraindications for implant choice were fracture characteristics, primarily a posterior tilt above 20 degrees on the lateral radiograph for Garden I and II fractures (Table 1). Here we opted for a THA instead of screws for patients to reduce the risk of reoperation (Palm et al. 2009). Patient morbidity and mobility describe situations such as young patients with severe osteoporosis or mental handicaps, or patients with no standing or walking ability. In such cases, guideline adherence would be deselected to reduce the risk of reoperation or having to perform extensive surgery. Other contraindications were patients declining the recommended implant.

Our study has several strengths. A major strength is a high level of external validity owing to inclusion of all consecutive patients with a hip fracture admitted to the department, including patients with severe cognitive impairment and multiple comorbidities, reducing selection bias. Another strength is the use of prospectively collected or documented data, reducing the risk of recall bias.

As with most studies, the design of our study is subject to limitations. First, we have missing data in relation to some variables. If information concerning antibiotics, thromboprophylaxis, postoperative mobilization, and the predefined contraindications were not documented during admission and therefore not available in patient records, these variables were interpreted as missing. This interpretation would have led to an underestimation of the adherence to the guideline. Despite this approach, we had a high degree of data completeness. Second, our study was limited by being a single-center study. While this ensured that patients were treated similarly, it also meant together with the descriptive nature of the study that we can only be sure the results are valid for our institution. However, these results could be true for other institutions, as previous studies have found similar results and the national audit had comparable adherence for matching indicators (Mcglynn et al. 2003, Sunol et al. 2015, Farrow et al. 2018, Seys et al. 2018, Danish Multidisciplinary Hip Fracture Registry 2019). Third, a lack of consensus on which best practice indicators to use as predictors for adherence in hip fracture treatment hampers comparison with other results. Previous studies have used a wide variety of indicators from procedures (orthopedic or geriatric assessment of patients), timing (of surgery, postoperative mobilization, admission to orthopedic wards, or assessment by senior doctors) and medical indicators (antibiotics, thromboprophylaxis, and pain management). A Delphi study was conducted by Seys et al. (2018), to identify indicators of importance in the patients with hip fracture. 4 of the 7 best practice indicators in our study were found to be important for treatment of patients with hip fracture in the Delphi study (surgical delay, antibiotics, thromboprophylaxis, and postoperative mobilization) and 1 was found to be of less importance (preoperative pain management). Further research should be conducted to establish general consensus on which best practice indicators to use, which will ease comparison between studies. Risk assessment for pressure ulcers and malnutrition may be important indicators in improving treatment; furthermore, indicators regarding the period after discharge, such as osteoporosis treatment, fall prophylaxis, and rehabilitation, should be considered in future studies.

Conclusion

In summary, we found that despite high adherence to individual best practice indicators, overall adherence is surprisingly low at our institution, especially among fragile and cognitively impaired patients. A local evaluation study, such as ours, can be used in the clinic to identify patient groups or treatment steps that need improvement and to deepen our understanding of treatment gaps.

Supplementary data

Tables 5 and 6 are available as supplementary data in the online version of this article, http://dx.doi.org/10.1080/17453674.2021.1925430

All the authors contributed to the study design, including defining the best practice indicators. CFF collected the data. CFF performed the analysis of data with support from ENG. All authors reviewed the results and discussed them. CFF wrote the manuscript draft and all authors revised and approved it.

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Australian & New Zealand Hip Fracture Registry. Annual Report 2019; 2019. https://anzhfr.org/2019-annual-report/

Bentler S E, Liu L, Obrizan M, Cook E A, Wright K B, Geweke J F, Chrischilles E A, Pavlik C E, Wallace R B, Ohsfeldt R L, Jones M P, Rosenthal G E, Wolinsky F D. The aftermath of hip fracture: discharge placement, functional status change, and mortality. Am J Epidemiol 2009; 170 (10): 1290-9. doi: 10.1093/aje/kwp266.

Danish Healthcare System. Vejledning om blodtransfusion. doi: j.rn: 572109/2; 2015.

Danish Multidisciplinary Hip Fracture Registry. Danish Multidisciplinary Hip Fracture Registry, Nationalrapport; 2019. https://www.sundhed.dk/content/cms/62/4662_hofterapport.pdf.

Dansk Ortopædisk selskab. Reference program for Patienter Med Hoftebrud; 2008. https://www.ortopaedi.dk/fileadmin/Guidelines/Referenceprogrammer/Referenceprogram_for_patienter_med_hoftebrud2008.pdf.

Dyer S M, Crotty M, Fairhall N, Magaziner J, Beaupre L A, Cameron I D, Sherrington C. A critical review of the long-term disability outcomes following hip fracture. BMC Geriatrics 2016; 16: 158. doi: 10.1186/s1287701603320.

Farrow L, Hall A, Wood A D, Smith R, James K, Holt G, Hutchison J, Myint P K. Quality of care in hip fracture patients: the relationship between adherence to national standards and improved outcomes. J Bone Joint Surg Am 2018; 100: 751-57. doi: 10.2106/JBJS.17.00884.

Guay J, Parker M J, Griffiths R, Kopp S. Peripheral nerve blocks for hip fractures (review). Cochrane Database Syst Rev 2017; 5(5): CD001159. doi: 10.1002/14651858.CD001159.pub2.

Kristensen M T, Foss N B, Kehlet H. Timed Up & Go og New Mobility Score til prædiktion af funktion seks måneder efter hoftefraktur [Timed Up and Go and New Mobility Score as predictors of function six months after hip fracture]. Ugeskr Laeger 2005; 167(35): 3297-3300. PMID: 16138973.

Kristensen P K, Thillemann T M, Søballe K, Johnsen S P. Are process performance measures associated with clinical outcomes among patients with hip fractures? A population-based cohort study. Int J Qual Health Care 2016; 28(6): 698-708. doi: 10.1093/intqhc/mzw093.

Leer-Salvesen S, Dybvik E , Engesaeter L B, Dahl O E, Gjertsen J. Low-molecular-weight heparin for hip fracture patients treated with osteosynthesis: should thromboprophylaxis start before or after surgery? An observational study of 45,913 hip fractures reported to the Norwegian Hip Fracture Register. Acta Orthop 2018; 89(6): 615-21. doi: 10.1080/17453674.2018.1519101.

Liu Z, Han N, Xu H, Fu Z, Zhang D, Wang T, Jiang B. Incidence of venous thromboembolism and hemorrhage related safety studies of preoperative anticoagulation therapy in hip fracture patients undergoing surgical treatment: a case-control study. BMC Musculoskeletal Disorders 2016; 17(76): 1-8. doi: 10.1186/s128910160917y.

Mcglynn E A, Asch S M, Adams J, Keesey J, Hicks J, Decristofaro A, Kerr E A. The quality of health care delivered to adults in the United States. N Engl J Med 2003; 348: 2635-45. doi: 10.1056/NEJMsa022615

NICE. National Institute for Health and Clinical Excellence (NICE) (2012) Management of hip fractures in adults; 2017. https://www.nice.org.uk/guidance/qs16.

Nielsen K A, Jensen N C, Jensen C M, Thomsen M, Pedersen L, Johnsen S P, Ingeman A, Bartels P D, Thomsen R W. Quality of care and 30-day mortality among patients with hip fractures: a nationwide cohort study. BMC Health Serv Res 2009; 9: 186. doi: 10.1186/147269639186.

Oakley B, Nightingale J, Moran C G, Moppett I K. Does achieving the best practice tariff improve outcomes in hip fracture patients? An observational cohort study. BMJ Open 2017; 7(2): e014190. doi: 10.1136/bmjopen2016014190.

Palm H, Gosvig K, Krasheninnikoff M, Jacobsen S, Gebuhr P. A new measurement for posterior tilt predicts reoperation in undisplaced femoral neck fractures 113 consecutive patients treated by internal fixation and followed for 1 year. Acta Orthop 2009; 80(3): 303-7. doi: 10.3109/17453670902967281.

Palm H, Krasheninnikoff M, Holck K, Lemser T, Foss N B, Jacobsen S, Kehlet H, Gebuhr P. A new algorithm for hip fracture surgery: reoperation rate reduced from 18% to 12% in 2,000 consecutive patients followed for 1 year. Acta Orthop 2012; 83(1): 26-30. doi: 10.3109/17453674.2011.652887.

Rogmark C. Further refinement of surgery will not necessarily improve outcome after hip fracture. Acta Orthop 2020; 91(2): 123-24. doi: 10.1080/17453674.2019.1706936.

Royal College of Physicians. The National Hip Fracture Database; 2019. https://www.nhfd.co.uk/.

Schuetze K, A Eickhoff, Dehner C, Gebhard F, Richter P H. Impact of oral anticoagulation on proximal femur fractures treated within 24 h: a retrospective chart review. Injury 2019; 50(11): 2040-4. doi: 10.1016/j.injury.2019.09.011.

Seys D, Sermon A, Sermeus W, Panella M, Bruyneel L, Boto P. Recommended care received by geriatric hip fracture patients: where are we now and where are we heading? Arch Orthop Trauma Surg 2018; 138: 1077-87. doi: 10.1007/s0040201829394.

Smith T, Pelpola K, Ball M, Ong Al, Myint P K. Pre-operative indicators for mortality following hip fracture surgery: a systematic review and meta-analysis. Age Ageing 2014; 43(4): 464-71. doi: 10.1093/ageing/afu065.

Sunol R, Wagner C, Arah O A, Kristensen S. Implementation of departmental quality strategies is positively associated with clinical practice: results of a multicenter study in 73 hospitals in 7 European countries. PLoS One 2015; 10(11): :e0141157. doi: 10.1371/journal.pone.0141157.

Sweden's National Quality Register. Annual Report 2018; 2018. https://rikshoft.se/wpcontent/uploads/2019/11/rikshoft_rapport2018_191023.pdf.

Supplementary data

Table 5. Adherence in the individual years 2011–2017 (only adherence corrected for contraindications is displayed). Values are observed numbers and % of patients fulfilling the given indicator

	2011 n = 420	2012 n = 408	2013 n = 428	2014 n = 364	2015 n = 377	2016 n = 403	2017 n = 404
1. Preoperative block	292 (77)	294 (77)	308 (79)	224 (70)	204 (57)	137 (35)	146 (37)
2. Surgical delay (within 24 hours)	253 (69)	269 (74)	288 (75)	251 (78)	295 (87)	340 (92)	351 (94)
3. Perioperative antibiotics	359 (92)	378 (94)	419 (99)	350 (96)	362 (97)	395 (98)	401 (99)
4. Implant choice	342 (92)	331 (89)	367 (92)	319 (94)	310 (94)	345 (88)	346 (92)
5. Thromboprophylaxis	303 (75)	362 (91)	378 (92)	317 (93)	328 (93)	359 (96)	345 (97)
6. Postoperative mobilization	231 (81)	322 (85)	334 (83)	291 (86)	319 (90)	355 (92)	336 (88)
7. Blood transfusions	85 (90)	97 (96)	102 (100)	93 (98)	84 (96)	83 (79)	84 (82)
All-or-none	60 (23)	106 (37)	135 (43)	94 (37)	106 (38)	75 (24)	76 (26)

Table 6. Chi-square test for no difference in adherence based on characteristics of the study population. Values are observed numbers (%)

Characteristics	Total	All or no adherence Fulfilled	Not fulfilled	p-value
Age (n = 2,028)				0.6
≤ 55 years	127 (6.3)	45 (35)	82 (65)	
56–69 years	256 (13)	92 (36)	164 (64)	
≥ 70 years	1,645 (81)	547 (33)	1,098 (67)	
Sex (n = 2,028)				0.9
Female	1,364 (67)	461 (34)	903 (66)	
Male	664 (33)	223 (34)	441 (66)	
ASA (n = 1,991)				0.008
ASA 1	192 (9.7)	67 (35)	125 (65)	
ASA 2	1,018 (51)	373 (37)	645 (63)	
ASA 3	731 (37)	222 (30)	509 (70)	
ASA 4	50 (2.5)	10 (20)	40 (80)	
Residence (n = 2,027)				0.004
Independently	1,537 (76)	545 (35)	992 (64)	
Institution	490 (24)	139 (28)	351 (72)	
Cognitive impairment (n = 2,017)				0.01
No cognitive impairment	1,647 (82)	578 (35)	1,069 (65)	
Cognitive impairment	370 (18)	104 (28)	266 (73)	
Fracture type (n = 2,026)				0.1
Garden I+II	313 (15)	90 (29)	223 (71)	
Garden III+IV	703 (35)	256 (36)	447 (64)	
Stable intertrochanteric	419 (21)	149 (36)	270 (64)	
Unstable intertrochanteric	499 (25)	161 (32)	338 (68)	
Subtrochanteric	40 (2.0)	9 (23)	31 (77)	
Basocervical	52 (2.6)	19 (37)	33 (63)	
Pre-fracture functional level [a] (n = 1,951)				< 0.001
Low NMS	968 (50)	284 (29)	684 (71)	
High NMS	983 (50)	383 (39)	600 (61)	
Walking aids (n = 1,882):				0.01
Independently	784 (42)	292 (37)	492 (63)	
Assisted walking	1,062 (56)	326 (31)	736 (69)	
No walking ability	36 (1.9)	12 (33)	24 (67)	

[a] NMS, see Table 2

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RESEARCH PAPER

Malnutrition, poor function and comorbidities predict mortality up to one year after hip fracture: a cohort study of 2800 patients

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Key summary points

Aim To examine the association of 19 risk factors with mortality among patients with hip fracture treated according to a well-defined guideline focusing on risk factors that can be optimised.

Findings Age, gender, residence, cognitive function, comorbidities, nutritional status, functional level and mobilisation were all associated with mortality at 30 days and one year.

Message The present study supports the efforts of orthogeriatric care in optimising risk factors such as comorbidities, malnutrition and in-hospital rehabilitation. Future studies exploring how and when optimisation should be implemented are warranted.

Abstract

Purpose Despite extensive research, a complete understanding of factors influencing mortality risk after hip fractures is lacking. Previous research has focused on static risk factors; however, to improve outcomes, attention should be directed towards risk factors that may be optimised. The present study aimed to investigate the association of 19 risk factors with mortality among patients with hip fracture treated according to a well-defined guideline.

Methods The study was a retrospective analysis of a large prospective patient cohort with all consecutive patients surgically treated for a hip fracture from January 2011 to December 2017 included ($n=2800$). Variables were obtained from patient records and the Holstebro Hip Fracture Database comprising prospectively registered data on demographics, comorbidity, malnutrition (low Body Mass Index (BMI) or albumin) and hospital stay (including fracture and surgical data, biochemistry, mobilisation and discharge). Outcomes were 30-day and one-year mortality.

Results Patients were predominantly female (66%); median age 81.6 years. Overall mortality was 9% at 30 days and 24% at one year. Age ≥ 75 years, male gender, nursing home residence, cognitive impairment, American Society of Anesthesiologists (ASA) score ≥ 3, BMI < 20 kg/m^2, albumin < 35 g/l, creatinine ≥ 100 µmol/l, a low New Mobility Score and no mobilisation were all associated with increased mortality at 30 days and one year.

Conclusion In addition to non-modifiable risk factors, comorbidities (expressed as high ASA score and creatinine), malnutrition, and failure to achieve early post-operative mobilisation were associated with increased short and long-term mortality among patients with hip fracture: these are potentially modifiable. The effect of optimisation interventions warrants further research.

Keywords Hip fracture · Mortality · Risk factors · Optimisation

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Introduction

The increased mortality risk following hip fracture is well documented and remains high despite advances in surgical techniques and aftercare. Numerous studies have focused on identifying factors that increase mortality following hip fracture. Generally accepted risk factors include age, gender, residence, comorbidities and cognitive impairment [1–4].

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These risk factors are all essential but static. Less attention has been given to identifying risk factors that may potentially be optimised. Most studies into such risk factors have been retrospective, limited by small study populations, or included only a few variables for adjustment [1, 4]. Rogmark expressed the need for a paradigm shift in 2020: "I strongly believe that now is the time for us as orthopaedic surgeons to raise our heads from the detailed comparisons of 2 well-functioning surgical procedures and take more responsibility for the entire clinical pathway" [5]. Provided the goal is to decrease mortality following hip fractures, a natural step would be to identify risk factors with an optimisation potential (RFOP) and test the effect of various interventions. Previous studies have suggested that surgical delay increases mortality. As this factor has already been optimised in most institutions, the majority of the remaining optimisation potential lies in the post-operative period.

Identifying and quantifying the impact of risk factors, especially RFOP, on mortality may facilitate early detection of patients who may benefit from a comprehensive assessment of risk factors known to impact mortality leading to optimization and a patient-specific enhanced recovery programme. Risk factors already known to increase mortality among older patients, in general, are also likely to have a negative effect on mortality in patients with hip fractures.

The aim of the present study was to explore further the association between mortality and multiple risk factors in a large prospective cohort of patients with hip fractures who had all been treated at a hip fracture unit according to a well-defined guideline.

Method

Participants

All patients admitted or transferred to our hospital between January 2011 and December 2017 with a hip fracture were considered for inclusion. The exclusion criteria were periprostetic fractures, pathological fractures or conservatively treated fractures. Only the first fracture was analysed if a patient experienced a second hip fracture during the study period.

Variables

The study was conducted as a retrospective analysis of a prospective cohort. A local hip fracture database was established in January 2011. Data were gathered prospectively by trained nurses, physiotherapists, and doctors and were informed continuously about how to report to the database, ensuring minimal variation in reporting during the study period. One head nurse and doctor were responsible for managing the database and going through the registration paper after discharge. During admission, nurses routinely reported data regarding patient characteristics, smoking, alcohol consumption, weight, height, residence, cognitive impairment, New Mobility Score (NMS) and admission date and time. The American Society of Anaesthesiology (ASA) score (1–5 points) was obtained from the anaesthesiologist's report along with the type of anaesthesia used. Using pre-operative radiographs, the authors classified fractures as either intracapsular or extracapsular. Nurses performed a fall risk assessment (FRA), and physiotherapists documented every mobilisation session during the hospital stay. Nurses and doctors registered discharge date, surgical date and time, surgical technique and blood results, including pre-operative haemoglobin, albumin and creatinine. All data were stored in the Holstebro Hip Fracture Database.

Each variable was categorised based on current research. The reference groups were expected to have the lowest mortality rate. To ease clinical application, age was treated as a categorical value (< 75, 75–84 and ≥ 85 years). ASA score was dichotomised into healthy (ASA 1–2) and sick (ASA 3–5). For the blood results, the dividing line was at 100 g/l for haemoglobin, 35 g/dl for albumin and 100 μmol/l for creatinine [3, 6]. Patients were divided into cognitively fit or known dementia based on previous diagnoses of dementia or similar by a neurologist or the patient's general practitioner. Height was primarily patient-reported, while weight was based on weighing the patients, and used to calculate Body Mass Index (BMI) was categorised as < 20 kg/m^2, 20–30 kg/m^2 and > 30 kg/m^2 [1].

FRA was based on a small questionnaire regarding previous falls, dizziness, medication, urinary elimination, visual impairment, cognitive status and previous stroke, with patients scoring between 0 and 8 points (See Fig. 1). The questionnaire was based on clinical experience and other FRA tools available at the time, e.g. Johns Hopkins FRA tool; however, the used questionnaire has not been validated [7]. Patients were divided based on clinical experience into a low-risk group (0–1 point), a medium-risk group (2–6 points) and a high-risk group (7–8 points).

NMS was chosen to reflect the pre-fracture functional level. NMS is a self-reported measure that categorizes a patient's ability to complete 3 functional activities: indoor walking, outdoor walking, and shopping. A score is given to each activity (0–3 points) and then combined to provide a final score between 0 and 9, where 9 is independent with no aid in all three activities, and 0 is not able to carry out any of the activities. NMS was dichotomized into a low functional level (0–5 points) and a high functional level (6–9 points), as this cut-off point have previously been used to predict mortality and functional outcomes following hip fracture surgery [8, 9]. Mobilisation was divided into mobilised to standing within 24 h of surgery, not mobilised within 24 h despite

Fig. 1 The questionnaire used during the fall-risk assessment at admission

Fall risk assessment (Please check the boxes below and count the score)

1. Has the patient previously fallen □ and/or is the patient afraid of falling □? Point: _________
2. Is the patient light-headed □ and/or unsure on his legs□? Point: _________
3. Does the patient take anti-psychotics □ and/or diuretics □, antihypertensive medications □ or anti-arrhythmical medicine □? Point: _________
4. Does the patient have frequent bathroom visits □? Point: _________
5. Does the patient have impaired vision affecting everyday life □ ? Point: _________
6. Is there a suspicion that the patient may be delirious □ / confused □? Point: _________
7. Is the patient cognitively impaired □ or is there a suspicion of cognitive impairment □? Point: _________
8. Is there suspicion of diminished mental function due to a stroke or similar cognitive problems that may affect the patient's ability to move around □? Point: _________

Total points (at admission): _________ (0-8 points)

indication, and no indication for mobilisation (e.g. patients without pre-fracture standing abilities, admitted to, e.g. ICU or very complex fractures making mobilisation impossible) [10]. First-time mobilisation was checked in the electronic patient records, where physiotherapists registered all mobilisations and attempts to mobilise, including the reasoning for not achieving the standing position within 24 h.

Fracture type was divided into intracapsular and extracapsular fractures to minimise misclassification seen in the more specific classification systems such as the Garden and the Evans classifications [1]. Internal fixation, dual mobility total hip arthroplasty (THA) and Girdlestone resection arthroplasty constituted the groups for surgical technique as hemiarthroplasty and external fixation were not used as treatments at our institution. Details of the osteosynthesis algorithm have been published previously [11]. Time from admission to surgery was calculated from the time of admission to the emergency room and the time of the surgery and was grouped into < 24 h, 24–36 h and > 36 h. These time points were selected based on the national register and guidelines [10, 12].

Outcomes

The outcome was 30-day and one-year mortality from the date of admission. A unique number for each patient in the Danish Death Register directly links the register to the electronic patient records. The date of death was obtained from the electronic records, which are automatically updated upon a patient's death; no patients were lost to follow-up at one year.

Statistics

A sample size calculation was performed based on an estimated one-year mortality rate of 20% and assuming 60% of the admitted patients would have an ASA score ≥ 3 [13]. To detect a 15% difference in mortality (power 0.80, significance limit 0.05), a sample size of 118 patients was needed, which is well within the subgroup size of the study. The study population was described using descriptive statistics with numbers and percentages in total and divided into survivors and deceased at 30 days and one year.

Logistic regression analysis was used to investigate which variables were statistically significant risk factors. The dependent variable was mortality in the analysis, and the list of risk factors can be seen in Table 1. For each independent variable, a univariate model was created for 30-day and one-year mortality. Odds ratios (OR) with corresponding 95% confidence intervals (CI) were reported. Confounders were adjusted for in 3 different models for multivariate logistic regression analyses were analysed with increasing numbers of confounders. The selection of risk factors in each model was informed by clinical experience and our review of existing mortality studies. Model 1 was adjusted for age, gender and residence, as these in most studies have been found to be associated with mortality following hip fracture surgery. Furthermore, they are collected and presented similarly making a comparison of results possible. Model 2 was additionally adjusted for ASA score, cognitive impairment and BMI. The measure of comorbidities differ among previous studies, some using Charlsson Comorbidity Index (CCI) or individual comorbidities. Equally, for cognitive impairment which can be based on, e.g. mental tests or diagnoses. BMI was selected as it can be a predictor for malnutrition and a reduced physiological reserve, confounding many of the other risk factors. Finally, Model 3 was adjusted for all the independent variables to not overlook significant correlations between risk factors, which could alter the impact of one of them on mortality, reducing the risk of rejecting a true association as false.

All statistical analyses were performed in STATA 17 software using a 5% significance level.

The study was approved by the Danish Data Protection Agency (number 2007-58-0010). Under national law, there was no requirement for informed consent. No funding was received for conducting this study, and the authors have no relevant financial or non-financial interests to disclose.

Table 1 Demographic characteristics of the study population in total and divided into survivors and deceased within 30 days and one year

		30 days post-operatively		One year post-operatively	
Variable	Total, *n* (%)	Alive, *n* (%)	Dead, *n* (%)	Alive, *n* (%)	Dead, *n* (%)
Total	2800 (100%)	2537 (91%)	263 (9%)	2141 (76%)	659 (24%)
Age (median (range))+	81.6 (31.2–104.9))	81.0 (31.2–104.2)	87.9 (53.2–104.9)	80.2 (31.2–103.1)	86.6 (47.3–104.9)
Gender+					
Female	1852 (66%)	1698 (92%)	154 (8%)	1458 (79%)	394 (21%)
Male	948 (34%)	839 (89%)	109 (11%)	683 (72%)	265 (28%)
Pre-fracture residence+					
Independent living	2062 (74%)	1952 (95%)	110 (5%)	1742 (84%)	320 (16%)
Nursing home	734 (26%)	582 (79%)	152 (21%)	398 (54%)	336 (46%)
Smoking*					
Non-smoker	2072 (74%)	1863 (90%)	209 (10%)	1565 (75%)	507 (25%)
Smoker	585 (21%)	551 (94%)	34 (6%)	479 (82%)	106 (18%)
Alcohol consumption*					
< 7 units a week	2565 (92%)	2329 (91%)	236 (9%)	1974 (77%)	591 (23%)
≥ 7 units a week	53 (2%)	51 (96%)	2 (4%)	44 (83%)	9 (17%)
BMI+					
< 20 kg/m^2	522 (19%)	454 (87%)	68 (13%)	352 (67%)	170 (33%)
20–30 kg/m^2	2006 (72%)	1840 (92%)	166 (8%)	1574 (79%)	432 (21%)
> 30 kg/m^2	210 (8%)	197 (94%)	13 (6%)	180 (86%)	30 (14%)
ASA score+ [a]					
ASA 1–2	1538 (55%)	1456 (95%)	82 (5%)	1315 (86%)	223 (15%)
ASA 3–5	1195 (43%)	1024 (86%)	171 (14%)	778 (65%)	417 (35%)
Haemoglobin+					
< 100 g/l	120 (4%)	98 (82%)	22 (18%)	67 (56%)	53 (44%)
≥ 100 g/l	2674 (96%)	2434 (91%)	240 (9%)	2071 (77%)	603 (23%)
Albumin+					
< 35 g/l	632 (23%)	516 (82%)	116 (18%)	375 (59%)	257 (41%)
≥ 35 g/l	2166 (77%)	2020 (93%)	146 (7%)	1766 (82%)	400 (18%)
Creatinine+					
< 100 µmol/l	2143 (77%)	2001 (93%)	142 (7%)	1717 (80%)	426 (20%)
≥ 100 µmol/l	634 (23%)	513 (81%)	121 (19%)	404 (64%)	230 (36%)
Known dementia+					
Yes	551 (20%)	429 (78%)	122 (22%)	295 (54%)	256 (46%)
No	2231 (80%)	2093 (94%)	138 (6%)	1833 (82%)	398 (18%)
Fall risk assessment+ [c (42)]					
Low risk	603 (22%)	590 (98%)	13 (2%)	557 (92%)	46 (8%)
Medium risk	2086 (74%)	1864 (89%)	222 (11%)	1514 (73%)	572 (27%)
High risk	15 (1%)	11 (73%)	4 (27%)	10 (67%)	5 (33%)
NMS*[b]					
Low functional level	1071 (38%)	892 (83%)	179 (17%)	639 (60%)	432 (40%)
High functional level	1604 (57%)	1548 (97%)	56 (3%)	1423 (89%)	181 (11%)
Mobilised to standing within 24 h from surgery*					
Yes	2185 (78%)	2047 (94%)	138 (6%)	1767 (81%)	418 (19%)
No	341 (12%)	288 (84%)	53 (16%)	214 (63%)	127 (37%)
No indication for mobilisation	148 (5%)	93 (64%)	55 (36%)	69 (47%)	79 (53%)
Fracture type+					
Intracapsular	1486 (53%)	1347 (91%)	139 (9%)	1149 (77%)	337 (23%)
Extracapsular	1307 (47%)	1185 (91%)	122 (9%)	988 (76%)	319 (24%)
Surgical technique+					

Table 1 (continued)

		30 days post-operatively		One year post-operatively	
Variable	Total, *n* (%)	Alive, *n* (%)	Dead, *n* (%)	Alive, *n* (%)	Dead, *n* (%)
Internal fixation	1810 (65%)	1643 (91%)	167 (9%)	1375 (76%)	435 (24%)
Total hip arthroplasty	972 (35%)	884 (91%)	90 (9%)	756 (78%)	216 (22%)
Girdlestone resection arthroplasty	12 (< 1%)	7 (58%)	5 (42%)	5 (42%)	7 (58%)
Anaesthesia⁺					
General anaesthetic	1695 (61%)	1521 (90%)	174 (10%)	1268 (75%)	427 (25%)
Spinal block	1100 (39%)	1011 (92%)	89 (8%)	868 (79%)	232 (21%)
Time from admission to surgery⁺					
< 24 h	2004 (72%)	1825 (91%)	179 (9%)	1578 (79%)	426 (21%)
24–36 h	381 (14%)	342 (90%)	39 (10%)	275 (72%)	106 (28%)
> 36 h	339 (12%)	301 (89%)	38 (11%)	233 (68%)	106 (32%)

ASA American Society of Anaesthesiologists, *BMI* Body Mass Index, *NMS* New Mobility Score

⁺Percentage of missing values < 5%

*Percentage of missing values 5–10%

[a]American Society of Anaesthesiologists

[b]New Mobility Score, 0–5 point = low functional level and 6–9 points = high functional level

[c]Fall risk assessment made retrospectively for the period leading up to the fracture. A score from 0–8 points, with an increasing risk of falling with higher points

Results

Demographics

A total of 3047 patients were admitted with a hip fracture in the study period. To evaluate the validity of our inclusion process, we extracted data from our regional server on all patients registered with a surgical procedure that could be a treatment for a hip fracture. Afterwards, the electronic patient records were checked for a diagnosis of a hip fracture, and 20 patients with a hip fracture but not included in the database was identified. Of the 3047 patients included in the database, 11 patients had no information regarding their hip fracture at the beginning of the period and were excluded. Of the 3036 patients eligible for inclusion, 41 patients were treated conservatively, and 20 patients had a pathological or periprostetic fracture. Furthermore, 175 patients experienced a second hip fracture in the study period, yielding a study population of 2800 patients (Fig. 2). The study population was predominantly female with a median age of 81.6 (31.2–104.2) years, and most were living independently. Almost half of the patients had an ASA score ≥ 3, 20% had a diagnosis of cognitive impairment prior to their hip fracture, and 19% had a BMI ≤ 20 kg/m^2. A near 50/50 split was recorded between intracapsular and extracapsular fractures (Table 1).

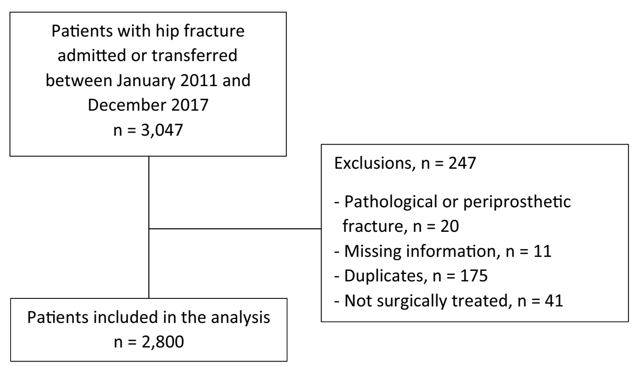

Fig. 2 Inclusion flowchart

Risk factors associated with 30-day and 1-year mortality are presented in Tables 2 and 3, respectively. The overall mortality rate at 30 days was 9%, and 24% at 1-year (Table 1). An approximately twofold increase in mortality at 30 days was found in model 3 for patients aged ≥ 75 years, male sex, nursing home residence, BMI < 20 kg/m^2, high creatinine, known cognitive impairment, low functional level, not mobilised within 24 h, and no indication for mobilisation. Age ≥ 85 years, creatinine > 100 µmol/l, and no indication for mobilization had the highest OR at 30 days (Table 2). 1-year mortality was

Table 2 Odds ratio (OR) for potential risk factors for increased 30 days mortality following a hip fracture adjusted stepwise in models 1[a], 2[b] and 3[c], shown with OR with 95% confidence intervals (CI) ($n = 2800$)

Variable	Crude OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Age (ref. < 75 years)				
75–84 years	**2.81 (1.73–4.56)**	**2.53 (1.54–4.14)**	**2.43 (1.44–4.09)**	**1.96 (1.03–3.72)**
≥ 85 years	**6.40 (4.06–10.09)**	**4.93 (3.06–7.94)**	**4.44 (2.67–7.37)**	**2.97 (1.58–5.58)**
Gender (ref. female)				
Male	**1.43 (1.11–1.86)**	**2.03 (1.54–2.69)**	**2.14 (1.58–2.90)**	**1.65 (1.14–2.40)**
Pre-fracture residence (ref. independent living)				
Institutionalised	**4.63 (3.57–6.02)**	**3.65 (2.77–4.79)**	**2.36 (1.58–2.90)**	**1.97 (1.32–2.94)**
Smoking (ref. non-smoker)				
Smoker	**0.55 (0.38–0.80)**	0.93 (0.62–1.39)	0.84 (0.55–1.29)	1.04 (0.63–1.69)
Alcohol consumption (ref. non-drinker)				
Drinker	0.39 (0.09–1.60)	0.92 (0.21–3.97)	0.46 (0.06–3.47)	0.74 (0.09–5.94)
BMI (ref. 20–30 kg/m^2)				
< 20 kg/m^2	**1.66 (1.23–2.24)**	**1.88 (1.36–2.59)**	**1.86 (1.34–2.60)**	**1.90 (1.27–2.82)**
> 30 kg/m^2	0.73 (0.41–1.31)	1.06 (0.58–1.94)	1.09 (0.59–2.03)	1.02 (0.47–2.21)
ASA (ref. ASA 1–2)				
ASA 3–5	**2.97 (2.25–3.91)**	**2.14 (1.60–2.86)**	**1.96 (1.46–2.65)**	1.20 (0.84–1.71)
Haemoglobin (ref. ≥ 6 mmol/l)				
< 100 g/l	**2.28 (1.41–3.68)**	**1.97 (1.17–3.29)**	**1.96 (1.15–3.32)**	1.48 (0.79–2.75)
Albumin (ref. ≥ 35 g/dl)				
< 35 g/dl	**3.11 (2.39–4.04)**	**2.74 (2.07–3.61)**	**2.54 (1.89–3.41)**	**2.09 (1.47–2.98)**
Creatinine (ref. < 100 µmol/l)				
≥ 100 µmol/l	**3.32 (2.56–4.32)**	**2.49 (1.87–3.32)**	**2.31 (1.70–3.14)**	**2.49 (1.74–3.58)**
Known dementia				
Yes	**4.31 (3.31–5.62)**	**2.04 (1.48–2.80)**	**2.11 (1.52–2.94)**	**1.80 (1.21–2.68)**
Fall risk assessment (ref. low risk)				
Medium risk	**5.41 (3.07–9.53)**	**2.75 (1.53–4.95)**	**2.23 (1.20–4.14)**	1.73 (0.85–3.51)
High risk	**16.50 (4.64–58.74)**	**6.51 (1.71–24.76)**	**4.38 (1.14–16.93)**	3.00 (0.62–14.43)
NMS (ref. high functional level)				
Low functional level	**5.55 (4.06–7.57)**	**3.05 (2.15–4.31)**	**2.35 (1.63–3.38)**	**1.93 (1.26–2.93)**
Mobilised to standing within 24 h from surgery (ref. yes)				
No	**2.73 (1.94–3.83)**	**1.97 (1.38–2.82)**	**1.87 (1.28–2.74)**	**1.90 (1.24–2.90)**
No indication for mobilisation	**8.77 (6.03–12.77)**	**6.70 (4.48–10.04)**	**5.38 (3.45–8.38)**	**3.86 (2.27–6.55)**
Fracture type (ref. intracapsular)				
Extracapsular	1.00 (0.77–1.29)	0.95 (0.73–1.24)	0.96 (0.72–1.27)	1.03 (0.64–1.66)
Surgical technique (ref. internal fixation)				
Total hip arthroplasty	1.00 (0.77–1.31)	1.04 (0.78–1.38)	1.02 (0.75–1.37)	1.08 (0.65–1.80)
Girdlestone resection arthroplasty	**7.03 (2.21–22.39)**	3.33 (0.96–11.61)	**5.12 (1.31–20.05)**	1.43 (0.30–6.81)
Anaesthesia (ref. general anaesthesia)				
Spinal block	0.77 (0.59–1.01)	0.86 (0.65–1.14)	0.98 (0.72–1.33)	0.97 (0.67–1.39)
Time from admission to surgery (ref. < 24 h)				
24–36 h	1.16 (0.81–1.67)	0.95 (0.65–1.40)	0.86 (0.56–1.31)	0.80 (0.48–1.32)
> 36 h	1.29 (0.89–1.86)	1.12 (0.76–1.66)	1.22 (0.82–1.80)	1.07 (0.66–1.74)

ASA American Society of Anaesthesiologists, *BMI* Body Mass Index, *NMS* New Mobility Score

Bold values highlight statistically significant results

[a]Adjusted for age group, gender and residence

[b]Adjusted for age group, gender, residence, BMI group, ASA score and cognitive impairment

[c]Adjusted for age group, gender, residence, smoking, alcohol consumption, BMI group, ASA score, haemoglobin, albumin, creatinine, known dementia, fall risk assessment, NMS, mobilised into standing within 24 h, fracture type, surgical technique, anaesthesia and time to surgery

Table 3 Odds ratio (OR) for potential risk factors for increased one-year mortality following hip fracture adjusted stepwise in models 1[a], 2[b] and 3[c], shown with OR with 95% confidence intervals (CI) ($n = 2800$)

Variable	Crude OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Age (ref. < 75 years)				
75–84 years	**2.59 (1.95–3.45)**	**2.52 (1.87–3.40)**	**2.22 (1.62–3.05)**	**1.97 (1.34–2.91)**
≥ 85 years	**5.51 (4.19–7.24)**	**4.73 (3.52–6.35)**	**4.17 (3.06–5.69)**	**3.49 (2.36–5.16)**
Gender (ref. female)				
Male	**1.44 (1.20–1.72)**	**2.09 (1.71–2.56)**	**2.09 (1.68–2.60)**	**1.92 (1.47–2.50)**
Pre-fracture residence (ref. independent living)				
Institutionalised	**4.60 (3.81–5.55)**	**3.74 (3.06–4.56)**	**2.49 (1.97–3.16)**	**1.97 (1.48–2.62)**
Smoking (ref. non-smoker)				
Smoker	**0.68 (0.54–0.86)**	1.15 (0.88–1.51)	0.98 (0.74–1.30)	1.06 (0.76–1.47)
Alcohol consumption (ref. non-drinker)				
Drinker	0.68 (0.33–1.41)	1.27 (0.57–2.81)	1.05 (0.45–2.49)	0.94 (0.33–2.66)
BMI (ref. 20–30 kg/m^2)				
< 20 kg/m^2	**1.76 (1.42–2.17)**	**2.09 (1.65–2.65)**	**2.05 (1.60–2.62)**	**1.90 (1.42–2.53)**
> 30 kg/m^2	**0.61 (0.41–0.91)**	0.83 (0.54–1.27)	0.81 (0.52–1.26)	0.76 (0.44–1.32)
ASA score (ref. ASA 1–2)				
ASA 3–5	**3.16 (2.63–3.81)**	**2.46 (2.01–3.00)**	**2.28 (1.85–2.79)**	**1.57 (1.22–2.00)**
Haemoglobin (ref. ≥ 100 g/l)				
< 100 g/l	**2.72 (1.87–3.94)**	**2.64 (1.74–3.99)**	**2.45 (1.59–3.78)**	1.59 (0.97–2.62)
Albumin (ref. ≥ 35 g/dl)				
< 35 g/dl	**3.03 (2.50–3.67)**	**2.89 (2.34–3.57)**	**2.52 (2.02–3.15)**	**2.21 (1.71–2.88)**
Creatinine (ref. < 100 µmol/l)				
≥ 100 µmol/l	**2.29 (1.89–2.78)**	**1.63 (1.31–2.02)**	**1.47 (1.16–1.85)**	**1.54 (1.18–2.02)**
Known dementia				
Yes	**3.99 (3.27–4.88)**	**1.86 (1.46–2.36)**	**1.93 (1.50–2.48)**	**1.60 (1.19–2.16)**
Fall-risk assessment (ref. Low risk)				
Medium risk	**4.57 (3.34–6.27)**	**2.56 (1.83–3.57)**	**1.97 (1.39–2.78)**	**1.61 (1.08–2.42)**
High risk	**6.05 (1.99–18.46)**	2.37 (0.73–7.73)	1.48 (0.45–4.84)	0.92 (0.24–3.53)
NMS (ref. high functional level)				
Low functional level	**5.32 (4.36–6.47)**	**3.15 (2.52–3.93)**	**2.52 (1.99–3.19)**	**2.14 (1.64–2.80)**
Mobilized to standing within 24 h from surgery (ref. yes)				
No	**2.51 (1.97–3.20)**	**1.88 (1.44–2.45)**	**1.69 (1.27–2.27)**	**1.72 (1.24–2.39)**
No indication for mobilisation	**4.84 (3.44–6.80)**	**3.61 (2.48–5.26)**	**2.92 (1.94–4.40)**	**2.22 (1.39–3.55)**
Fracture type (ref. intracapsular)				
Extracapsular	1.10 (0.92–1.31)	1.06 (0.88–1.29)	1.05 (0.86–1.29)	0.96 (0.69–1.34)
Surgical technique (ref. internal fixation)				
Total hip arthroplasty	0.90 (0.75–1.09)	0.92 (0.75–1.12)	0.91 (0.74–1.13)	0.95 (0.67–1.34)
Girdlestone resection arthroplasty	**4.43 (1.40–14.01)**	1.98 (0.57–6.92)	3.73 (0.79–17.63)	0.59 (0.12–2.76)
Anaesthesia (ref. general anaesthetic)				
Spinal block	**0.79 (0.66–0.95)**	0.89 (0.72–1.08)	1.01 (0.82–1.25)	1.04 (0.81–1.33)
Time from admission to surgery (ref. < 24 h)				
24–36 h	**1.43 (1.11–1.83)**	1.22 (0.93–1.60)	1.07 (0.79–1.44)	1.07 (0.76–1.51)
> 36 h	**1.69 (1.31–2.17)**	**1.59 (1.21–2.10)**	**1.71 (1.29–2.27)**	**1.74 (1.24–2.43)**

ASA American Society of Anaesthesiologists, *BMI* Body Mass Index, *NMS* New Mobility Score

Bold values highlight statistically significant results

[a]Adjusted for age group, gender and residence

[b]Adjusted for age group, gender, residence, BMI group, ASA score and cognitive impairment

[c]Adjusted for age group, gender, residence, smoking, alcohol consumption, BMI group, ASA score, haemoglobin, albumin, creatinine, known dementia, fall risk assessment, NMS, mobilised into standing within 24 h, fracture type, surgical technique, anaesthesia and time to surgery

additionally associated with ASA score ≥ 3, medium risk in the FRA, and surgical delay > 36 h. Albumin < 35 g/dl, low functional level, and no indication for mobilization all had a more than twofold increase in OR for 1-year mortality (Table 3).

Discussion

Main results

In this observational cohort study, the following risk factors were associated with increased mortality both at 30 days and one year; age ≥ 75 years, male gender, nursing home residence, BMI < 20 kg/m^2, albumin < 35 g/dl, creatinine > 100 µmol/l, cognitive impairment, low NMS and not being mobilised within 24 h.

Comparison with previous literature

Mortality rates and patient characteristics were comparable with those reported in previous studies regarding age, gender, residence and fracture type [14–16]. We confirmed that age ≥ 75 years, male gender, nursing home residence and cognitive impairment were associated with increased ORs. These are generally accepted risk factors but static. To reduce mortality following hip fractures, RFOP, e.g. comorbidities, have higher interest. A frequently used measure of patients' comorbidity level is the ASA score, which has previously been found to predict mortality [1, 4, 17]. In the present study, the ASA score was not significantly associated with increased mortality at 30 days in Model 3. However, it is unlikely that comorbidities do not affect mortality risk, and most previous studies have also found an association between comorbidities and mortality following a hip fracture [14, 16, 17]. This includes studies using ASA score as a comorbidity measure, and in the systematic review by Xu et al. [4], all 7 studies using ASA score found an association. Other risk factors such as cognitive impairment and blood results could have diluted the association between ASA score and mortality. Its rough division of comorbidities inherently limits ASA score. To detect changes made by optimisation on patients' comorbidities and studies into the effect of optimisation of comorbidities on survival following hip fracture surgery should opt for a different measure. Low albumin and high creatinine were associated with increased mortality as in previous studies [3, 6]. Vochteloo et al. [18] hypothesised that haemoglobin could be a proxy for comorbidities rather than an actual cause of mortality, as association disappeared after adjusting for confounders like that seen in the present study. Still, the literature is conflicting. A systematic review found a strong association between haemoglobin and mortality, leading the authors to recommend that future mortality studies include haemoglobin in their models [19]. Furthermore, our guideline had a liberal transfusion strategy, and almost all patients with a postoperative haemoglobin < 100 g/l was given a blood transfusion [11]. This strategy has previously been shown to affect mortality following hip fracture, maybe due to better and quicker mobilization [20].

FRA tools are used to identify individuals at increased risk of falling. We based our FRA tool on a small questionnaire with eight questions regarding vision, confusion, falling, comorbidities and medication. This may explain why a significant drop in OR was seen after adjusting for confounders and could have resulted in over-adjustment in model 3. The questions may have acted as a proxy for other variables, e.g. age, ASA score, cognitive impairment or functional level. Hence, the present study found no consistent association between a medium or high risk in our FRA tool and increased mortality. Nevertheless, that does not conclusively imply no association between FRA tools and increased mortality following hip fracture surgery. It is widely accepted that falling poses a risk for older persons by increasing the risk of injuries such as head trauma and hip fractures. However, there is no consensus on the best FRA tool among hip fracture patients, and tools currently used for the evaluation of older patients' fall risk vary greatly [21, 22]. Some FRA tools have been validated in patients with hip fractures, e.g. the Activities-specific Balance Confidence (ABC) scale, Berg Balance scale (BBS), Timed-up-and-go (TUG) and Tinnetti-Balance-Scale (TBS). However, limitations include complexity in a clinical setting, low specificity, high inter-test reliability, and difficulty for patients to complete [21–23]. Suppose a relatively simple FRA with high sensitivity, specificity and reliability could be validated in patients with hip fracture. In that case, it could be used to initiate measures to reduce the risk of falls, preventing readmissions and secondary hip fractures, and thereby, mortality. Further research into both FRA tools validated in patients with hip fracture and their prediction values are needed.

Comorbidities greatly affect patients' risk of death following hip fracture, and some comorbidities may be optimised through improved treatment (e.g., cardiovascular diseases). Our study suggested that increased mortality is associated especially with low albumin and high creatinine, and to some extent, a high ASA score. These are all standard clinical or biochemical measures already used in the clinic, facilitating their use in individual mortality risk assessments. In contrast to elective surgeries, pre-operative optimisation is challenging in patients with hip fractures as priority is given to reducing the time from admission to surgery. The focus should therefore be on postoperative assessments and optimisation. This highlights a need for enhanced recovery programmes among patients with hip fractures.

Malnutrition seems to represent a fragile physiological state, which might explain prior findings of an increased risk of adverse outcomes and hip fractures among older persons [24, 25]. In our study, BMI and hypoalbuminemia were used as indicators of malnutrition. Previous studies have found that hypoalbuminemia is associated with increased mortality [3, 6, 26]. We found an approximately two-fold increase in OR over the entire study period for low albumin. The association seemed to be relatively robust as adjusting for, e.g., BMI and ASA had little impact on the OR. Few have investigated BMI as a predictor of mortality [27–29]. Akinleye et al. and Solbakken et al. found a U-shaped association between BMI and mortality, with a higher risk among both underweight and morbidly obese patients (BMI > 40 kg/m^2) [27, 29]. Even though we confirm that low BMI increases mortality following hip fracture surgery, we were unable to demonstrate a U-shaped association due to the grouping of patients and the fact that only a few patients in the study population had a BMI > 40 kg/m^2. A randomised clinical trial found that an in-hospital nutritional intervention reduced mortality and complications [30]. However, more research is needed into implementing nutritional interventions after hip fracture surgery regarding which actions are effective and when to implement them. This is emphasised by a Cochrane review from 2016, which found little evidence that e.g. oral supplements reduce the mortality risk [31].

In line with previous publications, we found low NMS and not mobilised to standing within 24 h to be associated with increased mortality [8, 32, 33]. Patients' pre-fracture functional level is not modifiable after having sustained a hip fracture but may focus the efforts on patients with increased mortality risk. However, early mobilisation is modifiable. This study supports the importance of early mobilisation to improve outcomes following a hip fracture as a comparison was made between those allowed mobilisation and achieved it with those how were allowed and did not achieve a standing position. Furthermore, a comparison was made to those who had no indication for early mobilisation for different reasons.

We found no consistent association between mortality and fracture type, surgical technique, anaesthesia, and time from admission to surgery for surgical-related factors. Especially the timing of hip fracture surgery has been the subject of a long-standing debate. There is significant variation between countries' guidelines, which may lead to studies using different time points, e.g. 12, 24, 36 and 48 h, and contradictory results [10, 34–38]. A reduction in the time to surgery has been prioritized in many hospitals, and the association between surgery within 12 h and mortality have been investigated [36, 37]. However, long-term mortality was not associated with time to surgery < 12 h, but only for delays > 48 h. We reported on 24 and 36 h, as these time points are the recommendation in our country, and found > 36 h delay to be associated with 1-year mortality. This contradicts the results from Leer-Salvesen et al. [36]; however, they used total delay. Another possible explanation for this might be the reasoning for delaying surgery, as Lizaur-Utrilla et al. [35] found patients delayed for organizational reasons to have increased mortality but not for delays due to stabilizing active comorbidities. Hence, finding the correct time of surgery is probably more complex than just a specific time from admission. Factors such as time from injury to admission and reasoning for delays, based on patient characteristics, surgical-related and hospital-related factors may impact the timing.

The treatment of hip fractures is constantly evolving, e.g., the introduction of orthogeriatric wards and new guidelines for surgical technic, the timing of surgery and mobilisation. Research into patients with hip fractures, including mortality, have also evolved from being centred around the surgery to being patient-centred, as it should. The present study builds upon the foundation of previous research with similar results, however, it introduces new risk factors that were not generally considered decades ago [39, 40].

Strengths and limitations

The present study had several strengths, including a prospective design with all admitted patients being included consecutively, thereby eliminating recall and selection bias. Furthermore, the amount of missing data was low, although the study population was considerable. Inclusion of all patients, even patients with cognitive impairment and multiple comorbidities, ensures a high level of external validity. However, the findings cannot be directly extrapolated to populations not predominantly white men and women with sociodemographic characteristics similar to those of the study participants. On the other hand, it is plausible that our results may be replicated in other ethnic groups, as previous studies have shown little effect of ethnicity on outcome and treatment [1].

Some limitations should also be acknowledged. The study results originate from a single hospital; however, this also means that all patients were treated according to the same well-defined guideline and that data collection was similar for all patients [11].

A three-model adjustment was chosen in the analysis as some risk factors might be mediators in each other's pathway; e.g., fracture type would typically determine surgical technique. No gold standard exists for determining which variables to incorporate in each step of the model as each study has different risk factors. In Model 1, only a few general characteristics were chosen. Then, in Model 2, a few extra generally accepted and standardised variables available for most patients were added. Additionally, we included all variables which implied a risk of over adjustment. Nonetheless, over adjustment would be more transparent in the stepwise adjustment approach adopted than in a single multivariate analysis. Residual confounding may exist, e.g. medications and marital status.

Finally, the present study was observational. Therefore, we cannot conclude as to causality, only association. Future studies investigating RFOP and the implementation of enhanced recovery programmes would be interesting. Such studies may clarify if programmes implemented after hip fracture make a significant difference in mortality or if programmes are effective only if implemented prior to the hip fracture.

Conclusion

The high mortality rates following hip fractures indicate that there is still room for improvement in the treatment of patients with hip fractures. Age ≥ 75 years, male gender, nursing home residence, and cognitive impairment at the time of admission were risk factors for 30-day and one-year mortality in this study. However, these factors are static. The present study also indicates that clinicians may be able to optimise other risk factors of mortality, including some comorbidities, malnutrition and in-hospital rehabilitation. Future studies exploring how and when enhanced recovery programmes should be implemented are warranted.

Author contributions All authors contributed to the study's conception and design. CFF performed data collection along with the analysis assisted by ENG. The first draft of the manuscript was written by CFF, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials Upon reasonable inquiry to corresponding author protocol and data analysis files are available. To access data relevant authorities have to be contacted to obtain permission.

Declarations

Conflict of interest The authors have no conflicts of interest to declare.

Ethics approval The study was registered with the Danish Data Protection Agency (number 2007-58-0010).

Consent to participate and for publication Under Danish law, no requirement for informed consent applied.

References

1. Smith T, Pelpola K, Ball M, Ong A, Myint PK (2014) Pre-operative indicators for mortality following hip fracture surgery: a systematic review and meta-analysis. Age Ageing 43(4):464–471
2. Bai J, Zhang P, Liang X, Wu Z, Wang J, Liang Y (2018) Association between dementia and mortality in the elderly patients undergoing hip fracture surgery: a meta-analysis. J Orthop Surg Res 6:1–8
3. Meng D, Bai X, Wu H, Yao S, Ren P, Bai X et al (2019) Patient and perioperative factors influencing the functional outcomes and mortality in elderly hip fractures. J Investig Surg. https://doi.org/10.1080/08941939.2019.1625985
4. Xu BY, Yan S, Low LL, Vasanwala FF, Low SG (2019) Predictors of poor functional outcomes and mortality in patients with hip fracture: a systematic review. BMC Musculoskelet Disord 20(1):568
5. Rogmark C (2020) Further refinement of surgery will not necessarily improve outcome after hip fracture. Acta Orthop 91(2):123–124
6. Laulund AS, Lauritzen JB, Duus BR, Mosfeldt M, Jørgensen HL (2012) Routine blood tests as predictors of mortality in hip fracture patients. Injury 43(7):1014–1020. https://doi.org/10.1016/j.injury.2011.12.008
7. Poe SS, Cvach M, Dawson PB, Straus H, Hill EE (2007) The Johns Hopkins fall risk assessment tool: postimplementation evaluation. J Nurs Care Qual 22(4):293–298
8. Parker MJ, Palmer CR (1993) A new mobility after score for predicting mortality. J Bone Jt Surg Br 75(5):797–798
9. Kristensen MT, Bang N, Kehlet H, Centret JM (2005) Timed Up & Go og New Mobility Score til prædiktion af funktion seks måneder efter hoftefraktur [Timed up and go and new mobility score as predictors of function six months after hip fracture]. Ugeskr Laeger 3297–300
10. Danish Multidisciplinary Hip Fracture Registry (2019) Annual report 2019 [Internet]. https://www.sundhed.dk/content/cms/62/4662_hofterapport.pdf
11. Frandsen CF, Glassou EN, Stilling M, Hansen TB (2021) Poor adherence to guidelines in treatment of fragile and cognitively impaired patients with hip fracture: a descriptive study of 2,804 patients. Acta Orthop. https://doi.org/10.1080/17453674.2021.1925430
12. Jensen CM, Mainz H, Lamm M, Foss NB, Villadsen B, Ovesen O et al (2008) Reference programme for treatment of patients with proximal femur fractures. DanskSygeplejeråd, DanskeFysioterapeuter DanskOrtopædiskSelskab 1–128
13. Tsang C, Boulton C, Burgon V, Johansen A, Wakeman R, Cromwell DA (2017) Predicting 30-day mortality after hip fracture surgery—evaluation of the National Hip Fracture Database case-mix adjustment model. Bone Jt Res 6(9):550–556
14. Flikweert ER, Wendt KW, Diercks RL, Izaks GJ, Landsheer D, Stevens M et al (2018) Complications after hip fracture surgery: are they preventable? Eur J Trauma Emerg Surg 44(4):573–580
15. Yoo J, Lee JS, Kim S, Kim BS, Choi H, Song DY et al (2019) Length of hospital stay after hip fracture surgery and 1-year mortality. Osteoporos Int 30:145–153
16. Kristensen MT, Öztürk B, Röck ND, Ingeman A, Palm H, Pedersen AB (2019) Regaining pre-fracture basic mobility status after hip fracture and association with post-discharge mortality and readmission—a nationwide register study in Denmark. Age Ageing 48(January):278–284
17. Ercin E, Bilgili MG, Sari C, Basaran SH, Tanriverdi B, Edipoglu E et al (2017) Risk factors for mortality in geriatric hip fractures: a compressional study of different surgical procedures

in 785 consecutive patients. Eur J Orthop Surg Traumatol 27(1):101–106
18. Vochteloo AJH, Ls B, Burg B Van Der, Mertens BJA, Niggebrugge AHP, Vries MR De et al (2011) Outcome in hip fracture patients related to anemia at admission and allogeneic blood transfusion: an analysis of 1262 surgically treated patients. BMC Musculoskelet Disord 12(1):262. http://www.biomedcentral.com/1471-2474/12/262
19. Potter LJ, Doleman B, Moppett IK (2015) A systematic review of pre-operative anaemia and blood transfusion in patients with fractured hips. Anaesthesia 70:483–500
20. Gregersen M, Damsgaard EM, Borris LC (2015) Blood transfusion and risk of infection in frail elderly after hip fracture surgery: the TRIFE randomized controlled trial. Eur J Orthop Surg Traumatol 25(6):1031–1038
21. Vottis CT, Mitsiokapa E, Igoumenou VG, Megaloikonomos PD, Galanopoulos IP, Georgoudis G et al (2018) Fall risk assessment metrics for elderly patients with hip fractures. Orthopedics 41(3):142–156
22. Park SH (2018) Tools for assessing fall risk in the elderly: a systematic review and meta-analysis. Aging Clin Exp Res 30(1):1–16
23. Nygard H, Matre K, Fevang JM (2016) Evaluation of Timed Up and Go Test as a tool to measure postoperative function and prediction of one year walking ability for patients with hip fracture. Clin Rehabil 30(5):472–480
24. Huang Z, Himes JH, Mcgovem PG (1996) Nutrition and subsequent hip fracture risk among a national cohort of white women. Am J Epidemiol 144(2):124–134
25. Corti M, Guralnik J, Salive M, Sorkin J (1994) Serum albumin level and physical disability as predictors of mortality in older persons. JAMA J Am Med Assoc 272(13):1036–1042
26. Bohl DD, Shen MR, Hannon CP, Fillingham YA, Darrith B, Valle Della CJ (2017) Serum albumin predicts survival and postoperative course following surgery for geriatric hip fracture. J Bone Jt Surg Am 99:2110–2118
27. Solbakken SM, Meyer HE, Stigum H, Søgaard AJ, Holvik K (2017) Excess mortality following hip fracture: impact of self-perceived health, smoking, and body mass index. A NOREPOS study. Osteoporos Int 28:881–887
28. Vosoughi AR, Emami MJ, Pourabbas B, Mahdaviazad H (2017) Factors increasing mortality of the elderly following hip fracture surgery: role of body mass index, age, and smoking. Musculoskelet Surg 101(1):25–29
29. Akinleye SD, Garofolo G, Culbertson MD, Homel P, Erez O (2018) The role of BMI in hip fracture surgery. Geriatr Orthop Surg Rehabil 9:1–6
30. Eneroth M, Olsson U, Thorngren K (2006) Nutritional supplementation decreases hip fracture-related complications. Clin Orthop Relat Res 451:212–217
31. Avenell A, Smith T, Curtain J, Mak J, Myint P (2016) Nutritional supplementation for hip fracture aftercare in older people. Cochrane Database Syst Rev. https://doi.org/10.1002/14651858.CD001880.pub6
32. Goubar A, Martin FC, Potter C, Jones GD, Sackley C, Ayis S et al (2021) The 30-day survival and recovery after hip fracture by timing of mobilization and dementia: a UK database study. Bone Joint J 103-B(7):1317–1324
33. Ferris H, Brent L, Coughlan T (2020) Early mobilisation reduces the risk of in-hospital mortality following hip fracture. Eur Geriatr Med 11(4):527–533. https://doi.org/10.1007/s41999-020-00317-y
34. Royal College of Physicians (2019) National Hip Fracture Database (NHFD) annual report 2019
35. Lizaur-Utrilla A, Gonzalez-Navarro B, Vizcaya-Moreno MF, Miralles Muñoz FA, Gonzalez-Parreño S, Lopez-Prats FA (2019) Reasons for delaying surgery following hip fractures and its impact on one year mortality. Int Orthop 43(2):441–448
36. Leer-Salvesen S, Engesæter LB, Dybvik E, Furnes O, Kristensen TB, Gjertsen JE (2019) Does time from fracture to surgery affect mortality and intraoperative medical complications for hip fracture patients? An observational study of 73 557 patients reported to the Norwegian hip fracture register. Bone Jt J 101-B(9):1129–1137
37. Hongisto MT, Nuotio MS, Luukkaala T, Väistö O, Pihlajamäki HK (2019) Delay to surgery of less than 12 hours is associated with improved short- and long-term survival in moderate- to high-risk hip fracture patients. Geriatr Orthop Surg Rehabil 10:215145931985314
38. Mitchell SM, Chung AS, Walker JB, Hustedt JW, Russell GV, Jones CB (2018) Delay in hip fracture surgery prolongs postoperative hospital length of stay but does not adversely affect outcomes at 30 days. J Orthop Trauma 32(12):629–633
39. Keene GS, Parker MJ, Pryor GA (1993) Mortality and morbidity after hip fractures. Br Med J 307(6914):1248–1260
40. Hannan EL, Magaziner J, Wang JJ, Eastwood EA, Silberzweig SB, Gilbert M et al (2001) Mortality and locomotion 6 months after hospitalization for hip fracture risk factors and risk-adjusted hospital outcomes. J Am Med Assoc 285(21):2736–2742

Paper III

Active clinical issues at discharge predict readmission within 30 days and one year following hip fracture surgery

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Key summary points

Aim: To identify risk factors that may contribute to readmission within 30 days and one year after hip fracture surgery for all causes in general and medical causes in particular, and to investigate the impact of delay in surgery for medical causes and active clinical issues (ACIs) on 30-day readmission.

Findings: Readmission within 30 days and one year after hip fracture surgery was primarily due to medical causes – especially ACIs.

Message: Resolving ACIs before discharge may reduce readmission rates within 30 days and one year after hip fracture surgery and ensure a safer and more successful recovery for this fragile patient group.

Abstract

Purpose: To identify risk factors contributing to readmission within 30 days and one year after hip fracture surgery. Furthermore, to explore any association between 30-day readmission and: 1) medical issues as delaying surgery and 2) active clinical issues (ACIs) at the time of discharge.

Method: We studied a consecutive cohort of hip fracture patients surgically treated from 2011 to 2017. Data were collected prospectively about patient characteristics, proxy variables for comorbidities and hospital-related variables. ACIs were defined as unstable vital signs or antibiotic treatment at discharge.

Results: A total of 2,510 patients were included of whom 14% were readmitted within 30 days and 39% within one year after hip fracture surgery. The most frequent causes of readmission (30 days/one year) were medical causes unrelated to the hip fracture (62%/53%) and new trauma (13%/19%). After adjustment, patient characteristics associated with increased readmission risk were age > 85 years, male sex, living independently, smoking and a Body Mass Index (BMI) < 18.5 kg/cm^2. Proxy variables for comorbidities associated with a higher readmission rate were high ASA score, anticoagulation therapy, low albumin and high creatinine. For hospital-related variables, ACIs were associated with an increased risk of readmission, especially due to medical and infectious causes. ACIs attributed to 46% of readmissions for medical causes. However, medical issues resulting in surgery delays exceeding > 24 hours did not increase the risk of readmission within 30 days.

Conclusion: Readmission following hip fracture surgery is high, but some readmissions may be prevented. Resolving ACIs before discharge using tailormade discharge plans and focused follow-up may reduce readmissions following hip fracture surgery in this fragile patient group.

Keywords: *hip fracture, readmission, risk factors, optimization, active clinical issues, surgical delay*

Introduction

Predictions estimate that increasing life expectancy will result in 4.5 to 6.3 million annual hip fractures worldwide by 2050 [1]. Considering the increased mortality, morbidity and disability that follow after a hip fracture, these patients constitute a significant challenge for the healthcare systems and for society.

Readmissions are common and complicate recovery after hip fracture surgery. Furthermore, increased mortality rates have been reported in patients readmitted to hospital after hip fracture surgery [2, 3]. Early readmission to hospital may be seen as a preventable failure to ensure safe discharge; and some countries, like the US and UK, have imposed fines or non-payment policies to reduce readmission rates [1, 2). These financial incentives have led to more research into risk factors and preventive measures. Several studies have explored the prevalence and risk factors for early (30 days) [4–7] and late (one year) [2, 5, 7–9] readmissions. These studies have identified numerous risk factors for hospital readmission in patients treated for hip fracture, including age, gender, comorbidities, residence, functional level and cognitive status [1–3, 6, 7, 10]. However, a systematic review from 2017 found that no risk factor was consistently associated with readmission in all studies in which the risk factor had been investigated [1]. This highlights a key challenge; identifying patients with increased risk for readmission to target them for intervention.
A lack of knowledge exists regarding modifiable risk factors for readmissions. One such risk factor is time to surgery. Thus, some studies find that time to surgery predicts readmissions [2, 3, 7, 11], whereas others have found no such association [8, 10]. The reason why surgery is delayed may explain these inconsistent results. However, to our knowledge, no studies have scrutinised the reasons for delaying surgery and the association between the cause of delay and the risk of readmission following hip fracture surgery.

With more hospitals adopting fast-track treatment strategies for patients with hip fractures, the length of stay (LOS) has been shortened, which raises concern that some patients may be discharged prematurely [12]. Premature discharge may be evaluated based on vital signs at discharge and medical complications during the acute hospital stay. Such active clinical issues (ACIs) have received only little attention, but knowledge of ACIs may potentially help develop tailor-made treatment plans and follow-up measures upon discharge.

The present study aimed to understand the reasons for hospital readmission in patients treated for hip fracture, in general and for medical causes. Specifically, this prospective observational study investigated factors associated with readmission within 30 days and one year of hip fracture surgery. We hypothesised that both medical issues resulting in a delay in surgery and ACIs at the time of discharge would be associated with an increased risk of readmission within 30 days.

Methods

Patients

All patients admitted to our hospital between June 2011 and December 2017 with a hip fracture were considered for inclusion in the Holstebro Hip Fracture Database (n = 2,824). The exclusion criteria were patients (n = 157) who died during their primary hospital stay; patients with periprosthetic fractures, pathological fractures, or conservatively treated fractures; and patients operated at another hospital. If a patient experienced two hip fractures during the study period, the second fracture was excluded (n = 171) (**Figure 1**). The inclusion process was validated by searching the electronic patient records, and 46 (1.6%) patients were identified as treated for a hip fracture in the study period, but were not included in the database. The primary reason was that our department had performed the surgery, but the patient was admitted to another department, e.g., internal medicine or neurology.

Outcomes

The primary outcome was first-time readmission within 30 days and one year. Secondary analyses were performed regarding 1) risk factors for medical readmissions within 30 days and one year, as medical causes for readmission are reported to be the most common following hip fractures. 2) The association between medical issues delaying surgery and readmission within 30 days. 3) The impact of ACIs at discharge on readmissions for medical causes within 30 days as ACIs will most likely be indicators for medical rather than surgical issues. The 30-day follow-up period was chosen for both 2) and 3) as we expected medical issues delaying surgery and ACIs to be acute problems; hence, affecting short-term outcomes. Within the first year, information regarding first-time readmission to our hospital or other hospitals in the region was collected via the Central Denmark Region's hospital servers, which contain data on all admissions and operations. Readmission was defined as an unplanned, all-cause hospital visit, including emergency room visits without admission. Unplanned hospital visits are registered separately from planned visits on the servers. All Danish citizens have a unique 10-digit identification number, making it possible to link different databases at an individual level.

All causes of readmissions were checked in the electronic patient record. The cause of readmission was divided into causes unrelated to the hip fracture and causes directly related to the hip fracture. Unrelated causes were further divided into medical, trauma, surgical (e.g., general surgery, urology), unrelated orthopaedic (e.g., osteoarthritis), and other causes (e.g., psychiatric, poisoning, eye surgery). Medical causes for readmission were further subdivided into medical infectious or non-infectious causes, with medical infections including, e.g., sepsis, urinary tract infections and pneumonia. Causes related to the hip fracture were divided into THA dislocation, hip infection, reoperation or revision of the hip, and other causes directly related to the fracture (e.g., pain, rehabilitation).

Variables

The Holstebro Hip Fracture Database became operational in 2011. The objective of the database is to facilitate investigation into the treatment and outcomes of patients with hip fractures. The database contains information regarding patient characteristics, proxy variables for comorbidities, and hospital-related variables. Nurses, physiotherapists and doctors prospectively registered all data and were continuously instructed about how to report to the database, ensuring minimal variation in reporting.

<u>Patient characteristics</u>

Age was divided into < 75, 75-84 and ≥ 85 years. The patients' gender, residence, smoking status and alcohol consumption were documented. Height was primarily patient reported. Patients were weighed and their weight was used to calculate Body Mass Index (BMI). BMI was categorised as recommended by the World Health

Organization into underweight (< 18.5 kg/cm^2), normal weight (18.5-25 kg/cm^2) and obese (> 25 kg/cm^2) [13]. The pre-fracture functional level was based on the new mobility score (NMS) and dichotomised into a low functional level (1-5 points) and a high functional level (6-9 points). NMS is a hip-fracture-specific questionnaire consisting of three areas concerning walking ability in different contexts (indoor, outdoor and shopping) and has been shown to predict outcomes following hip fracture surgery [14, 15]. Fracture type was divided into intra- or extracapsular fractures based on pre-operative x-rays [16].

<u>Proxy-variables for comorbidities</u>

The American Society of Anesthesiologists (ASA) score was obtained from the anaesthesiology report and dichotomised into ASA 1-2 and ASA 3-5. Patients were categorised as cognitively fit or cognitively impaired based on previous diagnoses of dementia or similar. Pre-operative treatment with anticoagulation or antihypertensive medication was registered. Blood results included pre- and post-operative haemoglobin as a measure of chronic anaemia and acute anaemia to consider surgical blood loss, respectively, with a lower limit at 10 g/dl. Pre-operative albumin was used as a measure of malnutrition with the lower limit at 35 g/dl, and creatinine as a measure of renal function with the upper limit at 100 µmol/l.

<u>Hospital-related variables</u>

Hospital-related variables included time to surgery, surgical method, mobilisation to standing within 24 hours and ACIs. Time from admission to surgery was divided into < 24 hours, 24-36 hours and > 36 hours in accordance with national recommendations [16]. If the time exceeded 24 hours, the electronic patient records were checked for the delay reason; medical, anticoagulation therapy, organisational or other/missing. Medical reasons for a delay in surgery were, e.g., rhabdomyolysis treatment; cardiovascular diseases, e.g., arrhythmia; and acute myocardial infarction or pre-operative infections. Anticoagulation therapy was included as a reason for delaying surgery as elevated international normalized ratio (INR) values or the use of non-vitamin K antagonist oral anticoagulants (NOAC) could delay surgery based on prior guidelines. Organisational reasons for surgical delay covered, e.g., capacity issues such as a lack of surgical theatres or lack of surgeons. The category of other reasons for delaying surgery included fractures more than five days old at admission and awaiting consent from patients or family members. However, due to the very heterogeneous nature of this category, it was not included in the analysis. Surgical method was internal fixation (screws, pins or nails), total hip arthroplasty (THA) or Girdlestone resection arthroplasty.

ACIs were assessed at admission and discharge. An ACI was regarded as present if a vital sign met any of the following criteria: heart rate ≥ 100 /min, systolic blood pressure ≤ 90 mmHg, diastolic blood pressure ≤ 60 mmHg, temperature < 36.0 or ≥ 37.8 °C, oxygen saturation < 90%, or if a patient received additional antibiotics during the hospital stay (Figure 2). The choice of vital signs and dividing values were primarily based upon previously published studies [12, 17, 18]. An additional criterion was added to the temperature, < 36.0°C, which was chosen to reflect that some patients become hypothermic when infected. Furthermore, a criterion was added regarding additional antibiotics beyond the standard antibiotics given pre-operatively and on the first postoperative day. This criterion was added because additional antibiotics would indicate complications during the primary hospital stay. Patients' vital signs were compared at admission and discharge to investigate if abnormalities in the same vital sign at both admission and discharge impacted the prediction of readmission, as a continuous abnormality may potentially indicate a more chronic state.

Statistics

Data were analysed as time-to-event using the pseudo value approach with death as a competing risk to assess risk ratios (RRs) of readmission for all causes at 30 days and one year [19]. The following variables were selected for adjustment in the multivariate analysis: age, gender, residence, ASA score, cognitive status and NMS. All estimates were presented as RR with 95% confidence intervals (95% CI). Differences in subject characteristics between the groups were analysed using a χ^2-test and presented with p-values with $p < 0.05$ considered significant. The attributable fraction of readmission due to medical issues delaying surgery and ACIs was calculated. The attributable fraction is the proportion of the outcome that could be averted if the risk factor had been eliminated entirely. All analyses were conducted using Stata Statistical Software (Stata 17).

Ethics

The study was registered with the Danish Data Protection Agency (number 2007-58-0010). Under national law, written consent was not required. The authors have no competing interests of relevance to declare.

Results

A total of 2,510 patients were included in the study (median age 81 years, interquartile range (IQR): 14 years). Baseline characteristics for the total study population and those readmitted within 30 days and one year are provided in Table 1. Median LOS was five days (IQR: three days). Readmission was observed in 362 patients (14%) within 30 days and 987 patients (39%) within one year of the primary surgery. The median time to readmission was 53 days (IQR: 160 days). Among patients with readmission within 30 days, 39% died within one year of their hip surgery ($p < 0.01$).

The most frequent cause of readmission was medical conditions unrelated to the fracture for both 30 days and one year (62% and 53%, respectively), followed by new trauma (13% and 19%, respectively). Medical infections accounted for more than 50% of the medical readmissions within 30 days and 38% of medical readmissions within one year (Table 2). Within 30 days, the most frequent cause of readmission related to the hip fracture was THA dislocation (8%). Within one year, the most frequent cause became reoperations and revisions of the hip (13%).

Conservatively treated patients (n = 8) were older (median 83.5 years (IQR: 37)) and more frequently male (43%). We had no information regarding ASA score, but four patients had no ACIs at admission, three had one ACI and none had two or more.

Patients who died during their primary hospital stay (n = 100) were older (median: 85 years range: 11 years), more frequently male (48%), nursing-home residents (38%), patients with a high ASA score (72%) and cognitively impaired (28%). At admission, 56 had no ACIs, 16 had one ACI and 18 had two or more ACIs, which was higher than the corresponding figures for those who survived.

Patient characteristics

Underweight patients or patients with low pre-fracture functional levels had a 40% increase in readmission risk within 30 days after adjusting for confounders (Figure 3. For details, see Table 3 of the supplementary material). An increased risk of readmission within one year was found for patients aged > 85 years, male sex, living independently, pre-fracture smoking status and underweight (Figure 3. For details, see Table 3 of the supplementary material).

Proxy variables for comorbidities

High ASA score and low post-operative haemoglobin were associated with an increased risk of readmission within 30 days after adjusting for confounders (Figure 3. For details, see Table 3 of the supplementary material). A high ASA score remained a risk factor for readmission for all causes within one year. Additionally, low albumin and high creatinine were found to increase the risk of readmission by 20-30% (Figure 3. For details, see Table 3 of the supplementary material).

Hospital-related variables

Surgery more than 36 hours after admission, being treated with THA or Girdlestone resection arthroplasty, and ≥ 2 ACIs at discharge were associated with an increased risk of readmission within 30 days (Figure 3. For details, see Table 3 of the supplementary material). For readmission within one year, Girdlestone resection arthroplasty and ≥ 2 ACIs at discharge were found to increase readmission risk after adjusting for confounders (Figure 3. For details, see Table 3 of the supplementary material).

Medical causes for readmission

We identified risk factors for readmission for medical causes, including medical infections. Risk factors for readmission within 30 days after adjusting for confounders were; age > 75 years, male sex, underweight, low functional level, high ASA score, post-operative anaemia, high creatinine and ACIs at discharge. For readmission within one year, additional risk factors were identified; living independently, extracapsular, pre-operative anaemia, low albumin, time to surgery > 36 hours and surgical treatment with internal fixation compared with THA (for details, see Table 4 of the supplementary material).

Reasoning for the delay in surgery

No differences in readmission risk were found between patients with medical issues delaying surgery and delays due to organisational reasons or anticoagulation therapy (Table 5). Patients delayed for medical reasons were typically older, nursing-home residents and had an ASA score ≥ 3 (Table 6, supplementary material). Among those delayed for more than 24 hours, 22% (95% CI: 2-38) of readmissions for all causes could be eliminated if all patients had been operated within 24 hours.

ACIs at discharge

An association between ACIs at discharge and readmission for both medical and medical infectious causes within 30 days was found. ACIs predicted readmission better than individual variables (Table 7). Patients without ACIs were more likely to be younger, live independently, have a low ASA score, be cognitively fit and have a high functional level (Table 8, supplementary material). For readmission for all causes, 34% (95% CI: 18-47) of those discharged with an ACI could have avoided readmission if all had been discharged with no ACIs, especially among those 75-84 years and of male sex. This increased for readmissions due to medical causes, where ACIs attributed with 46% (95% CI: 28-59) of readmissions.

The proportion of patients with the same vital sign abnormality present at admission and discharge ranged from < 1% systolic blood pressure < 90 mmHg to 2% for heart rate ≥ 100 /min. However, taking into account whether the vital sign instability was present at admission did not significantly change the risk of readmission.

Discussion

We found a readmission rate of 14% within 30 days and 39% within one year. Medical reasons unrelated to the hip fracture were the primary cause of readmission followed by a new trauma. In this study, we explored risk factors of readmissions using a wide range of patient characteristics, proxy variables for comorbidities and hospital-related variables. Multiple risk factors were identified, including some that may guide clinicians with respect to safe discharge and indicate directions for future research regarding interventions to prevent readmissions following hip fracture surgery.

Readmissions are closely related to chronic illness; hence, not all readmissions can be prevented. The percentage of preventable readmissions within 30 days among geriatric patients differs widely (8% to 54%) in the literature [3, 20, 21]. One key question when evaluating how to reduce readmissions is which risk factors are modifiable and which are not. Most of the variables in the patient characteristics category are non-modifiable and not targetable through interventions. With that said, BMI as a risk factor for readmission has received only little attention and reported results are mixed. Basques et al. 2015 found BMI > 35 kg/m^2 to be associated with an increased risk of readmission. However, several other studies found no such association [4, 9, 22–24]. Conversely, we found that an BMI < 18.5 kg/m^2 predicted readmission within 30 days and one year. A low BMI may indicate malnourishment and a lower physiological reserve to tolerate the physiological stress of undergoing hip fracture and surgery. However, improving BMI would be difficult during the primary hospital stay. With our and others' results on this issue in mind, we recommend that attention be given to nutrition in the post-discharge period [23–26].

Another patient characteristic associated with a higher readmission rate was a low pre-fracture functional level measured by NMS. Kates et al. 2015 also used NMS in their analysis. However, unlike the present study, they observed the highest risk of readmission in patients with an NMS of 5-8 points [27]. Like this study, other studies have found an increased readmission risk among patients with a low pre-fracture functional level even if they used different means of assessing the functional level, e.g., activity of daily living or walking aids [2, 3, 22]. Although the pre-fracture functional level cannot be modified, this parameter may supplement other patient characteristics such as age, gender and residence, and hence inform interventions towards patients at risk and efforts to reduce readmission rates.

Most of the proxy variables for comorbidities are non-modifiable or difficult to modify during the primary hospital stay, like the patient characteristics. An ASA score ≥ 3 was found to increase the risk of readmission within 30 days and one year, which is in line results from other studies [1, 28]. Some studies have used the Charlson Comorbidity Index or explored individual comorbidities, finding, e.g., cardiovascular disease, pulmonary disease and renal failure to predict readmission [2, 4–6, 29]. We had some indicators on individual comorbidities; cognitive impairment, anticoagulation therapy, hypertensive treatment, haemoglobin, albumin and creatinine. Cognitive impairment was found to have no impact on the risk of readmission after adjustment, as also reported by Härstedt et al. 2015 [29]. Multiple studies have found that hypertension predicts readmission following hip fracture surgery. Even so, we found no such association [4, 6, 24, 29]. For haemoglobin, albumin and creatinine, mixed results are reported, and we found that these factors primarily predicted late readmission [2, 4, 8, 24].

When considering interventions to reduce readmissions, one place to start are hospital-related variables which may be more amenable to modification than non-hospital-related variables. THA treatment was one such variable associated with 30-day readmission. However, THA treatment is most likely due to THA dislocations which typically occurs within the first three months, and the association disappeared for readmissions within one year. Another variable is time to surgery which has generally been reduced in recent years, although time to surgery varies much between countries. Time to surgery has previously been investigated in relation to readmission following hip fracture surgery [2, 7, 8, 10, 24, 30]. However, to our knowledge, no prior study has explored the reasons for delay in relation to readmissions. Other studies have scrutinised reasons for delaying surgery in relation to mortality and found conflicting results. Öztürk et al. 2019 found that among the healthier patients, delaying surgery for more than 24 hours was associated with an increased 30-day mortality [31]. On the other hand, Hongisto et al. 2019 found that in the most comorbid patients, delaying surgery for more than 12 hours was associated with an increased 30-day mortality [32]. The favourable effect of early surgery on short-term survival seen in some studies may have to do with avoiding acute complications related to waiting for surgery, complications that could also lead to readmissions. However, we found no association between surgical delay and readmission following hip fracture surgery when comparing patients with medical issues at admission resulting in delay to patients whose surgery was delayed due to organisational reasons or administration of anticoagulation therapy.

One of the most interesting findings emerging from the present study is the association between ACIs at discharge and readmission rates. Assessing the stability of a patient's vital signs at discharge is a simple, objective and clinically sensible way of assessing the patient's readiness for discharge. Concerns have been raised that patients may be discharged prematurely, especially in light of the LOS decrease recorded in past decades [33]. Premature discharge, as indicated by ACIs at discharge in the present study, was associated with increased readmission rates, especially for medical and infectious causes. To our knowledge, the association between abnormal vital signs and the risk of readmission following hip fracture surgery has only been investigated by one previous study based on a relatively small study population [17]. Other studies have investigated the association between readmission and abnormal vital signs in other patient groups with mixed results [12, 18]. Halm et al. 2004 and Nguyen et al. 2017 found an association between ACIs and an increased risk of readmission that is in line with the one found in the present study [12, 17]. Furthermore, we divided readmissions by causes finding that ACIs are more closely associated with medical and especially infectious causes than with readmission for all causes. This is unsurprising as abnormalities in vital signs are most likely signs of medical issues that may be expected to lead to medical readmissions. The prevalence of ACIs was higher in the present study than in previous studies, probably because we included additional antibiotics as an ACI. Additional antibiotics were incorporated in our study because of the short LOS employed at our institution.

Despite intense efforts, interventions to reduce readmissions after hip fracture surgery have produced mixed results. However, a systematic review found that individualised discharge planning reduced readmission [34]. Furthermore, studies have demonstrated that follow-up upon discharge following hip fracture surgery may reduce readmission rates [21, 34]. Some ACIs may possibly be part of a chronic illness and therefore unsuitable for optimisation during the primary hospital stay, e.g., low oxygen saturation in patients with chronic obstructive pulmonary disease; in such patients, post-discharge follow-up may potentially help prevent readmissions. We recommend that patients with ACIs go through a thorough assessment before discharge and propose that hip fracture patients discharged despite ACIs receive tailormade follow-up, especially during the initial 30 days following their discharge, as most preventable readmissions occur within this period [35]. Our study also demonstrated that ACIs at admission do not predict readmissions and that most ACIs at discharge occur during the hospital stay.

In the present study, late readmission seemed to be related primarily to comorbidities. This mirrors the findings of others (5, 8). Almost all variables in the comorbidity group had a higher RR for readmission within one year than within 30 days. Furthermore, we found an increasing RR when studying readmissions for medical causes compared with readmission for all causes within one year. This could indicate that late readmissions are more closely related to chronic comorbidities; hence, they will be challenging to modify during the primary hospital stay.

Strengths and limitations

The strengths of this study include a relatively large study population and detailed prospective data collection with few missing values. Conversely, the study also has several limitations. Only first-time readmission was included, which might have meant that any subsequent readmission, e.g., a second hip fracture, would be missed. A limitation in general when investigating readmission following hip fracture surgery is the considerable variation between countries, e.g., LOS, which was a median of five days in the present study, whereas some countries report LOS two or three times longer than ours [36]. This will undeniably result in variation, especially in 30-day readmission, as patients readmitted with, e.g., pneumonia within five days in our study might have remained admitted in other countries and the pneumonia would then have been treated during the primary hospital stay. Hence, these patients might not have been readmitted in another country. Therefore, we included one-year readmission risk factors as they would probably be more applicable in countries with longer LOS. The study's external generalisability is strengthened by the fact that all hip fractures were included with no selection based on age or comorbidities. However, as described above, differences in variables such as LOS, treatment strategies and composition of the study population will limit the study's generalisability. Residual confounding will also be present, e.g. marital status, socio-economic status, specific comorbidities and unknown confounders.

In conclusion, readmission levels following hip fracture surgery are high, but some readmissions may be preventable. We identified some risk factors to guide clinicians in determining which patients should undergo a closer follow-up after discharge or for whom discharge should be delayed. One particular risk factor that warrants further study is the association with ACIs, and how to ensure a safe discharge.

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References

1. Ali AM, Gibbons CER (2017) Predictors of 30-day hospital readmission after hip fracture: a systematic review. Injury 48:243–252. https://doi.org/10.1016/j.injury.2017.01.005

2. Rutenberg TF, Rutenberg R, Vitenberg M, et al (2020) Prediction of readmissions in the first post-operative year following hip fracture surgery. Eur J Trauma Emerg Surg 46:939–946. https://doi.org/10.1007/s00068-018-0997-5

3. Kates SL, Behrend C, Mendelson DA, et al (2015) Hospital readmission after hip fracture. Arch Orthop Trauma Surg 135:329–337. https://doi.org/10.1007/s00402-014-2141-2

4. Martin CT, Gao Y, Pugely AJ (2016) Incidence And Risk Factors For 30-Day Readmissions After Hip Fracture Surgery. Iowa Orthop J 36:155–160

5. Lee T, Ho P, Lin H, et al (2017) One-Year Readmission Risk and Mortality after Hip Fracture Surgery : A National Population-Based Study in Taiwan. Aging Dis 8:402–409

6. Checketts JX, Dai Q, Zhu L, et al (2020) Readmission Rates After Hip Fracture: Are There Prefracture Warning Signs for Patients Most at Risk of Readmission? J Am Acad Orthop Surg 28:1017–1026. https://doi.org/10.5435/JAAOS-D-19-00751

7. Sarimo S, Pajulammi H, Jämsen E (2020) Process-related predictors of readmissions and mortality following hip fracture surgery: a population-based analysis. Eur Geriatr Med 11:613–622. https://doi.org/10.1007/s41999-020-00307-0

8. Heyes GJ, Tucker A, Marley D, Foster A (2015) Predictors for Readmission up to 1 Year Following Hip Fracture. Arch Trauma Res 4:. https://doi.org/10.5812/atr.4(2)2015.27123

9. Sofu H, Üçpunar H, Çamurcu Y, et al (2017) Predictive factors for early hospital readmission and 1-year mortality in elder patients following surgical treatment of a hip fracture. Ulus Travma ve Acil Cerrahi Derg 23:245–250. https://doi.org/10.5505/tjtes.2016.84404

10. Lizaur-Utrilla A, Serna-Berna R, Lopez-Prats FA, Gil-Guillen V (2015) Early rehospitalization after hip fracture in elderly patients: risk factors and prognosis. Arch Orthop Trauma Surg 135:1663–1667. https://doi.org/10.1007/s00402-015-2328-1

11. Glassou EN, Kjørholt KKE, Hansen TB, Pedersen AB (2019) Delay in surgery , risk of hospital-treated infections and the prognostic impact of comorbidity in hip fracture patients . A Danish nationwide cohort. Clin Epidemiol 11:383–395. https://doi.org/10.2147/CLEP.S200454

12. Nguyen OK, Makam AN, Clark C, et al (2017) Vital Signs Are Still Vital: Instability on Discharge and the Risk of Post-Discharge Adverse Outcomes. J Gen Intern Med 32:42–48. https://doi.org/10.1007/s11606-016-3826-8

13. World Health Organization Body mass index - BMI. https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi. Accessed 9 Sep 2021

14. Parker MJ, Palmer CR (1993) A NEW MOBILITY AFTER SCORE FOR PREDICTING MORTALITY. J Bone Jt Surg Br 75:797–798

15. Pedersen TJ, Lauritsen JM (2016) Routine functional assessment for hip fracture patients - Are there sufficient predictive properties for subgroup identification in treatment and rehabilitation? Acta Orthop 87:374–379. https://doi.org/10.1080/17453674.2016.1197534

16. Jensen CM, Mainz H, Lamm M, et al (2008) Reference programme for treatment of patients with proximal femur fractures. DanskSygeplejeråd, DanskeFysioterapeuter DanskOrtopædiskSelskab 1–128

17. Halm EA, Magaziner J, Hannan EL, et al (2003) Frequency and impact of active clinical issues and new impairments on hospital discharge in patients with hip fracture. Arch Intern Med 163:107–112. https://doi.org/10.1097/00006416-200307000-00017

18. Robinson R, Bhattarai M, Hudali T (2019) Vital sign abnormalities on discharge do not predict 30-day readmission. Clin Med Res 17:63–71. https://doi.org/10.3121/cmr.2019.1461

19. Overgaard M, Andersen PK, Parner ET (2015) Regression analysis of censored data using pseudo-observations: An update. Stata J 15:809–821. https://doi.org/10.1177/1536867x1501500313

20. Hallgren J, Aslan AKD (2018) Risk factors for hospital readmission among Swedish older adults. Eur Geriatr Med 9:603–611. https://doi.org/10.1007/s41999-018-0101-z

21. Holst L, Peter P, Catherine B, et al (2018) Avoidable readmissions seem to be reduced by early follow - up visits for geriatric patients discharged from hospital. Eur Geriatr Med 9:613–621. https://doi.org/10.1007/s41999-018-0078-7

22. Basques BA, Bohl DD, Golinvaux NS, et al (2015) Postoperative length of stay and 30-day readmission after geriatric hip fracture: An analysis of 8434 patients. J Orthop Trauma 29:e115–e120. https://doi.org/10.1097/BOT.0000000000000222

23. Akinleye SD, Garofolo G, Culbertson MD, et al (2018) The Role of BMI in Hip Fracture Surgery. Geriatr Orthop Surg Rehabil 9:1–6. https://doi.org/10.1177/2151458517747414

24. Ryan G, Nowak L, Melo L, et al (2020) Anemia at Presentation Predicts Acute Mortality and Need for Readmission Following Geriatric Hip Fracture. JBJS Open Access. https://doi.org/http://dx.doi.org/10.2106/JBJS.OA.20.00048

25. Frandsen CF, Glassou EN, Stilling M, Hansen TB (2021) Malnutrition , poor function and comorbidities predict mortality up to one year after hip fracture : a cohort study of 2800 patients. Eur Geriatr Med Epub ahead: https://doi.org/10.1007/s41999-021-00598-x

26. Solbakken SM, Meyer HE, Stigum H, et al (2017) Excess mortality following hip fracture: impact of self-perceived health, smoking, and body mass index. A NOREPOS study. Osteoporos Int 28:881–887. https://doi.org/10.1007/s00198-016-3795-0

27. Kates SL, Shields E, Behrend C, Noyes KK (2015) Financial Implications of Hospital Readmission After Hip Fracture. Geriatr Orthop Surg Rehabil 6:140–146. https://doi.org/10.1177/2151458515578265

28. Mathew SA, Gane E, Heesch KC, McPhail SM (2016) Risk factors for hospital re-presentation among older adults following fragility fractures: A systematic review and meta-analysis. BMC Med 14:1–20. https://doi.org/10.1186/s12916-016-0671-x

29. Härstedt M, Rogmark C, Sutton R, et al (2015) Impact of comorbidity on 6-month hospital readmission and mortality after hip fracture surgery. Injury 46:713–718. https://doi.org/10.1016/j.injury.2014.12.024

30. Ghani R, Usman M, Salar O, et al (2019) Unplanned Clinic Attendance, Readmission, and Reoperation in the First 12 Months Postoperatively Following Hip Hemiarthroplasty for Acute Hip Fractures: Who Is At Risk? Cureus 11:. https://doi.org/10.7759/cureus.6128

31. Öztürk B, Johnsen SP, Röck ND, et al (2019) Impact of comorbidity on the association between surgery delay and mortality in hip fracture patients: A Danish nationwide cohort study. Injury 50:424–431. https://doi.org/10.1016/j.injury.2018.12.032

32. Hongisto MT, Nuotio MS, Luukkaala T, et al (2019) Delay to Surgery of Less Than 12 Hours Is Associated With Improved Short- and Long-Term Survival in Moderate- to High-Risk Hip Fracture Patients. Geriatr Orthop Surg Rehabil 10:215145931985314. https://doi.org/10.1177/2151459319853142

33. Pascal L, Polazzi S, Piriou V, et al (2020) Hospital Length of Stay Reduction Over Time and Patient Readmission for Severe Adverse Events Following Surgery. Ann Surg 272:105–112. https://doi.org/10.1097/SLA.0000000000003206

34. Sutton EL, Kearney RS (2021) What works? Interventions to reduce readmission after hip fracture: A rapid review of systematic reviews. Injury 52:1851–1860. https://doi.org/10.1016/j.injury.2021.04.049

35. Benbassat J, Taragin M (2000) Hospital readmissions as a measure of quality of health care: Advantages and limitations. Arch Intern Med 160:1074–1081. https://doi.org/10.1001/archinte.160.8.1074

36. Richards T, Glendenning A, Benson D, et al (2018) The independent patient factors that affect length of stay following hip fractures. Ann R Coll Surg Engl 100:556–562. https://doi.org/10.1308/rcsann.2018.0068

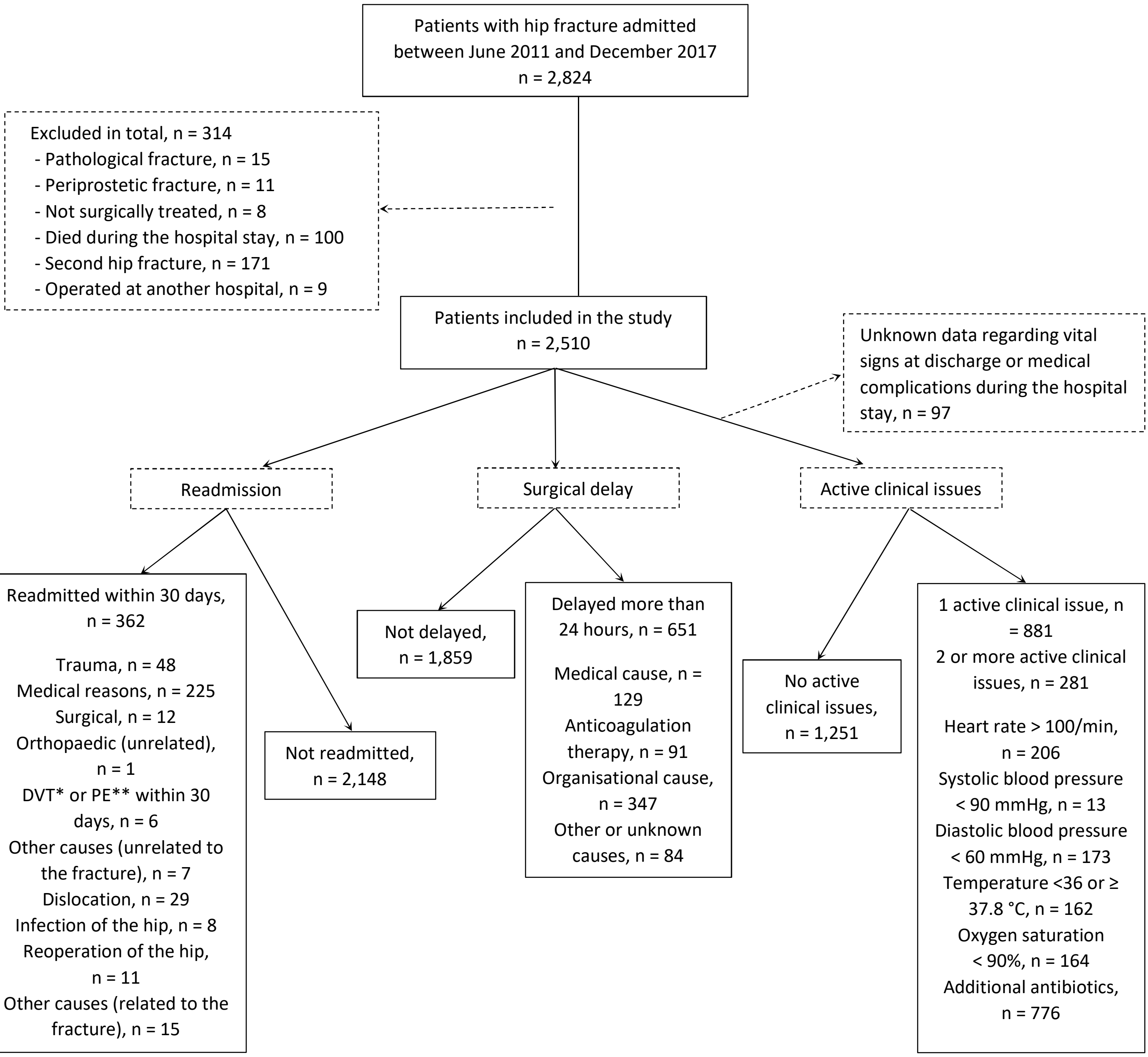

Figure 1 Inclusion process illustrated in a flow chart and overview of the distribution of readmission within 30 days and causes for readmission, reasons for time to surgery if more than 24 hours passed, and the frequency of active clinical issues at discharge.

* Deep vein thrombosis

** Pulmonary embolism

Active clinical issues upon discharge:
Heart rate > 100 /min
Systolic blood pressure < 90 mmHg
Diastolic blood pressure < 60 mmHg
Temperature < 36.0 °C or ≥ 37.8 °C
Oxygen saturation < 90%
Additional antibiotics[a]

[a] Additional to one or two rounds of intravenous cefuroxime given as perioperative surgical prophylaxis.

Figure 2 *Definition of active clinical issues.*

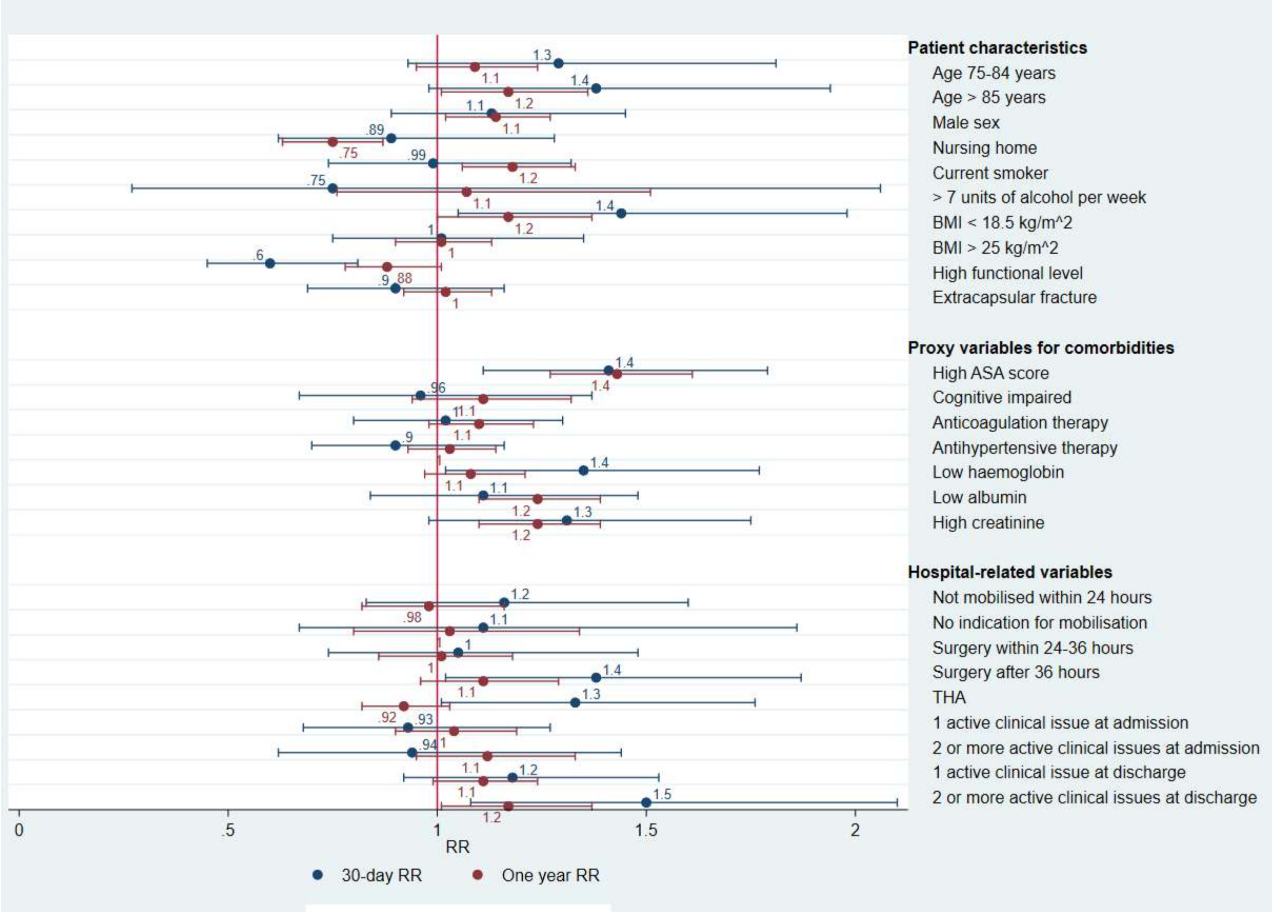

Figure 3 *Risk ratios with 95% confidence intervals for readmission for all causes within 30 days (blue) and 365 days (red) adjusted for age, gender, residence, ASA score, cognitive status and new mobility score.*

ASA = American Society of Anesthesiologists

BMI = Body Mass Index

RR = Risk ratio

THA = Total hip arthroplasty

Table 1. Baseline characteristics for the study population in numbers and percentages in total and for readmitted within 30 days and 1 year for all causes.

Variables	Total, number (%)	Readmitted within 30 days, number (%)	Readmitted within 1 year, number (%)
Total	2,510 (100)	362 (14)	987 (39)
Patient characteristics			
Age (median (IQR))	81 (11)	84 (11)	82 (13)
Gender (F/M)	1,682 (67) / 828 (33)	231 (64) / 131 (36)	630 (64) / 357 (36)
Residence			
Independent living	1,865 (74)	244 (67)	764 (77)
Nursing home	643 (26)	118 (33)	223 (23)
Smoker	539 (21)	78 (22)	246 (25)
Alcohol consumption > 7 units per week*	50 (2)	5 (1)	24 (2)
BMI[a]			
< 18.5 kg/m^2	257 (10)	54 (15)	111 (11)
18.5-25 kg/m^2	1,419 (57)	195 (54)	557 (56)
> 25 kg/m^2	794 (32)	106 (29)	304 (31)
Low pre-fracture functional level (NMS[b])	959 (38)	186 (51)	402 (41)
Intracapsular fracture	1,320 (53)	193 (53)	518 (52)
Proxy variables for comorbidities			
ASA score[c] ≥ 3	1,060 (42)	211 (58)	498 (51)
Cognitively impaired	488 (19)	86 (24)	170 (17)
Anticoagulation therapy	1,052 (42)	170 (47)	463 (47)
Antihypertensive therapy	880 (35)	125 (35)	357 (36)
Preoperative haemoglobin < 10 g/dl	100 (4)	17 (5)	53 (5)
Postoperative haemoglobin < 10 g/dl	657 (26)	128 (35)	275 (28)
Albumin < 35 g/l	549 (22)	106 (29)	268 (27)
Creatinine ≥ 100 µmol/l	547 (22)	118 (33)	265 (27)
Hospital-related variables			
Mobilised to standing within 24 hours			
Yes	2,110 (84)	289 (80)	823 (84)
No	289 (12)	53 (15)	116 (12)
No indication for mobilisation	106 (4)	19 (5)	44 (4)
Time from admission to surgery			
< 24 hours	1,859 (74)	246 (68)	712 (72)
24-36 hours	315 (13)	52 (14)	125 (13)
> 36 hours	300 (12)	58 (16)	132 (13)
Surgical method			
Internal fixation	1,635 (65)	218 (60)	666 (67)
THA[d]	864 (34)	139 (38)	315 (32)
Girdlestone resection arthroplasty	8 (< 1)	4 (1)	5 (1)
Active clinical issues at admission[e]			
0	1,852 (74)	260 (72)	707 (72)
1	379 (15)	54 (15)	155 (16)
≥ 2	206 (8)	33 (9)	89 (9)
Active clinical issues at discharge[d]			
0	1,243 (50)	146 (40)	457 (46)
1	887 (35)	132 (36)	366 (37)
≥ 2	283 (11)	64 (18)	123 (12)

[a] Body Mass Index.

[b] New Mobility Score. A maximum of 9 points can be achieved based on mobility indoor and outdoor; 1-5 equals a low functional level. 6-9 equals a high functional level.

[c] American Society Anesthesiologists.

[d] Total hip arthroplasty.

[e] Based on vital signs at discharge and additional antibiotics during the primary hospital stay.

Table 2. Causes for readmission presented for within 30 days, and from 31 days to one year after hip fracture surgery as numbers (%)

Cause	0-30 days (n = 362)	31 days-one year (n = 625)
Not directly related to the fracture		
Trauma	48 (13)	121 (19)
Medical	225 (62)	334 (53)
Infections [a]	*118 (33)*	*126 (20)*
General surgery, OB, vascular, urology	12 (3)	54 (9)
Orthopaedic causes (e.g. impingement, pressure ulcer, osteoarthritis)	1 (<1)	8 (1)
DVT[b] or LE[c] within 30 days	6 (2)	-
Other causes (e.g., psychiatric, poisoning, eye surgery)	7 (2)	10 (2)
Related to the fracture		
THA[d] dislocation	29 (8)	7 (1)
Infections around the hip	8 (2)	3 (<1)
Reoperation or revision of the hip	11 (3)	84 (13)
Other causes (e.g. pain, mobilisation)	15 (4)	4 (1)

[a] Infections are included in the medical causes and include, e.g., pneumonia, urinary tract infections and sepsis.

[b] Deep vein thrombosis.

[c] Lung embolism.

[d] Total hip arthroplasty.

Table 5. Surgical delay exceeding 24 hours or 36 hours due to medical issues, organisational reasons or anticoagulation therapy and risk of readmission for all causes within 30 days*.

		Readmitted within 30 days	
	Total no. (%)	No. (%)	RR (95% CI)[a]
Operated within 24 hours	1,859 (74)	246 (13)	
Operated > 24 hours from admission			
Organisational reasons	347 (14)	62 (18)	Reference
Medical reasons	129 (5)	25 (19)	0.92 (0.53-1.61)
Anticoagulation therapy	91 (4)	13 (14)	0.75 (0.40-1.39)
Operated > 36 hours from admission			
Organisational reasons	147 (6)	26 (18)	Reference
Medical reasons	82 (3)	19 (23)	1.07 (0.53-2.12)
Anticoagulation therapy	68 (3)	12 (18)	0.72 (0.29-1.78)

* Missing values have been omitted.

[a] Risk ratio with 95% confidence intervals adjusted for age, gender, residence, American Society of Anesthesiologists score, cognitive function and New Mobility Score.

Table 7. Impact of active clinical issues on readmission for medical causes and infectious causes in total, and divided into the different vital signs at discharge and additional antibiotics during the primary hospital stay.

		Readmitted within 30 days due to medical causes		Readmitted within 30 days due to infectious causes	
	Total no. (%)	No. (%)	RR (95% CI)[a]	No. (%)	RR (95% CI)[a]
Total	2,413 (100)	213 (9)		118 (5)	
Active clinical issues					
0	1,243 (52)	80 (38)	Ref.	31 (28)	Ref.
1	887 (37)	85 (40)	**1.50 (1.02-2.21)**	47 (42)	**2.73 (1.30-5.75)**
≥ 2	283 (12)	48 (23)	**2.32 (1.30-4.16)**	33 (30)	**6.69 (1.82-24.64)**
Different issues:					
Heart rate >100 /min	206 (9)	22 (10)	1.15 (0.65-2.03)	16 (8 / 14)	1.58 (0.76-3.26)
Systolic blood pressure <90 mmHg	13 (1)	2 (1)	2.42 (0.56-10.47)	2 (15 / 2)	**4.09 (1.10-15.20)**
Diastolic blood pressure <60 mmHg	173 (7)	26 (12)	**1.95 (1.20-3.16)**	14 (8 / 13)	**2.98 (1.46-6.07)**
Temperature < 36.0 or > 37.8 degrees	172 (7)	20 (9)	1.55 (0.84-2.84)	14 (8 / 13)	**2.25 (1.06-4.78)**
Oxygen saturation < 90%	164 (7)	23 (11)	1.25 (0.71-2.20)	17 (10 / 15)	2.07 (0.63-6.76)
Additional antibiotics	776 (32)	98 (46)	1.40 (0.99-1.97)	61 (8 / 55)	**1.81 (1.01-3.25)**

[a] Risk ratio with 95% confidence intervals adjusted for age, gender, residence, American Society of Anesthesiologists score, cognitive function and New Mobility Score.

Active clinical issues at discharge predict readmission within 30 days and one year following hip fracture surgery.

by

Christina Frölich Frandsen, Maiken Stilling, Eva Natalia Glassou, Anne Birgitte Langsted Pedersen

and Torben Baek Hansen

Supplementary material

Contents:

Table 3. Univariable and multivariable risk ratios (RRs) with 95% confidence intervals (95% CI) for readmission for all causes, n = 2,510. Adjusted for age, gender, residence, ASA score, cognitive status and NMS[a].

	Readmitted within			
	30 days		One year	
Variables	Crude RR (95% CI)	Adjusted RR (95% CI)	Crude RR (95% CI)	Adjusted RR (95% CI)
Patient characteristics				
Age (ref. < 75 years)				
75-84 years	**1.52 (1.14-2.03)**	1.29 (0.93-1.81)	1.12 (0.98-1.27)	1.09 (0.95-1.24)
≥ 85 years	**1.78 (1.34-2.35)**	1.38 (0.98-1.94)	**1.17 (1.03-1.34)**	**1.17 (1.01-1.36)**
Gender (ref. female)				
Male	1.08 (0.87-1.33)	1.13 (0.89-1.46)	**1.18 (1.06-1.30)**	**1.14 (1.02-1.27)**
Residence (ref. independent living)				
Nursing home	**1.44 (1.16-1.78)**	0.89 (0.62-1.28)	**0.88 (0.78-0.99)**	**0.75 (0.63-0.87)**
Smoker (ref. non-smoker)				
Smoker	0.93 (0.72-1.21)	0.99 (0.74-1.32)	**1.21 (1.08-1.36)**	**1.18 (1.05-1.33)**
Alcohol consumption (ref. ≤ 7 units per week)				
> 7 units per week	0.79 (0.34-1.82)	0.75 (0.27-2.06)	1.16 (0.84-1.59)	1.07 (0.76-1.51)
BMI[b] (ref. 18.5-25 kg/m^2)				
< 18.5 kg/m^2	**1.38 (1.02-1.86)**	**1.44 (1.05-1.98)**	1.13 (0.96-1.32)	**1.17 (1.00-1.37)**
> 25 kg/m^2	0.90 (0.71-1.14)	1.01 (0.75-1.35)	0.97 (0.87-1.09)	1.01 (0.90-1.13)
NMS[a] (ref. low pre-fracture functional level)				
High pre-fracture functional level	**0.52 (0.42-0.65)**	**0.60 (0.45-0.81)**	**0.86 (0.78-0.95)**	0.88 (0.78-1.01)
Fracture type (ref. intracapsular fracture)				
Extracapsular fracture	0.97 (0.79-1.19)	0.90 (0.69-1.16)	1.02 (0.92-1.12)	1.02 (0.92-1.13)
Proxy variables for comorbidities				
ASA score[c] (ref. ASA score 1-2)				
ASA score ≥ 3	**1.75 (1.42-2.16)**	**1.41 (1.11-1.79)**	**1.44 (1.30-1.59)**	**1.43 (1.27-1.61)**
Cognitive function (ref. cognitively fit)				
Cognitively impaired	**0.73 (0.58-0.93)**	0.96 (0.67-1.37)	1.13 (0.99-1.30)	1.11 (0.94-1.32)
Anticoagulation therapy (ref. no anticoagulation therapy)				
Anticoagulation therapy	**1.23 (1.00-1.51)**	1.02 (0.80-1.30)	**1.23 (1.12-1.36)**	1.10 (0.98-1.23)
Antihypertensive therapy (ref. no antihypertensive therapy)				
Antihypertensive therapy	0.93 (0.75-1.16)	0.90 (0.70-1.16)	1.04 (0.94-1.16)	1.03 (0.93-1.14)
Preoperative haemoglobin (ref. ≥ 10 g/dl)				
< 10 g/dl	1.17 (0.73-1.89)	1.15 (0.69-1.91)	**1.36 (1.11-1.66)**	1.21 (0.97-1.50)
Postoperative haemoglobin (ref. ≥ 10 g/dl)				
< 10 g/dl	**1.53 (1.24-1.89)**	**1.35 (1.02-1.77)**	**1.12 (1.00-1.24)**	1.08 (0.97-1.21)
Albumin (ref. ≥ 35 g/l)				
< 35 g/l	**1.38 (1.10-1.73)**	1.11 (0.84-1.48)	**1.35 (1.22-1.50)**	**1.24 (1.10-1.39)**
Creatinine (ref. < 100 µmol/l)				
≥ 100 µmol/l	**1.63 (1.31-2.02)**	1.31 (0.98-1.75)	**1.35 (1.22-1.50)**	**1.24 (1.10-1.39)**
Hospital-related variables				
Mobilised to standing within 24 hours (ref. yes)				
No	**1.37 (1.03-1.82)**	1.16 (0.83-1.60)	1.04 (0.89-1.21)	0.98 (0.82-1.16)
No indication for mobilisation	1.48 (0.97-2.26)	1.11 (0.67-1.86)	1.07 (0.85-1.36)	1.03 (0.80-1.34)
Time from admission to surgery (ref. < 24 hours)				
24-36 hours	1.15 (0.85-1.56)	1.05 (0.74-1.48)	1.02 (0.87-1.19)	1.01 (0.86-1.18)
> 36 hours	**1.52 (1.16-2.00)**	**1.38 (1.02-1.87)**	**1.17 (1.01-1.35)**	1.11 (0.96-1.29)
Surgical method (ref. internal fixation)				
THA	1.20 (0.98-1.48)	**1.33 (1.01-1.76)**	0.93 (0.84-1.04)	0.92 (0.82-1.03)
Girdlestone resection arthroplasty	**3.14 (1.27-7.77)**	**2.46 (1.07-5.66)**	1.60 (0.93-2.75)	**1.69 (1.04-2.76)1.11**
Active clinical issues at admission[e] (ref. 0)				
1	0.97 (0.71-1.33)	0.93 (0.68-1.27)	1.08 (0.94-1.25)	1.04 (0.90-1.19)
≥ 2	1.00 (0.69-1.47)	0.94 (0.62-1.44)	1.16 (0.98-1.37)	1.12 (0.95-1.33)
Active clinical issues at discharge[e] (ref. 0)				
1	1.18 (0.93-1.49)	1.18 (0.92-1.53)	**1.15 (1.03-1.28)**	1.11 (0.99-1.24)
≥ 2	**1.80 (1.35-2.39)**	**1.50 (1.08-2.10)**	**1.23 (1.06-1.44)**	**1.17 (1.00-1.37)**

[a] New Mobility Score. A maximum of 9 points can be achieved based on mobility indoor and outdoor; 1-5 equals a low functional level. 6-9 equals a high functional level.

[b] Body Mass Index.

[c] American Society Anesthesiologists.

d Based on vital signs at discharge and additional antibiotics during the primary hospital stay.

Table 4. Univariable and multivariable risk ratios (RRs) with 95% confidence intervals (95% CI) for readmission for medical causes within 30 days and 1 year, n = 2,510. Adjusted for age, gender, residence, ASA score, cognitive status and NMS[a].

	Readmitted within			
	30 days		One year	
Variables	Crude RR (95% CI)	Adjusted RR (95% CI)	Crude RR (95% CI)	Adjusted RR (95% CI)
Patient characteristics				
Age (ref. < 75 years)				
75-84 years	**2.22 (1.45-3.38)**	**1.96 (1.18-3.23)**	**1.40 (1.15-1.70)**	**1.35 (1.10-1.67)**
≥ 85 years	**2.49 (1.65-3.75)**	**1.84 (1.07-3.16)**	**1.35 (1.11-1.65)**	1.27 (0.99-1.63)
Gender (ref. female)				
Male	**1.37 (1.04-1.80)**	**1.56 (1.14-2.14)**	**1.41 (1.22-1.63)**	**1.38 (1.18-1.62)**
Residence (ref. independent living)				
Nursing home	**1.51 (1.14-2.00)**	0.87 (0.53-1.43)	0.90 (0.76-1.07)	**0.72 (0.57-0.90)**
Smoker (ref. non-smoker)				
Smoker	**0.51 (0.34-0.77)**	0.61 (0.37-1.01)	1.05 (0.88-1.25)	1.04 (0.85-1.25)
Alcohol consumption (ref. ≤ 7 units per week)				
> 7 units per week	0.52 (0.13-2.03)	0.79 (0.19-3.26)	1.37 (0.89-2.11)	1.29 (0.80-2.09)
BMI[b] (ref. 18.5-25 kg/m^2)				
< 18.5 kg/m^2	1.39 (0.94-2.06)	**1.62 (1.03-2.56)**	1.21 (0.96-1.51)	**1.30 (1.03-1.64)**
> 25 kg/m^2	0.87 (0.64-1.19)	0.94 (0.62-1.43)	0.95 (0.81-1.12)	0.95 (0.80-1.13)
NMS[a] (ref. low pre-fracture functional level)				
High pre-fracture functional level	**0.43 (0.32-0.57)**	**0.53 (0.36-0.78)**	**0.73 (0.63-0.85)**	**0.77 (0.63-0.93)**
Fracture type (ref. intracapsular fracture)				
Extracapsular fracture	1.24 (0.94-1.62)	1.15 (0.81-1.64)	**1.17 (1.01-1.36)**	**1.20 (1.03-1.40)**
Comorbidities				
ASA score[c] (ref. ASA score 1-2)				
ASA score ≥ 3	**2.09 (1.58-2.77)**	**1.52 (1.08-2.14)**	**1.69 (1.46-1.96)**	**1.57 (1.30-1.88)**
Cognitive function (ref. cognitively fit)				
Cognitively impaired	**0.70 (0.52-0.95)**	0.98 (0.57-1.67)	1.12 (0.93-1.36)	1.17 (0.91-1.51)
Anticoagulation therapy (ref. no anticoagulation therapy)				
Anticoagulation therapy	**1.44 (1.10-1.88)**	1.04 (0.75-1.44)	**1.36 (1.17-1.57)**	1.13 (0.95-1.34)
Antihypertensive therapy (ref. no antihypertensive therapy)				
Antihypertensive therapy	1.08 (0.81-1.43)	0.99 (0.70-1.38)	1.12 (0.96-1.30)	1.10 (0.94-1.28)
Preoperative haemoglobin (ref. ≥ 10 g/dl)				
< 10 g/dl	1.57 (0.91-2.72)	1.33 (0.70-2.52)	**1.71 (1.31-2.23)**	**1.36 (1.01-1.83)**
Postoperative haemoglobin (ref. ≥ 10 g/dl)				
< 10 g/dl	**1.78 (1.36-2.34)**	**1.55 (1.10-2.19)**	**1.19 (1.01-1.39)**	**1.19 (1.00-1.40)**
Albumin (ref. ≥ 35 g/l)				
< 35 g/l	**1.69 (1.27-2.25)**	1.24 (0.83-1.87)	**1.66 (1.43-1.93)**	**1.47 (1.24-1.74)**
Creatinine (ref. < 100 µmol/l)				
≥ 100 µmol/l	**2.25 (1.72-2.96)**	**1.76 (1.22-2.52)**	**1.78 (1.54-2.07)**	**1.51 (1.27-1.80)**
Hospital-related variables				
Mobilised to standing within 24 hours (ref. yes)				
No	**1.69 (1.19-2.40)**	1.32 (0.86-2.02)	1.18 (0.96-1.47)	1.08 (0.85-1.316
No indication for mobilisation	**2.03 (1.24-3.33)**	1.26 (0.64-2.50)	**1.41 (1.05-1.91)**	1.17 (0.81-1.69)
Time from admission to surgery (ref. < 24 hours)				
24-36 hours	1.09 (0.73-1.65)	0.98 (0.59-1.64)	1.16 (0.94-1.44)	1.11 (0.89-1.39)
> 36 hours	**1.47 (1.02-2.12)**	1.37 (0.86-2.17)	**1.33 (1.08-1.62)**	**1.24 (1.01-1.53)**
Surgical method (ref. internal fixation)				
THA	0.96 (0.72-1.28)	1.06 (0.71-1.59)	0.89 (0.76-1.04)	**0.84 (0.70-0.99)**
Girdlestone resection arthroplasty	3.19 (0.95-10.73)	1.99 (0.52-7.68)	1.64 (0.68-3.94)	1.49 (0.61-3.65)
Active clinical issues at admission[e] (ref. 0)				
1	1.12 (0.78-1.63)	0.98 (0.63-1.53)	1.10 (0.90-1.34)	0.97 (0.78-1.20)
≥ 2	0.97 (0.58-1.62)	0.81 (0.43-1.51)	1.26 (0.99-1.60)	1.14 (0.88-1.48)
Active clinical issues at discharge[e] (ref. 0)				
1	**1.44 (1.05-1.97)**	**1.50 (1.02-2.19)**	**1.26 (1.07-1.48)**	1.18 (0.99-1.40)
≥ 2	**2.54 (1.77-3.64)**	**2.32 (1.30-4.13)**	**1.56 (1.26-1.93)**	**1.44 (1.15-1.80)**

[a] New Mobility Score. A maximum of 9 points can be achieved based on mobility indoor and outdoor; 1-5 equals a low functional level. 6-9 equals a high functional level.

[b] Body Mass Index.

[c] American Society Anesthesiologists.

[d] Novel oral anticoagulation.

[e] Based on vital signs at discharge and additional antibiotics during the primary hospital stay.

Table 6. Demographics based on surgical delay for more than 24 hours presented as numbers (%). p-values are shown for chi-squared tests for each characteristic. Missing causes and other causes are omitted.

	Surgical delay				Total	p-value
	Not delayed	Medical causes	AC treatment	Organisational		
Total	1,859 (74)	129 (5)	91 (4)	347 (14)	2,510 (100)	
Age						0.01
< 75 years	546 (77)	24 (3)	15 (2)	89 (13)	707 (28)	
75-84 years	643 (73)	46 (5)	44 (5)	120 (14)	878 (35)	
≥ 85 years	670 (72)	59 (6)	32 (3)	138 (15)	925 (37)	
Gender						0.05
Female	1,270 (76)	82 (5)	50 (3)	226 (13)	1,682 (67)	
Male	589 (71)	47 (6)	41 (5)	121 (15)	828 (33)	
Residence						0.02
Independent living	1,409 (76)	82 (4)	74 (4)	236 (13)	1,865 (74)	
Nursing home	448 (70)	47 (7)	17 (3)	111 (17)	643 (26)	
ASA score[a]						< 0.01
ASA score 1-2	1,094 (59)	41 (3)	36 (3)	193 (14)	1,404 (56)	
ASA score ≥ 3	733 (39)	83 (8)	52 (5)	150 (14)	1,060 (42)	
Cognitive function						0.12
Cognitive fit	1,517 (69)	93 (5)	75 (4)	263 (17)	2,012 (80)	
Cognitive impaired	336 (75)	35 (7)	16 (3)	81 (13)	488 (19)	
NMS[b]						0.47
Low functional level	698 (73)	60 (6)	36 (4)	138 (14)	959 (38)	
High functional level	1,101 (75)	65 (4)	55 (4)	198 (13)	1,473 (59)	

[a] American Society of Anesthesiologists.

[b] New Mobility Score. A maximum of 9 points can be achieved based on mobility indoor and outdoor; 1-5 equals a low functional level and 6-9 equals a high functional level.

Table 8. Demographics based on the number of active clinical issues at discharge presented as numbers (%). p-values are shown for chi-squared tests for each characteristic.

	Active clinical issues			Total	p-value
	0	1	≥ 2		
Total	1,243 (52%)	887 (37%)	283 (12%)	2,413 (100%)[a]	
Age					< 0.01
< 75 years	424 (62)	212 (31)	53 (7)	689 (29)	
75-84 years	433 (51)	321 (37)	97 (11)	851 (35)	
≥ 85 years	386 (45)	354 (40)	133 (15)	873 (36)	
Gender					0.06
Female	814 (50)	621 (38)	190 (12)	1,625 (67)	
Male	429 (54)	266 (34)	93 (12)	788 (33)	
Residence					< 0.01
Independent living	1,007 (56)	628 (35)	177 (10)	1,812 (75)	
Nursing home	236 (39)	258 (43)	106 (18)	600 (25)	
ASA score[b]					< 0.01
ASA score 1-2	778 (57)	455 (34)	125 (9)	1,358 (56)	
ASA score ≥ 3	443 (44)	422 (42)	147 (15)	1,012 (42)	
Cognitive function					< 0.01
Cognitive fit	1,063 (54)	690 (35)	198 (10)	1,951 (81)	
Cognitive impaired	177 (39)	195 (43)	84 (18)	456 (19)	
NMS[c]					< 0.01
Low functional level	394 (43)	386 (42)	147 (16)	927 (38)	
High functional level	828 (57)	487 (34)	131 (9)	1,446 (60)	

[a] Missing values have been omitted.

[b] American Society of Anesthesiologists.

[c] New Mobility Score. A maximum of 9 points can be achieved based on mobility indoor and outdoor; 1-5 equals a low functional level and 6-9 equals a high functional level

Paper IV

Intramedullary nail versus dynamic hip screw with stabilising trochanteric plate in treatment of unstable intertrochanteric fractures

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Abstract

Purpose: The purpose of this study was to compare intramedullary nail (IMN) and dynamic hip screw with a trochanteric stabilising plate (DHS-TSP) in the treatment of unstable intertrochanteric fractures in terms of both short- and long-term clinical outcomes.

Methods: A prospective cohort study was conducted comprising 156 patients treated for an unstable intertrochanteric fracture with either IMN or DHS-TSP. The primary outcome was reoperation within three years. Secondary outcomes were measured during the hospital stay (operation time, total blood loss, blood transfusions, mobilisation and length of stay) and at a one-year postoperative follow-up (pain, patient-reported outcome measures (PROM) and regaining pre-fracture function).

Results: IMN was used more frequently than DHS-TSP in osteosynthesis of Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) type 31.3 fractures, but the groups were similar with respect to all other baseline characteristics. The IMN group had a higher total blood loss and a lower frequency of mobilisation within 24 hours, but this was not reflected in the number of blood transfusions or in a poorer function at the one-year follow-up. After one year, the IMN group had less pain but similar results in terms of all other outcomes, including regaining pre-fracture function, PROM and reoperation rates.

Conclusion: The findings suggest that both IMN and DHS-TSP may be used to treat unstable intertrochanteric fractures with similar results regarding function, PROM and reoperation rates.

Introduction

Hip fractures are life-altering events that often lead to diminished physical function or death. They are generally divided into two main types: intracapsular and extracapsular (intertrochanteric and subtrochanteric) fractures. Intertrochanteric fractures are typically classified into stable and unstable fractures based on the fracture pattern (**Figure 1**) [1]. Intertrochanteric fractures are typically treated with internal fixation. However, despite extensive research, the best choice of implant for intertrochanteric fractures remains controversial [2–5]. In stable intertrochanteric fractures, intramedullary nails (IMNs) and dynamic hip screws (DHSs) have shown comparable results. However, in unstable intertrochanteric fractures, IMNs have shown better results than DHSs [2, 3, 6]. This was reasoned by a lack of support of the lateral femoral wall in the DHS device, causing medialisation of the femoral shaft [2–4]. As a result, the trochanteric stabilising plate (TSP) was developed as an add-on to the DHS to stabilise the greater trochanter and lateral femoral wall and use of the TSP has shown promising results [7–9]. A recent systematic review and meta-analysis identified only five eligible studies comparing IMN and DHS-TSP [10]. However, one of these studies was later retracted due to plagiarism [11]; of the remaining four studies, three were retrospective studies and one was categorised as a randomised controlled trial (RCT). A scoping review has also recently been published. This review identified another two studies comparing DHS-TSP and IMN [12–14]. However, most studies were retrospective or had a small study population or a short follow-up time [12, 13, 15–18]. Thus, more information is required about the treatment of unstable intertrochanteric fractures with IMN and DHS-TSP, including patient-reported outcome measures (PROM) and functional outcomes.

We conducted a single-centre prospective cohort study comparing IMN and DHS-TSP in the treatment of unstable intertrochanteric fractures. We hypothesised that there would be no clinically significant difference between the two implants during the hospital stay (in terms of operative time, total blood loss, need for blood transfusions, mobilisation and length of stay (LOS)), at one year postoperatively (regarding pain, PROM and regaining pre-fracture function), and until three years regarding reoperation rate.

Material and methods

Patients

All patients admitted or transferred to our hospital between June 2011 and December 2017 with an intertrochanteric fracture were considered for inclusion (n = 1,256). The exclusion criteria were stable intertrochanteric fracture (n = 685), operated at a different hospital (n = 1), treated with fixation systems other than DHS-TSP or IMN (n = 393, primarily DHS without TSP) and conservatively treated fractures (n = 1). The second fracture was excluded if a patient experienced a second hip fracture during the study period (n = 20) (see details in **Figure 2**).

Measurements

Nurses, physiotherapists and doctors prospectively registered all data regarding age, sex, weight, height, residence, cognitive function, pre-fracture functional level assessed by the New Mobility Score (NMS), pre-fracture medication, comorbidities, blood transfusions during the hospital stay, fracture type, surgical date, surgical method, operating time, mobilisation during the hospital stay and biochemistry including pre- and postoperative haemoglobin. Body Mass Index (BMI), derived from the patients' height and weight, was categorised based on the World Health Organization's recommendations into underweight (< 18.5 kg/cm^2), normal weight (18.5-25 kg/cm^2) and overweight (> 25 kg/cm^2) [19]. Patients were dichotomised into cognitively fit or cognitively impaired patients based on previous dementia diagnoses. NMS was dichotomised into a low (1-5 points) and a high functional level (6-9 points) [20]. A cut-off point of six has been shown to be predictive of functional recovery [21, 22]. Anticoagulation therapy was defined as vitamin K antagonists, acetylsalicylic acid, direct oral anticoagulant or a combination of these, and dichotomised into no anticoagulation therapy or active anticoagulation therapy at the time of admission. Comorbidities were assessed using the American Society of Anesthesiology (ASA) score, which was obtained from the anaesthesiologist's report and dichotomised into ASA 1-2 and ASA 3-5.

Fractures were classified using the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA). The AO/OTA classifies intertrochanteric fractures into three groups: 31A1 are simple stable fractures; 31A2 are multifragmentary fractures with an incomplete lateral wall; and 31A3 are reverse obliquity fractures. The latter two fracture types are unstable [1]. Two authors (MS and CFF) classified 10% of the patients together to ensure alignment, and the remaining patients were then classified by one of the two authors.

The surgical methods were the DHS four-hole plate or longer with TSP or IMN with or without cerclage (**Figure 3**). The surgical methods utilised were based on the operating surgeon's fracture assessment. The patients were placed on a fracture table in a supine position, and closed reduction of the fracture was performed by traction and rotation using fluoroscopy. For DHS-TSP, a lateral approach was used and, using fluoroscopy, the screw was placed centrally-centrally. Usually, a four-hole plate was used. However, in the fractures with subtrochanteric extension, a six- or eight-hole plate was fitted and fixed to the femur. The size of TSP was assessed under fluoroscopy and then placed and fitted. For IMN, an incision proximally from the tip of the greater trochanter and a parallel incision were made through the fascia lata and gluteus medius. A guidewire was inserted followed by reaming, and then the size was measured and the IMN inserted. The neck screw was inserted centrally-centrally. Skin closure was done in layers for both procedures.

Outcomes

The primary outcome was reoperation within three years. Reoperation date and type were obtained from the [redacted] Regional Hospital's servers which hold data on admissions and operations within the region. Reoperations were side-matched to the primary surgery. Electronic patient records were checked for the cause for reoperation (**Table 1**). To allow for comparison with previous literature, causes for reoperations were also divided into mechanical failure (avascular necrosis and non-union) and infections (superficial and deep infections) (for definitions, see Table 1).

Secondary outcomes for the hospital stay included operative time, blood transfusions, total blood loss, mobilisation and LOS. All blood transfusions during the hospital stay were registered. Patients had a blood transfusion if their haemoglobin dropped below 10 g/dl and they were symptomatic. A previous publication has shown that 98% of patients in this cohort received blood transfusions if needed [23]. The need for blood transfusions is highly dependent on haemoglobin at admission [24]. Hence, haemoglobin level upon admission may not accurately assess the blood loss from the fracture and the difference between surgical methods. To evaluate this difference, the total blood loss was calculated based on the haemoglobin level and the estimated blood volume [25, 26]. The latter was calculated using Nadler's formula [27]:

$$\textit{Patient blood volume (l)} = k_1 \times \textit{height (m)}^3 + k_2 \times \textit{weight (kg)} + k_3$$

With $k_1 = 0.3669$, $k_2 = 0.03219$ and $k_3 = 0.6041$ for men, and $k_1 = 0.3561$, $k_2 = 0.03308$ and $k_3 = 0.1833$ for women. The calculated loss of haemoglobin in the perioperative period was based on the assumption that the blood volume would remain the same and that all blood transfusions contained the same amount of haemoglobin (52 ± 5.4 g Hgb [28]). The formula used to calculate loss of haemoglobin was:

$$Hgb_{loss}\ (g) = \textit{Patient blood volume} \times (Hgb_{pre} - Hgb_{post}) + Hgb_{trans}\ (g)$$

Hgb_{loss} is the calculated total haemoglobin loss, Hgb_{pre} is the haemoglobin value at admission, Hgb_{post} is the postoperative haemoglobin value on day one or two and Hgb_{trans} is the total amount of haemoglobin in the blood transfused before the measurement of Hgb_{post}. The calculated total blood loss was estimated using the following formula:

$$\textit{Total blood loss (ml)} = (Hgb_{loss} / Hgb_{pre}) \times 1000$$

To evaluate in-hospital rehabilitation, all electronic patient records were checked for the timing and execution of the first mobilisation session following surgery. The goal for all patients was mobilisation to a standing position within 24 hours of surgery unless otherwise instructed by the surgeon or if the patient had no pre-fracture standing ability. These patients were left out of the analyses for this variable.

Additional secondary outcomes at one year were functional outcome (regained pre-fracture NMS), pain during walking and PROMs including self-evaluation regarding walking ability, social life and general health, reported as poorer, the same, or better than the pre-fracture status. Contact by way of telephone interview was attempted in all surviving patients. The interview was conducted by a trained nurse one year after surgery. A standardised questionnaire was completed with the patient, relatives or caregivers, and it was documented who completed the questionnaire. The responder was asked about living arrangements, pain during walking, the three activities of the NMS, and was invited to compare their walking ability, social life and general health with their pre-fracture status.

Statistics

Results are presented as median (interquartile range (IQR)) or proportions (percentages), as appropriate for the data type and distribution. For continuous variables, normality was checked visually on QQ-plots. The Mann-Whitney U test was used as all data were nonparametric. For categorical variables, we evaluated between-group differences using the chi-squared test or Fisher's exact test depending on the number of events. All tests were two-sided and results were considered statistically significant if $p < 0.05$. Data analyses were performed using Stata statistical software (Stata 17).

Ethics

The study was registered with the [redacted] Data Protection Agency (record number 2007-58-0010). Under [redacted] law, no requirement exists for written consent for this study. The study was funded internally by the Orthopaedic Department only. The authors have no conflicts to declare.

Results

The dataset comprised 107 females and 49 males at a median age of 81.8 (IQR: 16.4) years who were primarily living independently and cognitively fit (**Table 2**). A tendency was seen for increased use of IMN among men and patients living independently, and IMN was used statistically significantly more for AO/OTA31.3 fractures. No difference between the two groups was found for the remaining baseline characteristics (**Table 2**). An increase in the use of IMN was seen throughout the study period. Time to surgery was less than 24 hours for 79% of the patients and less than 36 hours for 91% of the patients. LOS was similar between groups with a median LOS of six days (IQR of 4) for both groups (range 1-16 for DHS-TSP and 1-12 for IMN) ($p = 0.86$). Patients not treated with IMN or DHS-TSP (n = 393) were similar in terms of baseline characteristics except for fracture type, as they were more likely to have experienced an AO/OTA31.2 fracture ($p < 0.001$).

The overall reoperation rate within three years was 12%, with eight patients (DHS-TSP: 6 / IMN: 2) being reoperated for mechanical failure and two for infections (**Table 1**). The median operative time was 75 minutes for DHS-TSP and 82 minutes for IMN ($p = 0.16$). Patients treated with IMN were more likely to have a higher total blood loss. However, no statistically significant difference between the two groups was observed in terms of the number of patients receiving blood transfusions during their hospital stay. Of the 156 patients, no indication for mobilisation applied to seven patients (4%); of the remaining 149 patients, 120 patients were mobilised within 24 hours. Patients treated with IMN were more likely not to be mobilised to standing within 24 hours from surgery than were patients treated with DHS-TSP (**Table 3**).

At one year, 87 (56%) patients were interviewed. Patients treated with IMN reported less pain while walking than patients with DHS-TSP and tended to have a better self-evaluated walking ability. However, no difference between groups was found for regaining pre-fracture NMS and PROM at one year (**Table 3**).

Discussion

We compared the outcomes after treatment of unstable intertrochanteric fractures with either IMN or DHS-TSP. The three main findings of the present study are, firstly, that during the hospital stay, patients treated with IMN were more likely to have a higher total blood loss and longer time to mobilisation than patients treated with DHS-TSP. Secondly, during a telephone interview, patients treated with DHS-TSP reported more hip pain while walking and a tendency towards a poorer self-reported walking ability one year after surgery. Thirdly, at three years, the reoperation rate was 12% and similar for the two groups (DHS-TSP n = 14, IMN n = 5).

In the treatment of unstable intertrochanteric fractures, DHS-TSP and IMN have been shown to be superior to DHS alone, proximal femoral locked plate and compression screws [2, 3, 7, 9]. However, only few studies have directly compare DHS-TSP and IMN [12, 13, 15–18]. A systematic review and a scoping review concluded that IMN and DHS-TSP are reliable treatment options for unstable intertrochanteric fractures, but both reviews argued that more research was warranted [10, 14]. By a relatively small margin, the three cohort studies in the systematic review all recommended IMN [16–18]. IMM was recommended primarily because it was associated with shorter operation time, less bleeding, decreased frequency of full-weight-bearing and shorter LOS; however, most studies found similar results between the two groups for reoperation rates, function and mortality. Conversely, the RCT reported better outcomes for the DHS-TSP group with lower reoperation rates within six months and a tendency to better function [15]. It should be noted that Madsen et al. 1998 is not strictly an RCT as randomisation was done by changing treatment method during the study period [15]. We found no differences between reoperation rates for infections or mechanical failures within three years. Similarly, previous studies have found no differences in reoperation rates between the two groups [12, 13, 16]. However, the present study had a longer follow-up than any previous studies, which a strength of the present study. Nevertheless, some reoperations might have occurred after our study period concluded despite the relatively long follow-up time.

In all reported studies, including the present, selection bias is present because the operating surgeon had the final say about which implant was used [12, 13, 16–18]. Furthermore, surgeons may have more experience using one type of implant than other types, which may affect the surgical procedure, including operation time and implant position. Anatomical reduction and implant placement have previously been shown to impact reoperation rates following internal fixation of intertrochanteric fractures [29–31]. Müller et al. 2020 also concluded that some of the inferior performance of DHS-TSP in their study could be due to poorer placement and reduction in the DHS-TSP group [18]. The IMN guide system is user friendly, but correct fracture reduction remains the art of the individual surgeon and is critical to surgery outcome. Other studies have also found similarly good reduction and implant placement in the DHS-TSP group [15, 16]. Nuber et al. 2003 showed good radiological results in fracture reduction and implant placement for 96.9% of patients with DHS-TSP compared with 87.7% in the proximal femoral nail (PFN) group [16]. Unfortunately, we were unable to analyse the postoperative x-rays as most patients only had the fluoroscopy documentation taken during their hospital stay. This had two consequences. Firstly, we were unable to measure the fracture reduction and implant placement on the x-rays due to technical limitations. Secondly, since the patient was still on the operating table, no weight bearing had been done, and the traction applied during fracture reduction and surgery was not necessarily released during the fluoroscopy documentation. Thus, the fracture may have settled afterwards. However, based on previous studies, we do not suspect a difference in placement and reduction between the two groups, which would otherwise potentially skew results towards the null hypothesis.

In 2003, Klinger et al. 2003 concluded that PFN was superior to DHS-TSP because it was associated with a shorter operating time and shorter LOS, but reoperation and function were similar in the two groups [17]. However, this study demonstrates similar operation times for IMN and DHS-TSP, as also reported by Fu et al. 2020 [13]. In most studies, the difference was typically between 10 and 20 minutes [13, 15–17]. Although a shorter operative time may enable more surgeries during the day and reduce surgery-induced stress, it seems excessive to recommend one implant above the other based on this result. In this study, LOS was similar in the two groups, and we had a much shorter LOS with a median of six days compared with 12.9-21.3 days in other studies [12, 15–18]. This may indicate that LOS depends more on other factors than on implant type.

We found that compared with DHS-TSP, IMN treatment had some early disadvantages in the form of increased total blood loss and longer time to mobilisation. Despite the increased total blood loss in the IMN group, no differences in the number of patients needing blood transfusions were found between the two groups. These results are similar to those reported by Fu et al. [13]. In tis study, patients treated with DHS-TSP were more likely to be mobilised within 24 hours than were patients treated with IMN, but both groups had a high degree of mobilisation. One explanation may be that IMNs were more often used for AO/OTA31.3 fractures where restricted weight-bearing may apply, making mobilisation to standing more difficult. In previous studies, in-hospital rehabilitation has been measured by the percentage of patients capable of full-weight-bearing immediately after surgery, but we had no information regarding this issue [16, 17]. However, mobilisation to standing has been linked to a lower mortality and better functional outcomes

[32, 33]. The disadvantages recorded during the hospital stay in our IMN group were not reflected in a poorer function at one year. Actually, the IMN group seemed to have a slightly superior performance at one year with less hip pain and a tendency to better self-reported walking capabilities. Less hip pain was also reported by Nuber et al. and Fu et al. [13, 16]. Despite different functional measures used in the previous studies, most studies found no difference in function between the two groups [12, 13, 16, 17].

Strengths and limitations

This study has inherent limitations. Being an observational study, it cannot conclude on causality, merely on association. Conversely, study strengths include a prospective design with consecutive inclusion of all admitted patients, which eliminates recall bias. The inclusion process increases the external validity of the study, as the study population was representative of the actual patient group, which is demonstrated, e.g., by the higher median age in our population than in those of other studies [15, 17]. The study population may have been too small to detect minor differences in outcomes between the two groups (type 2 error). Furthermore, we had no information on fracture reduction and implant placement, and along with additional residual confounding, the lack of such information is a limitation. RCTs are warranted to eliminate these confounders and selection bias by the performing surgeon. However, studies need to be of a substantial size to detect small but clinically significant differences in function, reoperation or mortality.

Considering these limitations, our study suggests that both IMN and DHS-TSP may be used to treat unstable intertrochanteric fractures as they showed similar results regarding function, PROM and reoperation rates.

References

1. Wilber JH, Ricci WM, Kellam JF, et al (2018) Fracture and Dislocation Classification Compendium—2018. J Orthop Trauma 32:. https://doi.org/10.1097/BOT.0000000000001063

2. Socci AR, Casemyr NE, Leslie MP, Baumgaertner MR (2017) Implant options for the treatment of intertrochanteric fractures of the hip - RATIONALE, EVIDENCE, AND RECOMMENDATIONS. Bone Jt J 99-B:128–133. https://doi.org/10.1302/0301-620X.99B1.BJJ-2016-0134.R1

3. Li A, Zhang W, Wang J, et al (2017) Intramedullary and extramedullary fixations for the treatment of unstable femoral intertrochanteric fractures : a meta-analysis of prospective randomized controlled trials. Int Orthop 403–413. https://doi.org/10.1007/s00264-016-3308-y

4. Parker MJ, Raval P, Gjertsen JE (2018) Nail or plate fixation for A3 trochanteric hip fractures: A systematic review of randomised controlled trials. Injury 49:1319–1323. https://doi.org/https://doi.org/10.1016/j.injury.2018.05.017

5. Kumar P, Rajnish RK, Sharma S, Dhillon MS (2020) Proximal femoral nailing is superior to hemiarthroplasty in AO/OTA A2 and A3 intertrochanteric femur fractures in the elderly: a systematic literature review and meta-analysis. Int Orthop 44:623–633. https://doi.org/https://doi.org/10.1007/s00264-019-04351-9

6. Yu X, Wang H, Duan X, et al (2018) Intramedullary versus extramedullary internal fixation for unstable intertrochanteric fracture, a meta-analysis. Acta Orthop Traumatol Turc 52:299–307. https://doi.org/10.1016/j.aott.2018.02.009

7. Babst R, Renner N, Biedermann M, et al (1998) Clinical results using the trochanter stabilizing plate (TSP): The modular extension of the dynamic hip screw (DHS) for internal fixation of selected unstable intertrochanteric fractures. J Orthop Trauma 12:392–399

8. Matre K, Vinje T, Havelin LI, et al (2013) TRIGEN INTERTAN Intramedullary Nail Versus Sliding Hip Screw - A Prospective, Randomized Multicenter Study on Pain, Function, and Complications in 684 Patients with an Intertrochanteric or Subtrochanteric Fracture and One Year of Follow-up. J Bone Jt Surg Am 95:200–208

9. Selim A, Beder FK, Algeaidy IT, et al (2020) Management of unstable pertrochanteric fractures , evaluation of forgotten treatment options. SICOT-J 6:

10. Selim A, Ponugoti N, Naqvi AZ, Magill H (2021) Cephalo-medullary nailing versus dynamic hip screw with trochanteric stabilisation plate for the treatment of unstable per-trochanteric hip fractures: a meta-analysis. J Orthop Surg Res 16:1–9. https://doi.org/10.1186/s13018-020-02193-5

11. Patil SN, Srinivas P (2017) Comparative study between proximal femoral nail and dynamic hip screw with trochanteric stabilizing plate in unstable intertrochantric femur fractures. Int J Res Orthop 3:936. https://doi.org/10.18203/issn.2455-4510.intjresorthop20173198

12. Tucker A, Donnelly KJ, Rowan C, et al (2018) Is the Best Plate a Nail? A Review of 3230 Unstable Intertrochanteric Fractures of the Proximal Femur. J Orthop Trauma 32:53–60. https://doi.org/10.1097/BOT.0000000000001038

13. Fu C-W, Chen J-Y, Liu Y-C, et al (2020) Dynamic Hip Screw with Trochanter-Stabilizing Plate Compared with Proximal Femoral Nail Antirotation as a Treatment for Unstable AO/OTA 31-A2 and 31-A3 Intertrochanteric Fractures. Biomed Res Int 2020:1–7. https://doi.org/10.1155/2020/1896935

14. Alm CE, Gjertsen JE, Basso T, et al (2021) Trochanteric stabilizing plate in the treatment of trochanteric fractures: a scoping review. Acta Orthop 92:733–738. https://doi.org/10.1080/17453674.2021.1954305

15. Madsen JE, Næss L, Aune AK, et al (1998) Dynamic Hip Screw with Trochanteric Stabilizing Plate in the Treatment of Unstable Proximal Femoral Fractures: A Comparative Study with the Gamma Nail and Compression Hip Screw. J Orthop Trauma 12:241–248. https://doi.org/10.1097/00005131-199805000-00005

16. Nuber S, Schönweiss T, Rüter A (2003) Stabilisierung von instabilen trochantären mehrfragmentfrakturen. Vergleich zwischen PFN und DHS mit trochanterabstützplatte. Unfallchirurg 106:39–47. https://doi.org/10.1007/s00113-002-0476-6

17. Klinger HM, Baums MH, Eckert M, Neugebauer R (2005) Eine vergleichende untersuchung der versorgung instabiler per- und intertrochantärer femurfrakturen mittels DHS-osteosynthese unter verwendung der trochanterabstützplatte und dem proximalen femurnagel (PFN). Zentralbl Chir 130:301–306. https://doi.org/10.1055/s-2005-836784

18. Müller F, Doblinger M, Kottmann T, Füchtmeier B (2020) PFNA and DHS for AO/OTA 31-A2 fractures: radiographic measurements, morbidity and mortality. Eur J Trauma Emerg Surg 46:947–953. https://doi.org/10.1007/s00068-019-01251-w

19. World Health Organization Body mass index - BMI. https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi. Accessed 9 Sep 2021

20. Parker MJ, Palmer CR (1993) A NEW MOBILITY AFTER SCORE FOR PREDICTING MORTALITY. J Bone Jt Surg Br 75:797–798

21. Kristensen MT, Bandholm T, Foss NB, et al (2008) HIGH INTER-TESTER RELIABILITY OF THE NEW MOBILITY SCORE IN PATIENTS WITH HIP FRACTURE. J Rehabil Med 589–591.

https://doi.org/10.2340/16501977-0217

22. Kristensen MT, Foss NB, Kehlet H (2007) A new mobility score for predicting mortality after hip fracture. Physi 87:24–30

23. Frandsen CF, Glassou EN, Stilling M, Hansen TB (2021) Poor adherence to guidelines in treatment of fragile and cognitively impaired patients with hip fracture: a descriptive study of 2,804 patients. Acta Orthop 1–7. https://doi.org/10.1080/17453674.2021.1925430

24. Arshi A, Lai W, Iglesias B, et al (2021) Blood transfusion rates and predictors following geriatric hip fracture surgery. HIP Int 31:272–279. https://doi.org/10.1177/1120700019897878

25. Good L, Peterson E, Lisander B (2003) Tranexamic acid decreases external blood loss but not hidden blood loss in total knee replacement. Br J Anaesth 90:596–599. https://doi.org/10.1093/bja/aeg111

26. Foss NB, Kehlet H (2006) Hidden blood loss after surgery for hip fracture. J Bone Jt Surg Br 88:1053–1059. https://doi.org/10.1302/0301-620X.88B8.17534

27. Nadler SB, Hidalgo JU, Bloch T (1962) Prediction of blood volume in normal human adults. Surgery 51:224–232

28. Lisander B, Ivarsson I, Jacobsson SA (1998) Intraoperative autotransfusion is associated with modest reduction of allogeneic transfusion in prosthetic hip surgery. Acta Anaesthesiol Scand 42:707–712

29. Bojan AJ, Beimel C, Taglang G, et al (2013) Critical factors in cut-out complication after gamma nail treatment of proximal femoral fractures. BMC Musculoskelet Disord 14:1–9. https://doi.org/10.1186/1471-2474-14-1

30. Page PRJ, Field MH, Vetharajan N, et al (2020) Incidence and predictive factors of problems after fixation of trochanteric hip fractures with sliding hip screw or intramedullary devices. HIP Int September: https://doi.org/10.1177/1120700020959339

31. Yamamoto N, Tomita Y, Noda T, et al (2021) Reduction quality and nail fixation ratio as bone-implant stability factors associated with reoperation for trochanteric fractures. Injury 52:1813–1818. https://doi.org/10.1016/j.injury.2021.04.048

32. Siu AL, Penrod JD, Boockvar KS, et al (2006) Early Ambulation After Hip Fracture: Effects on Function and Mortality. Arch Intern Med 166:766–771. https://doi.org/10.1001/archinte.166.7.766

33. Frandsen CF, Glassou EN, Stilling M, Hansen TB (2021) Malnutrition, poor function and comorbidities predict mortality up to one year after hip fracture: a cohort study of 2800 patients. Eur Geriatr Med Epub ahead: https://doi.org/10.1007/s41999-021-00598-x

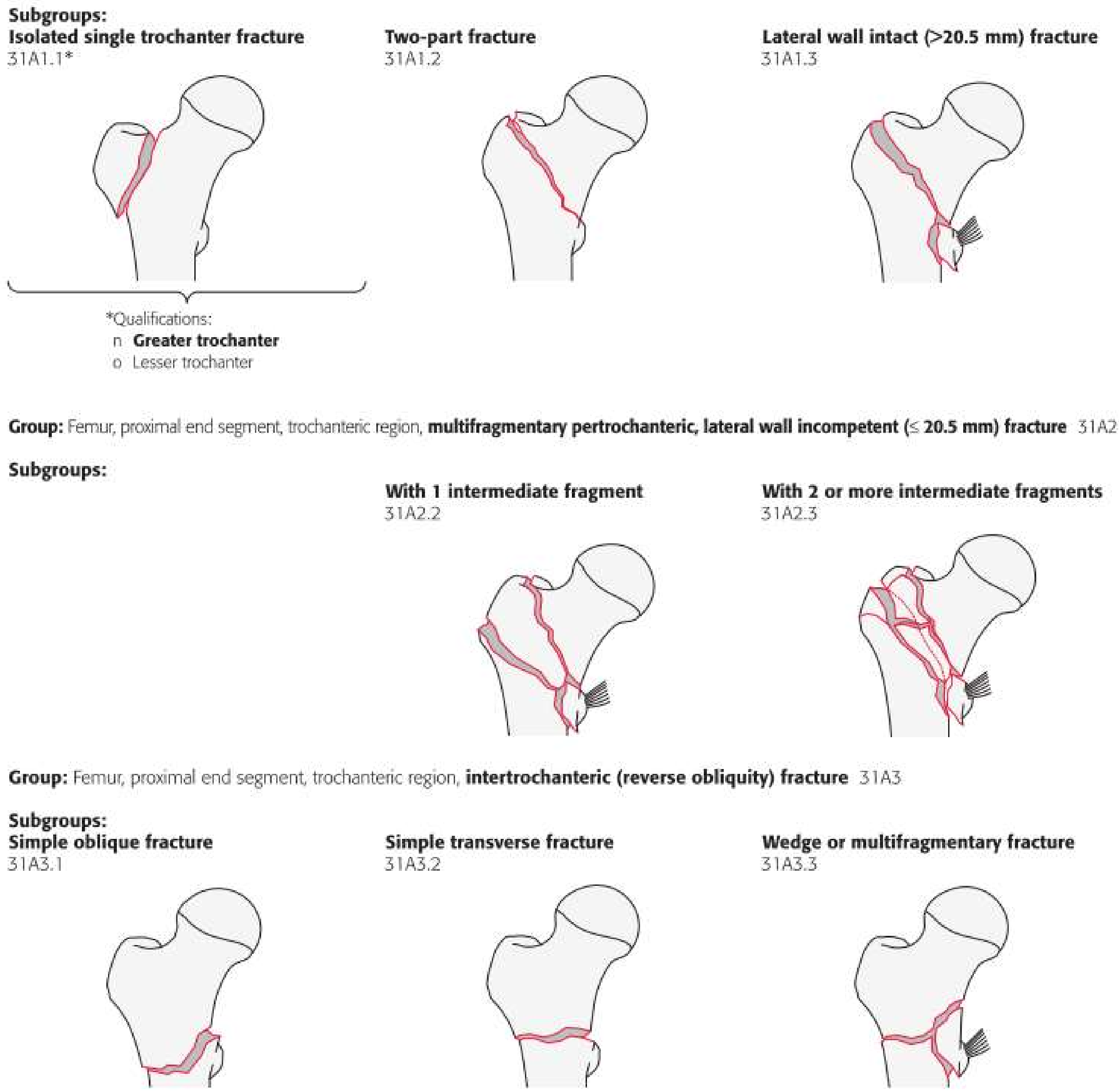

Figure 1. *AO/OTA fracture classification for intertrochanteric fractures (AO/OTA31). Copyright the AO Foundation, Switzerland.* [1]

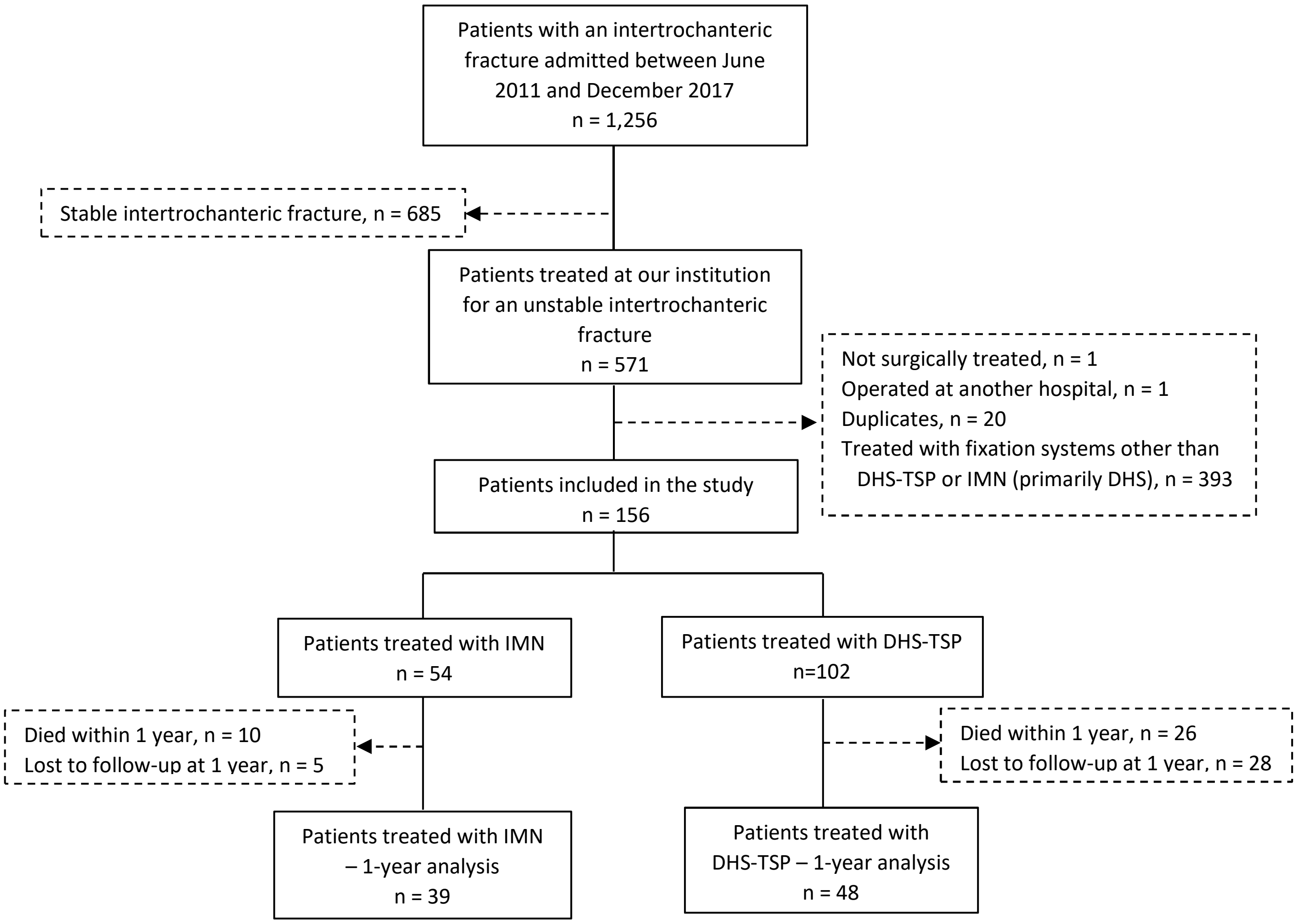

Figure 2. *Flowchart presenting the inclusion process during the study period.*

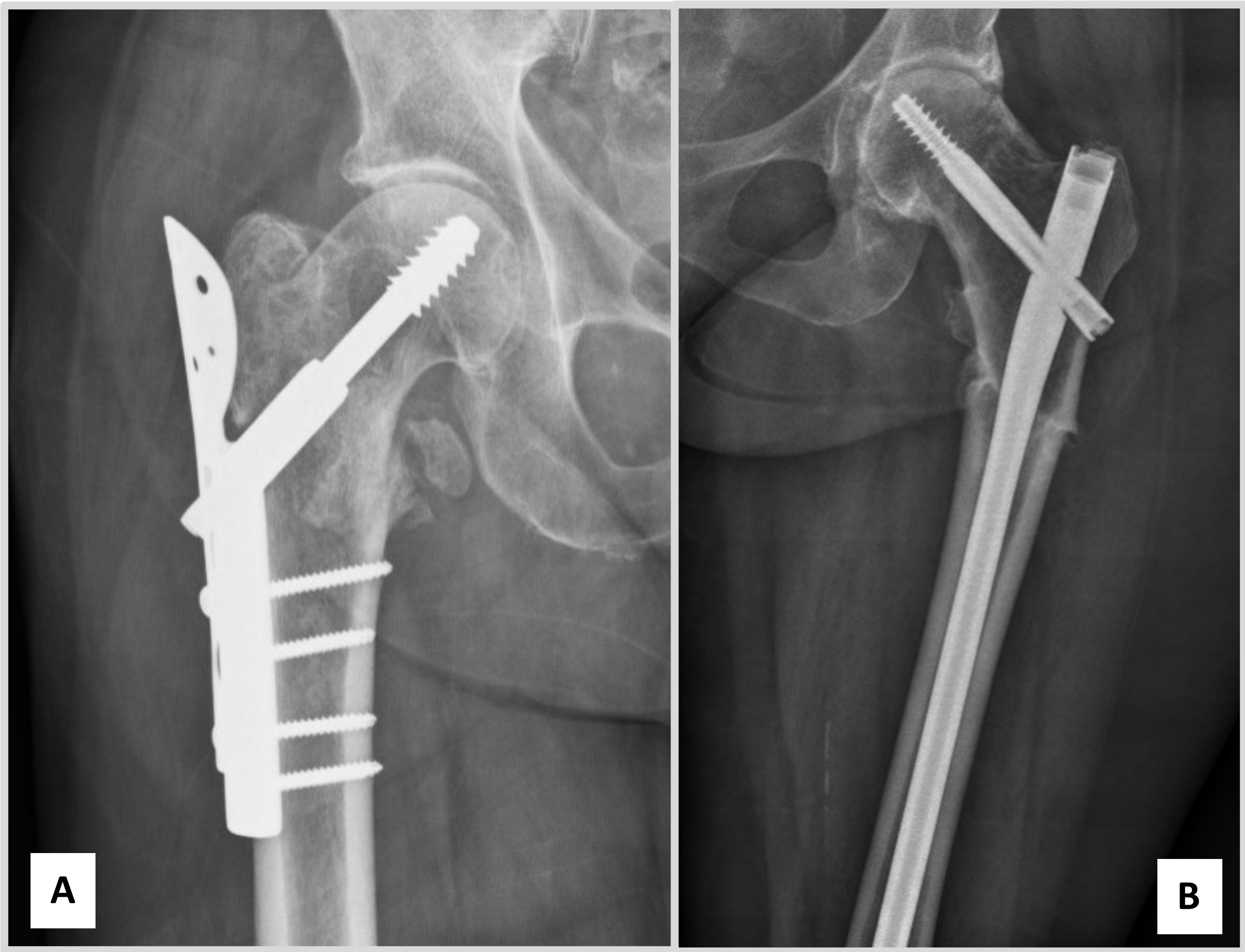

Figure 3. *X-ray showing (A) the dynamic hip screw with trochanteric stabilizing plate and (B) the intramedullary nail without cerclage.*

Table 1. Cause of reoperation. Definition of causes for reoperation and absolute numbers (percentages) divided into dynamic hip screw with trochanteric stabilising plate (DHS-TSP) and intramedullary nail (IMN).

Reoperation cause	DHS-TSP n=102 (65)	IMN n=54 (35)	Definition
Superficial infection	0 (0)	0 (0)	Reoperation of the surgical wound without involvement of osteosynthesis material.
Deep infection	1 (7)	1 (20)	Reoperation due to bacterial infection around osteosynthesis material.
Peri-implant fracture	2 (14)	1 (20)	Reoperation due to a new fracture involving osteosynthesis material or nearby, requiring either revision or additional osteosynthesis to stabilise the fracture.
Avascular necrosis	2 (14)	0 (0)	Radiographic signs of necrosis of femoral head or protrusion of screw through caput.
Non-union	4 (29)	2 (40)	A lack of healing or significant fracture compression with lateral protrusion of screws requiring reoperation.
Sequelae resulting in a revision to THA[a]	1 (7)	0 (0)	Revision from internal fixation to THA for reasons other than those specified in avascular necrosis or non-union, e.g., osteoarthritis and pain.
Local pain due to internal fixation	4 (29)	1 (20)	Removal of internal fixation material due to pain without signs of peri-implant fractures, avascular necrosis or non-union.
Bleeding	0 (0)	0 (0)	Bleeding from surgical site in initial post-operative period requiring reoperation.
Total	14 (14)	5 (9)	

[a] THA = Total hip arthroplasty

Table 2. Patient characteristics. Baseline characteristics of study population of patients treated with dynamic hip screw with trochanteric stabilising plate (DHS-TSP), intramedullary nail (IMN) and in total, presented as numbers (%).

Variable	DHS-TSP	IMN	Total	p-value
Total	102 (65)	54 (35)	156 (100)	
Age (median (IQR))	83.7 (17.4)	79.7 (14.9)	81.8 (16.4)	
< 70 year	17 (17)	10 (19)	27 (17)	0.62
70-84 years	39 (38)	24 (44)	63 (40)	
85 years	46 (45)	20 (37)	66 (42)	
Gender				
Female	75 (74)	32 (59)	107 (69)	0.07
Male	27 (26)	22 (41)	49 (31)	
Pre-fracture residence				
Independent living	70 (69)	44 (81)	114 (73)	0.09
Nursing home	32 (31)	10 (19)	42 (27)	
BMI[a]				
< 18.5 kg/m^2	14 (14)	4 (7)	18 (12)	0.49
18.5-25 kg/m^2	51 (50)	29 (54)	80 (51)	
> 25 kg/m^2	36 (35)	21 (39)	57 (37)	
Fracture type				
AT/OTA A31.2	72 (71)	24 (44)	96 (62)	**< 0.01**
AT/OTA A31.3	30 (29)	30 (56)	60 (38)	
ASA score[b]				
ASA[b] 1-2	54 (54)	28 (53)	82 (54)	0.89
ASA[b] 3-5	46 (46)	25 (47)	71 (46)	
Cognitive function				
Cognitively fit	75 (75)	40 (75)	115 (75)	0.95
Cognitively impaired	25 (25)	13 (25)	38 (25)	
Anticoagulation therapy				
No	60 (59)	26 (48)	86 (55)	0.18
Yes	41 (41)	28 (52)	69 (45)	
NMS[c]				
Low functional level	39 (41)	18 (33)	57 (38)	0.38
High functional level	57 (59)	36 (67)	93 (62)	

[a] Body Mass Index

[b] American Society of Anesthesiologists

[c] New Mobility Score, 0-5 point = low functional level. 6-9 points = high functional level

Table 3. Patient outcomes. Outcomes for patients treated with dynamic hip screw with trochanteric stabilising plate (DHS-TSP) or intramedullary nail (IMN), presented as numbers (%).

Variable	DHS-TSP	IMN	p-value
Total	102 (65)	54 (35)	
Operation time (min)			
Median (IQR)	75 (53)	82 (38)	0.16
Mobilised within 24 hours			
Not mobilised within 24 hours	14 (14)	15 (31)	**0.02**
Mobilised within 24 hours	86 (86)	34 (69)	
Blood transfusion			
Yes	69 (68)	35 (65)	0.73
No	33 (32)	19 (35)	
Total blood loss (ml)			
Median (IQR)	722 (562)	885 (562)	**< 0.01**
Function one year after surgery			
Did not regain pre-fracture function	28 (61)	23 (59)	0.86
Regained pre-fracture function	18 (39)	16 (41)	
Pain during walking one year after surgery			
No pain	22 (47)	29 (76)	**0.04**
Mild pain	10 (21)	5 (13)	
Moderate pain	8 (17)	3 (8)	
Sever pain	7 (15)	1 (3)	
Walking ability one year after surgery			
Deterioration compared with pre-fracture ability	27 (69)	17 (50)	0.09
No deterioration compared with pre-fracture ability	12 (31)	17 (50)	
PROM			
Worse than before fracture	27 (73)	20 (63)	0.35
The same as before fracture	10 (27)	12 (37)	
Reoperation within 3 years			
All causes	14 (14)	5 (9)	0.61
Mechanical failure	6 (6)	2 (4)	0.71
Infections	1 (1)	1 (2)	1.00

IQR = Inter quartile range

PROM = Patient-reported outcome measures

Paper V

The majority of community-dwelling hip fracture patients return to independent living with minor increase in care needs – A prospective cohort study

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Abstract

Introduction: Hip fracture patients are fragile, and the majority fail to fully recover to their pre-fracture functional level, resulting in an increase in institutionalization. We aimed to investigate risk factors for being dependent at discharge and for failure to return to independent living 12 months after a hip fracture.

Material and Methods: From 2011 through 2017, all surgically treated hip fracture patients admitted from their own homes were included in this prospective cohort study. Patient characteristics were registered, including age, sex, lifestyle, comorbidities, pre-fracture New Mobility Score (NMS), biochemical measures, fracture type, and surgical method. Dependency was measured at discharge using a cumulated ambulatory score (CAS < 6) and the timed-up-and-go test (TUG > 20 seconds). At 12 months, patients were interviewed regarding residence, NMS, and care needs.
Multivariable logistic regression was used, reporting odds ratio (OR) with 95% confidence intervals (CI).

Results: A total of 2,006 patients were included in the study with data regarding their hospital stay and discharge. In all, 1,342 patients underwent follow up at 12 months. The risk factors found to be associated with dependency at discharge were mostly static. Modifiable variables associated with dependency at discharge (CAS < 6) were hypoalbuminemia (OR: 1.94, 95% CI: 1.38-2.71), not having been mobilized to standing within 24 hours (OR: 1.88, 95% CI: 1.12-3.15), and general anesthesia (OR: 1.35, 95% CI: 1.07-1.71). Failure to return to independent living at 12 months was found in 10% of the patients and was primarily associated with patient characteristics and proxy variables for comorbidities, but also with dependency at discharge (CAS < 6).

Conclusions: Mobilizing patients to standing within 24 hours from hip fracture surgery was vital in maximizing short-term functional recovery. Failure to return to independent living was seen in the frailest patients. However, the majority remained in their own home with little increase in care needs.

Keywords
Hip fracture, functional outcome, functional recovery, institutionalization, cumulated ambulation score, timed-up-and-go

Introduction

The World Health Organization (WHO) and the United Nations have coined 2021-2030 the decade of healthy ageing [1]. The WHO defines this as: "the process of developing and maintaining the functional ability that enables wellbeing in older age" [1]. The WHO highlights functional ability, including meeting basic needs and being mobile as key terms [1]. However, for the patient sustaining a hip fracture is a catastrophic event and often associated with adverse outcomes including disability and mortality. Hip fractures often lead to deterioration in function with increased care needs that make independent living impossible and results in institutionalization. In Western countries, 10-36% of patients sustaining a hip fracture are institutionalized within 12 months after their fracture [2–4]. Previous studies have identified risk factors for failure to return to independent living, such as age, cognitive status, comorbidities, and pre-fracture functional level [5–7]. Additionally, a recent study found that a low functional level at discharge predicted failure to return to independent living 12 months after the hip fracture [4].
Early identification of patients at specific risk of functional loss and long-term institutionalization due to hip fracture is important. However, hip fracture patients' short-term functional recovery has not previously been in focus since most studies have investigated only predictors of long-term functional recovery [10–12]. One focus of hip fracture treatment should be timely and focused rehabilitation aiming at regaining pre-fracture function, enabling patients to remain in their own homes and preserve their independence. A key element in the improvement of functional recovery after hip fracture surgery is identification of modifiable risk factors that may be targeted by interventions. However, systemic reviews have highlighted the lack of consistent findings regarding risk factors for poor functional recovery [8, 9].

The present study aimed to describe risk factors for dependency at discharge in a hospital setting with a short length of stay (LOS) and subsequent failure to return to independent living at 12 months following hip fracture surgery.

Patients and Methods

This was an observational cohort study using prospectively and consecutively collected data from [redacted] Hip Fracture Database[redacted]. All patients in the database who were living independently in their own homes at the time of their hip fracture and who were treated at our institution between June 2011 and December 2017 were considered for inclusion. Excluded were patients with non-fragility hip fracture (e.g., caused by pathology or high-energy trauma), not surgically treated, operated at another hospital, and patients who died during their acute hospital stay. If a patient experienced a second hip fracture during the study period, the second fracture was not included.

Data were gathered prospectively by nurses, physiotherapists, and doctors at four time points; the day of admission, day one post-operatively, the day of acute hospital discharge, and 12 months post-operatively. One project nurse double checked the registration papers and the database to ensure the date quality and completeness of data after the patient's discharge. Nurses, physiotherapists, and doctors were continuously trained in reporting to the database, thereby minimizing variation in reporting practices during the study period.

Patient characteristics
Age was categorized into < 75, 75-84, and ≥ 85 years. The patients' gender, residence, smoking status, weekly alcohol consumption, and any visual impairment were documented. Body Mass Index (BMI), derived from the patients' height and weight, was categorized based on the World Health Organization into underweight (< 18.5 kg/cm^2), normal weight (18.5-25 kg/cm^2), and overweight (> 25 kg/cm^2) [13]. Height was primarily patient reported, whereas weight was obtained by weighing the patients. Fractures were grouped into intra- or extracapsular fractures based on pre-operative radiographs [14].

Proxy variables for comorbidities

Using the American Society of Anesthesiologists (ASA) classification system, the treating anesthesiologist assessed the patients' comorbidity status. ASA score was dichotomized into ASA 1-2 and ASA 3-5. Patients were divided into cognitively fit or cognitively impaired based on previous diagnoses of dementia or similar. Blood results included hemoglobin, albumin, and 25-hydroxy-vitamin D, with the lower limit at 10 g/dl for hemoglobin, 35 g/dl for albumin, and 50 µmol/l for 25-hydroxy-vitamin D. The pre-fracture functional level was based on the New Mobility Score (NMS) [15]. The NMS is a self-reported measure that categorizes a patient's ability to complete three functional activities: indoor walking, outdoor walking, and shopping. Each activity is given a score between 0 and 3, yielding a final score between 0 and 9, where 9 represents independent with no aid in all three activities, and 0 represents being unable to perform any of the activities. The NMS has a high inter-tester reliability, and a cut-off point of six has been shown to be predictive of functional recovery [16, 17]. Patients were divided into a high pre-fracture functional level with a score of 6 or above, and a low functional group with a score of 5 or below.

Hospital-related variables

Hospital-related variables included time to surgery, surgical method, type of anesthesia, mobilization to standing within 24 hours of surgery, post-operative pain management, discharge destination, LOS, and all-cause readmission within the first year.

Physiotherapy was initiated on the first post-operative day on weekdays as well as during weekends. The first mobilization was documented; so was whether the patient was mobilized to standing - including any reason for not being mobilized to standing. Patients were categorized as no indication for mobilization, i.e. if they were without pre-fracture standing ability, had very complex fractures, or were admitted to the intensive care unit after surgery. Hence, these patients were not part of the analyses regarding mobilization. Time to surgery was calculated from admission and divided into less than 24 hours, 24-36 hours, or more than 36 hours from admission based on [redacted] guidelines [14, 18]. All fractures were surgically managed according to a [redacted] protocol [19]. After surgery, patients either received only oral pain management with opioids and paracetamol or a combination of oral pain management and an epidural catheter in the initial three days.

Patients were primarily rehabilitated in the orthopedic ward and discharged with a rehabilitation plan and an individually assigned number of follow-up sessions with a municipal physiotherapist. Patients requiring extensive rehabilitation were discharged to a rehabilitation facility. Discharge destination was documented; own home, protective living, nursing home, rehabilitation, or transferred to another hospital.

Outcomes

The primary outcome was independence measured by the Cumulated Ambulation Score (CAS) assessed by the physiotherapist immediately before discharge. The CAS is a reliable outcome measure that evaluates a patient's ability to: get in and out of bed, sit down and stand up, and walk with or without a mobility aid [20, 21]. The scores for each task (0-2 points) are combined to provide a total score between 0 and 6, where 6 implies independence in all three tasks and 0 indicates the inability to perform any of the tasks despite assistance. Studies have demonstrated the CAS to be a valid predictor of functional recovery in patients with hip fracture [21, 22]. The total CAS score was dichotomized into whether the patient regained complete independence (CAS = 6) or not (CAS score ≤ 5) [22]. At discharge, patients also had a timed-up-and-go (TUG) test. The TUG test measures the time in seconds that a person requires to rise from a standardized chair, walk three meters with or without the use of walking aids, and return to the chair and sit down [23]. The TUG test is a reliable outcome measure that has been demonstrated to predict functional outcomes after a hip fracture [24, 25]. Based on previous research, a cut-off point of 20 seconds was chosen, meaning that a TUG test of less than 20 seconds indicated independence [23, 26, 27].

All patients who were alive 12 months after surgery received a telephone call by a project nurse; 77% of the surviving patients or their close relatives or caregivers were reached. A standardized questionnaire was completed, and it was documented if the patients had changed residence. Patients had changed residence if they had moved from independent living to either protective living or to a nursing home at the 12-month follow-up, with the hip fracture being the primary reason for the change of residence. Furthermore, the respondent was asked about changes in care needs compared with their care need prior to their hip fracture.

Statistical analysis

Continuous variables were presented as median with interquartile range (IQR). Categorical variables were summarized as frequencies and percentages. A univariable logistic regression analysis was conducted to explore risk factors for dependency at discharge and failure to return to independent living. The independent variables are presented in Table 1. Furthermore, CAS and TUG were used as independent variables in the analysis of failure to return to independent living. The dependent variables were CAS = 6 and TUG < 20 seconds for dependency at discharge and failure to return to independent living at 12 months. Multivariable logistic regression was conducted adjusting for age, gender, ASA score, cognitive function, pre-fracture functional level, mobilization, and fracture type reporting odds ratio (OR) with 95% confidence intervals (95% CI). All analyses were conducted using the statistical package STATA version 17.

Ethics

The study was registered with the national data protection agency; under national law, there is no requirement for written consent for non-interventional studies. The study was funded by the department only and received no external funding. The authors have no conflicts of interest to declare.

Results

In the study period, 3,047 patients were diagnosed with a hip fracture at our institution. Among these, 1,047 patients were excluded, and 2,006 patients were included in the study of short-term functional recovery (**Figure 1**). Clinical characteristics of the 2,006 eligible patients are presented in Table 1. Within the first year, 253 patients died and 411 were lost to follow-up, which left 1,342 patients for the analyses of risk factors for failure to return to independent living (**Figure 1**).

Dependency at discharge

The median CAS was 4 (IQR: 3), with 613 (31%) patients being independent at discharge (CAS = 6). Multiple risk factors were identified for CAS ≤ 5 after adjusting for confounders. For patient characteristics; older age, overweight, extracapsular fractures, and pre-fracture NMS ≤ 5 were associated with an increased risk of being dependent at discharge (**Table 2**). For proxy variables for comorbidity; high ASA score, cognitive impairment, and hypoalbuminemia were associated with increased risk of being dependent at discharge (**Table 2**). For hospital-related variables; not having been mobilized to standing within 24 hours, displaced intracapsular fracture treated with total hip arthroplasty (THA), transfer to another hospital, and longer LOS were associated with an increased risk for being dependent at discharge (**Table 2**). Only 398 (20%) patients could perform TUG at discharge, and only 84 (21%) of the patients performed it in less than 20 seconds. More patients treated with THA were able to perform the TUG test and complete it within 20 seconds ($p < 0.001$). Extracapsular fracture and post-operative anemia were associated with an increased risk of dependency measured by TUG > 20 seconds at discharge (**Table 2**).

A total of 13 (1%) patients were discharged without walking aids, 90% were discharged with a walking aid, and 9% were discharged without walking ability.

Failure to return to independent living

The one-year questionnaires were completed via a telephone interview with the patient in 83% of the cases. The majority of the patients (65%) were discharged directly to their own homes. Failure to return to independent living was reported for 136 (10%) patients. The following risk factors were identified; old age, extracapsular fracture, cognitive impairment, low pre-fracture NMS, discharge to rehabilitation, and being dependent at discharge (CAS = 6) (**Table 3**).
Care needs were reported to have increased in 26% of patients; 71% of the patients reported the same level as before their hip fracture. Furthermore, 667 (50%) patients regained their pre-fracture NMS at 12 months, whereas 600 (45%) patients experienced a decrease in their NMS; and 75 (5%) patients either had no information on pre-fracture or 12-month NMS.

Discussion

We set out to investigate a vast number of risk factors for both short-term functional recovery and failure to return to independent living following hip fracture surgery. Only one-third of patients gained independence before discharge, based on a CAS value of 6, which was predictive of returning to independent living at 12 months. Multiple risk factors were identified, some of which will be discussed below. In general, patients with poor health (physically, cognitively, and functionally) before their fracture were at higher risk of being dependent at discharge. Even so, some modifiable factors were identified, such as post-operative mobilization and anesthesia type. For failure to live independently at 12 months, pre-fracture health greatly impacted the ability to remain in the patient's own home.

Dependency at discharge

Older patients with multiple comorbidities and low pre-fracture functional level (NMS ≤ 5) had poorer short-term functional outcomes; this observation is in line with the findings reported in other publications [8, 28]. In our study, patients who were not mobilized to standing within 24 hours had an increased risk of being dependent at discharge, which shows the importance of getting patients back on their feet quickly after surgery. Likewise, time to mobilization was suggested as an underlying mechanism in the association between functional outcome and static factors, such as comorbidities, cognitive impairment, and fracture [9]. Early mobilization reduces the amount of time spent immobilized, which is important as immobilization carries an increased risk of complications such as pneumonia [29]. Furthermore, early mobilization has been shown to reduce mortality and disability following a hip fracture [30–32]. Common causes for not achieving early mobilization may be pain, nausea, and fatigue, which may be targeted with multimodal pain management, rehydration, and medical optimization. We found no association between epidural catheter use as post-operative pain management and independence at discharge. However, this may be due to only 4% of the patients receiving an epidural catheter. Regional nerve blocks have previously been found to reduce time to first-time mobilization, surgical delay, and LOS, influencing outcomes like mortality and readmissions [33–35]. Compared with general anesthesia, spinal anesthesia was associated with an improved short-term independence. However, there is a potential selection bias of patients by the anesthesiologist, where healthier patients are more likely to receive spinal anesthesia and, therefore, may be more likely to regain function. We attempted to adjust for this by including ASA score, cognitive function, and pre-fracture NMS in our model. However, some residual confounding may remain. Previous studies have found no differences between general anesthesia and spinal anesthesia regarding functional recovery [36, 37]. However, Fields et al. found more complications post-operatively in patients receiving general anesthesia that could delay mobilization [38].
Patients treated with THA carried an increased risk of being dependent at discharge. However, this is most likely a result of a three-month movement restriction (hip flexion > 90 degrees, hip adduction > 0 degrees, and hip internal rotation > 0 degrees) following THA surgery. These restrictions hamper activities in the CAS such as getting in and out of bed and may explain the association found between THA and dependency at discharge in the present study. This is supported by patients treated with

THA being more likely to complete the TUG test, which may indicate a better walking ability at discharge.
A longer LOS was associated with dependency measured by the CAS; which is confirmed in a recent study that showed a similar trend [22]. It would have been expected that patients admitted for a longer period of time would display decreased dependency as they would have had a longer period to recover and therefore had more rehabilitation. Likely, the explanation is reverse causality where patients more rapidly regaining function being discharged sooner, rather than early discharge ensuring better functioning. Furthermore, more dependent and frail patients may be admitted for an extra day or two after receiving the needed hospital care while awaiting transfer to a rehabilitation facility or nursing home. LOS varies considerably between countries and has been reported to range from 1 to 55 days, which may to some extent be explained by differences in time to surgery and length of in-hospital rehabilitation [9]. Obviously, these factors may influence the short-term in-hospital functional recovery.

A recent study found that the initial functional recovery during the acute hospital stay was a good predictor for functional recovery after a subsequent rehabilitation stay [39]. Furthermore, regaining CAS has previously been shown to predict 30-day readmission and mortality, and showed improved functional recovery by each additional CAS point those patients regained, even among patients who did not regain total independence upon discharge [22]. Therefore, it is crucial to find ways to improve short-term functional recovery as this may subsequently improve long-term functional recovery thereby reducing mortality and readmissions.

Only 20% of patients were able to perform the TUG test at discharge, supporting the statement by others that the TUG test may not be the optimal measure for functional assessment in the acute phase following hip fracture surgery [40]. This indicates a need for more objective measurements for functional recovery validated in patients with hip fracture.

Failure to return to independent living

Sustaining a hip fracture can have considerable consequences for the patient, including forgoing independent living due to diminished function and increased care needs. Similar to Dyer et al., we found that 10% of patients became institutionalized due to their hip fracture [3]. Furthermore, our results align with risk factors found for institutionalization and increased care needs among patients with hip fractures identified in previous studies [4, 5, 7, 41]. Generally, this indicates that patients with good health (cognitive and functional) have a better chance of returning to independent living.

Similar to the results by Gamboa-Arango et al., our results showed that dependence measured by CAS predicted failure to return to independent living at 12 months [4]. Furthermore, a recent study showed that short-term functional recovery predicted long-term functional recovery [39]. As declining function and increased care needs affect the ability to live independently, a focus on improving short-term functional recovery after hip fracture may help maintain preoperative functions and independency. However, as this is an observational study, no conclusions regarding causality can be made, and it may be argued that the healthiest patients who are mobilized more quickly regain independence at discharge, and continue to live independently.

Strengths and limitations

The strengths of this study were the large study population and the detailed prospective data collection with consecutive inclusion of all admitted patients, including cognitively impaired patients, and with few missing values. On the other hand, this study also carries several limitations. We had no information about patients' post-surgery weight-bearing limitations, which would influence short-term functional recovery, in particular. Additionally, marital status, cohabitation, and educational level may potentially affect the ability to live independently, along with residual confounding. As the one-year follow-up relied on a questionnaire, recall bias is inherent.

Conclusion

Most of the risk factors associated with dependency at discharge were static. However, mobilizing patients to standing within 24 hours from hip fracture surgery was associated with achieving independency at discharge, as measured by CAS=6, which, in turn, was associated with return to independent living at 12 months. Patients not returning to independent living following hip fracture surgery were typically frailer than those who did return. However, the prognosis was generally good and the majority of the patients remained in their own home with little increase in care needs.

References

1. World Health Organization (2020) Decade of healthy ageing.

2. Osnes EK, Lofthus CM, Meyer HE, et al. (2004) Consequences of hip fracture on activities of daily life and residential needs. Osteoporos Int 15:567–574. https://doi.org/10.1007/s00198-003-1583-0.

3. Dyer SM, Crotty M, Fairhall N, et al. (2016) A critical review of the long-term disability outcomes following hip fracture. BMC Geriatr 16:158. https://doi.org/10.1186/s12877-016-0332-0

4. Gamboa-Arango A, Duaso E, Malafarina V, et al. (2020) Prognostic factors for discharge to home and residing at home 12 months after hip fracture: an Anoia hip study. Aging Clin Exp Res 32:925–933. https://doi.org/10.1007/s40520-019-01273-9.

5. Vochteloo AJH, Van Vliet-Koppert ST, Maier AB, et al. (2012) Risk factors for failure to return to the pre-fracture place of residence after hip fracture: A prospective longitudinal study of 444 patients. Arch Orthop Trauma Surg 132:823–830. https://doi.org/10.1007/s00402-012-1469-8.

6. Martinez-Reig M, Ahmad L, Duque G (2012) The orthogeriatrics model of care: systematic review of predictors of institutionalization and mortality in post-hip fracture patients and evidence for interventions. J Am Med Dir Assoc 13:770–777. https://doi.org/10.1016/j.jamda.2012.07.011.

7. Uriz-Otano F, Pla-Vidal J, Tiberio-López G, Malafarina V (2016) Factors associated to institutionalization and mortality over three years, in elderly people with a hip fracture - An observational study. Maturitas 89:9–15. https://doi.org/10.1016/j.maturitas.2016.04.005.

8. Xu BY, Yan S, Low LL, et al. (2019) Predictors of poor functional outcomes and mortality in patients with hip fracture: a systematic review. BMC Musculoskelet Disord 20:568. https://doi.org/10.1186/s12891-019-2950-0.

9. Sheehan KJ, Williamson L, Alexander J, et al. (2018) Prognostic factors of functional outcome after hip fracture surgery: a systematic review. Age Ageing 47:661–670. https://doi.org/10.1093/ageing/afy057.

10. Ju J, Zhang P, Jiang B (2019) risk factors for functional outcomes of the elderly with intertrochanteric fracture: A retrospective cohort study. Orhtopaedic Surg 11:643–652. https://doi.org/10.1111/os.12512.

11. Meng D, Bai X, Wu H, et al. (2019) Patient and Perioperative factors influencing the functional outcomes and mortality in elderly hip fractures. J Investig Surg 0:1–8. https://doi.org/10.1080/08941939.2019.1625985.

12. Wong RMY, Qin J, Chau WW, et al. (2021) Prognostic factors related to ambulation deterioration after 1-year of geriatric hip fracture in a Chinese population. Sci Rep 11:1–8. https://doi.org/10.1038/s41598-021-94199-0.

13. World Health Organization Body mass index - BMI. https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi. Accessed 9 Sep 2021.

14. Jensen CM, Mainz H, Lamm M, et al. (2008) Reference programme for treatment of patients with proximal femur fractures. Dansk Sygeplejeråd, Danske Fysioterapeuter Dansk Ortopædisk Selskab 1–128.

15. Parker MJ, Palmer CR (1993) A new mobility after score for predicting mortality. J Bone Jt Surg Br 75:797–798.

16. Kristensen MT, Bandholm T, Foss NB, et al. (2008) High inter-tester reliability of the new mobility score in patients with hip fracture. J Rehabil Med 589–591. https://doi.org/10.2340/16501977-0217.

17. Kristensen MT, Foss NB, Kehlet H (2007) A new mobility score for predicting mortality after hip fracture. Physi 87:24–30

18. Danish Multidisciplinary Hip Fracture Registry (2019) Annual report 2019.

19. Frandsen CF, Glassou EN, Stilling M, Hansen TB (2021) Poor adherence to guidelines in treatment of fragile and cognitively impaired patients with hip fracture: a descriptive study of 2,804 patients. Acta Orthop 1–7.

https://doi.org/10.1080/17453674.2021.1925430.

20. Kristensen MT, Kehlet H (2018) The basic mobility status upon acute hospital discharge is an independent risk factor for mortality up to 5 years after hip fracture surgery - Survival rates of 444 pre-fracture ambulatory patients evaluated with the Cumulated Ambulation Score. Acta Orthop 89:47–52. https://doi.org/10.1080/17453674.2017.1382038.

21. Foss N, Kristensen M, Kehlet H (2006) Prediction of postoperative morbidity, mortality and rehabilitation in hip fracture patients: the cumulated ambulation score. Clin Rehabil 20:701–708.

22. Kristensen MT, Öztürk B, Röck ND, et al. (2019) Regaining pre-fracture basic mobility status after hip fracture and association with post-discharge mortality and readmission — a nationwide register study in Denmark. Age Ageing 48:278–284. https://doi.org/10.1093/ageing/afy185.

23. Podsiadlo D, Richardson S (1991) The timed "Up & Go": A test of basic functional mobility for frail elderly persons. JAGS 39:142–8.

24. Kristensen MT, Bandholm T, Holm B, Ekdahl C (2009) Timed Up & Go Test score in patients with hip fracture is related to the type of walking aid. Arch Phys Med Rehabil 90:1760–1765. https://doi.org/10.1016/j.apmr.2009.05.013.

25. Kristensen MT, Foss NB, Kehlet H (2007) Timed "up & go" test as a predictor of falls within 6 months after hip fracture surgery. Phys Ther 87:24–30. https://doi.org/10.1016/0308-5953(77)90120-9.

26. Bischoff HA, Stähelin HB, Monsch AU, et al. (2003) Identifying a cut-off point for normal mobility: a comparison of the timed ' up and go ' test in community-dwelling and institutionalised elderly women. Age Ageing 32:315–320.

27. Tabori-jensen S, Hansen TB, Bøvling S, et al (2018) Good function and high patient satisfaction at mean 2 . 8 years after dual mobility THA following femoral neck fracture: a cross-sectional study of 124 patients. Clin Interv Aging 13:615–621.

28. Sijp MPL Van Der, Eijk M Van, Tong WH, et al. (2020) Independent factors associated with long-term functional outcomes in patients with a proximal femoral fracture: A systematic review. Exp Gerontol 139. https://doi.org/10.1016/j.exger.2020.111035.

29. Kamel HK, Iqbal MA, Mogallapu R, et al. (2003) Time to Ambulation After Hip Fracture Surgery: Relation to Hospitalization Outcomes. J Gerontol 58:1042–1045. https://doi.org/https://doi.org/10.1093/gerona/58.11.M1042.

30. Morri M, Forni C, Marchioni M, et al. (2018) Which factors are independent predictors of early recovery of mobility in the older adults' population after hip fracture? A cohort prognostic study. Arch Orthop Trauma Surg 138:35–41. https://doi.org/10.1007/s00402-017-2803-y.

31. Goubar A, Martin FC, Potter C, et al. (2021) The 30-day survival and recovery after hip fracture by timing of mobilization and dementia : a UK database study. Bone Joint J 103-B:1317–1324. https://doi.org/10.1302/0301-620X.103B7.BJJ-2020-2349.R1.

32. Frandsen CF, Glassou EN, Stilling M, Hansen TB (2021) Malnutrition, poor function and comorbidities predict mortality up to one year after hip fracture: a cohort study of 2800 patients. Eur Geriatr Med, Epub ahead of print: https://doi.org/10.1007/s41999-021-00598-x.

33. Scurrah A, Shiner CT, Stevens JA, Faux SG (2018) Regional nerve blockade for early analgesic management of elderly patients with hip fracture – a narrative review. Anaesthesia 73:769–783. https://doi.org/10.1111/anae.14178.

34. Garlich JM, Pujari A, Debbi EM, et al. (2020) Time to Block: early regional anesthesia improves pain control in geriatric hip fractures. J Bone Jt Surg 102:866–872.

35. Guay J, Kopp S (2020) Peripheral nerve blocks for hip fractures in adults (Review). Cochrane Database Syst Rev https://doi.org/10.1002/14651858.CD001159.pub3.www.cochranelibrary.com.

36. Fukuda T, Imai S, Nakadera M, et al. (2018) Postoperative daily living activities of geriatric patients administered general or spinal anesthesia for hip fracture surgery: A retrospective cohort study. J Orthop Surg 26:1–9. https://doi.org/10.1177/2309499017754106.

37. Sieber F, Magaziner J, Marcantonio ER, et al. (2021) Spinal Anesthesia or General Anesthesia for Hip Surgery in Older Adults. N Engl J Med 1–11. https://doi.org/10.1056/NEJMoa2113514.

38. Fields AC, Dieterich JD, Buterbaugh K, Moucha CS (2015) Short-term complications in hip fracture surgery using spinal versus general anaesthesia. Injury 46:719–723. https://doi.org/10.1016/j.injury.2015.02.002.

39. Hershkovitz A, Borow Y, Beeri A, Nissan R (2020) Initial functional recovery as a measure for rehabilitation

outcome in post- acute hip fractured patients. Arch Gerontol Geriatr 89. https://doi.org/10.1016/j.archger.2020.104070.

40. Nygard H, Matre K, Fevang JM (2016) Evaluation of Timed Up and Go Test as a tool to measure postoperative function and prediction of one year walking ability for patients with hip fracture. Clin Rehabil 30:472–480. https://doi.org/10.1177/0269215515591039.

41. Schulz C, Büchele G, Peter RS, et al. (2020) Regional variation of care dependency after hip fracture in Germany: A retrospective cohort study using health insurance claims data. PLoS One 15:1–17. https://doi.org/10.1371/journal.pone.0230648.

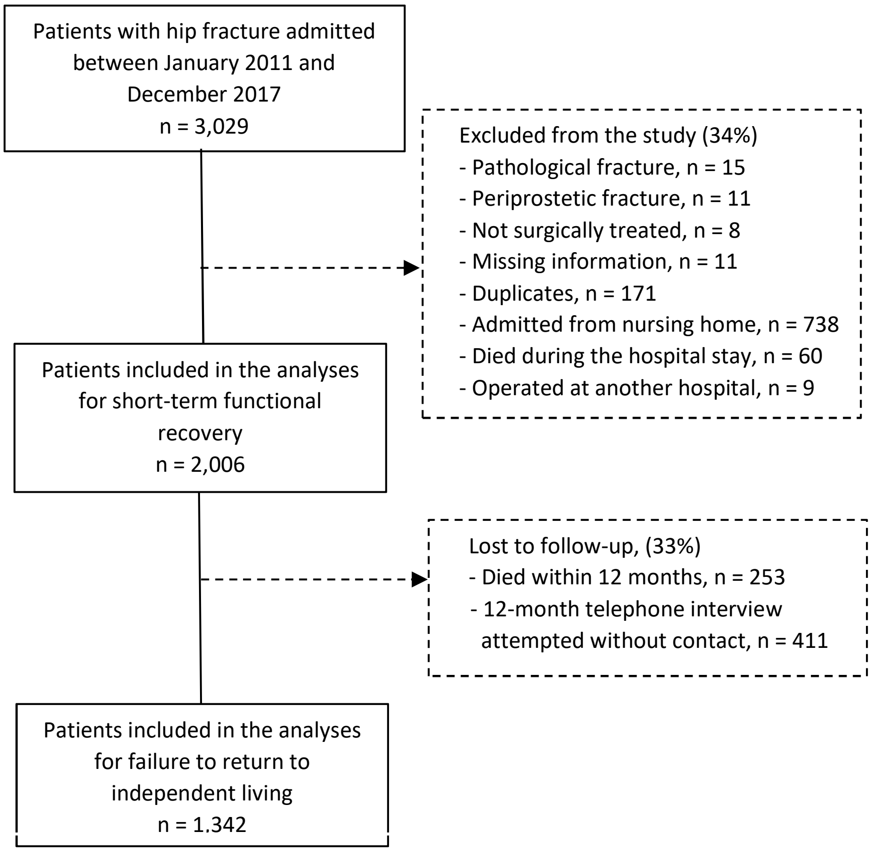

Figure 1. Flow chart for the inclusion process to the study and follow up.

Table 1. Demographics of the total study population at discharge. Values are presented as number of patients (percentage) for nominal data and as median (25–75% quartiles) for data in scales, n = 2,006. Missing values omitted.

Total	2,006 (100)
Patient characteristics	
Age (years)	80 (71-86)
Sex	
Female	708 (35)
Male	1,298 (65)
Pre-fracture smoking status	
Smoker	484 (24)
Non-smoker	1,451 (72)
Pre-fracture alcohol consumption	
> 7 units per week	49 (2)
≤ 7 units per week	1,861 (93)
BMI[1]	
< 18.5 kg/m^2	185 (9)
18.5-25 kg/m^2	1,128 (56)
> 25 kg/m^2	666 (33)
Pre-fracture functional level (NMS[2])	
NMS ≤ 5	511 (25)
NMS ≥ 6	1,425 (71)
Visual impaired	
Yes	221 (11)
No	1,701 (85)
Fracture type	
Intracapsular fracture	1,066 (53)
Extracapsular fracture	936 (47)
Proxy-variables for comorbidities	
ASA[3]	
ASA 1-2	1,241 (62)
ASA ≥ 3	723 (36)
Cognitive status	
Cognitive impaired	145 (7)
Cognitive fit	1,854 (92)
Post-operative hemoglobin	
< 10 g/dl	484 (24)
≥ 10 g/dl	1,516 (76)
Albumin	
< 35 g/l	397 (20)
≥ 35 g/l	1,609 (80)
25(OH)vitamin D	
< 50 µmol/l	890 (44)
≥ 50 µmol/l	859 (43)
Hospital-related variables	
Post-operative mobilization	
< 24 hours from surgery	1,698 885)
> 24 hours of surgery	170 (8)
Time from admission to surgery	
< 24 hours	1,489 (74)
24-36 hours	237 (12)
> 36 hours	251 (13)
Surgical method	
Internal fixation	1,289 (64)
THA[4]	711 (35)
Anesthesia technique	
Spinal anesthesia	838 (42)
General anesthesia	1,166 (58)
Post-operative pain management	
Oral pain management	1,908 (95)
Epidural catheter	86 (4)
Discharge destination	
Own home	1,297 (65)
Nursing home	84 (4)
Rehabilitation	534 (27)
Transferred to another hospital	69 (3)
Length of stay (days)	6 (4-7)
Readmitted within 12 months	764 (38)

[1] Body Mass Index

[2] New Mobility Score

[3] American Society Anesthesiologists

[4] Total hip arthroplasty

Table 2. Risk ratios for dependency at discharge predicted by CAS[1] < 6 and TUG[2] > 20 seconds. Odds ratios with 95% confidence intervals, n = 2,006.

	CAS[1]		TUG[2]*	
Variables	Univariate analysis OR (95%CI)	Multivariate analysis OR (95%CI)	Univariate analysis OR (95%CI)	Multivariate analysis OR (95%CI)
Patient characteristics				
Age (ref. <75 years)				
75-84 years	**2.43 (1.94-3.04)**	**2.09 (1.61-2.71)**	1.53 (0.88-2.64)	1.56 (0.85-2.87)
≥ 85 years	**5.68 (4.29-7.51)**	**4.39 (3.20-6.03)**	0.79 (0.41-1.52)	0.87 (0.39-1.94)
Male sex (ref. female sex)	0.93 (0.76-1.13)	1.05 (0.82-1.35)	**0.54 (0.33-0.89)**	0.61 (0.35-1.07)
Pre-fracture smokers (ref. non-smokers)	0.77 (0.62-0.96)	1.02 (0.78-1.34)	1.92 (0.99-3.74)	1.79 (0.87-3.70)
Pre-fracture alcohol consumption > 7 units per week (ref. ≤ 7 units per week)	0.67 (0.37-1.22)	0.84 (0.41-1.71)	0.77 (0.15-3.91)	0.91 (0.14-5.77)
BMI[3] (ref. 18.5-25 kg/m^2)				
< 18.5 kg/m^2	1.08 (0.77-1.52)	0.89 (0.59-1.35)	1.00 (0.41-2.43)	0.83 (0.33-2.08)
> 25 kg/m^2	1.07 (0.86-1.32)	**1.29 (1.00-1.66)**	0.75 (0.45-1.27)	0.78 (0.44-1.39)
Visual impairment (ref. no visual impairment)	1.36 (0.98-1.88)	0.83 (0.56-1.21)	0.87 (0.40-1.92)	0.88 (0.37-2.06)
NMS[4] ≤ 5 points (ref. NMS ≥ 6 points)	**6.03 (4.41-8.24)**	**4.34 (3.03-6.21)**	0.59 (0.27-1.28)	0.79 (0.27-2.30)
Extracapsular fracture (ref. intracapsular fracture)	**2.58 (2.11-3.17)**	**3.10 (2.45-3.93)**	**2.07 (1.15-3.76)**	**2.47 (1.26-4.86)**
Proxy-variables for comorbidities				
ASA[5] ≥ 3 (ref. ASA 1-2)	**2.98 (2.37-3.74)**	**2.22 (1.71-2.90)**	1.20 (0.66-2.21)	1.35 (0.67-2.74)
Cognitive impairment (ref. cognitive fit)	**9.84 (4.57-21.19)**	**6.34 (2.67-15.04)**	0.44 (0.10-1.87)	0.51 (0.09-3.03)
Postoperative anemia (ref. no anemia)	**2.37 (1.83-3.06)**	1.25 (0.92-1.70)	**3.37 (1.30-8.71)**	**3.16 (1.04-9.57)**
Hypoalbuminemia (ref. normal albumin)	**2.75 (2.05-3.67)**	**1.94 (1.38-2.71)**	0.96 (0.45-2.02)	0.92 (0.40-2.10)
25(OH)vitamin D < 50 µmol/l (ref. ≥ 50 µmol/l)	0.97 (0.79-1.19)	1.02 (0.80-1.30)	0.67 (0.40-1.13)	0.77 (0.43-1.36)
Hospital-related variables				
Post-operative mobilization > 24 hours from surgery (ref. < 24 hours)	**3.12 (1.96-4.95)**	**1.88 (1.12-3.15)**	1.62 (0.36-7.34)	1.47 (0.30-7.20)
Time from admission to surgery (ref. <24 hours)				
24-36 hours	1.07 (0.79-1.45)	0.95 (0.65-1.38)	1.25 (0.53-2.95)	1.34 (0.52-3.49)
> 36 hours	1.20 (0.89-1.63)	1.09 (0.75-1.59)	1.18 (0.54-2.56)	1.28 (0.50-3.30)
THA[6] (ref. internal fixation)	0.82 (0.67-1.00)	**1.86 (1.35-2.57)**	1.00 (0.61-1.62)	1.64 (0.89-3.03)
General anesthesia (ref. spinal anesthesia)	**1.55 (1.28-1.89)**	**1.35 (1.07-1.71)**	1.18 (0.73-1.93)	1.09 (0.64-1.87)
Post-operative epidural catheter (ref. oral pain management)	**0.59 (0.35-1.00)**	0.71 (0.39-1.28)	0.56 (0.12-2.54)	0.70 (0.15-3.30)
LOS[7] (per day)	**1.20 (1.15-1.26)**	**1.12 (1.06-1.18)**	1.08 (0.96-1.21)	1.12 (0.96-1.32)

* n=398

[1] Cumulated ambulation score

[2] Timed-up and go

[3] Body Mass Index

[4] New Mobility Score

[5] American Society Anesthesiologists

[6] Total hip arthroplasty

[7] Length of stay

Table 3. Odds ratio (OR) for failure to return to independent living at 12 months, n = 1,342. Displayed with 95% confidence intervals (95% CI).

Variables	Univariate analysis OR (95% CI)	Multivariate analysis OR (95% CI)
Patient characteristics		
Age (ref. < 75 years)		
75-84 years	**1.92 (1.21-3.04)**	**1.83 (1.11-3.02)**
≥ 85 years	**2.66 (1.65-4.31)**	**2.25 (1.32-3.85)**
Male sex (ref. female sex)	1.02 (0.70-1.48)	1.15 (0.76-1.74)
Pre-fracture smokers (ref. non-smokers)	**0.60 (0.38-0.97)**	0.71 (0.43-1.19)
Pre-fracture alcohol consumption > 7 units per week (ref. ≤7 units per week)	0.30 (0.04-2.24)	0.41 (0.05-3.20)
BMI[3] (ref. 18.5-25 kg/m^2)		
< 18.5 kg/m^2	0.97 (0.50-1.89)	0.84 (0.41-1.75)
> 25 kg/m^2	0.89 (0.60-1.30)	0.90 (0.59-1.36)
Visual impairment (ref. no visual impairment)	1.29 (0.75-2.22)	1.09 (0.61-1.95)
NMS[4] ≤ 5 points (ref. NMS ≥6 points)	**3.45 (2.36-5.05)**	**2.50 (1.65-3.80)**
Extracapsular fracture (ref. intracapsular fracture)	1.39 (0.97-1.98)	**1.65 (1.12-2.42)**
Proxy-variables for comorbidities		
ASA[5] ≥ 3 (ref. ASA 1-2)	**1.96 (1.36-2.81)**	1.34 (0.89-2.00)
Cognitive impairment (ref. cognitive fit)	**6.00 (3.56-10.10)**	**4.48 (2.54-7.91)**
Postoperative anemia (ref. no anemia)	**1.87 (1.28-2.74)**	1.39 (0.89-2.15)
Hypoalbuminemia (ref. normal albumin)	**1.58 (1.03-2.43)**	1.41 (0.88-2.24)
25(OH)vitamin D < 50 µmol/l (ref. ≥ 50 µmol/l)	0.97 (0.66-1.42)	0.95 (0.62-1.44)
Hospital-related variables		
Post-operative mobilization > 24 hours from surgery (ref. <24 hours)	1.74 (0.99-3.07)	1.19 (0.63-2.24)
Time from admission to surgery (ref. < 24 hours)		
24-36 hours	0.90 (0.49-1.65)	0.81 (0.42-1.58)
> 36 hours	1.50 (0.91-2.49)	1.44 (0.82-2.51)
THA[6] (ref. internal fixation)	0.85 (0.58-1.24)	0.86 (0.46-1.58)
General anesthesia (ref. spinal anesthesia)	0.87 (0.61-1.25)	1.03 (0.69-1.53)
Post-operative epidural catheter (ref. oral pain management)	0.81 (0.36-1.83)	0.95 (0.40-2.27)
LOS[5] per day	1.00 (0.99-1.02)	1.01 (0.95-1.08)
Readmitted within 12 months (ref. not readmitted)	**1.64 (1.15-2.35)**	1.43 (0.97-2.12)
Short-term functional recovery		
TUG[6] > 20 seconds (ref. < 20 seconds)	0.59 (0.18-2.00)	0.51 (0.13-1.95)
CAS[7] ≤ 5 (ref. CAS = 6)	**3.38 (2.06-5.53)**	**1.86 (1.06-3.26)**

[1] Body Mass Index

[2] New Mobility Score

[3] American Society Anesthesiologists

[4] Total hip arthroplasty

[5] Length of stay

[6] Timed-up and go

[7] Cumulated ambulation score

AARHUS UNIVERSITY

Declaration of co-authorship concerning <u>article for PhD dissertations</u>

Full name of the PhD student: Christina Frølich Frandsen

This declaration concerns the following article/manuscript:

Title:	Poor adherence to guidelines in treatment of fragile and cognitively impaired patients with hip fracture: a descriptive study of 2,804 patients
Authors:	Frandsen CF, Glassou EN, Stilling M, Hansen TB

The article/manuscript is: Published ☒ Accepted ☐ Submitted ☐ In preperation ☐

If published, state full reference: Frandsen CF, Glassou EN, Stilling M, Hansen TB. Poor adherence to guidelines in treatment of fragile and cognitively impaired patients with hip fracture: a descriptive study of 2,804 patients. Acta Orthop. 2021 Oct;92(5):544-550. doi: 10.1080/17453674.2021.1925430. Epub 2021 May 12.

If accepted or submitted, state journal:

Has the article/manuscript previously been used in other PhD or doctoral dissertations?

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Your contribution

Please rate (A-F) your contribution to the elements of this article/manuscript, and elaborate on your rating in the free text section below.

A. Has essentially done all the work (>90%)
B. Has done most of the work (67-90 %)
C. Has contributed considerably (34-66 %)
D. Has contributed (10-33 %)
E. No or little contribution (<10%)
F. N/A

Category of contribution	Extent (A-F)
The conception or design of the work:	C
Free text description of PhD student's contribution **(mandatory)** The PhD student wrote the protocol with the guidance of the supervisors and their knowledge on the topic.	
The acquisition, analysis, or interpretation of data:	B
Free text description of PhD student's contribution **(mandatory)** Data was obtained from a database, however, the student did the checks in the electronic patient records regarding some of the indicators and all contraindications. The student did all the statistical tests, and interpreted the data before presenting it to the co-authors.	
Drafting the manuscript:	B

Free text description of PhD student's contribution **(mandatory)** The student drafted the first manuscript, which was then reviewed by the co-authors. The revisions were preformed by the student until all authors were in agreement.

Submission process including revisions:	A

Free text description of PhD student's contribution **(mandatory)** The student submitted the paper, and performed all revisions, which was then accepted by the co-authors.

Signatures of first- and last author, and main supervisor

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28/1 2022	Torben Bæk Hansen	

Date: 28/1-2022

Signature of the PhD student

AARHUS UNIVERSITY

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Authors:	Frandsen CF, Glassou EN, Stilling M, Hansen TB

The article/manuscript is: Published ☒ Accepted ☐ Submitted ☐ In preperation ☐

If published, state full reference: Frandsen CF, Glassou EN, Stilling M, Hansen TB. Malnutrition, poor function and comorbidities predict mortality up to one year after hip fracture – a cohort study of 2,800 patients. Eur Geriatr Med. 2021 Dec 2. doi: 10.1007/s41999-021-00598-x. Epub ahead of print. PMID: 34854063.

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The acquisition, analysis, or interpretation of data:	B
Free text description of PhD student's contribution **(mandatory)** Data was obtained from a database, however, the student did the checks in the electronic patient records. The student did all the tests, and interpreted the data before presenting it to the co-authors.	
Drafting the manuscript:	B

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Free text description of PhD student's contribution **(mandatory)** The student drafted the first manuscript, which was then reviewed by the co-authors. The revisions were preformed by the student until all authors were in agreement.

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Free text description of PhD student's contribution **(mandatory)** The student submitted the paper, and performed all revisions, which was then accepted by the co-authors.

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This declaration concerns the following article/manuscript:

Title:	Active clinical issues at discharge predict readmission within 30 days and one year following hip fracture surgery
Authors:	Frandsen CF, Stilling M, Glassou EN, Pedersen ABL, Hansen TB

The article/manuscript is: Published ☐ Accepted ☐ Submitted ☒ In preperation ☐

If published, state full reference:

If accepted or submitted, state journal: European Geriatric Medicine

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Drafting the manuscript:	B

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Submission process including revisions:	A
Free text description of PhD student's contribution **(mandatory)** The student submitted the paper.	

Signatures of first- and last author, and main supervisor

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Category of contribution	Extent (A-F)
The conception or design of the work:	B
Free text description of PhD student's contribution **(mandatory)** The student designed the project regarding exposure and outcomes presented it for the supervisors. Followed by a discussion that lead to the final design of the study	
The acquisition, analysis, or interpretation of data:	B
Free text description of PhD student's contribution **(mandatory)** Data was obtained from a database, however, the student helped with one year interviews and did all the checks in the electronic patient records. The student did all the tests, and interpreted the data before presenting it to the co-authors.	
Drafting the manuscript:	B

Free text description of PhD student's contribution **(mandatory)** The student drafted the first manuscript, which was then reviewed by the co-authors. The revisions were preformed by the student until all authors were in agreement.

Submission process including revisions:	A
Free text description of PhD student's contribution **(mandatory)** The student handled the submission process the paper.	

Signatures of first- and last author, and main supervisor

Date	Name	Signature
28/1 2022	Christina Frølich Frandsen	
28/1 2022	Torben Bæk Hansen	

Date: 28/1-2022

Signature of the PhD student

Declaration of co-authorship concerning article for PhD dissertations

Full name of the PhD student: Christina Frølich Frandsen

This declaration concerns the following article/manuscript:

Title:	The majority of community-dwelling hip fracture patients return to independent living with a minor increase in care needs – A prospective cohort study
Authors:	Frandsen CF, Stilling M, Glassou EN, Hansen TB

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E. No or little contribution (<10%)
F. N/A

Category of contribution	Extent (A-F)
The conception or design of the work:	C
Free text description of PhD student's contribution **(mandatory)** The PhD student wrote the protocol with the guidance of the supervisors and their knowledge on the topic.	
The acquisition, analysis, or interpretation of data:	B
Free text description of PhD student's contribution **(mandatory)** Data was obtained from a database, however, the student help with one year interviews and did all the checks in the electronic patient records. The student did all the tests, and interpreted the data before presenting it to the co-authors.	
Drafting the manuscript:	B

Free text description of PhD student's contribution **(mandatory)** The student drafted the first manuscript, which was then reviewed by the co-authors. The revisions were preformed by the student until all authors were in agreement.

Submission process including revisions:	A
Free text description of PhD student's contribution **(mandatory)** The student submitted the paper.	

Signatures of first- and last author, and main supervisor

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