Tampere University

MARKUS HONGISTO

Fragility Hip Fracture

Predictive factors for mobility, institutionalization and survival

Tampere University Dissertations 293

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ACADEMIC DISSERTATION
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PunaMusta Oy – Yliopistopaino
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To my family

ABSTRACT

The purpose of this dissertation was to enhance older hip fracture patients' treatment by evaluating present treatment protocols according to scientific evidence and determining factors associated with need for assisted living arrangements, impaired mobility and poorer survival. First, a register-based study containing 49,514 patients aged 50 or more who had been operated on for femoral neck fracture in Finland during the period 1998–2011 was analysed to ascertain the surgical interventions applied. The study identified an increasing use of uncemented hemiarthroplasty (HA) from 2005 through 2011, which contradicts current scientific evidence. Further, increasing numbers of hip fracture patients had been treated by total hip arthroplasty (THA), while the use of internal fixation had become less common.

The material for the clinical studies was obtained from a prospectively collected dataset of consecutive hip fracture patients aged 65 years and over admitted to and operated on at Seinäjoki Central Hospital. Only the first hip fracture of each patient was included in the database. The telephone interviews at one, four and 12 months included eliciting information from the person contacted (patient or proxy). A comprehensive geriatric assessment was conducted 4–6 months after hip fracture.

In the second study we evaluated two common activities of daily living and cognitive screening instruments applied at the 4 to 6-month clinical control as prognostic indicators for institutionalization within one year after hip fracture and assessed the change in living arrangements during the first year after hip fracture. Institutionalized living arrangements at the time of injury were noted in 12.5% of the study population and the incidence of high-energy hip fracture was 6.1%. During one-year follow-up, a 22.7% mortality rate was observed. A total of 581 patients were analysed and optimal cut-off values for the Instrumental Activities of Daily Living (IADL) and Mini Mental State Examination (MMSE) were determined to predict the increased risk of institutionalization one year after hip fracture. A receiver operating characteristics (ROC) analysis revealed excellent discrimination for both variables. For IADL and

MMSE, the respective optimal thresholds predicting institutionalization were 5 (sensitivity 100%, specificity 38%) and 20 (sensitivity 83.5%, specificity 65%). Further, the change in residential location during between four and 12 months after hip fracture occurred in 11.3% of hip fracture patients.

Posterolateral and lateral approach are commonly used in HA depending on the surgeon's preference. Differences in living arrangements, use of mobility aids, pain and mortality were examined in the third study, which indicated that a posterolateral approach predisposed to hip dislocation and a lateral approach led to increased use of mobility aids at one year after HA. There was no difference between groups in mobility level, pain in the operated hip and living arrangements one year postoperatively.

Older hip fracture patients sustaining osteoporotic hip fracture are at increased risk of death several years afterwards. The mortality rate is the highest during the first months after the injury. The effect of time to surgery on survival has been investigated comprehensively in observational trials using a threshold of 24–72 hours for surgical timing. Only limited evidence is available on whether rapid surgery within 12 h of admission confers a survival benefit. In the fourth study, rapid surgery on hip fracture patients who have at least one severe disease (ASA ≥3, American Society of Anesthesiologists) was associated with lower short-term (30-day) and long-term (365-day) mortality. Patient-related factors affected long-term survival more.

In conclusion, the proportion of uncemented HA for femoral neck fractures increased markedly in Finland between 2005 and 2011, which contradicted scientific evidence. After 4 to 6 months from hospital discharge, IADL and MMSE may represent valuable clinical tests to screen the need for institutionalized living arrangements at 1 year after hip fracture. Hemiarthroplasty procedure using the lateral approach will increase the need for ambulatory aids at one year after hip fracture compared to the posterior approach at one year, whereas the posterior approach increases the risk of hip dislocation. Otherwise no differences between the two approaches were observed in regard with the one-year outcomes. Finally, delay in hip fracture surgery for more than 12 hours after admission may represent significant factor associated with impaired 30-day survival among patients with severe systemic disease (ASA ≥3).

TIIVISTELMÄ

Tämän väitöskirjatutkimuksen tarkoituksena oli edistää ikääntyneiden lonkkamurtumapotilaiden hoitoa vertaamalla tieteellistä näyttöä ja nykykäytäntöä, sekä selvittämällä tekijät, jotka vaikuttavat laitostumiseen, heikentyneeseen liikkumiskykyyn ja kuolleisuuteen. Ensimmäisessä osatyössä tutkittiin käytettyjen leikkausmenetelmien yleisyyttä vuosina 1998–2011 yhteensä 49 514 potilaalla, joilla oli todettu reisiluunkaulan murtuma. Vuosien 2005–2011 aikana sementittömän puolitekonivelen käyttö melkein kolminkertaistui vastoin tieteellistä näyttöä. Lisäksi kokotekonivelen suosio lisääntyi huomattavasti ja murtuman sisäisen kiinnityksen käyttö väheni.

Kliinisten tutkimusten materiaali koostuu Seinäjoen keskussairaalassa prospektiivisesti kerättyyn lonkkamurtuma-aineistoon, johon sisältyy kaikki 65 vuotta täyttäneet ensimmäisen lonkkamurtuman saaneet potilaat. Kaikki potilaat kutsuttiin geriatrian poliklinikalle kliiniseen kontrolliin 4–6 kuukauden kohdalla. Lisäksi järjestettiin puhelinhaastattelu yhden, neljän ja 12 kuukauden kohdalla murtumasta.

Toisessa osatyössä tutkittiin kahden tavanomaisen toimintakyky- ja kognitiomittarien ennustearvoa 4–6 kuukauden kliinisessä kontrollissa laitostumiseen vuoden kohdalla lonkkamurtumasta. Murtumahetkellä 12,5% potilaista asui laitoksessa, jossa on ympärivuorokautinen hoito. IADL ≤5 (sensitiivisyys 100%, spesifisyys 38%) ja MMSE ≤20 (sensitiivisyys 83,5%, spesifisyys 65%) osoittautuivat laitostumisen ennustetekijöiksi. Tutkimuksessa havaittiin myös, että 11,3% potilaista vaihtoi asumismuotoa 4 ja 12 kuukauden välillä murtumasta. Potilaiden yhden vuoden kuolleisuus oli 22,7 %.

Reisiluun kaulan murtuman hoidossa käytetään yleisimmin puolitekoniveltä, jonka asemoimiseksi Suomessa käytetään tyypillisimmin kahta eri leikkausavaustekniikkaa. Väitöskirjan kolmannessa osatyössä vertailtiin leikkausavausten vaikutusta lonkkamurtumapotilaan liikkumiseen ja apuvälineiden käyttöön, kuolleisuuteen ja asumismuotoon 1 vuoden kuluttua vammasta. Potilaat, jotka leikattiin käyttämällä posterolateraalista eli ”taka-avausta” tarvitsivat vähemmän liikkumisen apuvälineitä vuoden kuluttua leikkauksesta kuin potilaat, jotka leikattiin käyttämällä lateraalista avausta.

Taka-avauksesta leikatut kuitenkin altistuivat herkemmin lonkan sijoiltaanmenolle. Liikkumisen määrässä, kivussa tai laitostumisessa ei havaittu tilastotieteellisesti merkitsevää eroa leikkausavausten välillä.

Iäkkäiden lonkkamurtumapotilaiden kuolleisuusriski on koholla useita vuosia murtuman jälkeen. Kuolleisuus on suurinta ensimmäisten kuukausien aikana lonkkamurtumasta. Leikkausviiveen vaikutusta kuolleisuuteen on tutkittu runsaasti käyttäen 24–72 tunnin aikarajoja. Sen sijaan lyhyemmän alle 12 tunnin leikkausviiveen vaikutusta ei ole kattavasti tutkittu. Väitöskirjan neljännessä osatyössä tutkittiin leikkausviiveen vaikutusta niiden lonkkamurtumapotilaiden yhden kuukauden ja vuoden kuolleisuuteen, joilla oli vähintään yksi vakava systeeminen perussairaus (ASA ≥3). Yli 12 tunnin leikkausviive moninkertaisti erityisesti yhden kuukauden kuolleisuusriskin. Leikkausviiveellä oli merkittävä vaikutus myös yhden vuoden kuolleisuuteen, joskin potilaan sairastavuuden vaikutus kuolleisuuteen lisääntyi.

Yhteenvetona voidaan todeta, että Suomessa vuosina 2005–2011 reisiluun kaulan murtumapotilaat hoidettiin pääsääntöisesti tieteellistä näytön mukaisesti, mutta lisääntynyt sementittömän puolitekonivelen käyttö ei ollut perusteltua. Lisäksi osoitettiin, että IADL ja MMSE ovat käyttökelpoisia työkaluja laitostumisen ennustamisessa 4–6 kuukauden kuluttua murtumasta. Posterolateraalinen avaus altistaa puolitekonivelen sijoiltaanmenolle ja lateraalinen avaus lisääntyneelle apuvälineiden käytölle, mutta eroa avaustyyppien vaikutuksessa kuolleisuuteen, liikkumisen määrään, kipuun tai laitostumiseen vuoden kuluttua murtumasta ei havaittu. Viimeisen osatyön perusteella yli 12 tunnin leikkausviive saattaa moninkertaistaa kuolleisuusriskin ensimmäisen kuukauden aikana murtumasta potilailla, joilla on vakava yleissairaus (ASA-luokka ≥3).

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ABBREVIATIONS

ASA	American Society of Anesthesiologists
AUC	Area under curve
BCIS	Bone cement implantation syndrome
CGA	Comprehensive geriatric assessment
CI	Confidence interval
DHS	Dynamic hip screw
FN	False negative
FNF	Femoral neck fracture
FP	False positive
HA	Hemiarthroplasty
HR	Hazard ratio
HRQoL	Health-related quality of life
IADL	Instrumental Activities of Daily Living
IF	Internal fixation
IHS	Intramedullary hip screw
LMWH	Low molecular weight heparin
MMSE	Mini Mental State Examination
NHDR	Finnish national hospital discharge register
NPV	Negative predictive value
OR	Odds ratio
PPV	Positive predictive value

RCT	Randomized controlled trial
ROC	Receiver operating characteristics
SHS	Sliding hip screw
THA	Total hip replacement

ORIGINAL PUBLICATIONS

I Hongisto MT, Pihlajamäki H, Niemi S, Nuotio M, Kannus P, Mattila VM (2014): Surgical procedures in femoral neck fractures in Finland: a nationwide study between 1998 and 2011. International Orthopaedics. 38:1685-1690

II Hongisto MT, Nuotio M, Luukkaala T, Väistö O, Pihlajamäki HK (2016): Does cognitive/physical screening in an outpatient setting predict institutionalization after hip fracture? BMC Musculoskeletal Disorders. 17:444

III Hongisto MT, Nuotio M Luukkaala T, Väistö O, Pihlajamäki HK (2017): Lateral and posterior approaches in hemiarthroplasty. Scandinavian Journal of Surgery. 107(3):260-268.

IV Hongisto MT, Nuotio M, 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. Geriatric Orthopaedic Surgery and Rehabilitation 2019; 10: 2151459319853142. doi:10.1177/2151459319853142

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1 INTRODUCTION

Osteoporotic fractures are an increasing problem for older people resulting in disability and increased social and healthcare costs. In 2010, a total of 27.5 million people have been estimated to have osteoporosis in countries of the European Union, and of these 610,000 sustain hip fracture, 520,000 vertebral fracture and 560,000 forearm fracture (Hernlund et al. 2013). The most devastating osteoporotic event is a hip fracture, which is typically caused by falling on the same level. Hip fracture has an extensive impact on elderly people's medium- to longer-term function, abilities, quality of life and living arrangements (Dyer et al. 2016). Osteoporotic hip fractures are increasing problem for older people resulting in disability, impairment in quality of life and increased social and healthcare costs (Nikitovic et al. 2013; Borgström et al. 2013; Tajeu et al. 2014; Williamson et al. 2017).

The change in hip fracture incidence differs markedly globally (Schwartz et al. 1999; Kanis et al. 2012). In Scandinavia the age-adjusted hip fracture incidence is the highest worldwide (Dhanwal et al. 2011). In western countries, incidence rates are declining, yet the total number of hip fractures has remained constant or increased due to the greater number of ageing population (Brauer et al. 2009; Leslie et al. 2009; Korhonen et al. 2012; Nilson et al. 2013). Hip fracture incidence in Finland increased rapidly until 1997, followed by a continuous decline thereafter (Korhonen et al. 2013). The trend towards decreases in the incidence of hip fracture may be affected by preventive procedures such as medication and rehabilitation. Also, increased body mass index (BMI), a healthier ageing population and improved functional ability may have an effect on fallen hip fracture incidence in Scandinavia (Lönnroos et al. 2006; Dhanwal et al. 2011; Korhonen et al. 2013).

Older hip fracture patients sustaining a femoral neck fracture (FNF) are most commonly operated on using hemiarthroplasty (HA) (Wang and Bhattacharyya 2017). Recent evidence shows that the optimal choice is cemented HA, whereas uncemented HA will lead to a more painful hip and increased implant-related complications

(Gjertsen et al. 2012; Taylor et al. 2012; Viberg et al. 2013; Yli-Kyyny et al. 2014; Veldman et al. 2017; Moerman et al. 2017). Hip fracture patients who have hitherto been independent and fit may benefit more from total hip arthroplasty (THA). A trend for better functional outcomes without increased number of revision surgeries has been reported in hip fracture patient receiving THA (Burgers et al. 2012; Yu et al. 2012). However, THA predisposes to increased risk of hip dislocation, which should be born in mind in patient selection (Yu et al. 2012).

Rehabilitation after hip fracture surgery is crucial to avoid acute complications and impaired independence in the future (Huusko et al. 2000; Pfeifer et al. 2004; Morghen et al. 2011). The orthogeriatric care model currently in use appears to achieve better long-term functional outcomes and reduces mortality 30 days and one year after hip fracture compared to the traditional care models (Grigoryan et al. 2014; Prestmo et al. 2015; Kristensen et al. 2016; Gosch et al. 2016; Pajulammi et al. 2017). A multidisciplinary comprehensive orthogeriatric rehabilitation programme was shown to prevent institutionalization one year after hip fracture even in patients with memory disorders (Huusko et al. 2000). A Finnish randomized comparison of 538 patients showed that physical and geriatric rehabilitation significantly improved ability for independent living after four months especially among the femoral neck fracture patients but this effect could not be seen after 12 months (Lahtinen et al. 2015). Finding screening methods for those patients at the most markedly increased risk of needing supported living arrangements, disability, and loss of independence after hip fracture makes it possible to target limited rehabilitation resources at patients in greatest need after the primary care.

Several surgical approaches are available to perform HA on patients with FNF. (Watson-Jones 1936; Smith-Petersen 1949; Moore 1957; Hardinge 1982). The most commonly used HA exposures in hip fracture surgery are the posterior and lateral approaches (Parker and Pervez 2002). The differences between approaches have been studied in several trials including only THA (Jolles and Bogoch 2006; Petis et al. 2015; Wang et al. 2018; Miller et al. 2018; Putananon et al. 2018). As in THA, the debate is ongoing regarding the benefits and pitfalls of different surgical approaches for HA of the hip (Biber et al. 2012; Madanat et al. 2012; Rogmark et al. 2014; Parker 2015; Van der Sijp et al. 2018; Kunkel et al. 2018).

The effect of surgical delay on morbidity and mortality among hip fracture patients has been studied in several trials by using watersheds of 24 h, 36 h, 48 h, 60 h, and 72 h (Al-Ani et al. 2008; Simunovic et al. 2010; Carretta et al. 2011; Moja et al. 2012; Khan et al. 2013; Colais et al. 2015; Rosso et al. 2016). The impact of ultra-rapid surgery within 12 hours has been less studied (Uzoigwe et al. 2013; Bretherton and Parker 2015; Nyholm et al. 2015). However, there are practical challenges in operating on hip fracture patients within 12 hours after admission, and the evidence of the effect of ultra-rapid surgery on survival is still poorly documented.

The ultimate purpose of this dissertation was to provide new practical care-related data in order to improve the outcomes of mobility, living arrangements, survival and quality of life in patients with hip fracture.

2 REVIEW OF THE LITERATURE

2.1 Anatomy

The hip joint comprises the rounded head of the femur and the cup-like acetabulum of the pelvis. The articular surface of the acetabulum is composed of and supported by anterior and posterior columns of bone like an inverted "y". The glenoidal labrum is a fibrocartilaginous rim attached to the margins of the acetabulum. The shape of the acetabulum, the surrounding labrum and the joint capsule enable a wide range of motions with a good stability (Standring et al. 2008).

The upper part of the femur consists of the femoral head, femoral neck and the lesser and greater trochanters. The trochanters serve as sites for muscle attachments. The neck of the femur connects the femoral head with the femoral shaft. The angle of the femoral neck shaft may vary widely in population, the most typically between 120–136 degrees and an anteversion relative of the posterior surfaces of the femoral condyles with angles of 6–20 degrees (Reikerås et al. 1982; 1983). The iloefemoral, pubofemoral and ischifemoral ligaments encompass and form the hip joint capsule.

Arterial blood supply to the femoral head is achieved through an anastomosis of three sets of arteries. The extracapsular arterial ring located at the base of the femoral neck is formed posteriorly by a large branch of the medial femoral circumflex artery and anteriorly by smaller branches of the lateral femoral circumflex artery. These vessels anastomose with the terminal branches of the medullary artery from the shaft of the femur. Finally, the ligamentum teres arise from the acetabulum fovea to the femoral head to form anastomosis (Judet et al. 1955; Gautier et al. 2000).

Hip joint movements of flexion, extension, abduction, adduction and rotation are formed by several muscle groups. The primary hip flexors include the iliopsoas muscles, rectus femoris, sartorius and tensor fascia latae. All except the tensor fascia latae (innervated by the superior gluteal nerve) are innervated by the femoral nerve.

Hip extension is achieved by the gluteus maximus, hamstrings (semitendinosus, semimembranosus and biceps femoris) and the extensor head of the adductor magnus. The gluteus maximus is innervated by the superior gluteal nerve and other primary extensors by the tibial portion of the sciatic nerve. The gluteus medius and minimus and tensor fascia latae are the primary abductors of the hip joint, the gluteal muscles are innervated by the superior gluteal nerve. The nervus obturator innervates the primary hip adductors, which include the Pectineus, adductor brevis, adductor magnus (adductor head), adductor longus and gracilis. The primary hip internal rotators include the gluteus medius and minimus, and tensor fascia latae. The external hip rotators are located posteriorly to the hip joint and include the piriformis, obturator internus and externus, gemellus superior and inferior and the quadratus femoris (Standring et al. 2008; Netter 2011).

2.2 Epidemiology

Osteoporotic fragility hip fracture becomes more common as population ages. The incidence of hip fracture varies across countries. Scandinavia has the highest incidence in hip fracture worldwide, whereas the lowest rates of hip fracture are seen in Africa. The age-standardized incidence of hip fracture in women is approximately twice than that in men, with some variability across the world (Dhanwal et al. 2011; Cauley et al. 2014). Secular hip fracture rates have been reported to have declined since the 1990s in many western countries, whereas in South America and Asia the incidence rate is still rising (Orimo et al. 2009; Johansson et al. 2011; Xia et al. 2012; Korhonen et al. 2013). Little is known about the secular trends in India and Africa, even though their populations are rapidly growing, leading to a new problem arising from osteoporotic fractures. When interpreting the epidemiological rates of hip fracture between countries it is worth noting that there are several methodological issues concerning the validity of data, for example lack of standardization according to age or sex and the study population may not be representative of the entire country.

In Finland the incidence of hip fracture declined during the first decade of 2000s, especially in women. However, the total number of hip fractures is still raising due to the rapid increase in numbers of older people, but the rise has slowed down since 1997 (Kannus et al. 2018). In 2015, approximately 20% of hip fractures occurred in assisted or institutionalized living accommodation, the patients' mean age was 79 years and 34% were men (THL, PERFECT 2017).

2.3 Fracture classification

Hip fractures are classified into three categories according to the anatomical site of bone injury in the femur: femoral neck, pertrochanteric or subtrochanteric fractures (Fig 1). Further, hip fractures can be classified as intracapsular and extracapsular fractures according to on their location. Acetabular or pelvic fractures do not fit into the traditional classification of hip fractures although they may present as osteoporotic fractures anatomically near the hip.

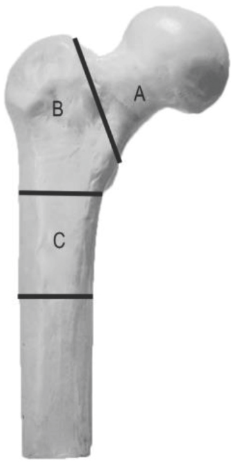

Figure 1. Hip fracture types

A) Femoral neck fracture
B) Pertrochanteric fractures
C) Subtrochanteric fractures

2.3.1 Femoral neck fracture

Femoral neck fracture is the most common type of hip fracture and accounts for approximately 60% of all hip fractures (Lönnroos et al. 2006; THL, PERFECT 2017). Femoral neck or cervical fracture is an intracapsular injury with limited natural healing potential due to constricted blood supply and lack of periosteal layer at the fracture site. Displacement of FNF may interrupt the blood supply to the fracture site and cause non- or mal-union. Further, FNF can be classified anatomically into subcapital, transcervical and basicervical fractures.

2.3.1.1 Garden classification

The Garden classification of femoral neck fractures is one of the most commonly used in the literature. The Garden classification is based on the degree of displacements of the fracture seen on the antero-posterior (AP) radiograph of the hip. Garden I fracture refers to an incomplete stable fracture with valgus impaction. Garden II fracture is non-displaced complete fracture with two groups of trabeculae in line. Garden III refers to a completely displaced fracture in the varus direction with all three trabeculae disturbed. Garden IV is completely displaced FNF with no contact between the fracture fragments (Garden 1961). In practice, it may be difficult to differentiate the four types of FNFs, and therefore the treatment chosen depends partly on whether the FNF is nondisplaced (Garden I and II) or displaced (Garden III and IV).

2.3.1.2 Pauwels Classification

The Pauwels classification is the first biomechanical classification of FNFs. Pauwels' angle is formed by extending the fracture line upwards to meet an imaginary horizontal line drawn through the iliac crest plane on AP film. Type I refers to an angle from 0 to 30 degrees, when compressive forces are dominant. Type II includes a Pauwels' angle from 30 to 50 degrees, which may cause shearing force and have a negative effect on fracture healing. Type III involves FNFs with a Pauwels' angle of 50 degrees or more, which leads to predominant shearing force with varus force and is more likely to result in displacement and collapse (Pauwels 1935). Pauwels' classification is less used in a clinical practice.

2.3.1.3 AO Classification

The AO classification identifies three types of FNF. Type 31-B1 fractures are subcapital, type 31-B2 fractures are transcervical, and type 31-B3 refers to basicervical fractures (Fracture and Dislocation Compendium 2018). The AO classification states the different anatomical location and fragmentation of FNFs without a clear statement of FNF stability. The AO classification is less used in clinical practice.

2.3.2 Pertrochanteric fracture

Pertrochanteric hip fracture is located between the bony greater and lesser trochanters and between the muscular attachments of the hip abductors and hip flexors. The muscular forces attempt to separate the fracture site.

2.3.2.1 AO Classification

AO types 31-A1 pertrochanteric fractures are simple with one fracture line and the medial cortex is broken in only one place. Types 31-A2 are multi-fragmentary pertrochanteric fractures involving the medial cortex broken in two places leading to the detachment of a third fragment which includes the lesser trochanter. Types 31-A3 are intertrochanteric fractures; the fracture line goes above the lesser trochanter medially and below the crest of the vastus lateralis laterally. Both femoral cortices are involved (Fracture and Dislocation Compendium 2018). The AO classification is an anatomical classification system which roughly describes the stability of pertrochanteric fractures. Fractures classified as type 31-A1 are considered to represent stable pertrochanteric fractures and types 31-A2 and 31-A3 unstable pertrochanteric fractures. The degree of fracture stability has an impact on the implant choice in the surgical intervention.

2.3.2.2 Boyd and Griffin classification

The Boyd and Griffin classification is based on the stability of the fracture: type I fractures are stable simple intertrochanteric fractures, type 2 fractures involve intertrochanteric fractures with posteromedial femoral comminution, type 3 fractures include a fracture line just distal to the lesser trochanter in the lateral cortex of the femur, but the lesser trochanter is still attached to the anatomic position, and type 4 fractures are combination of fracture lines in the intertrochanteric and subtrochanteric regions, with fracture lines in at least two planes (Boyd and Griffin 1949). The Boyd and Griffin classification is less used in clinical practice.

2.3.3 Subtrochanteric fracture

There are at least 15 different classifications for subtrochanteric femoral fractures with a wide variation in the definition of bone length involvement. The zone defined as that for subtrochanteric fractures diverges from 3 cm up to the level of the femoral isthmus (Figure 2) (Seinsheimer 1978; Zain Elabdien et al. 1984; Loizou et al. 2010).

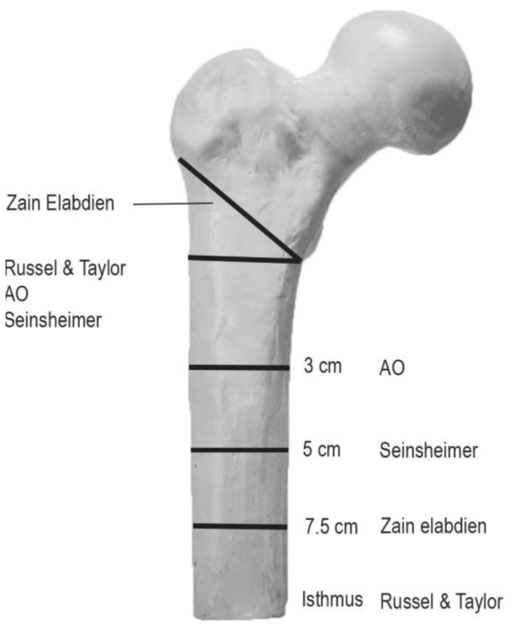

Figure 2. Variation in the definition of subtrochanteric fracture according to various authors.

The national Finnish current care guidelines for the treatment of hip fractures define subtrochanteric fracture as an area located immediately below the lesser trochanter and extending distally five cm (Hip fracture: Current Care Guidelines Abstract 2017).

2.4 Risk Factors for hip fracture

2.4.1 Age

The risk of sustaining a hip fracture rises rapidly as people age (Lönnroos et al. 2006; Stolee et al. 2009; Xia et al. 2012). Most hip fractures are low-energy fractures, such as falling in the same level or from a chair. As people age, physiological changes, co-morbidities and medications accumulate and lead the elevated risk of falling and subsequent hip fracture (Tinetti et al. 1988).

2.4.2 Gender

Females are more prone to hip fracture than males (Lönnroos et al. 2006; Stolee et al. 2009). Male hip fracture patients are younger, they have more co-morbidities including cerebrovascular disease, COPD, liver disease, renal disease, malignancy, congestive heart failure (CGF) and myocardial infarction (Kannegaard et al. 2010). Males are more prone than women to post-operative complications such as chest infections and heart failure (Roche et al. 2005; Hawkes et al. 2006; Kannegaard et al. 2010; Sterling 2011). However, an increased risk of complications after hip fracture surgery in men cannot be completely explained by the more extensive load of co-morbidities in males (Kannegaard et al. 2010).

2.4.3 Other risk factors

Other risk factors for sustaining hip fracture include cognitive impairment (Chen et al. 2009; Stolee et al. 2009), Parkinson's disease(Pouwels et al. 2013), former stroke (Pouwels et al. 2009), severe malnutrition (Stolee et al. 2009), unsteady gait or use of ambulatory aid (Stolee et al. 2009), heart failure, peripheral atherosclerosis, ischaemic heart disease (Sennerby et al. 2009), haemodialysis, liver cirrhosis and osteoporosis (Lin et al. 2014), lower body weight (Chen et al. 2009), alcoholism (Zhang et al. 2015), D-vitamin deficiency (Steingrimsdottir et al. 2014), medication (Bakken et al. 2013; Park et al. 2016; Ping et al. 2017) and previous osteoporotic fracture (Chen et al. 2009).

2.5 Surgical treatment options in hip fracture

In all hip fracture configurations the ultimate goal is to achieve normal or previous level of mobility as soon as possible to avoid complications related to immobility. Surgical intervention is the gold standard enabling in the recovery of the ability to ambulate. Non-operative treatment will lead to increased mortality and may be allocated only in patients who prior to the fracture were bed bound or critically ill (Sullivan et al. 2019). Even in patients with non-displaced Garden I femoral neck fractures the conservative treatment failure rate is decidedly high at 34% (Amsellem et al. 2019).

2.5.1 Femoral neck fracture

Three different surgical interventions are used in the treatment of femoral neck fractures depending on the fracture classification and patient characteristics: internal fixation (IF), hemiarthroplasty and total hip arthroplasty. Assessing patients' physiological age is crucial in making an appropriate choice of treatment. Population ageing is rapid and due to medical interventions chronological age has become less important. Patients with good bone quality, living in their own homes without assisted living arrangements and who are active with high functional demands and few medical comorbidities are considered to be physiologically young patients (Hirose et al. 2008). Internal fixation, whether cannulated screws or dynamic hip screws (DHS), is allocated for physiologically and chronologically young patients having non-displaced Garden I or II fractures without previous symptoms of osteoarthritis and low rate of co-morbidities because without fixation there is a 12–33% risk of fracture displacement prior to healing (Bentley 1980; Holmberg et al. 1987). Internal fixation reduces this risk to approximately 5% (Conn and Parker 2004). Further, in non-displaced FNFs, HA reportedly increases mortality and complication rate compared to IF (Parker et al. 2008). Controversies exist in the literature as to which IF is the optimal treatment choice: multiple cannulated screws or DHS. A recent meta-analysis reported that DHS fixation is related to lower rates of fixation failure, reoperation and postoperative complications compared to multiple cannulated screws (Zhang et al. 2017).

For displaced FNFs arthroplasty is the treatment of choice due to the complications related to IF (Lu-Yao et al. 1994; Rogmark et al. 2002; Gjertsen et al. 2010; Tseng et al. 2017). A prospective controlled trial by Rogmark et al. showed that failure rate was 43% in IF and 6% in the arthroplasty group two years after fracture. Further, in the IF group 36% had impaired walking and 6% had severe pain compared with 25% and 1.5% in the arthroplasty group (Rogmark et al. 2002). Moreover, patients with the displaced FNF treated with internal fixation are at 2.6 (CI 1.4–4.6) fold risk of a second operation compared to HA during the first two years after hip fracture. Two-thirds of the re-operations were conversions to arthroplasty (Lu-Yao et al. 1994).

Hemiarthroplasty is the most common type of arthroplasty procedure in the treatment of patients with FNF due to lower complication rates than with THA, especially in terms of hip dislocation (Burgers et al. 2012; Zi-Sheng et al. 2012). Other benefits of HA include decreased operating time and infection rate compared to THA. (Blomfeldt et al. 2007; Zi-Sheng et al. 2012). Further, the availability of the arthroplasty procedure may favour HA. However, HA has been reported to migrate into the pelvis due to periprosthetic acetabular wear, which is one of the most common reasons for conversion to THA. Other common reasons for HA revision surgery include periprosthetic fracture, hip dislocations, deep infection, unexplained pain, and aseptic loosening (Grosso et al. 2017; Iamthanaporn et al. 2018).

Total hip arthroplasty results in lower mortality, less morbidity and better functional scores than HA for previously active and mobile patients (Avery et al. 2011; Zhao et al. 2014). Some authors suggest that THA is a better treatment choice than HA even with the increased risk of hip dislocation (Baker et al. 2006; Yu et al. 2012). A significant proportional rise in the use of THA has been observed over the last decade (Stronach et al. 2019).

Uni- and bipolar HA with a modern shape-closed, tapered and anatomically s-shaped stem with 19-degree built-in anteversion represents no clinically significant differences in terms of ambulatory ability, mortality, likelihood of returning to own home and revision rate. However, the dislocation rate slightly favours the use of bipolar HA (Kanto et al. 2014). Uni- and bipolar HA may have comparable results in implant survival or revision rate, but unipolar hemiarthroplasty is a more cost-effective option than bipolar HA (Yang et al. 2015; Iamthanaporn et al. 2018). However, a large register-based study containing 23,509 HA procedures showed respective reoperation rates for unipolar and bipolar HA of 3.1% and 4.4%. The main reasons for increased reoperations rates in bipolar HA were higher infection rate, more dislocations and periprosthetic fractures (Leonardsson et al. 2012b).

2.5.1.1 Cemented vs. un-cemented HA

Studies conducted on an old design femoral stems show that better mobility and less pain is achieved with cemented HA than with uncemented HA (Sonne-Holm et al. 1982; Emery et al. 1991; Khan et al. 2002; Santini et al. 2005). After the launch of modern modular stems, promising early results suggested that uncemented HA may be used in the treatment of FNF with good results (Figved et al. 2009; Sköldenberg et al. 2011; DeAngelis et al. 2012). However, several studies have subsequently shown that the use of modern uncemented HA stems predispose to poorer mobility and increased implant-related complications rate (infections, periprosthetic fractures and reoperations) compared to cemented HA (Azegami et al. 2011; Taylor et al. 2012; Sköldenberg et al. 2014; Langslet et al. 2014; Inngul et al. 2015; Chammout et al. 2016; Grosso et al. 2017; Frenken et al. 2018). It is noteworthy that a meta-analysis conducted by Azegami et al. included only one study containing a modern hydroxyapatite-coated stem (Figved et al. 2009; Azegami et al. 2011). A recent meta-analysis involving only randomized controlled trials (RCTs) with modern stems showed that cemented HA offers better postoperative hip function and fewer post- and interoperative fractures than do uncemented stems (Lin et al. 2019).

Factors that may favour the use of uncemented HA include reduced operating time and blood loss (Talsnes et al. 2013; Grosso et al. 2017). Further, cemented HA is associated with a potentially fatal bone cement implantation syndrome (BCIS) characterized by hypotension, hypoxia, loss of consciousness, pulmonary hypertension and cardiac arrythmias (Modig et al. 1975; Duncan 1989, Parvizi et al. 1999; Clark et al. 2001; Olsen et al. 2014). A study of 1,016 patients showed that 1.7% acquired grade 3 BCIS, which was defined as cardiovascular collapse requiring cardiopulmonary resuscitation. Independent risk factors for the development of the BCIS were COPD, use of warfarin and diuretics, and high ASA (Olsen et al. 2014). J-E Gjertsen et al. showed that cemented HA was associated with more intra-operative complications than uncemented HA, and especially with intraoperative death (0.3% vs. 0.04%) and cardiac arrest (0.2% vs. 0%). They also reported respiratory failure with cementing (0.3%) (Gjertsen et al. 2012). Uncemented HA may represent the optimal choice in rare patient populations at high risk of acquiring BCIS (Griffiths and Parker 2015). A recent Finnish register-based study showed that in the most fragile HA patient group caution is needed at the moment of cementing (Ekman et al. 2019).

2.5.1.2 Posterior vs lateral surgical approach in HA

It is generally well known that in the HA procedure the posterior approach predisposes to hip dislocation more than the lateral approach (Enocson et al. 2008; Leonardsson et al. 2012b; Biber et al. 2012; Rogmark et al. 2014; Mukka et al. 2016; Van der Sijp et al. 2018). The hip dislocation rate has been reported to range from 0.9% to 16% in the HA procedure using the posterior approach, depending on whether or not the posterior structures are repaired (Pajarinen et al. 2003; Varley and Parker 2004; Sköldenberg et al. 2010; Biber et al. 2012; Parker 2015). An analysis of 33,205 HA procedures established an increased hazard ratio (HR) (2.2; 95% CI 1.8–2.6) for reoperation due to hip dislocation compared to the lateral approach (Rogmark et al. 2014). According to a Swedish register-based study containing 23,509 HA procedures, hip dislocation is the most common cause of reoperation and revision (Leonardsson et al. 2012b). The same study showed that the lateral approach involved a decreased risk of reoperation due to dislocation compared to the posterior approach in HR 0.72 (95 % CI 0.58–0.89). A prospective controlled cohort of 704 HA procedures exposed to the posterior approach to predispose to hip dislocation compared to the lateral approach, 3.9% vs, 0.5% respectively (Biber et al. 2012). A prospective cohort trial containing 739 consecutive HA procedures showed after adjustment for confounders that the posterior approach with (OR 3.9; 95% CI 1.6–10) or without posterior structure repair (OR 6.9; 95% CI 2.6–19) predisposed to more hip dislocation compared to the lateral approach (Enocson et al. 2008).

Other surgically important complications after HA include infection, periprosthetic fracture and bleeding. There is no comprehensive evidence of remarkable differences in these outcomes between posterior and lateral surgical approaches (Parker 2015; Mukka et al. 2016; Van der Sijp et al. 2018). By contrast, Biber et al. showed that postoperative bleeding or haematoma is nearly five times more likely to occur in lateral than in posterior approach (Biber et al. 2012).

Only a limited number of studies have been presented comparing lateral and posterior approaches in the treatment of FNF patients with HA in terms of retaining walking ability and functional outcomes (Parker 2015; Mukka et al. 2016; Sayed-Noor et al. 2016; Kristensen et al. 2017). A Norwegian register-based study containing 20,908 FNF patients operated on for HA studied pain and patient-reported outcomes between lateral and posterior approaches in 3-year follow-up. The authors concluded that patients operated on using the posterior approach had fewer walking problems postoperatively, less pain during the 3-year follow-up, were more satisfied and had a better quality of life than those operated on with a direct lateral approach (Kristensen et al. 2017). However, an RCT including 218 patients showed no difference in the degree of residual pain or regaining walking ability between these approaches during 1-year follow-up (Parker 2015). A prospective cohort study containing 185 HA procedures for FNF treatment using either lateral or posterior approach showed no statistically significant difference in functional outcome parameters (Harris Hip Score, Western Ontario and McMaster Universities Arthritis, and pain numeric rating scale) (Mukka et al. 2016).

2.5.2 Pertrochanteric fracture

Pertrochanteric hip fractures are most commonly treated with a closed anatomical reduction and osteosynthesis with a fixed-angle sliding hip screw (SHS) or intramedullary hip screw (IHS). The intramedullary hip screw is a short intramedullary nail with interlocking screws. Both methods are based on the controlled impaction of the proximal fracture segment to the stable medial wall of the femur. Without posterolateral or medial support pertrochanteric fractures are classified as unstable fractures. Pertrochanteric fractures with a three or more fragments are also considered unstable with varying degrees of instability (Evans 1949; Jensen and Michaelsen 1975).

Stable pertrochanteric fractures can be operated on using a SHS with a laterally placed trochanteric stabilizing plate or IHS (Barton et al. 2010; Socci et al. 2017; Hao et al. 2018). A short nail is recommended in stable fractures (Dunn et al. 2016; Socci et al. 2017). Short or long IHSs are used in more complex unstable fracture patterns (Kim et al. 2001; Sadowski et al. 2002; Matre et al. 2013; Yu et al. 2018). Long IHS is associated with increased operating time and heavier blood loss than short IHS, but may potentially decrease the likelihood of secondary femoral shaft fractures (Boone et al. 2014; Vaughn et al. 2015).

The optimal positioning of the lag screw has been comprehensively studied. With the fixed angle SHS, Baumgaertner et al. established a numerical tip-apex distance describing the optimal lag screw position. The definition includes the sum of the distance (in millimeters) from the tip of the lag screw to the apex of the femoral head, as measured on an anteroposterior and lateral radiograph, after magnification correction has been made. The apex is considered to be located at the point of intersection between the subchondral bone and a line in the centre of and parallel to the femoral neck. A cut-off value of 25 mm or more indicated screw cutout and failure in the hip fracture treatment (Baumgaertner et al. 1995). A displaced greater trochanteric fragment is associated with poorer mobility (Studer et al. 2015)

2.5.3 Subtrochanteric fracture

A sliding hip screw or long IHS has traditionally been used in the treatment of subtrochanteric fractures with comparable outcomes (Lee et al. 2007). However, increasing evidence favours the use of long IHS over SHS (Rahme and Harris 2007; Saarenpää et al. 2007; Matre et al. 2013; Xie et al. 2019).

2.6 Outcome

The target in the treatment of hip fracture patients is to achieve the previous level of independence and enable the patient to return to the same living arrangements as before the hip fracture. The assessment of functional status is crucial to provide objective information to meet individualized rehabilitation needs or plan specific in-home services, such as medication management, personal care and nursing and homecare services.

2.6.1 Independence

Lawton and Brody introduced in 1969 an instrument to assess the skills needed in independent living, Instrumental Activities of Daily Living Scale (IADL) (Lawton and Brody 1969). The questionnaire pattern includes eight domains addressing abilities to live independently: ability to use the telephone, to do shopping, food preparation, housekeeping, laundry, to manage transportation, to take responsibility for own medication and the ability to handle finances. Summary score ranges from 0 (low function) to 8 (high function). After hip fracture, only a half or less may reach the pre-fracture level of independence in IADLs (Bertram et al. 2011; Dyer et al. 2016; Moerman et al. 2018).

2.6.2 Mobility

Restoration of mobility is one of the most important factors for previously independent hip fracture patients to ensure their capabilities to live independently. Elderly mobility can be broadly defined and various mobility assessment tools exist for the measurement of walking and moving capabilities, for example the Cumulated Ambulation Score (validated for hip fracture patients), the Timed Up and Go test, the Elderly Mobility Scale, need for ambulatory aids, and the Short Physical Performance Battery (Podsiadlo and Richardson 1991; Smith 1994; Guralnik et al. 1994; Foss et al. 2006; Vochteloo et al. 2013; Chung et al. 2015). Approximately half of hip fracture patients are able to regain pre-fracture level of mobility during the first year, and patients who were mobile without an aid before the hip fracture are at the greatest risk of not regaining their previous mobility level (Vochteloo et al. 2013). Regardless of patients' baseline condition, therapy and physiotherapy are associated with early recovery of mobility after hip fracture (Morri et al. 2018). Lower extremity function has been reported to improve steadily within the first six months after hip fracture measured by objective functional tests, whereas subjective functional recovery continues for up to nine months (Fischer et al. 2019).

2.6.3 Living arrangements

Any reduction in independence can result in a need for more supported living arrangements among hip fracture patients and cause extra healthcare costs. Living situation should be assessed three months and 12 months after hip fracture because the destination on discharge from hospital is often temporary. Also, living arrangements should be measured according to residence and the need for assistance (Liem et al. 2013). Hip fracture increases the risk of needing assisted living arrangements and possibly even institutionalization by six to 12 months following hip fracture is reported to vary from approximately 10 to 20% (Parker and Palmer 1995; Nurmi et al. 2003; Givens et al. 2008; Hektoen et al. 2016).

2.6.4 Pain

In cognitively impaired patients, the Verbal Rating Scale (VRS) performs better than the Visual Analogue Scale (VAS) (Hounsome et al. 2011; Pesonen et al. 2009). For noncommunicative patients, Pain Assessment in Advanced Dementia (PAINAD) provides a clinical tool to evaluate the degree of pain. PAINAD is based on evaluating breathing, negative vocalization, facial expression, body language and consolability (Warden et al. 2003).

2.6.5 Survival

Hip fracture is an independent risk factor for worse long-term survival (Katsoulis et al. 2017). Excess mortality continues to be amplified more than ten years after hip fracture (Omsland et al. 2014; Choi et al. 2018). Several factors, both modifiable and unmodifiable, have an influence on survival (Chang et al. 2018). One-year mortality after hip fracture has been reported to vary between approximately 15 and 30%, whereas elderly patients are at greatest risk of death in the first year after hip fracture (Klop et al. 2014; Omsland et al. 2014; Lin and Liang 2017; Chow et al. 2018).

Even though male hip fracture patients are younger, they are more prone than women to worse survival. The difference in mortality between genders may not be completely explained by the excess slightly higher prevalence of chronic comorbidities in males (Kannegaard et al. 2010). However, postoperative complications such as confusion (46.7% vs. 32.8%), pressure sores (21.7% vs. 13.8%), congestive heart failure (11.2% vs. 5.8%), and renal failure (5.9% vs. 1.3%) are seen more often in males, which may explain the difference in survival (Hawkes et al. 2006).

The American Society of Anesthesiologists classification (ASA) score is a very powerful indicator in predicting survival. Hip fracture patients with a high ASA score are at increased risk for postoperative mortality after surgery (Khan et al. 2009; Bretherton and Parker 2015; Morrissey et al. 2017; Chow et al. 2018).

2.6.5.1 Delay to surgery

There is continuous debate concerning the optimal surgical timing for patients with hip fracture. Although previous trials have reported an association between delay to surgery and mortality, the definition of delay to surgery is heterogenous varying from six to 48 hours and the reason for this association is unknown (Table 1) (Khan et al. 2009). The most recent evidence suggests that hip fracture surgery within 48 hours is associated with decreased mortality and morbidity (Colais et al. 2015; Bohm et al. 2015; Cha et al. 2017; Sasabuchi et al. 2018). Some authors conclude that hip fracture surgery should be performed within 24 hours after admission and even a 12-hour cut-point has been reported to be beneficial in terms of decreased mortality and complications (Uzoigwe et al. 2013; Nyholm et al. 2015; Bretherton and Parker 2015; Morrissey et al. 2017; Fu et al. 2017; Maheshwari et al. 2018). Meta-analyses have established that early surgery improves short- and long-term survival, but the definition of early surgery differs from 24 hours to 72 hours (Shiga et al. 2008; Simunovic et al. 2010; Moja et al. 2012).

However, there are studies showing no or low association between mortality and surgical timing. Moran et al. conducted a prospective study on 2,660 patients and concluded that hip fracture surgery performed within four days of admission had no effect on mortality among patients who were otherwise fit for the operation (Moran et al. 2005). A prospective cohort study of 2,250 patients reported that most of the mortality risk during admission associated with longer delay to surgery in patients with hip fracture is explained by the cause of the delay and not by the delay itself (Vidán et al. 2011). A register study with 23,973 patients indicated that surgical procedure performed within less than 48 hours measured by the time between the time of the fracture and the day of the surgical procedure showed no association with 30-day mortality rate (Forni et al. 2016). Further, a prospective observational study demonstrated that by excluding patients unfit for early surgery, there was no significant difference in 3-month or 1-year mortality between patients operated on within 2 days and those with delayed surgery (Table 1) (Lizaur-Utrilla et al. 2016).

Table 1. Recently published studies investigating the effect of surgical timing on mortality after hip fracture.

Study	Year	Patient number	Surgical delay	Mortality
Prospectively collected data				
Lizaur-Utrilla	2016	628	≤2 days, 3–4 days, >4 days	No effect
Bohm	2015	6542	≤48 h vs. >48h	Surgery ≤48 h decrease in in-hospital and 1-year mortality.
Bretherton	2015	6638	6h, 12h, 18h, 24h, 36h, 48h, <72h	Surgery ≤12 h decrease in 30-day mortality.
Uzoigve	2013	2056	12 h time intervals	Surgery ≤12 decrease in in-hospital mortality
Retrospectively collected data				
Maheshwari K	2018	720	<18 h, 18–24, 24–36, 36–48, 48–60, >60	Increased 1-year mortality, odds ratio 1.05 (95% CI: 1.02–1.08) per 10-hour surgical delay
Cha Young-Han	2017	1290	≤48 h vs. >48h	Surgery ≤48 h decrease in 30-day and 1-year mortality.
Morrisey N	2017	1913	12h, 18h, 24h, and 36h	Every hour of delay increased mortality risk, the association with 30-day mortality only became statistically significant when delaying over 24 h.
Register-based studies				
Sobolev	2018	139 119	day of admission, inpatient day 2, day 3 or after 3 day	Increased mortality if operated on on inpatient day 3 or later
Forni	2016	23 973	≤inpatient day 2 vs. >inpatient day 2	No effect
Colais	2015	405 037	≤inpatient day 2 vs. >inpatient day 2	Surgery ≤2 inpatient day decreased 1-year mortality.
Nyholm	2015	3517	≤12h, >12-24, >24–36, >36–48, >48–72, >72	Surgical delay >12h increased 30-day mortality and a surgical delay >24h hours 90-day mortality
Meta-analyses				
Moja	2012	191 873		Surgery within one or two days from hospital admission have significantly less mortality than patients scheduled for surgery after the second day.
Simunovic	2010	13 478		Surgery conducted before 24–72 h is associated with lower mortality
Shiga	2008	257 367		Operative delay beyond 48 h after admission may increase 30-day and 1-year mortality

3 AIMS OF THE STUDY

The aim of this dissertation was to provide new data applicable to everyday patient care to improve the rehabilitation, mobility, living arrangements, survival and quality of life outcomes in patients with hip fracture. The more specific purposes of the study were:

1. To assess the incidence of surgical procedures for femoral neck fractures in Finland and evaluate proportions of different treatment methods in light of scientific evidence from 1998 to 2011.
2. To examine the ability of instrumental daily activities and cognitive screening instruments used (the IADL index and the MMSE) at four to six month clinical control after hip fracture to predict institutionalization one year after hip fracture.
3. To study the differences between lateral and posterolateral surgical approaches in the outcomes of mobility, survival and living arrangements one year after hip fracture.
4. To investigate the effect of surgical timing of hip fracture surgery on survival in moderate to high-risk patients.

4 MATERIALS AND METHODS

4.1 Study settings and populations

This academic thesis is based on four separate studies, of which Study I was a national register-based population study and Studies II–IV population based prospective observational studies based on data collected from the referral area of the Hospital District of Southern Ostrobothnia. All patients sustaining hip fracture inside the referral area were admitted and underwent surgery at Seinäjoki Central Hospital. In all studies, pathologic and periprosthetic fractures were excluded. Only patients suffering their first hip fracture during the follow-up period were included in the studies. All patients were invited to attend a postoperative clinical follow-up examination at the geriatric outpatient clinic four to six months after the fracture.

4.1.1 Study I

The Finnish National Hospital Discharge register (NHDR) is a mandatory register, which covers practically all inpatient care provided at university, general and primary care health centres, as well as treatment on military and prison wards and in private hospitals. For the purposes of the study, all patients 50 years of age or older with a code of femoral neck fracture S72.0 according to 10th version of the International Classification of Diseases (ICD-10, 1994) and valid surgical code (Table 2) between 1 January 1998 and 31 December 2011 were included. The surgical procedures were identified using the Finnish version of the Nordic Medico-Statistical Committee (NOMESCO) Classifications' procedure codes. Uncemented HA, cemented HA, THA and internal fixation constituted valid procedures for the treatment of femoral neck fractures. A total of 49,514 patients were included in the study.

Table 2. Procedure codes and surgical procedures in femoral neck fracture.

Code	The procedure
NFB10	Primary uncemented hemiarthroplasty
NFB20	Primary cemented hemiarthroplasty
NFB30	Primary uncemented total hip arthroplasty
NFB40	Primary total hip arthroplasty using hybrid technique
NFB50	Primary cemented total hip arthroplasty
NFJ50	Internal fixation of femoral neck fracture with nail or screw
NFJ52	Internal fixation of fracture of upper femur with screws and sideplate
NFJ54	Internal fixation of fracture of upper femur with intramedullary nail
NFJ64	Other internal fixation of other parts of femur

4.1.2 Study II

For Study II, the sample consisted of 1,033 consecutive patients admitted to hospital due to the first hip fracture during the study period between 1 April 2008, and 31 May 2013. Inclusion criteria were age 65 or older. Exclusion criteria were institutionalized living arrangements prior to hip fracture and "high energy" hip fractures, such as pedestrian/traffic accidents, bicycle accidents and falling other than on the same level. Living in a health centre hospital or in 24-hour residential care were taken to be institutionalized living arrangements. The final study population consisted of 584 patients who survived the 12-month follow-up (Figure 3).

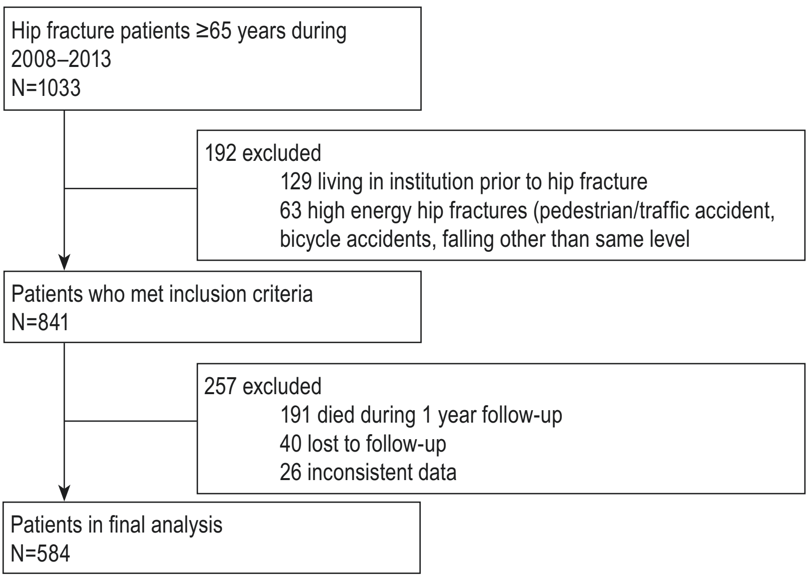

Figure 3. Flow chart of the population analysed for Study II.

4.1.3 Study III

For the purposes of Study III, 822 patients aged 65 years or older sustaining their first hip fracture during the study period between 1 September 2008 and 31 August 2012 were initially assigned to the study. In all, 393 mobile patients suffered from an osteoporotic fragile FNF and were treated with HA using a lateral or posterolateral approach. In total 269 patients survived until 12-month follow up and constituted the final study population (Figure 4).

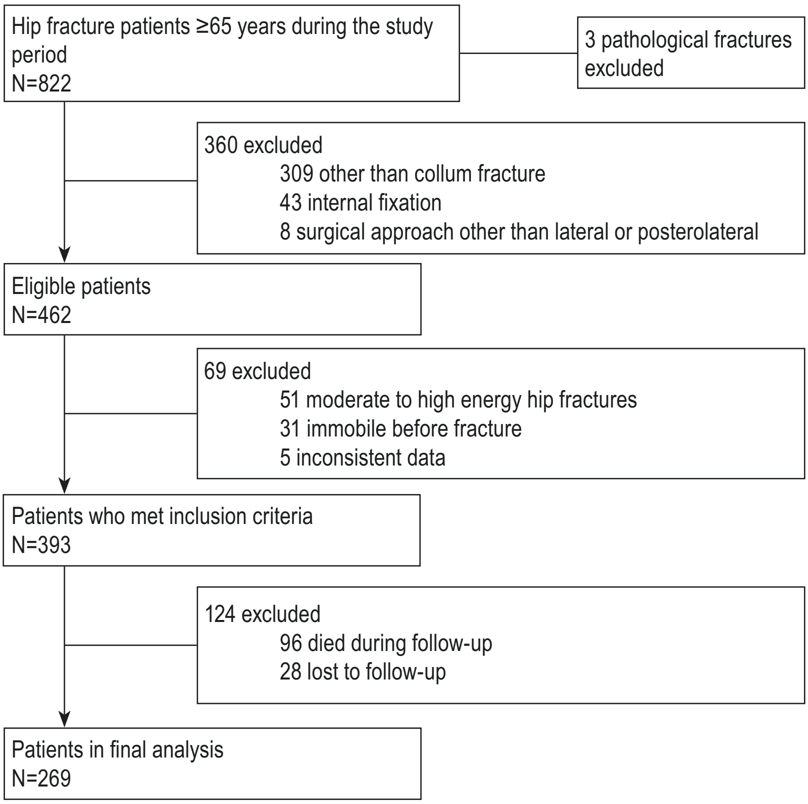

Figure 4. Flow chart of the population analysed for Study III.

4.1.4 Study IV

In Study IV, 884 patients aged 65 years or more who sustained their first hip fracture during the study period from 1 January 2012 to 31 May 2016 were enrolled in the study. One patient had suffered a pathologic fracture and 24 patients had inconsistent data leading to the exclusion of a total of 25 patients from the study. To investigate the survival among moderate to high-risk patients, patients with ASA score from 1 to 2 (n= 135) were excluded from the study. The final study population consisted of 724 patients.

4.2 Data collection and methods

4.2.1 Study I

The register-study based on NHDR encompassing 49,514 patients was conducted. No exclusion criteria were applied other than age under 50 years. Incidence ratios of surgically treated femoral neck fracture were calculated. For this, the annual mid-population of Finland was obtained from the Official Statistics of Finland. The population was categorized according to age into five categories: from 50 to 59 years, from 60 to 69 years, from 70 to 79 years, from 80 to 89years and age 90 or older.

4.2.2 Studies II–IV

The hip fracture programme was initiated at Seinäjoki Central Hospital in 2007 to improve and standardize hip fracture patients' treatment during and after hospitalization (Pajulammi et al. 2017). At the same time, a database for qualifying the effects of changed treatment protocols was constructed. To ensure data validity, pre-defined questionnaires were used during the study. In 2009, a multidisciplinary team was established including physicians from orthopaedic surgery, geriatric medicine, emergency department and anaesthesia. Other professions represented on the team included nurses and physiotherapists from the orthopaedic ward and from the geriatric outpatient clinic. The optimal goal for the team was to update the treatment protocols used according to the most recent scientific evidence, follow the literature and apply new scientific evidence to practice. The team was also responsible for staff education with regard to the treatment of hip fracture patients.

Data extraction was routinely initiated on admission to hospital by interviewing the hip fracture patient and continued during hospitalization after having obtained informed consent. A telephone interview was conducted by a study nurse at 1, 4, and 12 months after hip fracture. Further, all hip fracture patients were invited, regardless of residential location, to attend the geriatric out-patient clinic for a comprehensive clinical assessment from four to six months after hip fracture. If a patient was unable to provide the information needed due to a health condition, we used proxy respondents. Family members, friends and nurses from an institution constituted the proxies.

A pre-defined questionnaire modified from the British Hip Fracture Database was filled in on admission or on the orthopaedic ward during hospitalization, providing data concerning the patient's age, gender, if living with somebody, need for mobility aids before fracture, mobility level before fracture, previous living arrangements and use of home help services, previous diagnosis of memory disorder, number of medications on admission, previous fracture of any bone, hip fracture pattern, ASA grade, delay to operation, duration of surgery, surgeon's experience and need for blood transfusion during hospitalization. The first author completed the database retrospectively by ascertaining the surgical approach and implants used during the study period. Patients who suffered hip dislocation within one year of the hip arthroplasty were identified retrospectively from the patient records.

The telephone interviews at one, four and 12 months included eliciting information from the person contacted (patient or proxy). We collected data concerning living arrangements and use of home help services, mobility level, need for ambulatory aids and pain in the operated hip.

MMSE (Mini-Mental-State-Examination) and IADL (Instrumental Activities of Daily Living) were measured at the geriatric outpatient clinic for to six months after hip fracture by trained geriatric nurses.

Data on deaths were obtained from the Official Cause of Death Statistics of Finland and integrated into the study database electronically.

4.2.3 Treatment protocol

All patients underwent the same hip fracture treatment protocol regardless of their participation in the present study. The hip fracture treatment protocol was initiated on admission to the emergency department by defining the hip fracture pattern and surgical treatment needed, followed by medical, fluid balance, pain relief and anticoagulation optimization. The target timing to hip fracture surgery was within 24 hours of admission. Hip fracture patients are routinely operated on during daytime working hours.

The orthopaedic surgeon on duty decided on the surgical methods and approaches to repair the hip fracture. An orthopaedic surgeon specialized in THA was consulted if a patient with displaced femoral neck fracture was physiologically "young". Cemented or uncemented HA was implanted using modified Hardinge (lateral) or posterior approach according to the surgeon's preference. In the modified Hardinge approach, the split flap of the gluteus medius and vastus lateralis muscles was repaired to the greater trochanter with a tendon-to-tendon or tendon-to-bone attachment. Detached external hip rotators were fixed to the original position of the femur with bone sutures in the posterior approach. A single injection of antibiotics (most typically cefuroxime 3g) as a prophylaxis against infection was given to all patients 30–60 minutes before the operation.

From six to eight hours after hip fracture surgery, deep venous thrombosis prophylaxis was initiated with a low molecular weight heparin. LMWH treatment continued for four weeks after the hip fracture surgery unless patient had been taking anticoagulants prior to the hip fracture.

When available, a comprehensive geriatric assessment (CGA) initiated on the first post-operative day including early detection and treatment of complications, patient examination (examination: orthostatic blood pressure test, oxygen saturation, orientation, auscultation of cardiac and pulmonary sounds, any additional examination as needed, evaluation of mobility), evaluation and adjustment of medications, detection of delirium and malnutrition and mobilizing the patient. Full weight bearing was allowed to practically all patients after hip fracture surgery, but in very rare cases partial weight bearing was recommended. However, if partial weight bearing resulted in immobility due to patient-related health conditions, full weight bearing was allowed. Discharge criteria after hip fracture surgery are shown in Table 3.

Table 3. Discharge criteria after hip fracture surgery.

Discharge criteria
Haemoglobin >90 g/L (>100 g/L if severe cardiac condition)
Pain under control
Patient mobilized
Medication updated to the outpatient file
Stable haemodynamic (oxygen saturation, pulse, blood pressure, cardiac rhythm)
Urinary catheter removed
If treated for infection, declining C-reactive protein and fever
2nd or later postoperative day
No discharge for patients with immediate poor prognosis

4.2.4 Variable definition and categorization

In Studies II–IV, patient co-morbidity became apparent in the number of medications on admission, ASA score and previous diagnosis of memory disorder. Regularly taken medicines on admission were categorized into three groups: <4, 4–10 and >10. ASA score was categorized into three groups (ASA I–II, ASA III and ASA IV–V) in Studies II–IV, due to the very small number of patients into ASA I and ASA V.

Living arrangements were recorded in the study database as follows: own home, own home with organized home care, assisted living accommodation and institutionalized. For the purposes of Study II, living arrangements were classified as institutionalized or not institutionalized. In Studies III and IV living arrangements were handled as recorded in the study database.

The need for mobility aids and mobility level were recorded to measure the movability and walking capabilities of hip fracture patients. Mobility aids were registered in the database as follows: independent, cane, canes, folding walker or rollator, wheelchair, or immobile. In Studies II and IV the need for mobility aids was categorized into three groups: mobile without an aid, mobile with aid or unable to ambulate. Due to the small number of patients analysed (n=269) in Study II, groups of patients needing a cane (n=18) or canes (n=11) were too small to be examined separately. Thus patients were divided into two groups: mobile without an aid and mobile with an aid or immobile. Mobility level was recorded in the database as follows: full community, limited community, full mobility indoors, limited mobility indoors, and immobility. In Studies III and IV mobility level was classified as full or limited community, full or limited mobility indoors, and unable to move.

4.3 Statistical analyses

In Studies II–IV statistical differences between categorial variables were calculated using Pearson's chi-square test or Fisher's exact test. Mann-Whitney test was used to determine differences in continuous variables which were not normally distributed. A p-value ≤ 0.05 was considered statistically significant.

4.3.1 Surgical procedures in femoral neck fractures (Study I)

Incidence ratios were used to compare the use of different surgical methods annually. Yearly mid-population obtained from Official Statistics Finland were used to calculate incidence ratios. Because the data consisted of the entire adult population of Finland aged 50 years or more rather than of sample- or cohort-based estimates, 95% confidence intervals were not calculated.

4.3.2 Cognitive and physical screening in outpatient setting (Study II)

To determine sensitivity, specificity and optimal cut-off values for MMSE and IADL to predict institutionalization, a receiver operating characteristics (ROC) analysis was performed. Positive (PPV) and negative (NPV) predictive values and ORs with 95% CI were calculated. The area under the curve (AUC) value was defined. The optimal cut-off value for IADL and MMSE to predict institutionalization after a hip fracture was 5 and 20 respectively. IADL and MMSE were handled in a dichotomous manner according to the optimal cut-off values from the ROC analysis.

Age-adjusted univariate regression analyses with odds ratios (ORs) and 95% confidence interval (CI) were calculated to measure the effect of independent variables on institutionalization at one year. To handle the confounding effects of independent variables on institutionalization at one year, statistically significant variables from the univariate logistic regression analysis were used to build multivariate a logistic regression model with the enter method. MMSE score at the geriatric outpatient clinic was used instead of previous diagnosis of memory disorder in the final analysis.

A sex- and age-adjusted Cox hazard model was calculated to examine mortality and one-year survival. All statistical analyses were performed using SPSS version 21.

4.3.3 Comparison of lateral and posterior approaches (Study III)

Predictive variables for need for mobility aids one year after hip fracture were analysed using age-adjusted univariate logistic regression analysis. ORs with 95% CIs were calculated for each variable. A multivariate logistic regression model with enter method was calculated by using confounders with a p value ≤0.25. A Cox hazard regression model was built to investigate 1, 3, 6 and 12-month survival between patients operated on using different surgical approaches. Age, gender and delay to hip fracture surgery were used as covariates. All statistical analyses were performed using SPSS version 23.

4.3.4 Survival after hip fracture (Study IV)

Cox hazard regressions models with enter method were built to investigate HRs for death 30 days and 365 days after hip fracture. The need for mobility aids and mobility before the hip fracture were associated with previous living arrangements, and therefore not included in the survival analysis as covariates. All statistical analyses were performed using SPSS version 23.

4.4 Ethical considerations

The study was approved by the South Ostrobothnia Hospital District Ethics Committee. The Helsinki Declaration 1964 and its later amendments were followed throughout the study. Informed consent was obtained from the participants or their caregivers or legal representatives.

5 RESULTS

5.1 Patient characteristics

The mean age of the 49,514 patients in Study I was 79.2 years and 35,376 (71.4%) were women. The largest group (21,822; 44.1%) were patients aged 80-89 years (Table 4).

Table 4. Patient age distribution in Study I

Age	n	(%)
50–59	2676	(5.4)
60–69	5175	(10.5)
70–89	13979	(28.2)
80–89	21822	(44.1)
≥90	5862	(11.8)

Studies II–IV are based on the same hip fracture population gathered from Seinäjoki Central Hospital with different collection times and sample sizes. Background data in Studies II–IV are shown in Table 5.

Table 5. Background data in Studies II–IV

	Study II, entire cohort, n=841		Study III, entire cohort, n=393		Study IV, patients with ASA III–V, n=724	
Variable	**n**	**(%)**	**n**	**(%)**	**n**	**(%)**
Age						
65–74	117	(13.9)	40	(10.2)	74	(10.2)
75–84	352	(41.9)	147	(37.4)	268	(37.0)
≥85	372	(44.2)	206	(52.4)	382	(52.8)
Mean (Sd)	82.8	(7.1)	83.7	(6.4)	84.1	(7.1)
Median (25–75% percentile)	84.0	(78–88)	85.0	(79–88)	85.0	(80–89)
Sex						
Female	624	(74.2)	300	(76.3)	514	(71.0)
Male	217	(25.8)	93	(23.7)	210	(29.0)
Living with somebody						
Yes	502	(59.7)	253	(64.4)	468	(64.6)
No	339	(40.3)	140	(35.6)	256	(35.4)
Mobility aids before hip fracture						
Mobile without an aid	333	(39.6)	145	(36.9)	250	(34.5)
Mobile with an aid or aids	495	(58.9)	248	(63.1)	455	(62.8)
Unable to ambulate	11	(1.3)	*		15	(2.1)
Information missing	2	(0.2)	*		4	(0.6)
Mobility level before fracture						
Full or limited community	600	(71.3)	266	(67.7)	356	(49.2)
Full or limited mobility indoors	225	(26.8)	127	(32.3)	352	(48.6)
Unable to move	12	(1.4)			12	(1.7)
Information missing	4	(0.5)			4	(0.6)
Previous living arrangements						
Own home	390	(46.4)	168	(42.7)	273	(37.7)
Own home with organized home care	265	(31.5)	107	(27.2)	227	(31.4)
Assisted living accommodation	186	(22.1)	71	(18.1)	65	(9.0)
Institutionalized	*		47	(12.0)	159	(22.0)
Previous diagnosis of memory disorder						
Yes	180	(21.4)	101	(25.7)	237	(32.7)
No	657	(78.1)	292	(74.3)	487	(67.3)
Information missing	4	(0.5)				
Medications on admission						
<4	169	(20.1)	66	(16.8)	86	(11.9)
4–10	531	(63.1)	260	(66.2)	467	(64.5)
>10	141	(16.8)	67	(17.0)	171	(23.6)
ASA grade						
1–2	114	(13.6)	45	(11.5)	*	
3	517	(61.5)	242	(61.6)	543	(75.0)
4–5	197	(23.4)	106	(27.0)	181	(25.0)
Information missing	13	(1.5)				
Hip fracture type						
Femoral neck	539	(64.1)	393	(100)	427	(59.0)
Pertrochanteric	259	(30.8)	*		249	(34.4)
Subtrochanteric	43	(5.1)	*		48	(6.6)

* Patients were excluded from the cohort.

5.2 Surgical procedures in femoral neck fracture (Study I)

Cemented HA was the most common surgical procedure (28,613; 57.8%) during the entire study period followed by IF (11,189; 22.6%), uncemented HA (6,618; 13.4%) and THA (3,094; 6.2%). A moderate decline in uncemented HA procedures (from 13.5 to 8.1%) and a minor increase in cemented HA procedures (from 56.2 to 63.9%) was shown from 1998 to 2005, while no major changes were observed in IF or THA procedures (Figure 5 and Table 6).

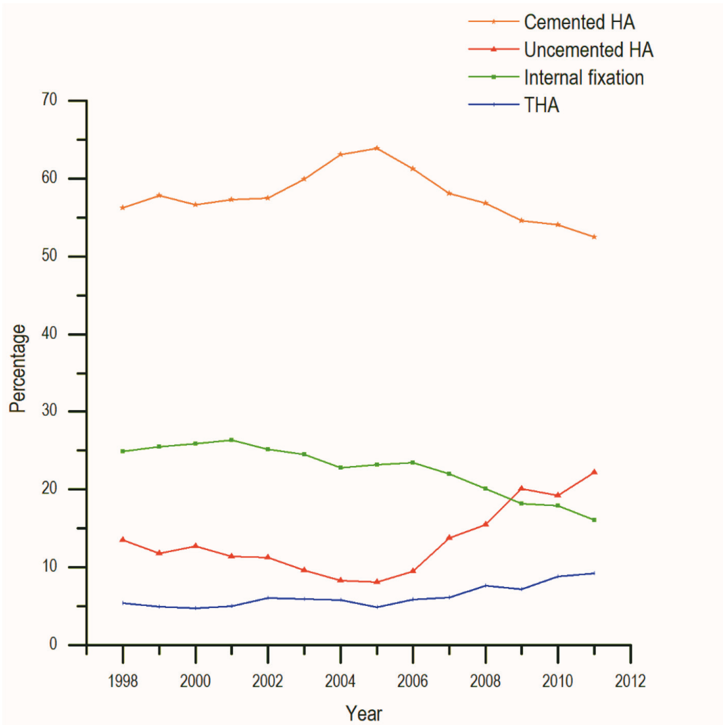

Figure 5. Proportional distribution of femoral neck fracture procedures during the study period.

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From 2005 to 2011, the proportion of cemented HA procedures decreased from 63.9 to 52.5%, while the use of uncemented HA procedures increased from 8.1 to 22.2%. During the same time, the proportional use of THA increased from 4.9 to 9.2% and internal fixation decreased from 23.2 to 16.1% (Figure 5 and Table 6).

Table 6. Percentage distribution of procedures used in the repair of femoral neck fractures.

Year	Uncemented HA	Cemented HA	Internal fixation	THA
1998	13.5	56.2	24.9	5.4
1999	11.8	57.8	25.5	4.9
2000	12.7	56.6	25.9	4.8
2001	11.4	57.3	26.3	5.0
2002	11.3	57.5	25.2	6.1
2003	9.6	59.9	24.5	5.9
2004	8.3	63.1	22.8	5.8
2005	8.1	63.9	23.2	4.9
2006	9.5	61.2	23.5	5.8
2007	13.8	58.0	22.0	6.1
2008	15.5	56.8	20.1	7.6
2009	20.1	54.6	18.2	7.2
2010	19.2	54.0	17.9	8.8
2011	22.2	52.5	16.1	9.2

5.2.1 Proportion of surgical procedures stratified by age

5.2.1.1 Age group 50–59 years

The youngest age group (50–59) revealed a substantial proportional decline in internal fixation procedure from 62.9 to 40.3%, while the percentage of THA procedures increased from 15.7 to 29.6 %. Only minor changes were observed in the proportional use of uncemented HA and cemented HA (Figure 6).

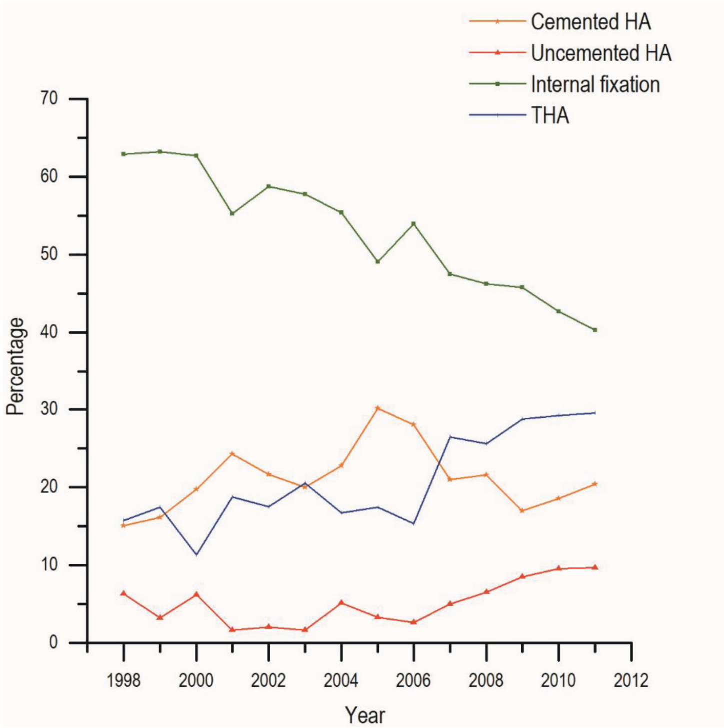

Figure 6. Distribution of femoral neck fracture procedures in the age group from 50 to 59.

5.2.1.2 Age Group 60-69 years

In patients 60–69 years of age there was increase in THA procedures from 14.1 to 29.9%, while the proportion of IF procedures showed a substantial decline from 39.2 to 23.7%. The use of cemented HA and uncemented HA procedures did not show significant changes in trend during the study period (Figure 7).

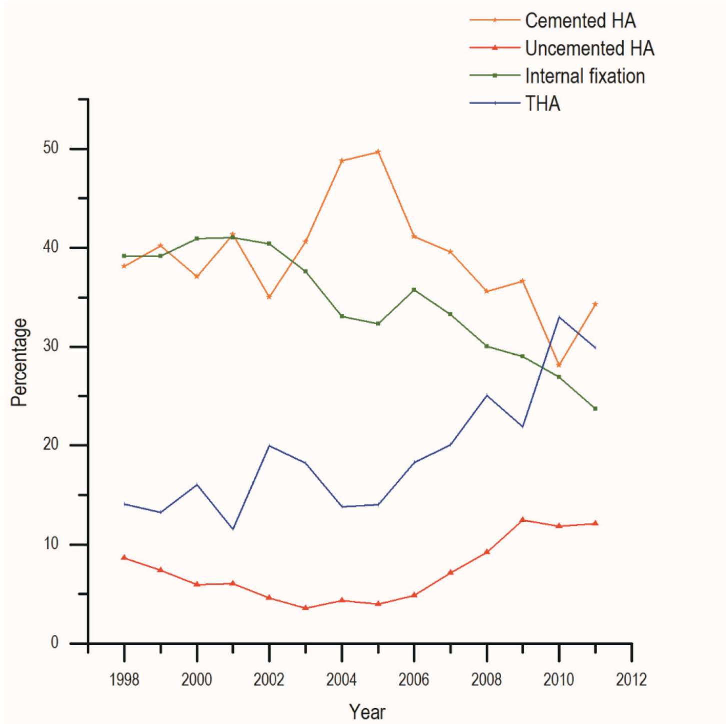

Figure 7. Distribution of femoral neck fracture procedures in the age group from 60 to 69.

5.2.1.3 Age group 70–79 years

In patients aged 70–79 years a substantial proportional increase was observed in uncemented HA procedures (from 14.6 to 24.1%) and THA procedures (from 6.3 to 11.4%), whereas there was a decrease in cemented HA procedures from 55.2 to 47.0% and in internal fixation from 23.9 to 17.5% (Figure 8).

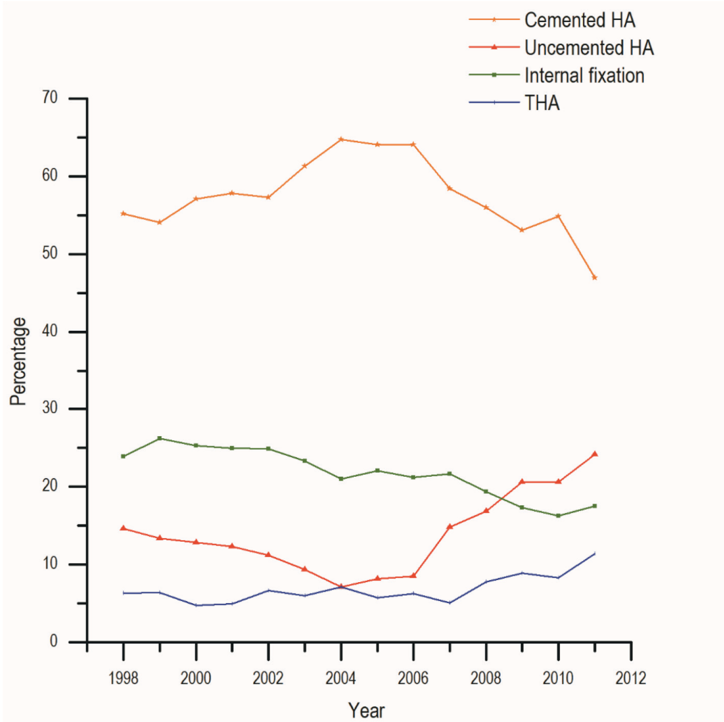

Figure 8. Distribution of femoral neck fracture procedures in the age group from 70 to 79.

5.2.1.4 Age group 80–89

Elderly patients aged 80–89 years showed a significant proportional increase in uncemented HA procedures from 14.4 to 25.3%, while there was no noticeable change in cemented HA procedures (from 63.0 to 60.1%) and THA (from 2.5 to 2.9%). However, a proportional decrease was seen in internal fixation from 20.2 to 11.8% (Figure 9).

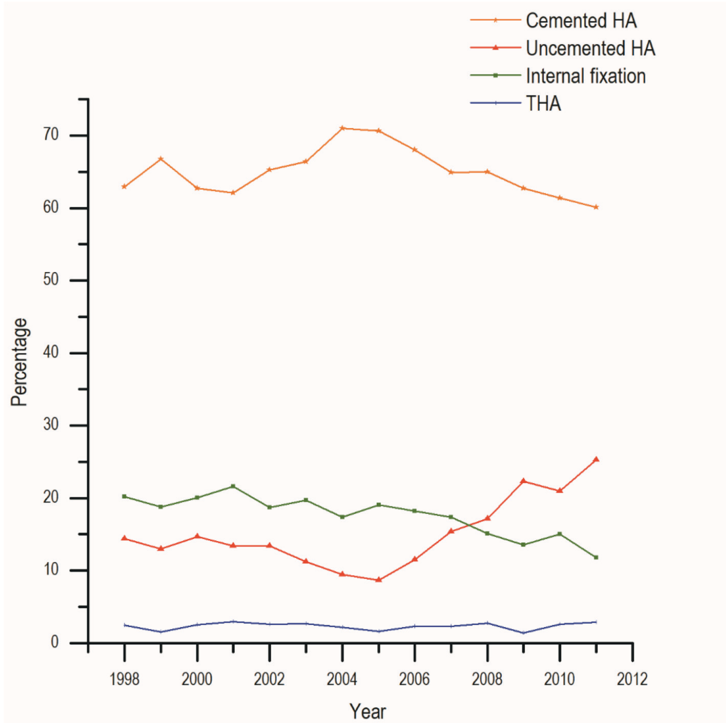

Figure 9. Distribution of femoral neck fracture procedures in the age group from 80 to 89.

5.2.1.5 Elderly aged 90 or more

Patients aged 90 years or more presented a moderate increase in uncemented HA procedures from 14.5 to 21.4% and a decrease in IF from 16.6 to 12.2%. The proportional use of cemented HA (from 67.4 to 64.6%) and THA (from 1.5 to 1.7%) procedures did not markedly change (Figure 10).

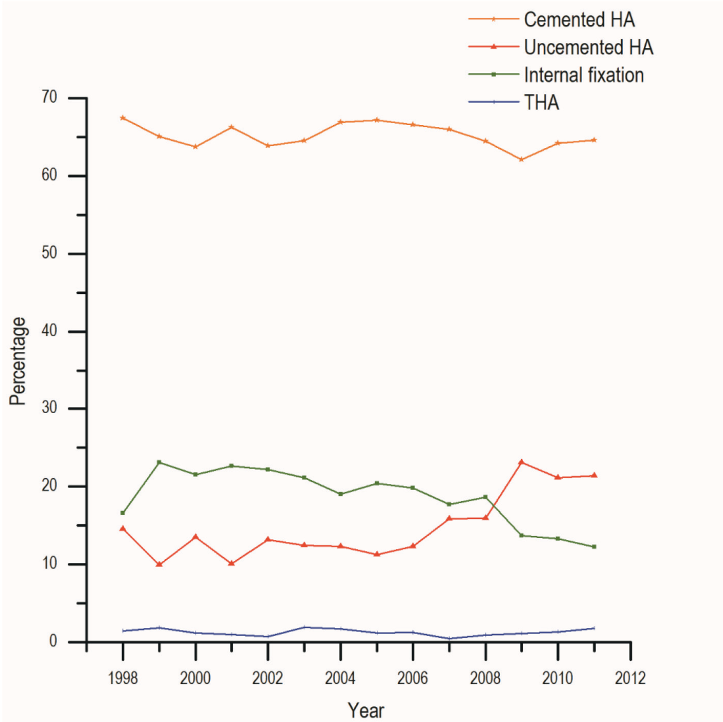

Figure 10. Distribution of femoral neck fracture procedures in elderly patients aged 90 years or more.

5.3 IADL and MMSE as predictors of institutionalization

The receiver operating characteristics analysis established excellent discrimination for IADL and MMSE, 0.88 (95% CI 0.85–0.91) and 0.83 (95% CI 0.79–0.86) respectively (Figure 10). A cut-off value of 5 for IADL indicated 100% (95% CI 96–100%) sensitivity and 38% (95% CI 33–43%) specificity for institutionalization. Because no patients with IADL score ≥5 were institutionalized, OR could not be calculated. For MMSE, 84% (74–91%) sensitivity and 65% specificity (95% CI 60–70%) with OR 9.4 (95% CI 5.0–17.7) were calculated using a cut-off value of 20 to determine institutionalized living arrangements one year after hip fracture. Other cut-off values with calculations are shown in Table 7 and Figure 11.

Table 7. Alternative cut-off values for IADL and MMSE in predicting institutionalization.

Cut-offs	Sensitivity	Specificity	PPV	NPV	OR	(95% CI)
IADL						
2	92.9%	69.5%	0.388	0.979	29.6	(12.6–69.7)
3	98.8%	57.3%	0.325	0.996	111.5	(15.4–808.7)
4	98.8%	49.1%	0.288	0.995	80.2	(11.1–581.5)
5	100 %	38.0%	0.251	1.0	Undefined	
MMSE						
10	22.8%	96.3%	0.293	0.865	7.7	(3.7–16.1)
15	55.7%	86.5%	0.444	0.909	8.0	(4.7–13.6)
20	83.5%	65.0%	0.317	0.953	9.4	(5.0–17.7)
25	96.2%	29.3%	0.209	0.975	10.5	(3.3–34.0)

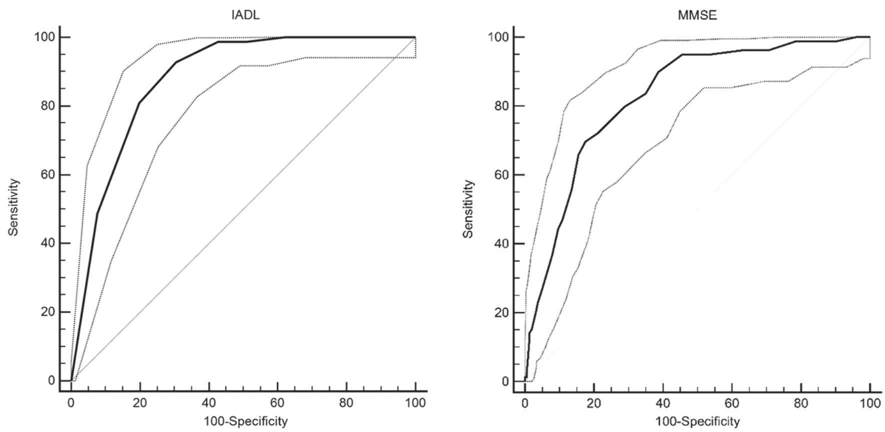

Figure 11. ROC curves with 95% confidence intervals for IADL and MMSE.

Multivariate logistic regression analysis showed that institutionalized living arrangements at four months (OR 16.26; 95% CI 7.37–35.86), IADL <5 (OR 12.86; 95% CI 1.26–103.9), and MMSE <20 (OR 4.19; 95% CI 1.82–9.66) predicted institutionalization one year after hip fracture (Table 8).

Errata for PhD thesis
"Fragility Hip Fracture - Predictive Factors for Mobility, Institutionalization and Survival"
Markus Hongisto

- page 54, Table 8 is wrong and should be presented as in the original publication

	Age-adjusted univariate n=584			Multivariate n=472		
Variable	n	OR (95% CI)	P	n	OR (95% CI)	P
Living arrangements at 1 months						
Own home or assisted living accommodation	260	1.00		219	1.00	
Institution*	324	3.81 (2.34-6.16)	<0.001	253	1.56 (0.67-3.63)	0.304
Living arrangements at 4 months						
Own home or assisted living accommodation	463	1.00		393	1.00	
Institution*	121	33.24 (19.39-56.00	<0.001	79	16.26 (7.37-35.86)	<0.001
IADL	487	2.54 (2.00-3.22)	<0.001			
5-8	199	1.00		197	1.00	
0-4	288	73.11 (10.03-532)	<0.001	275	12.96 (1.62-103.9)	0.016
MMSE		1.22 (1.16-1.27)	<0.001			
20-30	305	1.00		197	1.00	
0-19	180	9.00 (4.93-16.43)	<0.001	175	4.19 (1.82-9.66)	0.001
Age						
65-74	87	1.00		78	1.00	
75-85	268	3.49 (1.45-8.41)	0.005	221	1.12 (0.31-4.11)	0.865
>85	229	5.47 (2.27-13.14)	<0.001	173	1.29 (0.35-4.71)	0.915
Mobility aids before fracture						
Mobile without an aid	258	1.00				
Mobile with an aid	320	1.23 (0.78-1.89)	0.360			
Unable to ambulate	6	5.03 (0.93-27.14)	0.061			
Mobility level before fracture						
Unassisted outdoors	393	1.00		343	1.00	
Assisted outdoors	63	6.18 (3.41-11.21)	<0.001	46	1.39 (0.53-3.65)	0.510
Unassisted indoors	108	4.27 (2.56-7.11)	<0.001	68	0.93 (0.37-2.34)	0.879
Assisted indoors	13	8.23 (2.61-25.98)	<0.001	8	0.96 (0.14-6.53)	0.968
Unable to move	7	12.04 (2.53-57.23)	0.002	7	0.89 (0.11-7.04)	0.914
Previous living arrangements						
Own home	298	1.00		256	1.00	
Own home with organized home ca	193	2.74 (1.65-4.55)	<0.001	153	1.14 (0.48-2.76)	0.764
Assited living accomodation	98	6.16 (3.51-10.81)	<0.001	63	1.17 (0.40-3.40)	0.777
Living with somebody						
Yes	325	1.00		253	1.00	
No	259	0.51 (0.34-0.78)	0.002	219	0.79 (0.33-1.87)	0.589
ASA grade						
1-2	95	1.00		79	1.00	
3	386	2.87 (1.32-6.20)	0.008	319	1.14 (0.33-3.97)	0.834
4-5	99	2.10 (0.86-5.12)	0.103	74	0.24 (0.05-1.13)	0.071
Medications on admission						
<4 medicine	135	1.00		108	1.00	
4-10 medicine	366	1.76 (1.03-3.03)	0.040	297	1.01 (0.38-2.69)	0.991
>10 medicine	83	2.06 (1.03-4.12)	0.041	67	1.72 (0.48-6.18)	0.406
Previous fracture of any bone						
Yes	182	1.00				
No	402	0.93 (0.60-1.43)	0.732			
Gender						
Female	456	1.00				
Male	128	0.94 (0.59-1.63)	0.871			
Hip fracture type						
Femoral neck fracture	380	1.00				
Pertrochanteric fracture	180	0.95 (0.61-1.47)	0.819			
Subtrochanteric fracture	24	1.05 (0.37-2.97)	0.930			

Table 8. Age adjusted univariate and multivariate logistic regression analyses demonstrating institutionalization one year after hip fracture.

	Age-adjusted univariate n=584				Multivariate n=472			
Variable	**n**	**OR (95% CI)**		**P**	**n**	**OR (95% CI)**		**P**
Living arrangements at 1 month								
Own home or assisted living accommodation	260	1.00			219	1.00		
Institution*	324	3.81	(2.34–6.16)	<0.001	253	1.52	(0.64–3.64)	0.345
Living arrangements at 4 months								
Own home or assisted living accommodation	463	1.00			393	1.00		
Institution*	121	33.24	(19.39–56.00)	<0.001	79	13.53	(5.88–31.14)	<0.001
IADL (8 to 0)	487	2.54	(2.00–3.22)	<0.001	472	1.73	(1.27–2.36)	0.001
MMSE (30 to 0)	485	1.22	(1.16–1.27)	<0.001	472	1.10	(1.02–1.19)	0.012
Age								
65–74	87	1.00			78	1.00		
75–85	268	3.49	(1.45–8.41)	0.005	221	0.93	(0.24–3.57)	0.911
>85	229	5.47	(2.27–13.14)	<0.001	173	1.08	(0.28–3.13)	0.915
Mobility aids before fracture								
Mobile without an aid	258	1.00						
Mobile with an aid	320	1.23	(0.78–1.89)	0.360				
Unable to ambulate	6	5.03	(0.93–27.14)	0.061				
Mobility level before fracture								
Unassisted outdoors	393	1.00			343	1.00		
Assisted outdoors	63	6.18	(3.41–11.21)	<0.001	46	1.02	(0.37–2.83)	0.962
Unassisted indoors	108	4.27	(2.56–7.11)	<0.001	68	0.70	(0.27–1.83)	0.462
Assisted indoors	13	8.23	(2.61–25.98)	<0.001	8	1.00	(0.15–6.50)	0.999
Unable to move	7	12.04	(2.53–57.23)	0.002	7	0.73	(0.06–8.39)	0.797
Previous living arrangements								
Own home	298	1.00			256	1.00		
Own home with care in place	193	2.74	(1.65–4.55)	<0.001	153	1.14	(0.45–2.86)	0.789
Assisted living accommodation	98	6.16	(3.51–10.81)	<0.001	63	0.94	(0.31–2.83)	0.912
Living with somebody								
Yes	325	1.00			253	1.00		
No	259	0.51	(0.34–0.78)	0.002	219	0.90	(0.36–2.24)	0.824
ASA grade								
1–2	95	1.00			79	1.00		
3	386	2.87	(1.32–6.20)	0.008	319	1.42	(0.39–5.21)	0.598
4–5	99	2.10	(0.86–5.12)	0.103	74	0.24	(0.05–1.20)	0.081
Medications on admission	135	1.00	(1.03–3.03)	0.040		1.00	(0.31–2.51)	0.820
<4 medicines	366	1.76	(1.03–4.12)	0.041	108	0.89	(0.45–6.13)	0.452
4–10 medicines	83	2.06			297	1.65		
>10 medicines					67			
Previous fracture of any bone								
Yes	182	1.00						
No	402	0.93	(0.60–1.43)	0.732				
Gender								
Female	456	1.00						
Male	128	0.94	(0.59–1.63)	0.871				
Hip fracture type								
Femoral neck fracture	380	1.00						
Pertrochanteric fracture	180	0.95	(0.61–1.47)	0.819				
Subtrochanteric fracture	24	1.05	(0.37–2.97)	0.930				

5.3.1 Changes in living arrangements

Of the 584 survivors who were not institutionalized before the fragility hip fracture 293 (50.2%) patients were living in their own homes without assistance, 193 (33.0%) were living in their own homes with home care in place and 98 (16.8%) were living in assisted living accommodation. Institutionalized living arrangements were observed in 324 (55.5%) and in 121 (20.7%) at 1 and 4 months after hip fracture respectively. On hundred and twenty-seven (21.7%) patients were living in institutions one year after hip fracture (Figure 12).

The major changes in living arrangements occurred during the first four months after hip fracture (Figure 13). One month after hip fracture, 324 (55.5%) were living in institutions, and of these 221 (68.2%) had no need for 24-hour care at 4 months. Of the 260 patients living their own homes or in assisted living accommodation at one month, 18 (6.9%) were institutionalized at four months. One hundred and twenty-one patients were institutionalized at four months, and of these 30 (24.8%) could be rehabilitated from institutional care to their own homes or assisted living accommodation between four and 12 months. By contrast, of the 463 patients who were not institutionalized at four months, 36 (7.8%) were living in institutions providing 24-hour care at 12 months.

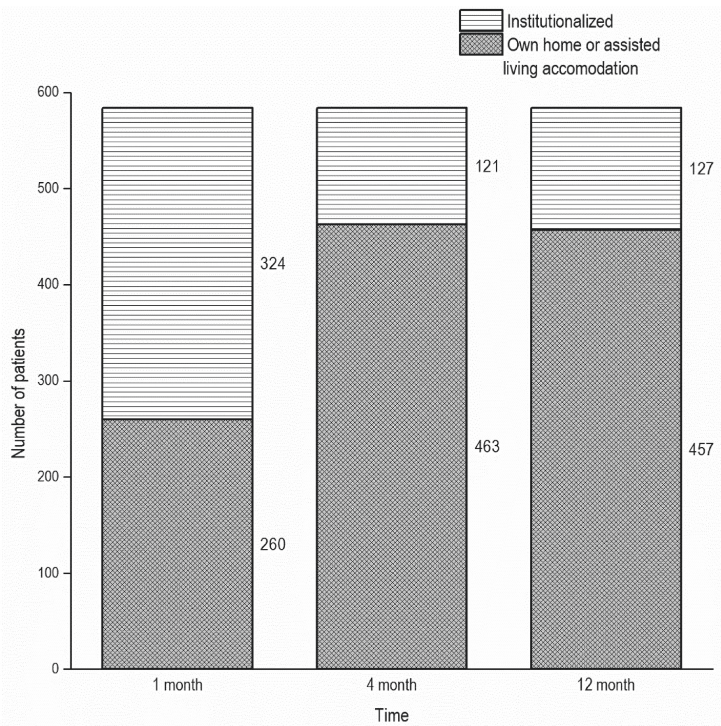

Figure 12. Living arrangements of hip fracture patients at 1, 4, and 12 months after hip fracture.

Overall, changes in living arrangements occurred in 66 (11.3%) patients between four and 12 months after hip fracture (Figure 13).

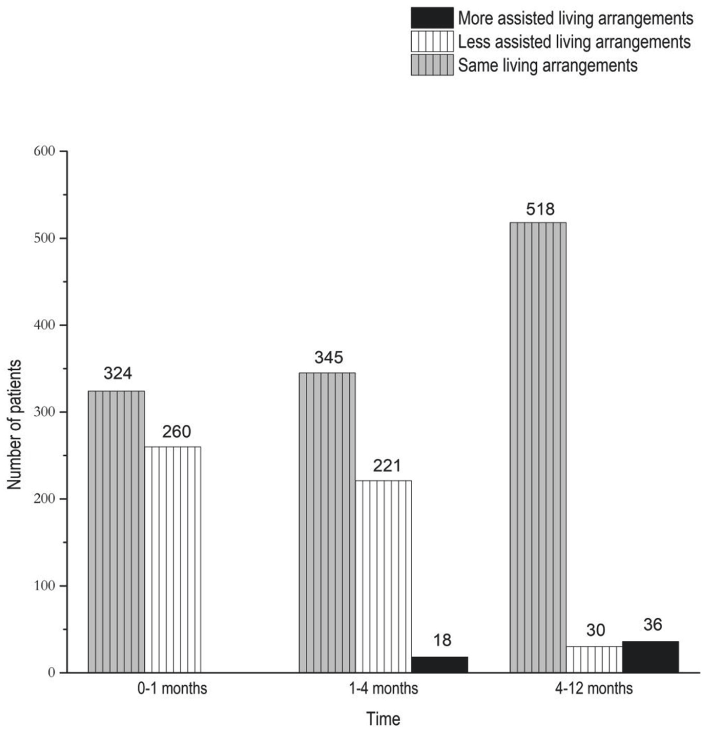

Figure 13. Change in living arrangements after hip fracture stratified by time elapsing since hip fracture.

5.4 Comparison of lateral and posterior approach in HA (Study III)

Of the 269 fragility hip fracture patients operated on, a lateral and posterior surgical approach was used in 151 (56.1%) and 118 (43.9%) patients respectively. Uncemented HA was used more often in the lateral than in the posterior approach (92.1 vs. 79.7%; p=0.003). Surgeon's experience differed between the approaches used. The posterior approach was adopted more often than the lateral approach (45.8 vs. 23.8%; p<0.001) by registrar surgeons under the supervision of a consultant orthopaedic surgeon.

The ability to ambulate without aids one year after hip fracture was observed in 26 (22.0%) patients operated on using the posterior approach compared to 18 (11.9%) patients operated on using the lateral approach. The difference was statistically significant (p=0.026).

Age-adjusted logistic univariate regression analyses revealed increased age, male gender, lateral approach, uncemented implant, prior use of mobility aids, decreased mobility level before injury and more than ten regularly taken medicines to increase the risk of need for ambulatory aids one year after hip fracture (Table 9). After adjusting for confounders, prior use of mobility aids (OR 13.5; 95% CI 4.29–42.25) was the strongest factor explaining the need for mobility aids one year after hip fracture, followed by age of 85 years or older (OR 3.8; 95% CI 1.09–13.44) and a lateral approach (OR 2.73; 95% CI1.15–6.50) (Table 9).

Hip dislocation occurred in four (3.4%) patients operated on using the posterior approach and in no patients in lateral approach group.

No statistically significant differences between approaches were established regarding living arrangements, pain in operated hip or mobility level one year after the hip fracture.

Table 9. Age-adjusted univariate logistic regression analysis and multivariate analysis showing the risk in terms of independent variables for needing mobility aids one year after the fracture.

		Age-adjusted univariate n=269			Multivariate n=269		
	n	OR	(95% CI)	P	OR	(95% CI)	P
Age (years)							
65–74	31	1.00			1.00		
75–84	114	2.30	(0.96–5.49)	0.061	1.70	(0.56–5.08)	0.341
≥85	124	5.65	(2.16–14.78)	<0.001	3.83	(1.09–13.44)	0.036
Sex							
Female	212	1.00			1.00		
Male	57	4.45	(1.45–13.71)	0.009	3.59	(1.05–12.22)	0.041
Surgical approach							
Posterolateral	118	1.00			1.00		
Lateral	151	2.11	(1.07–4.14)	0.031	2.73	(1.15–6.50)	0.023
Surgeon's experience							
Registrar	90	1.00			1.00		
Post-registrar	179	0.64	(0.30–1.36)	0.242	0.60	(0.21–1.68)	0.325
Implant							
Uncemented	233	1.00			1.00		
Cemented	36	0.38	(0.16–0.93)	0.033	0.57	(0.16–1.97)	0.371
Delay to operation							
<24 h	121	1.00					
24–47h	116	1.09	(0.53–2.27)	0.812			
48–72 h	26	0.92	(0.30–2.79)	0.876			
>72 h	6	1.09	(0.12–10.26)	0.939			
Mobility aids before fracture							
Mobile without an aid	111	1.00			1.00		
Mobile with an aid or immobile	158	13.66	(5.09–36.64)	<0.001	13.46	(4.29–42.25)	<0.001
Mobility level before fracture							
Full or limited mobility outdoors	205	1.00			1.00		
Full of limited mobility indoors	64	4.80	(1.41–16.38)	0.012	2.40	(0.57–10.09)	0.233
Previous living arrangements							
Own home	132	1.00			1.00		
Own home with home care in place	74	2.40	(1.05–5.49)	0.038	1.24	(0.45–3.46)	0.678
Assisted living accommodation	41	5.68	(1.27–25.42)	0.023	2.25	(0.35–14.30)	0.391
Institutionalized	22	6.84	(0.86–54.33)	0.069	1.32	(0.12–14.41)	0.822
Previous diagnosis of memory disorder							
Yes	65	1.00			1.00		
No	204	0.40	(0.16–1.02)	0.054	0.69	(0.20–2.36)	0.552
Living with someone							
Yes	156	1.00					
No	113	0.78	(0.40–1.53)	0.471			
ASA grade							
1–2	37	1.00			1.00		
3	180	1.77	(0.75–4.19)	0.191	1.90	(0.62–5.84)	0.260
4–5	52	1.65	(0.54–5.04)	0.382	0.76	(0.17–3.41)	0.720
Medications on admission							
<4 medications	58	1.00			1.00		
4–10 medications	174	1.16	(0.53–2.56)	0.705	0.51	(0.18–1.42)	0.198
>10 medications	37	8.71	(1.05–71.91)	0.045	3.10	(0.30–31.68)	0.341

Results are shown as odds ratios (OR) with 95% confidence intervals (CI). Variables with p value ≤0.25 in age-adjusted univariate logistic regression analysis were subjected to multivariate regression analysis.

5.5 Survival (Study IV)

The study consisted of 724 analysed patients, of whom 514 (71%) were women. The mean time elapsing from the need for fracture repair to surgery was 32.3 (25–75% percentile 19.4–42.2) hours and 66 patients (9.1%) were operated on within 12 hours. Patients who waited 48 hours or more for their hip fracture operation were younger ($p=0.003$) and had fewer previous diagnoses of memory disorder ($p=0.010$) than had the other groups.

Higher age and male gender were independent factors predicting worse 30-day and 365-day survival (Table 10).

Worse 30-day survival in the Cox hazard regression model was established in patients undergoing hip fracture surgery with 12–24 hours' (HR 8.30; 95% CI 1.13–61.4) and ≥48 hours (HR 11.75; 95% CI 1.53–90.2) delay than in patients operated on within 12 hours of determining the need for surgery. A surgical delay of 24–48 hours (HR 7.21; 95%CI 0.98–52.9) and institutionalized living arrangements before hip fracture (HR 1.84; 95% CI 0.94–3.62) indicated a trend towards poorer 30-day survival (Table 10, Figure 14).

Surgical delay of 48 hours or more (HR 2.02; 95% CI 1.08–3.80) compared to <12 hours' surgical delay was associated with worse 365-day survival in the Cox hazard regression model. Other factors increasing the risk of death during 365 days were 4–10 regularly taken medicines on admission, >10 regularly taken medicines on admission and more supported living arrangements or institutionalization prior to the hip fracture (Table 10, Figure 15).

Table 10. A multivariable cox hazard regression model showing the risk of independent variables for 30-day and 365-day survival.

	30-day survival			365-day survival		
Variable	**HR**	**(95% CI)**	**P**	**HR**	**(95% CI)**	**P**
Age (years)	1.07	(1.03–1.11)	<0.001	1.05	(1.03–1.08)	<0.001
Sex						
Female	1.00			1.00		
Male	1.79	(1.11–2.88)	0.017	1.57	(1.17–2.10)	0.002
Delay to operation						
<12hrs	1.00			1.00		
12–24hrs	8.30	(1.13–61.14)	0.038	1.75	(0.98–3.11)	0.057
24–48hrs	7.21	(0.98–52.91)	0.052	1.49	(0.84–2.63)	0.169
>48hrs	11.75	(1.53–90.24)	0.018	2.02	(1.08–3.80)	0.029
Previous diagnosis of memory disorder						
No	1.00		0.577	1.00		
Yes	1.15	(0.70–1.91)		1.00	(0.74–1.36)	0.982
Medications on admission						
<4	1.00			1.00		
4–10	0.98	(0.43–2.21)	0.960	2.17	(1.13–4.15)	0.020
>10	1.42	(0.59–3.39)	0.435	3.12	(1.58–6.17)	0.001
Previous living arrangements						
Own home	1.00			1.00		
Own home with home care in place	0.88	(0.45–1.73)	0.708	1.22	(0.82–1.80)	0.329
Assisted living accommodation	1.68	(0.75–3.78)	0.209	2.18	(1.35–3.51)	0.001
Institutionalized	1.84	(0.94–3.62)	0.076	2.16	(1.43–3.26)	<0.001
Hip fracture type						
Femoral neck fracture	1.00			1.00		
Pertrochanteric fracture	1.15	(0.71–1.85)	0.574	1.04	(0.78–1.39)	0.804
Subtrochanteric fracture	0.78	(0.28–2.21)	0.645	0.95	(0.54–1.66)	0.848

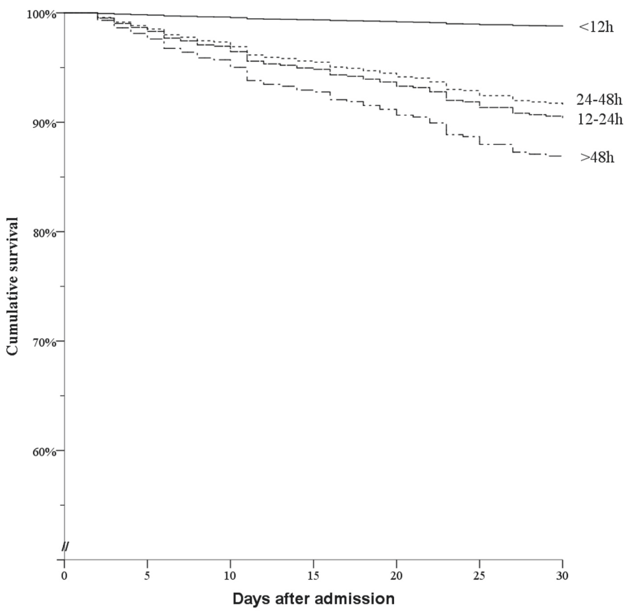

Figure 14. Thirty-day survival of hip fracture patients stratified by surgical delay.

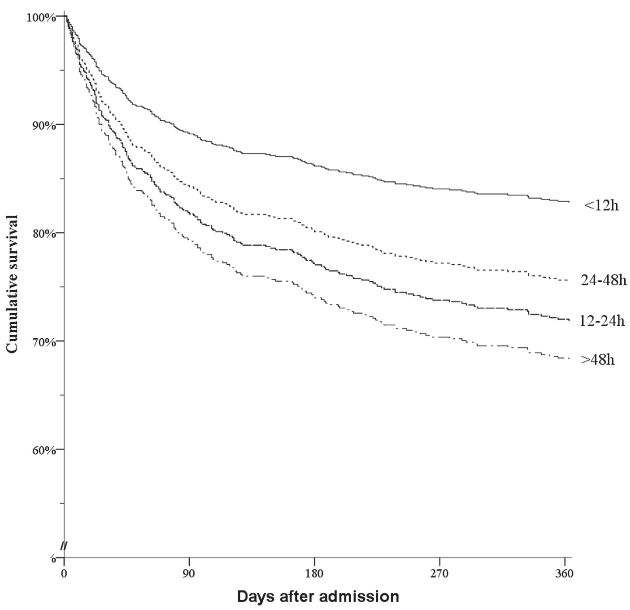

Figure 15. One-year survival of hip fracture patient stratified by surgical delay.

6 DISCUSSION

This thesis aimed to improve the treatment of hip fracture patients. A patient with an osteoporotic hip fracture poses medical and financial challenges to the healthcare system. Avoiding individual suffering and restoring prior level of mobility, independence and living conditions without complications are the main goal in comprehensive hip fracture management. To achieve this goal, multidisciplinary professional healthcare workers should actively follow new scientific evidence and review the prevailing treatment protocol. The whole treatment pathway from time of injury to rehabilitation should be evaluated to ensure high quality care.

The most important result in our national population-based study was that the use of uncemented HA procedure in the treatment of FNF patients increased markedly from 2005 to 2011, which was contrary to the scientific evidence. Our prospective follow-up study showed that IADL and MMSE present additional information for the risk assessment of change in living arrangements. The third study of this thesis showed that HA procedures for patients with displaced FNF conducted using a lateral approach rather than a posterior approach predispose to a need for ambulatory aids one year after hip fracture. However, the posterior approach predisposes to hip dislocation. The fourth study indicated that even a delay of more than 12 hours to hip fracture surgery may have an adverse effect on survival.

6.1 Change in implant choice for the treatment of FNF

6.1.1 Increased use of uncemented HA

To the best of my knowledge, this is the first Finnish nationwide study to report the incidence of surgical methods used in the treatment of FNFs. The most important finding in our register-based study was that the use of uncemented HA procedures increased nearly threefold from 8.1 to 22.2% from 2005 to 2011. At the same time, the use of cemented HA procedures declined. The rise in the use of uncemented HA procedure in the treatment of FNF patients, especially among the oldest patients, contradicts scientific evidence available during the study period. It is noteworthy that older studies comparing uncemented and cemented HA were mainly conducted during the era when only the old-fashioned non-modular femoral stems were available. These are now outdated and infrequently used (Leonardsson et al. 2012a). Most of these studies indicate, however, that cemented HA offer better mobility and is less painful than uncemented HA in the treatment of FNF (Sonne-Holm et al. 1982; Emery et al. 1991; Khan et al. 2002; Santini et al. 2005; Parker et al. 2010). In 2009, Figved et al. published the first RCT comparing modern uncemented and cemented HA and concluded that both stems could be used in the treatment of FNF with similar functional outcomes and complication rates (Figved et al. 2009). However, the trial did not have sufficient statistical power to address differences between procedures in rare complications, such as BCIS and periprosthetic fractures. From the same RCT study population, five-year follow-up results were reported with worrying results in 2014: postoperative periprosthetic femoral fractures were more often observed when uncemented HA was used (7.4 % vs. 0.9%; HR 9.3; 95% CI 1.16–74.5) (Langslet et al. 2014).

A meta-analysis including RCT studies containing only a modern stem design showed that uncemented HA achieved shorter operating time compared to cemented HA, but better postoperative hip function, fewer postoperative and interoperative fractures resulted in cemented HA. No notable difference was seen between HA procedures regarding intraoperative blood loss, mortality, wound infection, general complications and reoperation rate (Lin et al. 2019). Another meta-analysis which included only current generation stems for the treatment of FNF patients showed that cemented HA resulted in fewer implant-related complications and similar mortality to cementless HA (Veldman et al. 2017). Contrary to the meta-analysis conducted by Lin et al., two large register-based studies showed an increased risk of reoperation after FNFs treated with uncemented HA (Leonardsson et al. 2012b; Rogmark et al. 2014). According to the literature, the shift from cemented HA to uncemented HA procedures contradicts scientific evidence. In my opinion, the reduced shorter operating time does not justify the use on uncemented HA in the treatment of patients with FNF.

Bone cement implantation syndrome (BCIS) is a feared and potentially fatal complication in cemented HA, which may be one explanation for favouring uncemented HA. After the introduction of a new definition of BCIS, Olsen et al. reported overall 28% incidence of BCIS (Donaldson et al. 2009; Olsen et al. 2014). However, grade 3 BCIS defined as cardiovascular collapse requiring cardiopulmonary resuscitation was observed in 1.7% of patients undergoing HA procedure, among whom 30-day mortality was 88%. Significant pre-existing factors for developing BCIS include prior pulmonary hypertension and significant cardiac disease, high ASA score, COPD and medication with warfarin or diuretics (Donaldson et al. 2009; Olsen et al. 2014). Also, a number of surgical techniques may be undertaken to reduce the BCIS risk, such as medullary lavage, good haemostasis before cement implementation, and venting medulla (Donaldson et al. 2009). Although BCIS is rare, there may be a minimal FNF patient population who benefit from uncemented HA, but this should not explain nearly the three-fold increase in the use of uncemented HA between 2005 and 2011. According to a recent Finnish study, cemented HA is a safe option for the treatment of patients suffering from FNF, but caution is warranted in patients with severe systemic disease that is a constant threat to life (ASA score IV or more) (Ekman et al. 2019)

A third reason for the increased use of uncemented HA may be the erroneous use of study findings obtained by comparing different stem types in THA which should not be directly applied to the moribund and fragility hip fracture population.

6.1.2 Increased use of THA

The use of THA procedure for the treatment of FNF nearly doubled from 4.9 to 9.2% during the study period 1998–2011. The change was most marked among younger FNF patients 50–69 years of age. Patients of the youngest age groups 50–59 and 60–69 years of age represented an increase in the use of the THA procedure from 15.7 to 29.6% and from 14.1 to 29.9% respectively. Also, FNF patients 70–79 years of age showed a proportional rise in the use of THA procedures from 6.3 to 11.4%, whereas no noticeable change was discernible in patients 80 years of age or more. Our study results concur with those of publications from the United States. Stronach et al. studied the trends in the treatment of FNFs with arthroplasty from 2004 to2013 and identified an increase in the use of THA during the study period from 8.4 to 12.9% (Stronach et al. 2019). Another register-based study showed increasing use of THA from 5.9 to 7.4% in the treatment of patients with FNFs between 2003 and 2013 (Ju et al. 2017).

Several studies have reported lower re-operation rates and improved functional outcomes when THA is used for active elderly patients with FNF. Baker et al. conducted an RCT comparing the use of THA and HA on active patients. They defined active patients as follows: patients 60 years of age or more with no or minimal osteoarthritic changes, able to ambulate ≥800 m before hip fracture, normal MMSE score, and living independently without reliance on a caregiver (Baker et al. 2006). They concluded that THA offers superior short-term clinical results and fewer complications than HA in previously active elderly patients. Avery et al., in an RCT comparing THA to HA among active elderly patients established that there was lower mortality and a trend towards superior function with THA at 7–10 year follow-up (Avery et al. 2011). A meta-analysis of RCTs showed THA had decreased the risk of reoperation and yielded higher functional scores at one and four years postoperatively, but increased the risk of dislocation (Yu et al. 2012). As expected, THA exposed patients to longer duration of operation and increased intra-operative blood loss compared to HA (Blomfeldt et al. 2007). A large Swedish register-based study including FNF patients aged 60 or more operated on using cemented stems demonstrated that THA is associated with more hip complications than HA, but fewer medical complications (Hansson et al. 2019).

The rise in the proportional use of THA procedures in younger FNF patients compared to the HA procedure in Finland from 1998- to 2011 is justified according to the literature. Younger hip fracture patients 50–79 years of age represent more likely an independently living active elderly patient group than octogenarians and older. However, there persist major problems in how to define an active elderly person likely to benefit from the THA procedure. Age should not be the only discriminatory factor. Further studies investigating the definitions and more accurate screening parameters for how to define an active independently living elderly are needed.

6.2 Screening patients at risk of institutionalization

Several risk factors for moving to institutionalized living arrangements after hip fracture have been reported, such as polypharmacy, admission from a care facility, increased age, pre-injury dependence, male sex, lower pre-fracture level of ADL, and dementia (Titler et al. 2006; Deakin et al. 2008; Vochteloo et al. 2012). Institutionalization is a common consequence of hip fracture and leads to increased healthcare costs (Nurmi et al. 2003; Hektoen et al. 2016). According to a Finnish study published in 2003, the average annual cost per hip fracture was 14,400 €, whereas institutionalization of previously home-dwelling patient costs 36,683 €. Regarding the financial and patient aspects, clinicians and healthcare workers treating and rehabilitating these vulnerable patients should be able to identify potential predictors of institutionalization after the hip fracture. IADL and MMSE are common tests in comprehensive geriatric assessments and health care to describe functional capabilities for surviving at home and screening for cognitive disorder (Lawton and Brody 1969; Folstein et al. 1975). Earlier studies clearly show that decreased pre-fracture level of IADL and MMSE exposes to more supported living arrangements after hip fracture (Vochteloo et al. 2012; Schaller et al. 2012; Balzer-Geldsetzer et al. 2019). This may be explained by worse scores in patients admitted to hospital from more assisted living arrangements. However, the optimal cut-off value for IADL and MMSE in outpatient settings to determine those at risk of institutionalization is unknown.

In this study, for hip fracture patients who were not institutionalized before fracture, increased age, living with somebody, need for mobility aids and lower mobility level before fracture, more supported previous living arrangements, previous diagnosis of memory disorder, and higher ASA grade represented an individual risk factor for institutionalization, whereas polypharmacy show a trend towards more assisted living arrangements one year after hip fracture. Further, an IADL cut-off value of 5 in 4–6 months out-patient setting provided 100% sensitivity and 38% specificity for institutionalization by 12 months. Using a cut-off value of 20, MMSE showed strong sensitivity at 84% and fair specificity of 65% for institutionalization. With this cut-off value, the MMSE failed to predict institutionalization for 17% of patients, but falsely predicted institutionalization for 35% of patients.

An ideal test predicts the risk of impaired living arrangements after the hip fracture as early as possible. However, in-hospital screening methods based on patients' active participation may have reliability problems due to a different state of recovery in perioperative time. Acute complications and change of environment may impair the mental and cognitive capacity as well as co-operation. For example, signs of post-operative delirium are seen in as many as 17.5% of hip fracture patients who were community dwelling prior to the hip fracture (Levinoff et al. 2018).

Discrepancies in the literature exist as to how long improvements in functional outcomes and living arrangements occur after hip fracture. Lin et al. reported that IADL capabilities show the most significant progress in the first three months after hip fracture, but significant improvements were also seen at between three and 12 months (Lin and Chang 2004). In a prospective cohort study 24% of patients were able to regain their previous level of IADL at three months after the hip fracture, and at 12 months postoperatively the rate was 29% (Moerman et al. 2018). A study with a 6-month follow-up reported that mobility improves for at least six months, especially regarding climbing stairs and walking two blocks (Ouellet et al. 2019). On the other hand, Heikkinen et al. proposed a 4-month follow-up because living-arrangements and most ADL functions do not change comprehensively thereafter (Heikkinen and Jalovaara 2005). Another study conducted on patients with subcapital hip fractures showed that functional improvements continued for up to six months after hip fracture, but thereafter recovery slowed down and remained constant for 12 months (Young et al. 2010). Our finding contradicts the absence of change in living arrangements reported by Heikkinen et al. In our study population 11% changed living arrangements at 4 to 12 months, and of those (n=121) who were institutionalized at four months 25% (n=30) were able to return to their own homes with home care in place or to assisted living accommodation by 12 months. Further, of the 463 patients who were not institutionalized at four months, 36 (7.8%) were institutionalized by 12 months after surgery. The major change in the living arrangements, however, occurs within the first four months after hip fracture. As a conclusion, we suggest that the major functional improvements occur within the first four to six months after hip fracture and thereafter the recovery rate decelerates, but changes are perceptible by 12 months. This is supported by our finding that as many as 25% of patients institutionalized at four months were able to improve their living arrangements by 12 months.

If IADL and MMSE are used in out-patient settings between four and six months after hip fracture to predict institutionalization, this involves only a minor hip fracture population who may benefit from additional rehabilitation. Further, there is no evidence of the cost-effectiveness and benefits of any rehabilitation protocols involving only patients with low scores on IADL and MMSE. Thus, we cannot recommend arranging out-patient clinic visits solely for measuring IADL and MMSE to predict institutionalization. However, if the routine care pathway protocol includes following-up in out-patient settings to optimize health conditions and medications, measured IADL and MMSE give additional information for the risk assessment of change in living arrangements.

6.3 Surgical approach in HA

Several approaches exist in the insertion of HA, of which the most commonly used are lateral and posterior. The lateral approach with all modifications includes separating the gluteus medius and vastus lateralis insertions from the greater trochanteric insertions, which are attached after prosthesis implantation into their original position (Hardinge 1982). The posterior approach includes separating the gluteus maximus muscle following the detachment of external rotators from the femoral insertion (Moore 1957). Differences in outcomes comparing these approaches mostly arise from studies conducted with patients undergoing elective THA. However, patients operated on with THA due to a hip arthrosis probably represent aged population with good prior mobility and independence and study results cannot directly be adapted to the moribund hip fracture population with multiple comorbidities.

In the THA procedure, postoperative limping has been reported to vary from four to 20% in the lateral approach and 0–16% in the posterior approach. The lateral approach includes a risk of damage to the superior gluteal nerve and the strongest abductor muscle gluteus medius, which may predispose to post-operative limping (Masonis and Bourne 2002). Further, compared to patients undergoing elective THA procedure, hip fracture patients probably have more health-impairing conditions and multiple comorbidities, which may impede tissue healing and lead to an unsuccessful attachment of the de-attached gluteus medius muscle. However, an RCT involving 216 patients treated with HA showed no differences between approaches in regaining mobility and residual pain one year after admission. The use of walking aids was registered but not reported (Parker 2015). In our study, 22% of surviving FNF patients operated on using the posterior approach needed no ambulatory aids, whereas of patients operated on using the lateral approach only 11% survived without need for ambulatory aids one year after hip fracture. When interpreting this finding, attention should be paid to the fact that more patients were operated on using uncemented HA (92%) in the lateral approach than using the posterior approach (80%). The use of modern uncemented HA for the treatment of patients with FNF predisposes to poorer mobility and more implant-related complications compared to cemented HA (Lin et al. 2019). There is controversy as to whether the posterior approach results in better functional outcomes than the lateral approach in the HA procedure (Mukka et al. 2016; Kristensen et al. 2017). In our study no significant difference in mobility level was seen between approaches, which suggests that mobility level is affected by multiple reasons, such as a patient's overall state of health and living environment. Comprehensively deteriorated mobility would probably lead to more assisted living arrangements. No such difference between approaches was observed in our study, indicating that both approaches are acceptable for treating patients with FNF.

The dislocation rate in this study was 3.4% when the posterior approach was used to implant HA, which is one of the lowest dislocation rates to be reported so far. This may be affected by the surgical technique, where the piriformis tendon is left intact and acts as a block preventing the prosthesis from dislocating posteriorly. Parker et al. reported a dislocation rate of only 0.9% with the same surgical technique (Parker 2015). Ko et al. reported decreased incidence of dislocation after repair of posterior structures in HA (Ko et al. 2001). According to the literature, it is evident that the posterior approach predisposes to hip dislocation more than the lateral approach. The outcome after dislocation can be disastrous and the major issue is that what kind of long-term consequences hip dislocation may cause. A Swedish register-based study showed that the lateral approach involved a lower risk of reoperation due to dislocation than the posterior approach, but surgical approach had no statistically significant effect on the risk of reoperation overall (Leonardsson et al. 2012b). Rogmark et al. in a large register-based study with 2.7-year mean follow-up showed that overall reoperation is higher when using the posterior approach than the lateral approach, 4.0% and 3.2% respectively (Rogmark et al. 2014). Recurrent hip dislocation results in a significant and persisting decline in HRQoL during the first year after the hip fracture, whereas only one dislocation decreases HRQoL at four months followed by HRQoL recovery to a level similar to that of patients with no dislocations at 12 months (Enocson et al. 2009).

Which approach should be used in the HA procedure? According to our study, both posterior and lateral approaches are acceptable in the treatment of FNF patients with HA. First, the surgeon should be familiar with the approach to be used in order to ensure standardized good quality treatment. Second, if the surgeon in charge is competent in both approaches, a careful patient selection will probably yield the best results. Patients at especially great risk of suffering hip dislocation may benefit from the lateral approach, for example, patients with flexion-adduction contractures before fracture or minimally mobile patients with severe cognitive disorders or neurological diseases. However, mobile FNF patients may benefit more from the posterior approach than the lateral approach due to reduced need for mobility aids one year after hip fracture.

6.4 Timing of surgery

The optimal timing for hip fracture surgery has been widely investigated in observational studies using 24-hour time intervals and with controversial results. Most studies discuss only patients undergoing surgery. This will lead to the exclusion of hip fracture patients who died while waiting for surgery and effect of surgical delay on mortality may be underestimated. On the other hand, in observational studies patients are divided into those who receive treatment in good time or with a delay, which may overestimate the benefit of early surgery because patients with multiple co-morbidities are more prone to pre-operative investigations and medical stabilization leading to delays before surgery. This concurs with our study, which showed that patients with ASA score from 1 to 2 are operated on sooner than are patients with ASA score from 3 to 5. The lack of RCTs derives from ethical problems concerning surgery timing. It would be unethical to postpone hip fracture treatment if a patient is medically fit for surgery and resources for the operation are immediately available. Large register-based studies entail concerns about identifying the degree of overall state of health and co-morbidities affecting survival.

Regardless of the modest evidence in the literature defining the ideal cut-off value for delayed surgical timing, national guidelines have been established for early intervention in several countries. In the United Kingdom, National Institute for Health and Care Excellence (NICE) recommends performing surgery on the day of, or the day after admission(<36h) (NICE 2017). The American Academy of Orthopedic Surgeons (AAOS) states that moderate evidence supports performing hip fracture surgery within 48 hours of admission and that this is associated with better outcomes (AAOS 2014). In Canada, Health Quality Ontario & the Ministry of Health and Long-term Care recommend performing hip fracture surgery as soon as possible within 48 hours of initial presentation (Health Quality Ontario & Ministry of Health and Long-Term Care 2013). The New Zealand Guidelines Group recommends surgery within 24 hours of admission (New Zealand Guidelines Group 2003). The Finnish guidelines state that surgery within 24 hours may lead to lower mortality and fewer post-operative complications (Hip fracture: Current Care Guidelines Abstract 2017).

The most often used cut-off values for investigating delay before surgery include only limits from 24 h and thereafter. However, a limited number of studies using a 12 h watershed has been conducted to investigate the effect of ultra-rapid surgery on survival, and yielded controversial results (Smektala et al. 2008; Sebestyén et al. 2008; Uzoigwe et al. 2013; Bretherton and Parker 2015; Nyholm et al. 2015; Morrissey et al. 2017).

After adjusting for confounders, our study showed that more than 12 hours' delay to surgery is significantly associated with worse 30-day survival among patients with ASA score ≥3, and surgical delay of more than 48h has an adverse effect on 365-day survival. Acute complications related to waiting for surgery may explain the more satisfactory effect of ultra-rapid surgery on short-term survival, whereas patient-related unmodifiable factors have more influence on long-term survival. Complications related to waiting for surgery include increased risk of pressure ulcers, pneumonia, delirium, stroke, myocardial infarction, cardiac arrest and sepsis (Al-Ani et al. 2008; Anthony et al. 2017). Delirium is a severe complication involving as many as a quarter of patients undergoing hip fracture surgery. Postoperative delirium decreases short- and long-term survival in these patients (Bai et al. 2019).

The existing clinical evidence on managing the effect of surgical delay on survival and complications is weak. Most of the studies are of low quality. In current evidence-based medicine, the decision-making of treatment protocols should be based on meta-analyses and systematic reviews. Meta-analyses involve pooled data and calculations based on original publications. Thus, the assessment of individual study quality is essential when interpreting the results of meta-analyses. As in our study, there is no study showing any advantage from delaying surgery on patients who are medically ready for the operation. From a humanitarian perspective, postponing surgery leads to the prolongation of pain and in the worst case to extended preoperative fasting and catabolism. Immobilization before surgery exposes these frail and vulnerable hip fracture patients to avoidable complications. By combining information from the literature and our study, no conclusion can be drawn about optimal surgical timing, but it seems that even a delay of more than 12 hours to surgery may have an effect on survival. Thus, we recommend a pragmatic approach in the treatment of hip fracture patients. Definitive surgical treatment should be performed as soon as possible on the day of, or the day after admission without undue haste to operate on patients within a few hours. All effort should be targeted at eliminating unjustifiable administrative delays.

6.5 Strengths and weakness of the study

For the first study, the data was obtained from the Finnish National Hospital Discharge Register (NHDR). The register does not contain clinical details, but faithfully records inpatient history (Sund et al. 2007). Because of the lack of clinical details, especially on prior mobility and functional level before the FNF and Garden classification, no conclusions could be drawn as to whether the surgical method or implant used was in keeping with current treatment concepts.

Studies II–IV are based on prospectively collected data from population of the Hospital District of Southern Ostrobothnia constituting 196,578 patients in 2016. Data collection was initiated as a quality control register in 2007. The data inquiry was rapidly updated to meet the quality needed to conduct prospective cohort studies. During the data collection period lasting until 2018, new relevant measurable variables were continuously added to the data register with different coverage. Because some study hypotheses were set retrospectively, important information that would have added to the value of the results was not available. Clear strengths of data collection were low refusal rate (2%) to participate to this study, and data collection methods were based on pre-defined inquiries which were continuously updated. Also, practically all data were collected and coded into datasheets by one professional study nurse.

Data on deaths were obtained from the Official Cause of Death Statistics of Finland, which cover ~100% of deaths in Finland.

The variables used in this study might come in for criticism. First, this study does not contain a validated co-morbidity scale to describe patients' states of health. Number of regularly taken medications on admission and ASA score were used to evaluate the disease burden. However, Bjorgul et al. showed that ASA score may be used as a comorbidity index in hip fracture surgery (Bjorgul et al. 2010). Second, no validated mobility scale was used in this study to evaluate the degree or change in walking capabilities. We applied the need for mobility aids to describe mobility capabilities and assumed that patients not using mobility aids have better chances of walking independently than those who rely on cane or rollator. Also, mobility level was used to describe the mobility capabilities. The data collection of the Timed Up and Go (TUG) test or Elderly Mobility Scale (EMS) started during the study period and the use of these variables would have led to a major patient drop-out and significant problem with the study power and generalization. Third, the definition of high-energy hip fracture has not previously been validated. To study only the most typical low-energy hip fracture occurring in elderly people, we excluded moderate-to-high energy hip fractures (traffic-, bicycle- or pedestrian-accidents, and falling other than on the same level) from Studies II and III. We also considered these exclusion criteria in Study IV, but survival studies in the literature typically cover whole populations with restrictions only based on patient related variables.

For the third study, information on hip dislocation inside the referral area was retrospectively acquired from patient records. However, hip dislocations occurring outside the hospital district may not be part of the hip fracture database. Also, the posterior approach was used more often by registrar surgeons and uncemented stem was implemented more frequently when the lateral approach was used.

The fourth study suffers from the same problem as previously conducted studies concerning the effect of surgical timing on survival. Patients who are in good health may be operated on sooner that those with multiple co-morbidities. This will lead to bias which overestimates the beneficial effects of early surgery. Conversely, to minimize this effect, we excluded the healthiest patients according to ASA scale from the study, but at the same time the generalizability of this study to the entire hip fracture population is thus impaired.

The level of evidence in this study is a limitation. The Centre for Evidence-based Medicine (CEBM) develops, promotes and disseminates better evidence for healthcare.

The levels of evidence were first introduced in 1998 and updated in 2011 (Howic et al. 2011). According to the updated level of evidence, the observational studies in this thesis represent level III evidence. It is noteworthy that acquiring level I or II evidence by conducting an RCT is extremely troublesome among hip fracture patient population due to the high degree of co-morbidities, co-operation problems and mortality as well as the ethical considerations arising.

7 SUMMARY AND CONCLUSIONS

The main findings and conclusion of the study were:

1. Between 2005 and 2011, the proportion of uncemented HA procedures for the treatment of patients with FNF increased markedly in Finland, while the use of cemented HA and IF declined. During this time, the use of THA nearly doubled. The current evidence-based guidelines for the FNFs were mainly followed, but the increase in uncemented HA procedures contradicted recent scientific evidence.
2. IADL and MMSE tests to measure instrumental daily activities and cognitive function performed on fragility hip fracture patients ≥65 years of age from 4 to 6 months after hospital discharge predict institutionalization at 1 year after hip fracture.
3. Hemiarthroplasty procedures for patients with displaced FNF conducted using a lateral approach rather than a posterior approach predisposes to the need for ambulatory aids 1 year after hip fracture. However, the posterior approach predisposes to hip dislocation. Patient selection must be considered when deciding on the appropriate surgical approach.
4. Early hip fracture surgery within 12 hours from admission is associated with improved 30-day survival among patients with ASA score ≥3. Surgical delay of more than 48h has an adverse effect on 365-day survival but factors describing patient co-morbidities have a greater influence on long-term survival.

8 FUTURE RESEARCH AND CLINICAL IMPLICATIONS

Implant selection for patients suffering from femoral neck fracture are decisive for long-term outcome. In our nationwide study, the rise in the use of uncemented HA procedures from 2005 to 2011 was a surprising finding. The use of uncemented HA compared to cemented HA leads to worse postoperative hip function, more post-operative pain and increased number of interoperative fractures. Further, different types of cemented femoral stems exist, which may have an impact on post-operative complications such as periprosthetic fractures. More research is warranted to compare the outcomes of different types of cemented femoral stems in the treatment of patients suffering from FNF. A nationwide hip fracture register could provide real-time information on implants used, timing of surgery and other important outcome measures.

Despite advances in surgical intervention and anesthesia, the mortality rate remains high in the year following the hip fracture, and only about half of patients are able to regain their pre-fracture level of mobility during the first year. Multidisciplinary comprehensive orthogeriatric rehabilitation is reported to prevent institutionalization one year after hip fracture and reduce short-term mortality. However, no optimal orthogeriatric care model has been established. More research is needed, especially randomized controlled trials, to identify the best orthogeriatric care model in terms of regaining functional ability and improving survival.

The delay to hip fracture surgery has been widely studied using time intervals of 24 hours or more. A limited amount of evidence exists on whether ultra-rapid surgery within 12 hours has favorable effect on post-operative complications and survival. Our study showed that delay to surgery of over 12 hours has an adverse effect on short-term survival, which should be taken into account in clinical practice. However, more studies are needed to ascertain the effect of ultra-rapid surgery on crucial outcome parameters.

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11 ORIGINAL PUBLICATIONS

PUBLICATION
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Surgical procedures in femoral neck fractures in Finland: a nationwide study between 1998 and 2011

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SURGICAL PROCEDURES IN FEMORAL NECK FRACTURES IN FINLAND: A NATIONWIDE STUDY BETWEEN 1998 AND 2011

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ABSTRACT

Purpose: For femoral neck fractures, recent scientific evidence supports cemented hemiarthroplasty (HA) over uncemented HA, and suggests that total hip arthroplasty (THA) should be performed more frequently. We report the current surgical trends in treating femoral neck fractures in Finland.

Methods: The study was conducted using the Finnish National Hospital Discharge register and included all Finns at least 50 years of age who underwent surgery for femoral neck fractures from 1998-2011. Age- and sex-specific incidence rates, and annual proportion of each treatment method were calculated.

Results: 49,514 operations for femoral neck fracture were performed in Finland during 1998-2011. The proportion of uncemented HA increased from 8.1% in 2005 to 22.2% in 2011. During the same time, the proportion of cemented HA decreased from 63.9% to 52.5%, internal fixation decreased from 23.2% to 16.1%, and THA increased from 4.9% to 9.2%.

Conclusion: Between 2005-2011, the proportion of uncemented HA for femoral neck fractures increased markedly in Finland, while cemented HA and internal fixation declined. During this time, the use of THA nearly doubled. The current evidence-based guidelines for treatment of femoral neck fractures were mainly followed, but the increase in uncemented HA procedures contradicts recent scientific evidence.

INTRODUCTION

Hip fractures are a common injury in elderly adults leading to increased mortality, loss of function, and consumption of social and community health care services [1, 2]. Approximately 7500 persons sustain hip fractures annually in Finland. Based on a recent Finnish study, the age-adjusted incidence of hip fracture has continuously declined, especially in women, but the rapid aging of the population will result in an increase the total number of hip fractures in the near future [3]. Based on Scandinavian study, femoral neck fractures represent 60% of all hip fractures [4].

Treatment of femoral neck fracture is aimed at normal ambulation without weight-bearing restrictions. Non-displaced or impacted (Garden I or II) fractures should be stabilized surgically, because without fixation there is a 12% to 33% risk of fracture displacement prior to healing [5–7]. Desirable reduction and internal fixation reduce this risk to approximately 5%, thus clearly supporting surgical treatment [8]. For non-displaced femoral neck fractures, hemiarthroplasty (HA) is associated with increased mortality and a higher complications rate compared with internal fixation [9].

Arthroplasty and internal fixation also represent possible surgical methods for the treatment of displaced femoral neck fractures (Garden III or IV). The literature supports the use of the former method; in patients older than 60 years, HA reportedly results in fewer reoperations compared with internal fixation [10]. HA is also the most cost-effective surgical treatment available [11].

Cemented HA is associated with better mobility and less pain compared with traditional uncemented HA [12]. A recently published randomized trial regarding a modern uncemented stem had the same visual analog scale score for cemented vs. uncemented HA, but a higher Oxford Hip Score and less pain in flexion to 45° for a cemented stem at 6 weeks after surgery [13]. In addition, the uncemented stem was also associated with an increased number of intra- and postoperative fractures during the 2-year follow-up. In contrast, another recent randomized trial between cemented and uncemented HA showed no difference in mortality, disposition, or need for assistance with ambulation during a 1-year follow-up [14].

A patient's physiologic age, an assessment of physical health and previous activity level, may be more important than chronologic age in the decision-making between different surgical treatment options for femoral neck fractures [15]. Clearly, HA is the most common procedure performed for the treatment of displaced femoral neck fractures. Recent data, however, suggest that total hip arthroplasty (THA) is a better alternative for previously independent and healthy subjects [16, 17].

As noted above, four surgical treatment options are available for patients with a femoral neck fracture (internal fixation, cemented HA, uncemented HA, and THA), but the optimal approach remains under debate. The aim of this study was to assess the incidence of surgical procedures for femoral neck fractures in Finland and to evaluate whether the proportions of different treatment methods have changed from 1998 through 2011.

MATERIALS AND METHODS

For the purpose of this study, femoral neck fracture patients were obtained from the Finnish National Hospital Discharge register (NHDR). The Finnish NHDR is a mandatory national register for all hospitals encompassing private, public, and other institutions. The data in the NHDR includes variables such as patient identification number; sex; domicile of the subject; duration and type of hospital stay; external cause for injury; primary, secondary, and tertiary diagnosis; and all procedures performed during the stay. The coverage and accuracy of the NHDR injury data is excellent [18, 19].

In this study, all patients 50 years of age or older with femoral neck fracture code S72.0 (10th version of International Classification of Diseases, ICD-10, 1994) and valid surgical procedure code between January 1, 1998 and December 31, 2011 were included. The surgical procedures were identified by using the Finnish version of the Nordic Medico-Statistical Committee (NOMESCO) Classifications' Procedural codes and the following procedures were established: uncemented HA, cemented HA, THA, and internal fixation (Table 1).

To calculate the incidence ratios of surgically treated femoral neck fractures, the annual mid-population of Finland was obtained from the Official Statistics of Finland, a statutory electronic population register of the country. The rates of surgically treated femoral neck fractures (per 100,000 persons) were based on the entire adult (50-year-old and older) population of Finland rather than sample- or cohort-based estimates and thus 95% confidence intervals were not calculated. The population was categorized into five age-based classes (50-59, 60-69, 70-79, 80-89, and ≥90) for further analyses. No exclusion criteria were used other than age under 50 years. Statistical analyses were performed using IBM SPSS Statistics version 21.

RESULTS

During the study period between 1998 and 2011, a total of 49,514 patients 50 years of age and older underwent surgery for femoral neck fracture. Mean patient age was 79.2 years (range: 50-106) and 35,376 of them (71.4%) were women. Patients aged 80 to 89 years comprised the largest group (21,822; 44.1%). During the entire study period, the most common surgical procedure was cemented HA (28,613; 57.8%), followed by internal fixation (11,189; 22.6%), uncemented HA (6618; 13.4%), and THA (3094; 6.2%).

From 1998 through 2005, there was a modest decline in uncemented HA procedures (from 13.5% to 8.1%) and a slight increase in cemented HA procedures (from 56.2% to 63.9%). No major changes were noted in internal fixation (from 24.9% to 23.2%) or THA (from 5.4% to 4.9%) procedures during the same time period (Figure 1).

From 2005 through 2011, the proportions of uncemented HA and THA procedures increased from 8.1% to 22.2% and from 4.9% to 9.2%, respectively. In contrast, the proportions of cemented HA and internal fixation procedures decreased from 63.9% to 52.5% and 23.2% to 16.1%, respectively (Figure 1).

Age-specific results from 1998 through 2011

A separate analysis of the youngest age-group (50 to 59 years) revealed only minor changes in the use of uncemented HA and cemented HA. The proportion of internal fixation procedures, however, declined from 62.9% to 40.3%, while the proportion of THA procedures increased from 15.7% to 29.6%. No marked changes occurred in the proportion of uncemented HA (from 6.3% to 9.7%) or cemented HA (from 15.1% to 20.4%) procedures.

Persons aged 60 to 69 years showed a substantial proportional decline in internal fixation (from 39.2% to 23.7%) and an increase in THA (from 14.1% to 29.9%). The proportions of cemented HA (from 38.1% to 34.3%) and uncemented HA (from 8.6% to 12.1%) remained unaltered.

In patients 70 to 79 years of age, there was an increase in the proportions of uncemented HA procedures from 14.6% to 24.1% and in THA procedures from 6.3% to 11.4%, whereas there was a decrease in cemented HA procedures from 55.2% to 47.0% and in internal fixation from 23.9% to 17.5%.

In patients 80 to 89 years, uncemented HA procedures nearly doubled from 14.4% to 25.3%, while there were no marked changes in cemented HA (from 63.0% to 60.1%) and THA (2.5% to 2.9%) procedures. Internal fixation was used less frequently in 2011 (11.8%) than in 1998 (20.2%).

In the oldest age group (90+ years), there was a moderate increase in uncemented HA from 14.5% to 21.4%, and a decrease in internal fixation from 16.6% to 12.2%. The incidence of cemented HA (67.4% to 64.6%) and THA (1.5% to 1.7%) procedures did not change markedly.

DISCUSSION

Our nationwide study showed that the proportion of uncemented HA procedures for the treatment of femoral neck fractures increased nearly three-fold from 8.1% to 22.2% from 2005-2011, while the proportion of cemented HA procedures declined. The increased proportion of uncemented HA procedures was mainly due to the increase in patients over 70 years of age. This finding is interesting, although not consistent with the evidence from previous randomized controlled trials favoring cemented HA. The reason for the shift from cemented HA to uncemented HA procedures remains unknown. We may speculate that the shorter operation time and reduced cardiovascular effects associated with uncemented HA are contributing factors to this shift [20, 21]. Better implant availability and more active marketing systems for modern uncemented stems may have also contributed to the change.

Accumulating evidence indicates that assessment of a patient's physiologic age is essential in deciding between the procedures [15]. A patient's medical comorbidities and previous activity level should also be taken into account. Each procedure has limitations and its own complication spectrum, and some complications are associated with poor bone quality and osteoporosis. In the case of an old fragile patient with a non-displaced femoral neck fracture, the surgeon must choose between internal fixation and HA. In chronologically or physiologically young patients, internal fixation should be used to retain the indigenous hip joint, especially in previously symptomless patients.

In cases of displaced femoral neck fracture, patient characteristics are important. In a prospective study of 60 cognitively impaired patients older than 70 years, displaced femoral neck fractures treated by cemented HA provided a safe option with better health-related quality of life and less risk for reoperation compared to internal fixation [22]. A recent randomized controlled trial revealed that HA has predictable and good long-term results after femoral neck fracture and is the treatment of choice compared with internal fixation [23]. In displaced fractures, results of HA in the worst cases have reported to be better than those of internal fixation in the best cases [24]. While younger healthy patients should be treated with internal fixation or THA to avoid further complications related to HA over time, older fragile patients who have significant medical comorbidities should be treated with HA.

HA is the most common treatment for displaced femoral neck fractures in elderly adults. The Cochrane review published in 2010 concluded that patients with cemented HA experienced less pain at 1 year or later and had improved postoperative mobility compared with patients having uncemented HA, while mortality and surgical complications were not significantly different between these groups [25]. A recent systematic review concluded that cemented HA reduces the risk of residual pain and provides better functional outcomes [26]. Furthermore, cemented HA was not associated with higher mortality, reoperation, or complications. Also, the latest meta-analysis concluded that the available evidence indicates that cemented HA procedures can achieve better hip function, lower residual pain, and less implant-related complications with no increased risk of mortality, cardiovascular and cerebrovascular complications, general complications, local complications, or reoperation rate in elderly patients with femoral neck fractures [27]. A point worth noting, however, is that most of the randomized controlled trials included in the systematic review and meta-analysis were conducted using traditional uncemented stems and thus the results cannot be directly generalized to the newer stems.

Recently published randomized trials provide somewhat contradictory answers to the question of whether to use cemented or uncemented implants. A 5-year follow-up of a randomized trial with modern stems demonstrated a higher hip score for uncemented HA, but also increased risk of later femoral fractures [28]. Furthermore, two randomized controlled trials conducted by comparing modern uncemented and cemented stems concluded that both methods lead to equivalent functional results [14, 21]. In patients 70 years or older, uncemented and cemented HAs were comparable with regard to pain, but implant-related complications were significantly lower in patients treated with cemented HA [13]. Thus, according to the latest available data, we suggest that functional outcomes of modern-design uncemented and cemented stems are similar, but implant-related complications are higher in uncemented HA.

Another important finding was the increased use of THA for the treatment of femoral neck fracture from 4.9% to 9.2%. This increase was especially observable in younger patients aged 50-69 years. In patients 80 years of age or older, there was no such change. A recent meta-analysis revealed no difference in mortality, infections, or general complications between patients undergoing HA and THA, but demonstrated a significant increase in the dislocation rate for THA. Based on the evidence patients may benefit from THA compared with HA, despite an increased dislocation rate [17]. The latest systematic review indicated that THA may lead to better patient-related outcomes in fit patients, but has a higher dislocation rate compared to HA [16].

Our data showed an increased use of THA for femoral neck fractures, especially in younger patients. At the same time, internal fixation became less popular. It appears that active young patients should be treated with internal fixation especially in cases of non-displaced fractures, but poor reduction and posteroinferior displacement of the femoral head increase the rate of nonunion [29]. Therefore, THA may have a role in the treatment of femoral neck fractures in younger age groups if the fracture is highly displaced and the potential for anatomic reduction with suitable internal fixation is excluded.

Our third finding showed a decrease in use of internal fixation from 24.9% to 16.1% annually from 1998 to 2011. Patients aged 50-79 years accounted for the major decrease in the incidence and proportion of internal fixation procedures. Thus, internal fixation has limitations for femoral neck fracture treatment, especially in older adults. First, elderly patients with osteoporosis and poor bone quality demonstrate a higher risk of nonunion [30]. Second, internal fixation is an appropriate treatment method for non-displaced Garden I and II femoral neck fractures only [31]. Third, complication and reoperation rates are markedly higher in older patients treated with internal fixation [31–33]. It is unclear why the trend toward internal fixation procedures is decreasing, especially in younger patients. We suspect that the improved THA survivorship and the potential risk of early re-operation related to internal fixation play a role.

A limitation of our study was that we were not able to assess a detailed classification of the femoral neck fractures or patients' physical activity. Thus, we could draw no conclusion about whether the surgical method or implant used was according to current treatment concepts. A major strength of the study was that true nationwide data were used, as medical treatment in Finland is equally available to everyone and the study population comprised the entire Finnish adult population over the age of 50 years. Thus, with coverage of an entire country, including all hospitals, the changes in the trends of a treatment method obviously represent the general opinion of all actively practicing orthopedic surgeons in Finland. A second strength was that during the study period there were no changes in diagnostics, ICD-coding, or hospital registry. Finally, another strength of the present study is that the coverage and accuracy of the NHDR injury codes are excellent [18, 19].

In conclusion, the age-adjusted incidence and proportion of uncemented HA procedures performed for femoral neck fractures increased considerably in Finland between 2005 and 2011, whereas the use of cemented HA and internal fixation procedures declined during the same period. During the same period, the use of THA nearly doubled, although the procedure was yet rather uncommon in 2011. Thus, the current evidence-based guidelines for treatment of femoral neck fractures were mainly followed in Finland, although the increased use of uncemented HA contradicts recent scientific evidence.

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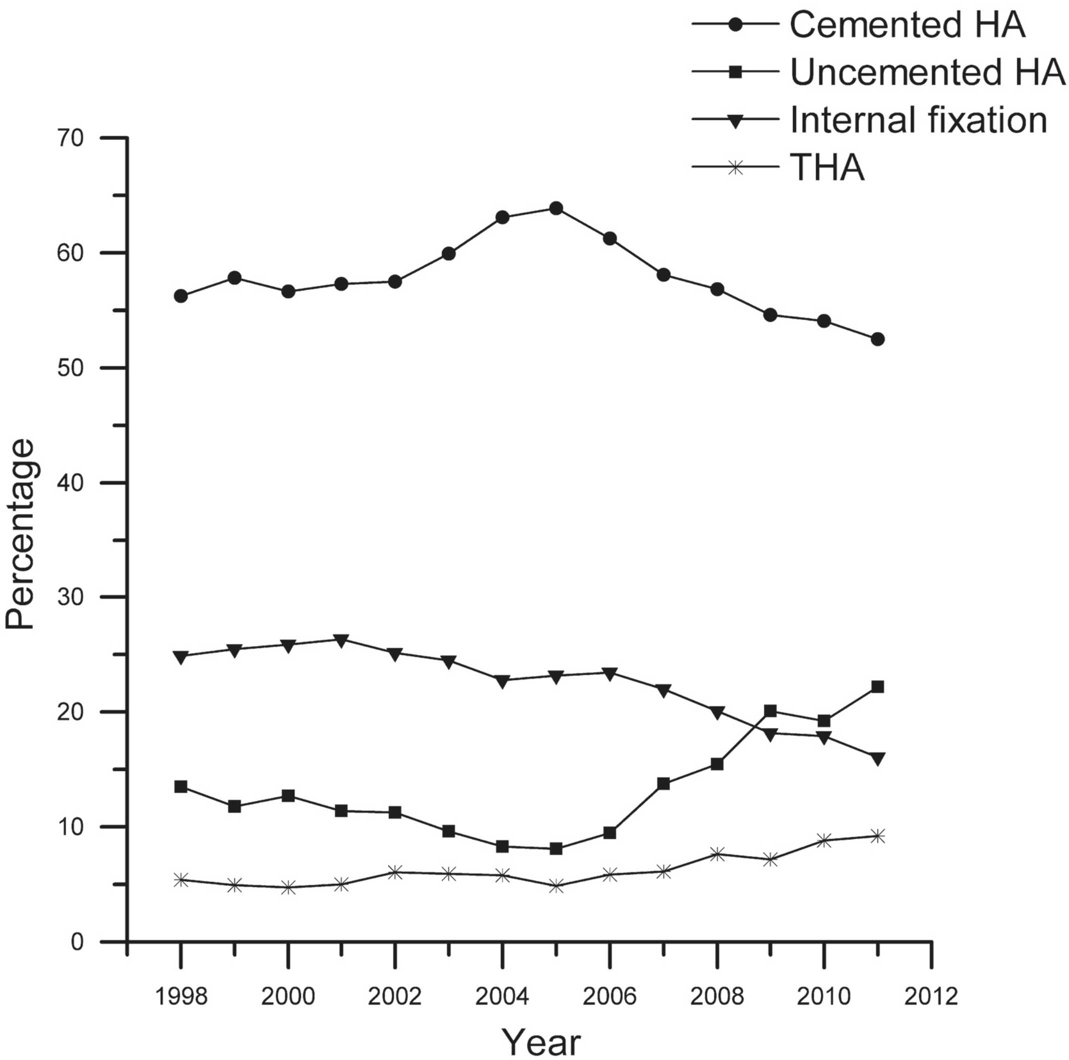
Table 1 The procedural (NOMESCO) codes used in the study

Code	**The Procedure**
NFB10	Primary partial prosthetic replacement of hip joint not using cement
NFB20	Primary partial prosthetic replacement of hip joint using cement
NFB30	Primary total prosthetic replacement of hip joint not using cement
NFB40	Primary total prosthetic replacement of hip joint using hybrid technique
NFB50	Primary total prosthetic replacement of hip joint using cement
NFJ50	Internal fixation of fracture of neck of femur with nail or screw
NFJ52	Internal fixation of fracture of upper femur with screws and sideplate
NFJ54	Internal fixation of fracture of upper femur with intramedullary nail
NFJ64	Other internal fixation of other parts of femur

Fig 1 Percentage distribution of femoral neck fracture procedures in Finland from 1998 through 2011. HA= hemiarthroplasty, THA= total hip arthroplasty.



PUBLICATION
II

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RESEARCH ARTICLE Open Access

Does cognitive/physical screening in an outpatient setting predict institutionalization after hip fracture?

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Abstract

Background: Institutionalization after hip fracture is a socio-economical burden. We examined the predictive value of Instrumental Activities of Daily Living (IADL) and Mini Mental State Examination (MMSE) for institutionalization after hip fracture to identify patients at risk for institutionalization.

Methods: Fragility hip fracture patients ≥65 years of age ($n = 584$) were comprehensively examined at a geriatric outpatient clinic 4 to 6 months after surgery and followed 1 year postoperatively. A telephone interview with a structured inquiry was performed at 1, 4, and 12 months after hip fracture.

Results: Age-adjusted univariate logistic regression analysis revealed that IADL and MMSE scores measured at the outpatient clinic were significantly associated with living arrangements 1 year after hip fracture. Multivariate logistic regression analysis established that institutionalization 1 year after hip fracture was significantly predicted by institutionalization at 4 months (odds ratio [OR] 16.26, 95 % confidence interval [CI] 7.37–35.86), IADL <5 (OR 12.96, 95 % CI 1.62–103.9), and MMSE <20 (OR 4.19, 95 % CI 1.82–9.66). A cut-off value of 5 was established for IADL with 100 % (95 % CI 96 %–100 %) sensitivity and 38 % (95 % CI 33 %–43 %) specificity and for MMSE, a cut-off value of 20 had 83 % (95 % CI 74 %–91 %) sensitivity and 65 % (95 % CI 60 %–70 %) specificity for institutionalization. During the time period from 4 to 12 months, 66 (11 %) patients changed living arrangements, and 36 (55 %) of these patients required more supportive accommodations.

Conclusion: IADL and MMSE scores obtained 4 to 6 months after hospital discharge may be applicable for predicting institutionalization among fragility hip fracture patients ≥65 years of age at 1 year after hip fracture. An IADL score of ≥5 predicted the ability to remain in the community. Changes in living arrangements also often occur after 4 months.

Keyword: Hip fracture, IADL, MMSE, Living arrangements, Institutionalization, Rehabilitation

Background

Hip fracture is a devastating event for older people that leads to increased risk of death and disability [13, 18]. Only half of the survivors rehabilitate to the level of previous mobility and activities of daily living (ADL) [15]. The age-adjusted incidence of fall-induced hip fractures has been decreasing in Western countries, yet the total number of hip fractures will rise due to the rapid growth of the older population [10]. In addition, comorbidities among hip fracture patients have been increasing at least since 1986 [3]. Mortality is high within the first year after hip fracture, and the increase in mortality continues until 5 years after hip fracture [5, 12].

Although several comorbidities and predictive factors for survival following hip fracture have been reported, there have been few clinical studies, especially prospective studies, regarding the role of mobility, need for assistance, and living arrangements in hip fracture mortality and disability. Risk factors for institutionalized living arrangements have been reported: increased age, admission from a care facility, high number of medications, pre-injury

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dependence, male sex, dementia, and a lower pre-fracture level of ADL [4, 22, 23].

Assessment of survivor health condition is crucial for allocating public health care resources to patients at risk for institutionalization. The ideal clinical test for recognizing hip fracture patients at risk for institutionalization would be easy to conduct, reliable, and inexpensive, with excellent sensitivity or specificity. Optimal predictive tests could be carried out as soon as possible after hip fracture, because the rehabilitation program should begin as soon as possible after hip fracture surgery. Recovery after surgery differs comprehensively and clinical tests conducted within the first few weeks after surgery may have reliability problems, especially in patients with surgical complications or mental disorientation. Therefore, clinical tests performed a few months later to predict those hip fracture patients at risk of institutionalized living arrangements could be useful, especially in cases of previously independent patients. The Instrumental Activities of Daily Living (IADL) assessment and Mini Mental State Examination (MMSE) carried out 4 to 6 months after hip fracture are clinical tests that may predict living arrangements 1 year after hip fracture. The IADL assesses the complex skills needed to successfully live independently, such as the ability to prepare meals, use the telephone, manage medications, travel in the community, and perform housework and basic home maintenance [11]. The MMSE is a quantitative measure of cognitive status in adults. It can be used to screen or estimate the severity of cognitive impairment at a given time-point [6].

The purpose of the present study was to examine the IADL and MMSE, as part of a comprehensive outpatient assessment 4 to 6 months after hip fracture, as predictors of living arrangements 1 year after hip fracture.

Methods

A prospective population-based observational cohort study of 1033 consecutive hospital admissions of patients aged ≥65 years with hip fracture was conducted during the study period between April 1, 2008, and May31, 2013. Only the first hip fracture in each patient during the follow-up period was included. Pathologic and periprosthetic fractures were excluded. The referral area for hip fracture patients was the Hospital District of Southern Ostrobothnia, Finland, which has a population of 193,977. Residents ≥65 years of age represent 21 % of the total population according to Official Statistics of Finland, a statutory electronic population register. All patients who sustained a hip fracture inside referral area were admitted and underwent surgery at Seinäjoki Central Hospital.

For the purpose of the study, patients who were considered institutionalized, such as living in a health care center hospital or a care home providing 24-h care at baseline were excluded from the study. Other living arrangements were defined as living independently in their own home, living in their own home with organized home care, or living in an assisted living accommodation. Data on deaths were obtained from the Official Cause of Death Statistics of Finland, which covers essentially 100 % of the deaths in Finland

The flow chart of the patient population is shown in Fig. 1. In all, 584 (70 %) patients completed the study with 12 months of follow-up and constituted the study

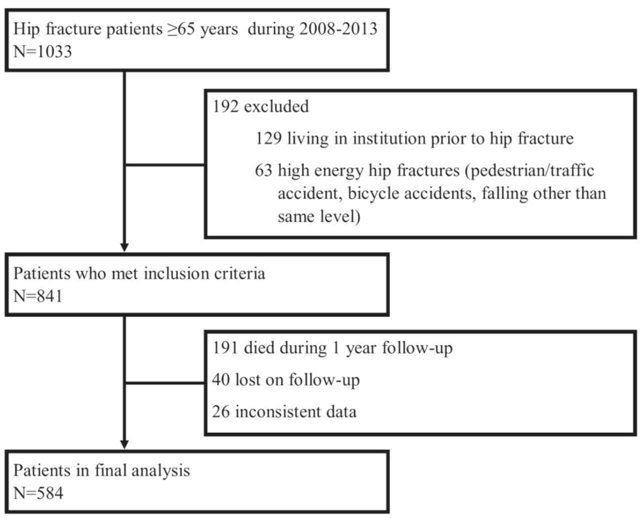

Fig. 1 Study flow chart

Table 1 Patient characteristics on admission ($n = 841$) and information of the 584 analyzed patients followed by baseline comparison between not institutionalized and institutionalized patients 1 year after hip fracture

			1 Year ($n = 584$)		
	Entire Cohort ($n = 841$)	Patients in Primary Analysis ($n = 584$)	Not institutionalized ($n = 457$)	Institutionalized ($n = 127$)	*P*-value
Variable	n (%)	n (%)	n (%)	n (%)	
Age					<0.001
65–74	117 (13.9)	87 (14.9)	81 (17.7)	6 (4.7)	
75–84	352 (41.9)	268 (45.9)	213 (46.6)	55 (43.3)	
> 85	372 (44.4)	229 (39.2)	163 (35.7)	66 (52.0)	
Mean (SD)	82.8 (7.1)	81.9 (6.77)	81.2 (6.8)	84.4 (6.1)	<0.001
Median (25–75 % percentile)	84.0 (78–88)	83.0 (77–87)	82.0 (76–86)	85.0 (81–88)	<0.001
Sex					0.352
Female	624 (74.2)	456 (78.1)	353 (77.2)	103 (81.1)	
Male	217 (25.8)	128 (21.9)	104 (22.8)	24 (18.9)	
Living with somebody					0.007
Yes	502 (59.7)	325 (55.7)	241 (52.7)	84 (66.1)	
No	339 (40.3)	259 (44.3)	216 (47.3)	43 (33.9)	
Mobility aids before hip fracture					0.012
Mobile without an aid	333 (39.6)	258 (44.2)	214 (46.8)	44 (34.6)	
Mobile with an aid	495 (58.9)	320 (54.8)	240 (52.5)	80 (63.0)	
Unable to ambulate	11 (1.3)	6 (1.0)	3 (0.7)	3 (2.4)	
Missing information	2 (0.2)				
Mobility level before hip fracture					<0.001
Unassisted outdoors	499 (59.3)	393 (67.3)	349 (76.4)	44 (34.6)	
Assisted outdoors	101 (12.0)	63 (10.8)	33 (7.2)	30 (23.6)	
Unassisted indoors	197 (23.4)	108 (18.5)	66 (14.4)	42 (33.1)	
Assisted indoors	28 (3.3)	13 (2.2)	6 (1.3)	7 (5.5)	
Unable to move	12 (1.4)	7 (1.2)	3 (0.7)	4 (3.1)	
Missing information	4 (0.5)				
Previous living arrangements					<0.001
Own home	390 (46.4)	293 (50.2)	263 (57.5)	30 (23.6)	
Own home with organized home care	265 (31.5)	193 (33.0)	141 (30.9)	52 (40.9)	
Assisted living accommodation	186 (22.1)	98 (16.8)	53 (11.6)	45 (35.4)	
Previous diagnosis of memory disorder					<0.001
Yes	180 (21.4)	120 (20.5)	63 (13.8)	57 (44.9)	
No	657 (78.1)	462 (79.1)	392 (86.2)	70 (55.1)	
Missing information	4 (0.5)	2 (0.3)			
Number of medications on admission					0.068
< 4	169 (20.1)	135 (23.1)	115 (25.2)	20 (15.7)	
4–10	531 (63.1)	366 (62.7)	281 (61.5)	85 (66.9)	
> 10	141 (16.8)	83 (14.2)	61 (13.3)	22 (17.3)	
Previous fracture of any bone					0.927
Yes	264 (31.4)	182 (31.2)	142 (31.1)	40 (31.5)	
No	576 (68.5)	402 (68.8)	315 (68.9)	87 (68.5)	
Missing information	1 (0.1)				

Table 1 Patient characteristics on admission ($n = 841$) and information of the 584 analyzed patients followed by baseline comparison between not institutionalized and institutionalized patients 1 year after hip fracture *(Continued)*

Hip fracture type					0.979
Femoral neck fracture	539 (64.1)	380 (65.1)	298 (65.2)	82 (64.6)	
Pertrochanteric fracture	259 (30.8)	180 (30.8)	140 (30.6)	40 (31.5)	
Subtrochanteric fracture	43 (5.1)	24 (4.1)	19 (4.2)	5 (3.9)	
ASA grade					0.002
1–2	114 (13.6)	95 (16.3)	87 (19.1)	8 (6.4)	
3	517 (61.5)	386 (66.1)	290 (63.7)	96 (76.8)	
4–5	197 (23.4)	99 (17.0)	78 (17.1)	21 (16.8)	
Missing information	13 (1.5)	4 (0.6)			

Institution represents hospital, health care center hospital, nursing home or rehabilitation unit providing 24-h care
Instrumental Activities of Daily Living (IADL), Mini Mental State Examination (MMSE), and American Society of Anesthesiologists (ASA) scores. Differences were tested for continuous age by Mann-Whitney U-test and median test. Categorical variables were tested by Pearson chi-square test or Fisher's exact test

population. The mean time from the hip fracture to an outpatient clinic visit was 5.1 (standard deviation 2.0) months with a median of 5 months (25–75 interquartile range: 4–6).

Patient information was collected using predefined inquiries and procedures on admission and a telephone interview was conducted by the same study nurse at 1, 4, and 12 months after surgery. To collect as accurate data as possible, we used data sheets modified from the British Hip Fracture Database [2]. If the patient was unable to provide the information, we used proxy respondents. Family members, friends, and nurses from an institution constituted the proxies. In addition, all patients, regardless of their place of residence, were invited to the geriatric outpatient clinic for comprehensive clinical assessment with a target time between 4 and 6 months after the fracture.

The primary outcome variable was living arrangements 1 year after hip fracture, which was categorized into two groups: not institutionalized (with or without organized home care in their own home or an assisted living accommodation) or institutionalized. IADL and MMSE performed at the outpatient visit were evaluated as predictor variables for living arrangements 1 year after the hip fracture. The Lawton-Brody IADL scale measures eight functional domains. IADL and MMSE were categorized in a dichotomous manner by using the best cut off value from the ROC analysis in this study, 5 and 20 respectively. Mobility aids were registered in the database as follows: independent, a cane, canes, folding or rollator walker, wheelchair, or immobile and bedbound. In this study, we categorized the need of mobility aids into mobile without an aid, mobile with an aid, or unable to ambulate. Further, the mobility level was classified as unassisted or assisted outdoors, unassisted or assisted indoors, and unable to move. Patients with an American Society of Anesthesiologists (ASA) grade of I or II were combined into one group because there were so few grade I patients ($n = 3$). Likewise, patients with an ASA grade of IV or V were combined because the number of patients with an ASA grade V, a moribund sub-population not expected to live 24-h with or without surgery, was also very small.

Statistical differences between categorical variables were calculated using Pearson's chi-square test or Fisher's exact. A P-value ≤0.05 was considered statistically significant. Institutionalized living arrangements 1 year after hip fracture were analyzed with age-adjusted univariate logistic regression analysis, and odds ratios (ORs) with 95 % confidence intervals (CI) for each variable were calculated. Multivariate logistic regression analysis using the enter (all variables included simultaneously into the model) method was used to investigate the independent effects of each statistically significant variable, except MMSE as measured at the outpatient clinic was used instead of previous diagnosis of memory disorder.

Receiver operating characteristics (ROC) analysis was used to compare the predictive power. The area under the curve (AUC) was calculated. A perfect model will score an AUC of 1, while random guessing will score an AUC of ~0.5. An AUC of 0.7 to 0.8 is considered to have good predictive power, that of 0.8 to 0.9 is considered to have excellent predictive power, and that >0.9 is considered to have outstanding predictive power. Sensitivity, specificity, positive (PPV) and negative (NPV) predictive values, and ORs were calculated with 95 % CI.

Survival analysis was conducted with age- and sex-adjusted Cox regression models to determine hazard ratios (HRs) for death 1 year after hip fracture. For this analysis, we used the study population ($n = 841$) that met the inclusion criteria. All statistical analyses were performed using SPSS version 21.

Table 2 Age adjusted univariate and multivariate logistic regression analysis demonstrating institutionalization at 1 year after hip fracture

		Age-adjusted univariate $n = 584$				Multivariate $n = 472$		
Variable	n	OR (95 % CI)		*P*	n	OR (95 % CI)		*P*
Living arrangements at 1 months								
Own home or assisted living accommodation	260	1.00			219	1.00		
Institution [a]	324	3.81	(2.34–6.16)	<0.001	253	1.56	(0.67–3.63)	0.304
Living arrangements at 4 months								
Own home or assisted living accommodation	463	1.00			393	1.00		
Institution [a]	121	33.24	(19.39–56.00)	<0.001	79	16.26	(7.37–35.86)	<0.001
IADL	487	2.54	(2.00–3.22)	<0.001				
5–8	199	1.00			197	1.00		
0–4	288	73.11	(10.03–532)	<0.001	275	12.96	(1.62–103.9)	0.016
MMSE		1.22	(1.16–1.27)	<0.001				
20–30	305	1.00			197	1.00		
0–19	180	9.00	(4.93–16.43)	<0.001	175	4.19	(1.82–9.66)	0.001
Age								
65–74	87	1.00			78	1.00		
75–85	268	3.49	(1.45–8.41)	0.005	221	1.12	(0.31–4.11)	0.865
> 85	229	5.47	(2.27–13.14)	<0.001	173	1.29	(0.35–4.71)	0.915
Mobility aids before fracture								
Mobile without an aid	258	1.00						
Mobile with an aid	320	1.23	(0.78–1.89)	0.360				
Unable to ambulate	6	5.03	(0.93–27.14)	0.061				
Mobility level before fracture								
Unassisted outdoors	393	1.00			343	1.00		
Assisted outdoors	63	6.18	(3.41–11.21)	<0.001	46	1.39	(0.53–3.65)	0.510
Unassisted indoors	108	4.27	(2.56–7.11)	<0.001	68	0.93	(0.37–2.34)	0.879
Assisted indoors	13	8.23	(2.61–25.98)	<0.001	8	0.96	(0.14–6.53)	0.968
Unable to move	7	12.04	(2.53–57.23)	0.002	7	0.89	(0.11–7.04)	0.914
Previous living arrangements								
Own home	298	1.00			256	1.00		
Own home with organized home care	193	2.74	(1.65–4.55)	<0.001	153	1.14	(0.48–2.76)	0.764
Assisted living accommodation	98	6.16	(3.51–10.81)	<0.001	63	1.17	(0.40–3.40)	0.777
Living with somebody								
Yes	325	1.00			253	1.00		
No	259	0.51	(0.34–0.78)	0.002	219	0.79	(0.33–1.87)	0.589
ASA grade								
1–2	95	1.00			79	1.00		
3	386	2.87	(1.32–6.20)	0.008	319	1.14	(0.33–3.97)	0.834
4–5	99	2.10	(0.86–5.12)	0.103	74	0.24	(0.05–1.13)	0.071
Medications on admission								
< 4 medicine	135	1.00			108	1.00		
4–10 medicine	366	1.76	(1.03–3.03)	0.040	297	1.01	(0.38–2.69)	0.991
> 10 medicine	83	2.06	(1.03–4.12)	0.041	67	1.72	(0.48–6.18)	0.406

Table 2 Age adjusted univariate and multivariate logistic regression analysis demonstrating institutionalization at 1 year after hip fracture *(Continued)*

Previous fracture of any bone				
Yes	182	1.00		
No	402	0.93	(0.60–1.43)	0.732
Gender				
Female	456	1.00		
Male	128	0.94	(0.59–1.63)	0.871
Hip fracture type				
Femoral neck fracture	380	1.00		
Pertrochanteric fracture	180	0.95	(0.61–1.47)	0.819
Subtrochanteric fracture	24	1.05	(0.37–2.97)	0.930

[a]Institution represents hospital, health care center hospital, nursing home, or rehabilitation unit providing 24-h care
Instrumental Activities of Daily Living (IADL), Mini Mental State Examination (MMSE), and American Society of Anesthesiologists (ASA) score. Results are shown as odds ratios (OR) with 95 % confidence intervals (CI). Statistically significant age adjusted variables from univariate logistic regression analysis were admitted to multivariate regression analysis

Results

Mean patient age was 81.9 (SD 6.8) years, and 456 (78 %) of the 584 patients were women. In all, 380 (65 %) patients had a femoral neck fracture, 180 (31 %) had a pertrochanteric fracture, and 24 (4.1 %) a subtrochanteric fracture. Details of the baseline patient characteristics are provided in Table 1.

Age-adjusted univariate logistic regression analysis indicated that institutionalized living arrangements at 1 or 4 months, IADL and MMSE performed at the outpatient clinic, mobility level or living arrangements before fracture, living with somebody, ASA grade, age, and the number of medications on admission predicted living arrangements at 1 year after hip fracture (Table 2).

Multivariate logistic regression revealed institutionalized living arrangements at 4 months (OR 16.26, 95 % CI 7.39–35.86), IADL < 5 (OR 12.96, 95 % CI 1.62–103.9), and MMSE < 20 (OR 4.19, 95 % CI 1.82–9.66) were independently significant predictors for institutionalization (Table 2).

ROC analysis revealed excellent discrimination for the IADL (0.88, 95 % CI 0.85–0.91) and MMSE (0.83, 95 % CI 0.79–0.86; Fig. 2). With regard to institutionalization, a cut-off value of 5 was established for IADL with 100 % (95 % CI96%–100 %) sensitivity and 38 % (95 % CI 33 %–43 %) specificity, which lead to a PPV of 0.251 and NPV of 1.00. The OR could not be calculated, because no patient with an IADL score of ≥5 was institutionalized when the 95 % CI was used. For the MMSE, a cut-off value of 20 had 84 % (95 % CI 74 %–91 %) sensitivity and 65 % (95 % CI 60 %–70 %) specificity with a PPV of 0.317 and an NPV of 0.953. An OR of 9.4 (95 % CI 5.0–17.7) was determined for institutionalization. Alternative cut-off values with detailed statistical information are provided in Table 3.

Overall mortality during the 12-month follow up was 23 % ($n = 191$). The highest proportional mortality 62 % ($n = 119$) was observed within the first 3 months, followed by 16 % ($n = 31$) proportional mortality between 3 to 6 months after hip fracture. During the 6 to 9 months and 9 to 12 months after hip fracture, the proportional mortality was 7.9 % ($n = 15$) and 14 % ($n = 26$), respectively. Age- and sex-adjusted Cox regression models showed that institutionalization at 1 (HR 2.28, 95 % CI 1.47–3.54) and 4 (HR 3.50, 95 % CI 2.00–6.11) months after hip fracture considerably increased the HR for death 12 months after hip fracture.

The living arrangements were observed at 1, 4, and 12 months after hip fracture (Fig. 3). Changes in the living arrangements are shown in Fig. 4. One month after hip fracture, 324 (56 %) were institutionalized, of which 221 (68 %) had improved living arrangements at 4 months. Of the 260 patients living in their own home or in an assisted living accommodation prior to the hip fracture, 18 (6.9 %) were institutionalized at 4 months. Of the 121 patients institutionalized at 4 months, 30 (25 %) were able to live on their own or in an assisted living accommodation by 12 months. Of the 463 patients who were not institutionalized at 4 months, 36 (7.8 %) were institutionalized by 12 months. All changes in living arrangements were statistically significant. A total of 66 (11 %) patients changed their living arrangement during between 4 and 12 months after hip fracture.

Discussion

Our findings revealed that IADL and MMSE performed 4 to 6 months after hip fracture in older patients independently predicted institutionalized living arrangements 1 year after hip fracture. Further, an IADL cut-off value of ≥5 provided 100 % sensitivity and 38 % specificity for

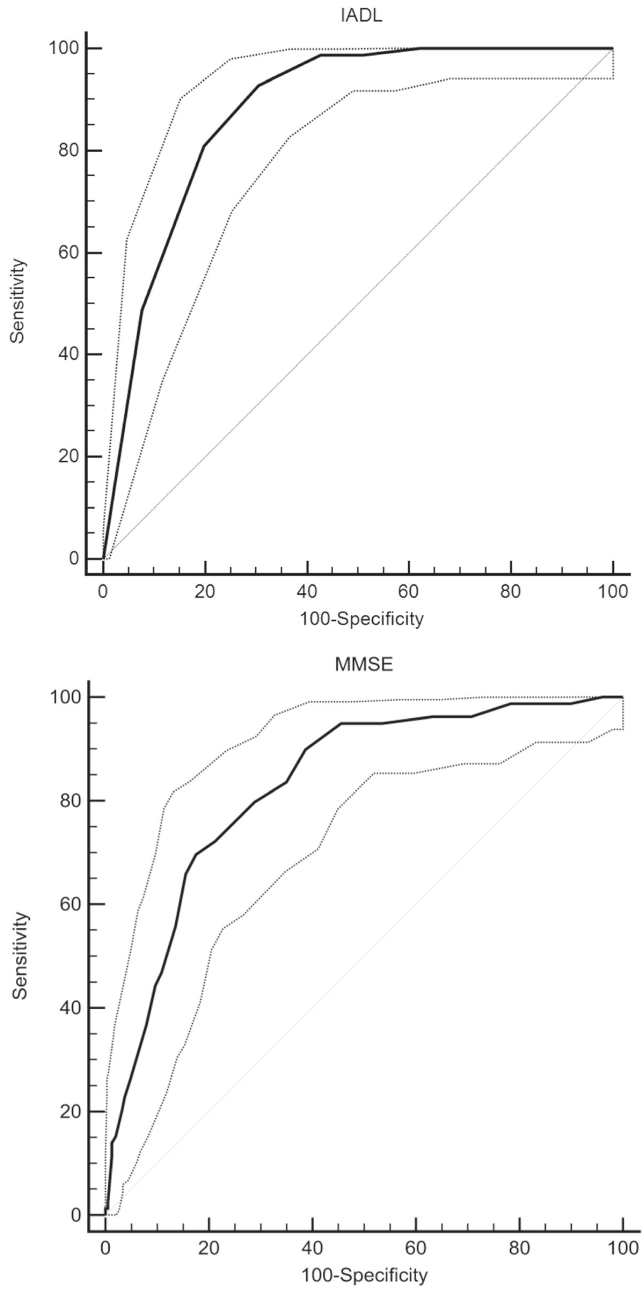

Fig. 2 ROC curves for IADL and MMSE with 95 % confidence interval

institutionalization. Thus, the IADL results identified patients at risk for institutionalized living. Mortality after hip fracture surgery was highest during the first 3 postoperative months and patients living in an institution 1 or 4 months after hip fracture had a higher HR for death. Further, rehabilitation occurred mostly within

Table 3 Receiver-operating characteristics (ROC) analysis. Cut-off values, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and odds ratios (ORs) with 95 % confidence intervals (95 % CI) for Instrumental Activities of Daily Living (IADL) and Mini Mental State Examination (MMSE) for predicting institutionalized living arrangement at 1 year after fragility hip fracture

Cut-offs	Sensitivity	Specificity	PPV	NPV	OR (95 % CI)
IADL					
2	92.9 %	69.5 %	0.388	0.979	29.6 (12.6–69.7)
3	98.8 %	57.3 %	0.325	0.996	111.5 (15.4–808.7)
4	98.8 %	49.1 %	0.288	0.995	80.2 (11.1–581.5)
5	100 %	38.0 %	0.251	1.000	Undefined
MMSE					
10	22.8 %	96.3 %	0.293	0.865	7.7 (3.7–16.1)
15	55.7 %	86.5 %	0.444	0.909	8.0 (4.7–13.6)
20	83.5 %	65.0 %	0.317	0.953	9.4 (5.0–17.7)
25	96.2 %	29.3 %	0.209	0.975	10.5 (3.3–34.0)

the first 4 months, and thereafter the cumulative changes in the living arrangements were minor.

We focused on finding statistically significant variables and cut-off values for older hip fracture patients at risk for institutionalization. A previous study reported significant improvement in IADL abilities between 3 months and 1 year after hip fracture [14]. On the other hand, a 1-year longitudinal study with 225 community residents aged ≥65 showed functional improvement at 2 months following post-acute rehabilitation with continued improvement up to 6 months, after which functional recovery slowed and remained constant through 12 months [24]. That study population, however, comprised patients with only subcapital hip fractures and the recovery patterns were heterogeneous, indicating that the study results cannot be generalized to all hip fracture patients. Heikkinen et al examined 196 consecutive hip fracture patients aged ≥50 years to compare functional

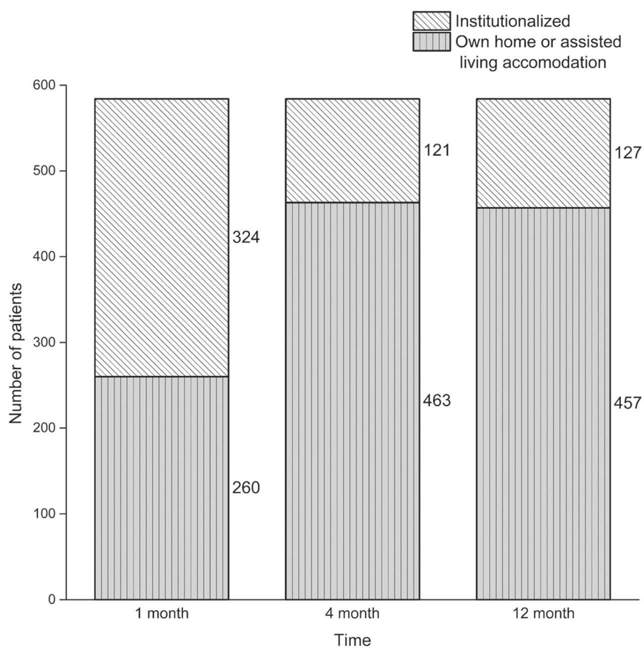

Fig. 3 The absolute number of patients with different living arrangements at 1, 4, and 12 months after hip fracture. Institutionalized represents hospital, health care center hospital, nursing home, or rehabilitation unit providing 24-h care

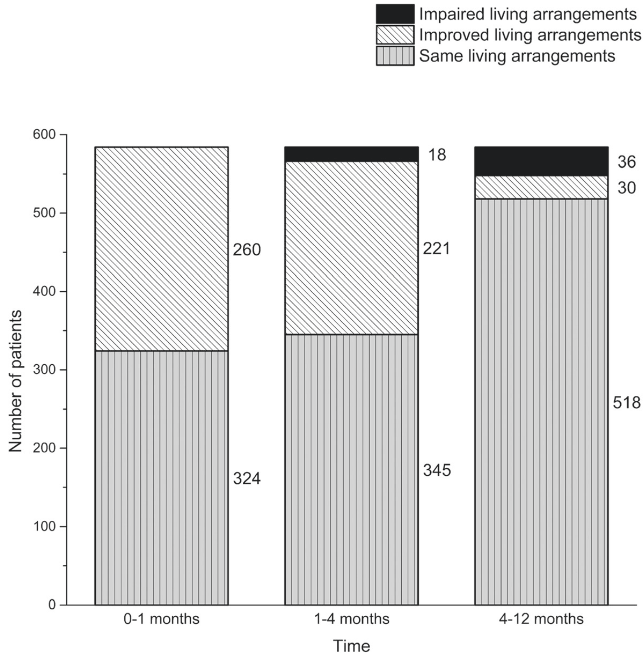

Fig. 4 Change in living arrangements between hospital discharge and 1, 4, and 12 months

outcome at 4 and 12 months after hip fracture. They concluded that a 4-month follow-up is the shortest possible period, because living arrangements and most functional outcomes do not change significantly after 4 months [8]. Our findings were similar within the first 4 months, but contradict the change in residential location thereafter; in our study population, 66 (11 %) changed living arrangements between 4 and 12 months.

The MMSE is the most commonly used instrument for screening cognitive function. Hip fracture is more common in older people with cognitive impairment, and hip fracture patients with cognitive impairment, including mild to moderate dementia benefit from postoperative geriatric rehabilitation [1, 16, 17, 20]. Further, a lower MMSE score increases the fall risk [7, 19]. In a randomized control trial, 173 patients with mild or moderate cognitive impairment (MMSE range 15–25) had a more than 7-fold increased risk for nursing home admission in the first year after hip fracture [21]. Our results are consistent with this finding when we applied a cut-off value of 20. Education level affects the MMSE score; a highly educated person with mild cognitive impairment may have a normal MMSE score, whereas a patient with less education will have a subnormal MMSE score [9]. ROC analysis established excellent discrimination for the MMSE and a cut-off value of 20 indicated strong (84 %) sensitivity, but only fair (65 %) specificity, with an OR 9.4 for institutionalization. With this cut-off value, the MMSE failed to predict institutionalization for 17 % of patients, but falsely predicted institutionalized living arrangements for 35 % of patients. Thus, setting optimal cut-off values remains controversial, though in the multivariate logistic regression analysis lower MMSE scores predicted institutionalization at 12 months. Increasing the cut-off value would increase false positives and decrease the true negative test results for institutionalization. Therefore, the ideal cut-off value cannot be confirmed.

Some baseline characteristics and clinical tests in the univariate analysis also predicted institutionalization, although they were inferior compared to the IADL and MMSE overall. Unexpectedly, the need for ambulatory aids before hip fracture did not predict institutionalization after adjusting for age (Table 2). Notably, only six patients among the patients who completed the study were unable to ambulate before hip fracture, and for this group the *p*-value for institutionalization was 0.061. Thus, according to our study, the need for ambulatory aids before fragility hip fracture did not markedly affect the living accommodations of hip fracture patients with the exception of immobile patients who had a moderate risk for more supported living arrangements in the future.

Chronologic age appeared to have a significant effect on living arrangements 1 year after hip fracture, but after adjusting for confounders, the effect of was no longer statistically significant. We believe that patients with several co-morbidities and impaired functional status prior to hip fracture are more likely to die within the first year after an accident. Thus, we suggest that survivors represent a sub-population younger in biologic age and in better health, which reduced the effects of increased chronologic age.

After adjusting for confounders, institutionalized living arrangements 1 month after hip fracture, in contrast to the 4-month living arrangements, did not predict institutionalization at 1 year after hip fracture. We conclude that rehabilitation after hip fracture proceeds favorably for at least first 4 months, but thereafter the recovery rate decreases and the risk for less independent living arrangements and death is increased. Therefore, we recommend that the most intensive rehabilitation continue for at least the first 4 months after hip fracture and then special attention should be focused on patients with known risk factors for institutionalization to avoid future institutionalized living arrangements.

This study has some limitations: 1) Dependence on data reported by patients or proxies, which might lead to under- or overestimation of patient mobility and living facilities; 2) Although we used pre-defined inquiries for the data collection, we could build a multivariate logistic regression model for only 472 (81 %) patients due to inconsistent data; 3) Living arrangements 1 and 4 months after hip fracture provide information only about institutionalization, and long-term care and rehabilitation were not differentiated; 4) Living arrangements and rehabilitation regimens after hip fracture differ greatly among countries, and the study results may not be universal. A major strength of the study was that the research material represented a population-based sample of older hip fracture patients. Finally, only 40 (4.8 %) patients were lost to follow-up and all patients inside the referral area were admitted and operated on at Seinäjoki Central Hospital, instead of multiple centers, which could lead to different surgical techniques and implant usage as well as different rehabilitation programs.

Conclusion

IADL and MMSE tests performed in fragility hip fracture patients ≥65 years of age 4 to 6 months after hospital discharge predicted institutionalization at 1 year after hip fracture. An IADL score of ≥5 predicted the ability to remain in the community. Changes in residential location occurred mainly within the first 4 months, but changes in living arrangements were also observed from 4 to 12 months, indicating the need for screening methods to detect hip fracture patients at greater risk of institutionalization.

Abbreviations

ADL: Activities of daily living; ASA-grade: American society of anesthesiologists grade; AUC: Area under the curve; HR: Hazard ratio; IADL: Instrumental activities of daily living; MMSE: Mini mental state examination; NPV: Negative predictive value; PPV: Positive predictive value; ROC: Receiver operating characteristics

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Availability of data and materials

The datasets supporting the conclusions of this article are not available in an open access repository, because datasets contain direct or indirect identifiers and there is possibility that participants will not be fully anonymous. Informed consent was obtained for publication of study results, but not for publication of patient raw-data separately. Further, the data used in this study is a part of a clinical quality register of Seinäjoki Central Hospital and is continuously being updated. If anyone is interested in exploring specific issue, please contact Maria Nuotio, MD, PhD.

Authors' contributions

MH, MN, and HP were in charge and contributed to all stages of the present study. MN was responsible for the original data collection. TL contributed to interpreting the data and writing the final manuscript. OV contributed to reviewing the accuracy of the data and writing the final manuscript. All authors read and approved the final manuscript.

Competing interest

We declare that we do not have any conflicts of interest.

Consent for publication

Not applicable.

Ethics approval and consent to participate

The study design was approved by the Ethical Committee of the Hospital District of Southern Ostro-Bothnia. All participants gave informed consent.

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PUBLICATION
III

Lateral and posterior approaches in hemiarthroplasty

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Original Research Article

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LATERAL AND POSTERIOR APPROACHES IN HEMIARTHROPLASTY

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ABSTRACT

Purpose: **Hemiarthroplasty is a common treatment for patient with a fragility displaced femoral neck fracture. We compared lateral and posterior approaches with respect to need for mobility aids, mobility level, living arrangements, pain, hip dislocation, and survival 12 months after hip fracture.**

Methods: **A total of 393 fragility femoral neck fracture patients aged 65 years or more who underwent hemiarthroplasty were observed for 12 months. Patient information was collected on admission, during hospitalization, and by telephone interview 1 year after the hip fracture. A total of 269 patients were included in the final analysis.**

Results: **At 1 year after hip fracture, more patients undergoing hemiarthroplasty with the posterior approach (22%) survived without mobility aids compared to those with the lateral approach (12%; p = 0.026). Multivariate logistic regression analysis revealed that the need for mobility aids 1 year after hip fracture was significantly predicted by the use of mobility aids before the fracture (odds ratio = 13.46, 95% confidence interval = 4.29–42.25), age ≥85 years (odds ratio = 3.85, 95% confidence interval = 1.09–13.44), male sex (odds ratio = 3.59, 95% confidence interval = 1.05–12.22), and lateral approach (odds ratio 2.73, 95% confidence interval 1.15–6.50). The posterior approach resulted in four (3.4%) dislocated hips, compared with none by the lateral approach. Survival, mobility level, pain in the operated hip, and living arrangements 1 year postoperatively were not significantly different between groups.**

Conclusion: **Hemiarthroplasty using a lateral approach predisposed to the need for ambulatory aids 1 year after hip fracture. The posterior approach, however, predisposed**

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to hip dislocation. Patient selection must be considered when deciding the appropriate surgical approach.

Key words: Femoral neck fracture; lateral approach; posterior approach; arthroplasty; functional outcome

INTRODUCTION

Hemiarthroplasty (HA) is a common treatment choice for displaced fragility hip fractures. HA enables immediate full weight-bearing without the risk of typical complications related to internal fixation, including avascular necrosis and nonunion. Moreover, in patients older than 60 years, HA results in fewer reoperations compared with internal fixation (1, 2). Furthermore, total hip arthroplasty (THA) is considered a better option for previously independent and healthy patients due to the functional results, despite an increased incidence of hip dislocation (3, 4). The best approach for hip joint arthroplasty, however, remains controversial.

The anterior approach (Smith-Petersen) utilizes the tissue plane between the sartorius and tensor fasciae latae superficially and between the rectus femoris and gluteus medius (5). The anterolateral approach (Watson-Jones) utilizes the intermuscular plane between the tensor fasciae latae and gluteus medius (6). The lateral approach includes separating the gluteus medius and vastus lateralis insertions from the greater trochanteric insertions, which are attached after prosthesis implantation into their original position (7). All modifications of the lateral approach involve the division and later repair of the gluteus medius. The posterior approach includes separating the gluteus maximus muscle following the release of external rotators from the femoral insertion (8). Each approach has advantages and a different spectrum of complications. Previously conducted studies of hip fracture patients treated with HA indicate that the posterior approach increases the risk of hip dislocation and reoperation compared to the lateral approach (9–11).The lateral approach, however, may predispose to hematoma. Rates of infection, seroma, and perioperative fractures are similar after both approaches (11).

Most studies comparing the outcomes between hip arthroplasty approaches have mainly evaluated patients undergoing THA. The study results cannot be directly applied to fragility hip fracture patients, a moribund population with multiple comorbidities, frailty, and a higher risk of altered living arrangements and impaired mobility. Furthermore, most previous studies focused only on the dislocation rate, early complications, and reoperations. Measurements of other important outcomes, such as a change in the living arrangement, need for mobility aids, and mobility level, are crucial among fragility hip fracture patients. Avoiding mortality, immobility, and institutionalization represent essential goals in the comprehensive treatment of fragility hip fracture patients. This study compared HA using the lateral and posterior approaches among fragility hip fracture patients and evaluated the differences in living arrangements, need for mobility aids, mobility level, pain, and survival 1 year postoperatively.

PATIENTS AND METHODS

This study comprised a prospectively and retrospectively documented cohort including 462 consecutive patients treated with a unipolar hip HA using a lateral or posterior approach in the Department of Trauma and Orthopaedic Surgery at the Seinäjoki Central Hospital between 1 September 2008 and 31 August 2012. The cohort represents a subpopulation of a prospectively collected comprehensive hip fracture database. For this study, only information on the implanted femoral stems (cemented or uncemented) and hip dislocations was collected retrospectively. All patients aged ≥65 years with a low-energy, non-pathological fragility cervical hip fracture treated with HA were included in the study and followed for 1 year postoperatively. Only the first hip fracture in each patient during the follow-up period was included. Exclusion criteria included immobility (mobile with wheelchair or bed bound) before hip fracture and moderate-to-high energy hip fractures; traffic-, bicycle- or pedestrian-accidents, and falling other than at the same level.

The referral area for hip fracture patients was South Ostrobothnia in Finland, which has a population of 193,977. Residents over 65 years of age represent 21% of the total population according to the Official Statistics of Finland, a statutory electronic population register of the country. All patients who sustain a hip fracture or surgical complication after treatment of a hip fracture inside the referral area are admitted and operated on at Seinäjoki Central Hospital. Data on deaths were obtained from the Official Cause of Death Statistics of Finland, which cover ~100% of deaths in Finland.

A flowchart of the patient population is shown in Fig. 1. A total of 269 patients were analyzed in this study, 151 underwent the lateral approach, and 118 underwent the posterior approach. There were no statistically significant differences between groups in age, sex, living with someone, need for mobility aids or extent of need before fracture, previous living arrangements, diagnosis of memory disorder, medications on admission, or American Society of Anesthesiologists (ASA) grade (Table 1).

The surgeon on duty selected whether to use a lateral (modified Hardinge) or posterior approach with repair of the posterior capsule and external rotators (7, 8). Regardless of the surgical approach selected, every patient was positioned laterally on the operating

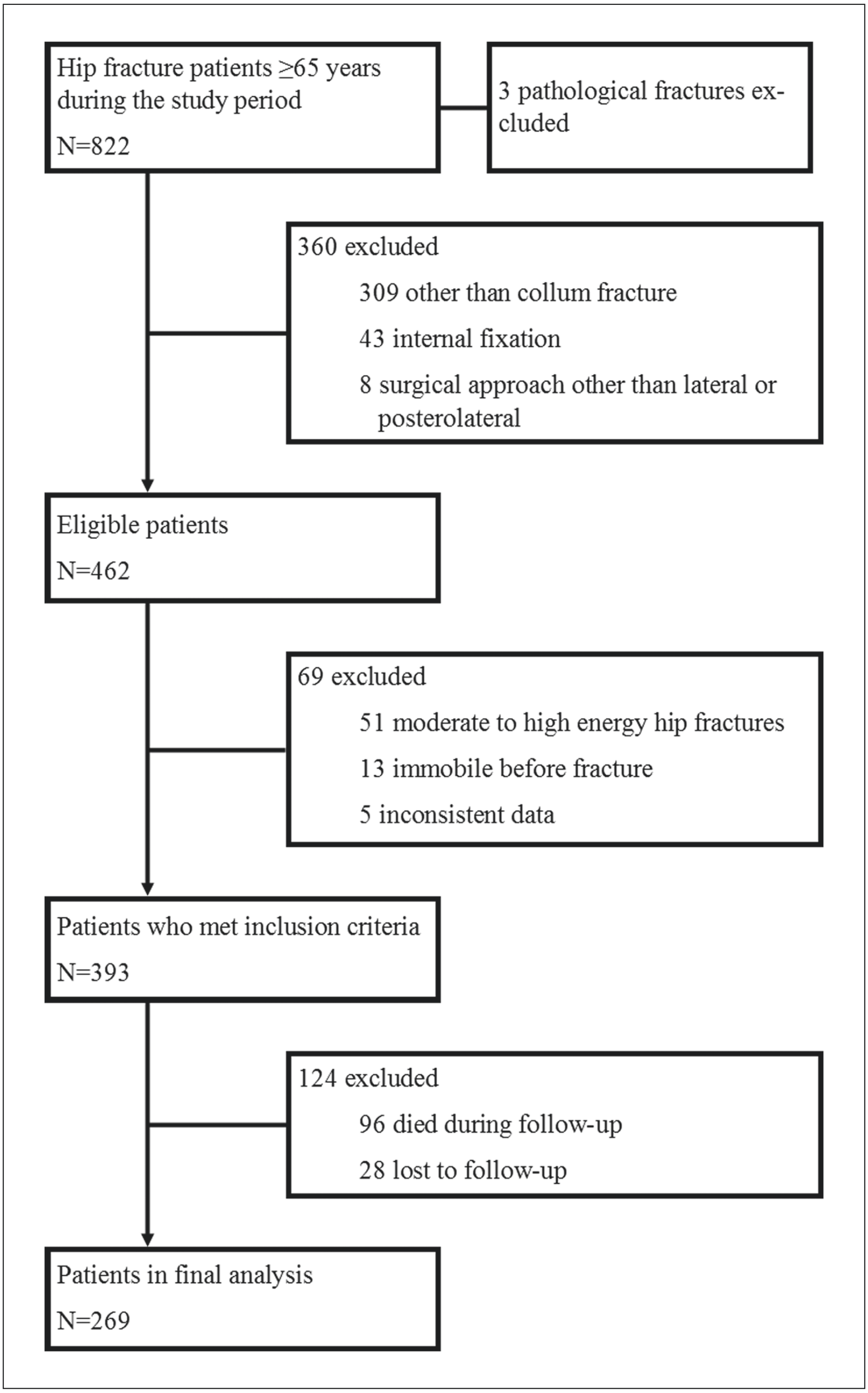

Fig. 1. Study flowchart.

table. In the modified Hardinge approach, access to the hip joint was achieved through an abductor muscle split; the gluteus medius was split longitudinally at the junction of the anterior third to posterior two-thirds of the muscle width and the split was not extended more than 3 cm superior to the trochanter insertion. The split flap (gluteus medius and minimus and vastus lateralis) was repaired to the greater trochanter with a tendon-to-tendon or tendon-to-bone attachment. In the posterior approach, the hip joint was revealed by detaching the short external rotators from femur insertion with preservation of the piriformis tendon. The joint capsule was incised to expose the femoral neck fracture. After prosthesis implantation, detached posterior structures were fixed to the original position with bone sutures. Registrar surgeons were supervised by consulting orthopedic surgeons. All patients received a single shot of antibiotics as prophylaxis against infection unless ongoing antibiotics for other reasons were administered 1 h before operation. The orthopedic surgeon in charge decided whether to use an uncemented or cemented stem. Patients were mobilized allowing for full weight-bearing as soon as possible.

Patient characteristics were collected on admission, during hospitalization, and 12 months after hip fracture by phone interview. If a patient was unable to provide information due to health or cognitive problems, data were acquired from a proxy who knew the patient, such as family members, friends, and nurses from a health care institution. During the study period, predefined inquiries modified from British hip fracture register were used to obtain as accurate data as possible (12).

The need for ambulatory aids, mobility level, pain in operated hip, HA dislocation, and living arrangements were variables of interest 12 months after hip fracture. Mobility aids were registered in the database as follows: independent, cane, canes, folding walker or rollator, wheelchair, or immobile. The need for mobility aids was categorized into two groups: mobile without aids and mobile with aids or immobile, because groups of patients who needed a cane, canes, or were immobile were too small to be analyzed separately (Fig. 2A and B). Mobility level was classified as unassisted or assisted outdoors, unassisted or assisted indoors, and unable to move. Pain was handled as a dichotomous variable. Patients were categorized as ASA grade I to II and ASA grade IV to V, because ASA group I ($n = 3$) was too small to be analyzed separately and ASA groups IV and V were combined in the hip fracture database due to the small number of patients with ASA grade V.

Pearson's chi-square or Fisher's exact test was used to compare the difference between categorical variables and Mann–Whitney U-test with continuous variables. A p value ≤0.05 was considered statistically significant. Predictive variables for the need of mobility aids 12 months after hip fracture were analyzed with age-adjusted univariate logistic regression analysis, and odds ratios (ORs) with 95% confidence intervals (CIs) were calculated. A multivariate logistic regression model was built using the enter method (all variables entered simultaneously into the model); variables with a p value ≤0.25 were included into the multivariate model, because more traditional levels (e.g. 0.05) can fail to identify variables known to be important (13).

A Cox regression model was built to compare survival between patients operated on using the lateral or posterior approach. For this model, we used a patient sample of 393, all of whom met the inclusion criteria. Age, sex, and delay to surgery represented covariates. All statistical analyses were performed using IBM SPSS Statistics version 23.

RESULTS

Mean age of the 269 patients was 82.8 (standard deviation (SD) 6.3) years and 212 (79%) were women. The lateral and posterior surgical approaches were used in 151 (56%) and 118 (44%) patients, respectively. Prior to the hip fracture, 111 (41%) were able to ambulate without mobility aids, 205 (76%) moved unassisted or assisted outdoors, and 206 (77%) were living in their own home with or without organized home care (Table 1).

Table 2 shows the operative information and outcomes of several measured variables 1 year after hip fracture; the posterior approach was most often selected ($p < 0.001$). An uncemented stem was used more often in patients operated on using the lateral approach compared to the posterior approach (93% vs 80%; $p = 0.002$). No significant differences between groups were detected in the operation delay or need for blood transfusion. From 118 patients operated on using the posterior approach, 26 (22%) were able to ambulate without aids 1 year after hip fracture, but only 18 (12%) of 151 patients who were operated on using the lateral approach were able to ambulate without aids ($p = 0.026$). Furthermore, dislocations occurred in four (3.4%) patients in the posterior approach group compared with no patients in the lateral approach group. There was no difference in between groups in mobility level, pain in operated hip, and living arrangements 1 year postoperatively.

Age-adjusted univariate logistic regression analysis revealed increased age, male sex, lateral approach, uncemented stem, previous need for ambulatory aids or immobility, mobility level, and previous living arrangements influence the need for mobility aids or immobility 1 year after hip fracture (Table 3). Multivariate logistic regression analysis indicated previous use of mobility aids or immobility (OR = 13.46, 95% CI = 4.29–42.25), age >85 years (OR = 3.83, 95% CI = 1.09–13.44), male sex (OR = 3.59, 95% CI = 1.05–12.22), and lateral approach (OR = 2.73, 95% CI = 1.15–6.50), as independent risk factors regarding the need for ambulatory aids or immobility (Table 3).

The survival rates in postoperative months 1, 3, 6, and 12 were 91%, 84%, 81%, and 76%, respectively. In multivariate Cox regression analysis, death during the 1-year follow-up was predicted by age ≥85 years (hazard ratio (HR) = 2.56, 95% CI = 1.10–5.97), male sex (HR = 1.65, 95% CI = 1.08–2.54), and delay to surgery more than 72 h (HR = 2.65, 95% CI = 1.31–5.39), but lateral versus posterior approach had no statistically

TABLE 1

Patient characteristics for baseline population and survivors at the time of hip fracture.

Variable	Entire cohort (N = 393)		Patients in primary analysis (N = 269)		Lateral approach (N = 151)		Posterolateral approach (N = 118)		p value
	n	(%)	n	(%)	n	(%)	n	(%)	
Age (years)									0.957
65–74	40	(10.2)	31	(11.5)	18	(11.9)	13	(11.0)	
75–84	147	(37.4)	114	(42.4)	63	(41.7)	51	(43.2)	
≥85	206	(52.4)	124	(46.1)	70	(46.4)	54	(45.7)	
Mean (SD)	83.7	(6.4)	82.8	(6.3)	82.9	(6.3)	82.5	(6.2)	0.628
Median (25%–75% percentile)	85.0	(79–88)	84.0	(78–87)	84.0	(78–87)	83.0	(78–87)	0.923
Sex									0.763
Female	300	(76.3)	212	(78.8)	118	(78.1)	94	(79.7)	
Male	93	(23.7)	57	(21.2)	33	(21.9)	24	(20.3)	
Living with somebody									0.722
Yes	253	(64.4)	156	(58.0)	89	(58.9)	67	(56.8)	
No	140	(35.6)	113	(42.0)	62	(41.1)	51	(43.2)	
Mobility aids before hip fracture									0.939
Mobile without an aid	145	(36.9)	111	(41.3)	62	(41.1)	49	(41.5)	
Mobile with an aid or aids	248	(63.1)	158	(58.7)	89	(58.9)	69	(58.5)	
Mobility level before fracture									0.578
Full or limited community	266	(67.7)	205	(76.2)	117	(77.5)	88	(74.6)	
Full or limited mobility indoors	127	(32.3)	64	(23.8)	34	(22.5)	30	(25.4)	
Previous living arrangements									0.766
Own home	168	(42.7)	132	(49.1)	76	(50.3)	56	(47.5)	
Own home with organized home care	107	(27.2)	74	(27.5)	40	(26.5)	34	(28.8)	
Assisted living accommodation	71	(18.1)	41	(15.2)	21	(13.9)	20	(16.9)	
Institutionalized	47	(12.0)	22	(8.2)	14	(9.3)	8	(6.8)	
Previous diagnosis of memory disorder									0.313
Yes	101	(25.7)	65	(24.2)	40	(26.5)	25	(21.2)	
No	292	(74.3)	204	(75.8)	111	(73.5)	93	(78.8)	
Medications on admission									0.229
<4	66	(16.8)	58	(21.6)	37	(24.5)	21	(17.8)	
4–10	260	(66.2)	174	(64.7)	97	(64.2)	77	(65.3)	
>10	67	(17.0)	37	(13.8)	17	(11.3)	20	(16.9)	
ASA grade									0.908
1–2	45	(11.5)	37	(13.8)	22	(14.6)	15	(12.7)	
3	242	(61.6)	180	(66.9)	100	(66.2)	80	(67.8)	
4–5	106	(27.0)	52	(19.3)	29	(19.2)	23	(19.5)	

ASA: American Society of Anesthesiologists scores.
Institution represents hospital, health care center hospital, nursing home, or rehabilitation unit providing 24-h care.

significant effect on the 1-year survival (HR = 1.36, 95% CI = 0.88–2.10; p = 0.166).

DISCUSSION

Our findings revealed that fragility hip fracture patients who underwent HA using a posterior approach required fewer ambulatory aids 1 year after hip fracture than those who underwent HA using a lateral approach. The difference was mainly due to the increased use of a cane (5.1% vs 10.6%) and folding walker or rollator (66% vs 71%) by patients operated on using the lateral approach. No differences in survival, mobility level, living arrangements, and pain were established. The posterior approach, however, might predispose to hip dislocation compared with the lateral approach.

A previous study demonstrated that the lateral approach increases the risk of damage to the superior gluteal nerve and the gluteus medius muscle, which leads to limping secondary to abductor weakness in 4%–20% THA patients, but dislocation rate was only 0.55% (14). Furthermore, worse patient-reported outcome after the lateral approach compared to the anterior or posterior approach in primary hip arthroplasty is reported (15). Abductor weakness may increase the need for ambulatory aids among hip fracture patients operated on using the lateral approach. Moreover, fragility hip fracture patients may be more prone to abductor weakness compared with THA patients due to multiple comorbidities and impaired health condition, frailty, and sarcopenia in particular, which may attenuate tissue

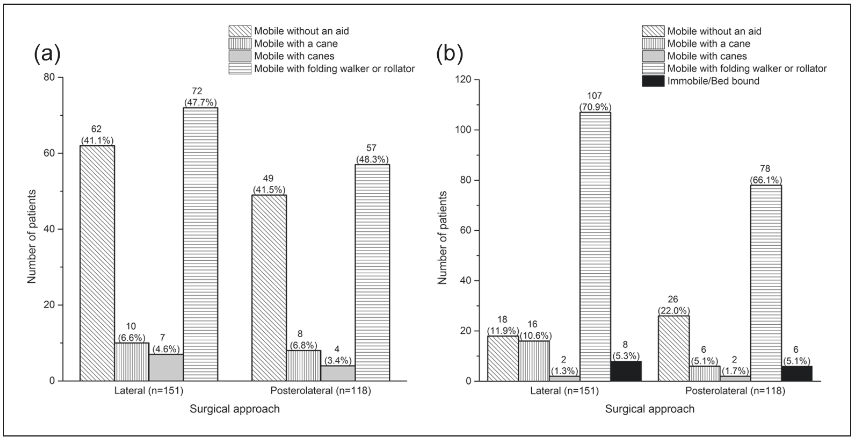

Fig. 2. Details of ambulatory aids required at baseline and one year after hip fracture.

regeneration and healing processes of the re-attached gluteus medius insertion.

An interesting finding of this study is that regardless of the increased need for ambulatory aids among patients operated using the lateral approach, there was no significant difference in mobility level or pain between groups. Our results are consistent with those of a recent randomized controlled trial, which reported no notable differences in the pain and mobility outcomes between the two approaches (16). Furthermore, a prospective observational study found no difference between approaches in patient-perceived health-related quality of life (HRQoL), residual pain, or patient satisfaction 1 year after surgery on patients aged >70 years (17).

A recent register-based study, however, revealed that patients have more pain and are less satisfied with the operated hip after the direct lateral approach than after the posterior approach at 4, 12, and 36 months postoperatively. Furthermore, patients reported having more walking problems after the direct lateral approach even 36 months after surgery (18).

The posterior approach predisposes the patient to hip dislocation, but has fewer adverse effects on gait (14). The hip dislocation rate is reported to range from 5.1% to 16% among femoral neck fracture patients undergoing HA using the posterior approach, depending on whether or not posterior structures are repaired (19–21). Dislocation after hip HA is a rare complication that may increase mortality (22). Furthermore, even a single dislocation temporarily decreases the HRQoL, while recurrent dislocation results in a persisting deterioration of the HRQoL during the first year after the primary operation (23). In our study, the dislocation rate was relatively small compared to that in previously reported studies, which may be related to preservation of the piriformis tendon and repair of the posterior structures. All hip dislocations occurred in patients that underwent the posterior approach. Of the four hip dislocations, closed reduction successfully prevented additional surgery in only one patient.

Several risk factors affect discharge to own home after hip fracture, including age at admission, concomitant chronic systemic diseases and dementia, and walking disability before injury (24). The relationship between the surgical approach used among hip fracture patients undergoing HA and residential location postoperatively is not well studied. Abram and Murray (25) reported that increased age, male sex, cognitive impairment, dislocation, and delay to surgery represented risk factors for failure to return to own home within 30 days; surgical approach, however, was not a significant factor. Our study indicates that the posterior and lateral approaches produce similar outcomes with regard to residential location 1 year after hip fracture.

If the surgeon in charge is familiar with both approaches, careful patient selection may result in a favorable outcome. The complication rates are similar, but the posterior approach will result in a more than eight-fold risk of dislocation compared with the lateral approach. In contrast, the lateral approach may increase the risk of bleeding five-fold compared with the posterior approach (11). Postoperative hematoma was not a recorded variable in our study, but differences between groups in the need for blood transfusion during hospitalization were small and statistically non-significant. This may reflect the similar incidence of clinically relevant postoperative bleeding. Some risk factors for hip dislocation after HA are reported: posterior approach, cognitive impairment, and delay to surgery >24 h (10, 26, 27). A subpopulation of patients will benefit from either approach; patients with risk factors for hip dislocation may benefit from the lateral approach compared with the posterior approach. The surgeon's use of a familiar approach, however, will most likely result in lower complications.

This study has several limitations. First, the patients were not randomized and the approach

TABLE 2

Comparison between direct lateral and posterior approaches with regard to operative information and outcomes 1 year after hip fracture.

Variable	All patients (N = 269)		Lateral approach (N = 151)		Posterolateral approach (N = 118)		p value
	n	(%)	n	(%)	n	(%)	
Surgeon's experience							<0.001
Registrar	179	(66.5)	36	(23.8)	54	(45.8)	
Post-registrar	90	(33.5)	115	(76.2)	64	(54.2)	
Delay to operation							0.275
<24 h	121	(45.0)	71	(47.0)	50	(42.4)	
24–47h	116	(43.1)	67	(44.4)	49	(41.5)	
48–72 h	26	(9.7)	10	(6.6)	16	(13.6)	
>72 h	6	(2.2)	3	(2.0)	3	(2.5)	
Blood transfusion							0.765
Yes	103	(38.3)	59	(39.1)	44	(37.3)	
No	166	(61.7)	92	(60.9)	74	(62.7)	
Implant							0.003
Uncemented	233	(86.6)	139	(92.1)	94	(79.7)	
Cemented	36	(13.4)	12	(7.9)	24	(20.3)	
Need for mobility aids							0.026
Mobile without an aid	44	(16.4)	18	(11.9)	26	(22.0)	
Mobile with an aid or immobile	225	(83.6)	133	(88.1)	92	(78.0)	
Mobility level							0.406
Full or limited mobility outdoors	134	(49.8)	80	(54.4)	54	(46.2)	
Full or limited mobility indoors	115	(42.8)	59	(40.2)	56	(47.8)	
Unable to move	15	(5.6)	8	(5.4)	7	(6.0)	
Missing information	5	(1.9)	4		1		
Pain in operated hip							0.950
Yes	62	(23.0)	35	(23.8)	27	(23.5)	
No	200	(74.3)	112	(76.2)	88	(76.5)	
Missing information	7	(2.6)	4		3		
Hip dislocation							0.036
Yes	4	(1.5)	0	0	4	(3.4)	
No	265	(98.5)	151	(100)	114	(96.6)	
Living arrangements							0.708
Own home	83	(30.9)	44	(29.7)	39	(34.2)	
Own home with organized home care	55	(20.4)	35	(23.6)	20	(17.5)	
Assisted living accommodation	51	(19.0)	29	(19.7)	22	(19.4)	
Institutionalized	73	(27.1)	40	(27.0)	33	(28.9)	
Missing information	7	(2.6)	3		4		

Institution represents hospital, health care center hospital, nursing home or rehabilitation unit providing 24-h care. Differences were evaluated using the Pearson chi-squared test or Fisher's exact test.

used depended on the respective surgeon's preference, which may distort the results. Generally, patients with low compliance may be operated more often using Hardinge approach. However, in this study, patients who were immobile or bed bound before hip fracture were excluded. Moreover, the baseline characteristics did not differ according to surgical approach. Second, the sample size differed between groups. Third, data on implanted femoral stems and hip dislocations were retrospectively collected—all hip dislocations inside the referral area were admitted and treated at Seinäjoki Central Hospital. Hip dislocations occurring outside the hospital district, however, may not be part of the hip fracture database. Fourth, the use of uncemented femoral stems for the treatment of fragility hip fracture patients contradicts recent scientific evidence (28, 29). Uncemented stems were used more often in the lateral approach. Finally, because the number of patients using a cane, canes, or who were immobile was too small, we had to categorize the need for ambulatory aids in a dichotomous manner to perform the statistical analysis. At the beginning of the study, however, the proportional rates of uncategorized mobility aids did not differ comprehensively between groups. A major strength of this study is that patients represent a real-life population and the only exclusion criteria were age <65 years, pathological fracture, moderate-to-high energy hip fractures, and immobility. Second, new surgical protocols were not implemented and patients were provided similar postoperative care during the study period. Third, only 7.1% of patients were lost to follow-up.

TABLE 3

Age-adjusted logistic univariate and multivariate analysis regarding need for ambulatory aids 1 year after hip fracture.

	n	Age-adjusted univariate (N = 269)		p	Multivariate (N = 269)		p
		OR	(95% CI)		OR	(95% CI)	
Age (years)							
65–74	31	1.00			1.00		
75–84	114	2.30	(0.96–5.49)	0.061	1.70	(0.56–5.08)	0.341
≥85	124	5.65	(2.16–14.78)	<0.001	3.83	(1.09–13.44)	0.036
Sex							
Female	212	1.00			1.00		
Male	57	4.45	(1.45–13.71)	0.009	3.59	(1.05–12.22)	0.041
Surgical approach							
Posterolateral	118	1.00			1.00		
Lateral	151	2.11	(1.07–4.14)	0.031	2.73	(1.15–6.50)	0.023
Surgeon's experience							
Registrar	90	1.00			1.00		
Post-registrar	179	0.64	(0.30–1.36)	0.242	0.60	(0.21–1.68)	0.325
Implant							
Uncemented	233	1.00			1.00		
Cemented	36	0.38	(0.16–0.93)	0.033	0.57	(0.16–1.97)	0.371
Delay to operation							
<24 h	121	1.00					
24–47 h	116	1.09	(0.53–2.27)	0.812			
48–72 h	26	0.92	(0.30–2.79)	0.876			
>72 h	6	1.09	(0.12–10.26)	0.939			
Mobility aids before fracture							
Mobile without an aid	111	1.00			1.00		
Mobile with an aid or immobile	158	13.66	(5.09–36.64)	<0.001	13.46	(4.29–42.25)	<0.001
Mobility level before fracture							
Full or limited mobility outdoors	205	1.00			1.00		
Full of limited mobility indoors	64	4.80	(1.41–16.38)	0.012	2.40	(0.57–10.09)	0.233
Previous living arrangements							
Own home	132	1.00			1.00		
Own home with organized home care	74	2.40	(1.05–5.49)	0.038	1.24	(0.45–3.46)	0.678
Assisted living accommodation	41	5.68	(1.27–25.42)	0.023	2.25	(0.35–14.30)	0.391
Institutionalized	22	6.84	(0.86–54.33)	0.069	1.32	(0.12–14.41)	0.822
Previous diagnosis of memory disorder							
Yes	65	1.00			1.00		
No	204	0.40	(0.16–1.02)	0.054	0.69	(0.20–2.36)	0.552
Living with someone							
Yes	156	1.00					
No	113	0.78	(0.40–1.53)	0.471			
ASA grade							
1–2	37	1.00			1.00		
3	180	1.77	(0.75–4.19)	0.191	1.90	(0.62–5.84)	0.260
4–5	52	1.65	(0.54–5.04)	0.382	0.76	(0.17–3.41)	0.720
Medications on admission							
<4 medications	58	1.00			1.00		
4–10 medications	174	1.16	(0.53–2.56)	0.705	0.51	(0.18–1.42)	0.198
>10 medications	37	8.71	(1.05–71.91)	0.045	3.10	(0.30–31.68)	0.341

ASA: American Society of Anesthesiologists score.
Institution represents hospital, health care center hospital, nursing home, or rehabilitation unit providing 24-h care. Results are shown as odds ratios (OR) with 95% confidence intervals (CI). Variables with p value ≤0.25 in age-adjusted univariate logistic regression analysis were submitted to multivariate regression analysis.

In conclusion, HA using the lateral approach will increase the need for ambulatory aids at 1 year after hip fracture compared to the posterior approach 1 year, whereas the posterior approach increases the risk of hip dislocation. This study revealed no significant differences between the lateral and posterior approaches in the outcomes of survival, mobility, pain, and living arrangements 1 year after hip fracture.

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DECLARATION OF CONFLICTING INTERESTS

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IV

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

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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

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Abstract

Introduction: The effect of delays before surgery of 24 hours, 48 hours, and 72 hours on short- and long-term survival has been investigated comprehensively in hip fracture patients, but with controversial results. However, there is only limited evidence for how a threshold of 12-hour delay before hip fracture surgery affects survival. **Materials and Methods:** A prospective observational study of 884 consecutive hip fracture patients (age $\geq$ 65 years) undergoing surgery was carried out in terms of 30- and 365-day survival. A Cox hazard regression survival model was constructed for 724 patients with American Society of Anesthesiologists score $\geq$3 with adjustments of age, gender, cognition, number of medications on admission, hip fracture type, and prior living arrangements. **Results:** Patients who underwent surgery within 12 hours had better chances of survival than did those with 12 to 24 hours (hazard ratio [HR]: 8.30; 95% confidence interval [CI]: 1.13-61.4), 24 to 48 hours (HR: 7.21; 95% CI: 0.98-52.9), and >48 hours (HR: 11.75; 95% CI: 1.53-90.2) delay before surgery. Long-term survival was more influenced by non-adjustable patient features, but the adverse effect of >48 hours delay before surgery was noticed with HR: 2.02; 95% CI: 1.08-3.80. Increased age and male gender were significantly associated with worse short- and long-term survival. **Discussion/Conclusions:** Early hip fracture surgery within 12 hours of admission is associated with improved 30-day survival among patients with ASA score $\geq$3. Delay to surgery of more than 48 hours has an adverse effect on 365-day survival, but factors related to patients' comorbidities have a great influence on long-term survival.

Keywords

trauma surgery, geriatric trauma, delay to surgery, hip fracture, hip fracture, and survival

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Introduction

Hip fracture is a common serious injury among elderly people leading to disability, increased mortality, and institutionalization, resulting in a heavy financial burden on the public healthcare system.[1,2] During the first year after hip fracture, excess mortality has been reported to range from 8.4% to 36% and patients are at increased risk for premature death for many years after hip fracture.[3]

Several risk factors for increased 1-year mortality after hip fracture have previously been reported, of which the most notable are increased age, male gender, higher ASA grade, cognitive impairment, prefracture mobility level, and institutionalized living arrangements prior to the fracture.[4] The

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effect of surgical delay on short- and long-term mortality has been examined in numerous observational studies with controversial results.[5-10] Acquiring level 1 evidence from randomized controlled trials has never been attempted due to the inherent ethical problems. Large register-based studies offer a massive study population, but the validation of data and identification of existing comorbidities are limited. High-quality prospective cohort studies taking account of existing comorbidities currently seem to represent the best method for studying outcomes with delayed surgery among hip fracture patients.

Mounting evidence shows that a delay before surgery may have a negative influence on the morbidity and mortality of hip fracture patients. The most often used watersheds for investigating delay before hip fracture surgery are 24 hours, 36 hours, 48 hours, 60 hours, and 72 hours.[11-18] Further, in register-based studies, delay before surgery is defined according to the day of admission and the day of the surgical intervention. A limited amount of evidence suggests that delay over 12 hours before surgery may increase in-hospital or short-term (30-day) mortality in patients sustaining hip fracture.[5-7] To the best of our knowledge, the few studies on the effect of early (<12 hours) surgery after hip fracture on mortality have yielded contradictory findings.[5-10]

The aim of the present prospective observational study was to examine the impact of early timing (<12 hours) of hip fracture surgery on short- and long-term survival. In particular, we focused on examining the effect of early surgery on mortality in moderate- to high-risk patients as classified by ASA scores.

Materials and Methods

The study was performed according to the 1964 Helsinki Declaration and its later amendments and approved by the ethics committee of the Hospital District of Southern Ostrobothnia. Informed consent was obtained from the participants or their caregivers.

This retrospective study on a prospective controlled cohort covers 884 consecutive hip fracture patients aged $\geq$65 years operated on at Seinäjoki Central Hospital during the study period from January 1, 2012, to May 31, 2016. Only the first hip fracture in each patient during the follow-up period was included. Pathologic ($n = 1$) and periprosthetic fractures were excluded from the study population. Inconsistent data were revealed in 24 patients. The Hospital District of South Ostrobothnia, Finland, represented the referral area constituting 196 578 patients in 2016. All patients who sustained a hip fracture inside the referral area were admitted and underwent surgery at Seinäjoki Central Hospital. Data on deaths were obtained from the Official Cause of Death Statistics of Finland, which covers fundamentally 100% of deaths in Finland.

Patient information was collected during hospitalization by specially trained research nurses. If the patient was unable to provide the information, we used proxy respondents. Relatives, friends, and nurses from an institution who were aware of the patient's health condition served as proxies.

The primary outcome variables were short- and long-term survival, which were considered to represent 30-day and 365-day survival, respectively. For the purpose of the study, we analyzed several patient variables as presented in Table 1. Surgical delay to a precision of minutes was defined as time elapsing from admission to the emergency department to the time of surgery and categorized as follows: <12 hours, 12 to 24 hours, 24 to 48 hours, and >48 hours. Need for mobility aids was categorized into 2 groups: mobile without an aid and mobile with an aid or unable to ambulate. Mobility level was classified as full or limited community, full or limited mobility indoors, and unable to move. We also registered the need for blood transfusion during hospitalization. As there is inconsistent evidence on an optimal cutoff value of hemoglobin for red blood cell transfusions, a cutoff value under 90 g/L was chosen in each patient. This lies between the most commonly used cutoff values found in the literature for restrictive (under 80 g/L) and liberal (under 100 g/L) red blood cell transfusion practices. Patients with an ASA score of 1 or 2 were combined into one group because there were only 2 patients with ASA 1. Likewise, patients with an ASA score of 4 to 5 were combined because of the small number of patients with ASA grade 5. Initial analysis showed that patients with ASA score 1 to 2 ($n = 135$) were operated on sooner ($P = .05$) and 30-day mortality was only 1.5% and 365-day mortality was 5.9%. To minimize the confounding effect of low ASA on the final results and marked low short- and long-term mortality among patients with ASA score 1 to 2, the final analysis was only performed for patients with higher ASA score 3 to 5, which constituted the final population ($n = 724$, 84.3%) of the study.

All patients were treated with a standardized hip fracture protocol during hospitalization. A comprehensive orthogeriatric rehabilitation program was initiated immediately after admission to emergency department, taking account of pain management, supporting mobility, nutrition and optimization of medications, renal function, fluid therapy, and so on.[19] Surgery was performed as soon as possible, depending on system- or patient-related reasons. Patients with a femoral neck fracture were operated on with hemiarthroplasty ($n = 374$, 87.6%), total hip replacement ($n = 30$, 7.0%), or closed reduction and internal fixation with a fixed-angle sliding hip screw or cannulated screws ($n = 23$, 5.4%). Internal fixation was used only in stable Garden I and II fractures with relatively healthy patients who were fully mobile without mobility aids before the injury and when there were no radiological signs of osteoarthrosis. Total hip replacement was implemented for community-dwelling physiologically "young" patients who were active and had a high functional demand. Pertrochanteric fractures were treated by an intramedullary hip nail or fixed-angle sliding hip screw. Subtrochanteric fractures were treated using long intramedullary nail. Low-molecular heparin was initiated 6 to 8 hours after surgery to prevent thromboembolic complications. Practically, all patients were allowed immediate mobility with full weight-bearing. In very rare cases, partial weight-bearing was recommended, but if this led to immobility or the use of a wheelchair due to a limited cooperation, full weight-bearing was allowed.

Table 1. Patient Demographics Classified by Delay to Surgery.

Variable	All Patients, N = 724 n (%)	<12 Hours, n = 66 n (%)	12-24 Hours, n = 241 n (%)	24-48 Hours, n = 312 n (%)	>48 Hours, n = 105 n (%)	*P*
Age						.024
65-74	74 (10.2)	3 (4.5)	26 (10.8)	29 (9.3)	16 (10.2)	
75-85	268 (37.0)	30 (45.5)	79 (32.8)	111 (35.6)	48 (37.0)	
>85	382 (52.8)	33 (50.0)	136 (56.4)	172 (55.1)	41 (39.0)	
Mean (SD)	84.1 (7.1)	85.3 (6.0)	84.7 (7.5)	84.2 (6.7)	81.6 (7.4)	.003
Gender						.204
Female	514 (71.0)	45 (68.2)	175 (72.6)	228 (73.1)	66 (62.9)	
Male	210 (29.0)	21 (31.8)	66 (27.4)	84 (26.9)	39 (37.1)	
Living with somebody						.947
Yes	468 (64.6)	44 (66.7)	153 (63.5)	204 (65.4)	67 (63.8)	
No	256 (35.4)	22 (33.3)	88 (36.5)	108 (34.6)	38 (36.2)	
Previous living arrangements						.064
Own home	273 (37.7)	22 (33.3)	103 (42.7)	106 (34.0)	42 (40.0)	
Own home with organized home care	227 (31.4)	24 (36.4)	62 (25.7)	104 (33.3)	37 (35.2)	
Assisted living accommodation	65 (9.0)	9 (13.6)	17 (7.1)	27 (8.7)	12 (11.4)	
Institutionalized	159 (22.0)	11 (16.7)	59 (24.5)	75 (24.0)	14 (13.3)	
Mobility aids before hip fracture						.965
Mobile without an aid	250 (34.7)	24 (37.5)	83 (34.6)	108 (34.6)	35 (33.7)	
Mobile with an aid or aids	470 (65.3)	40 (62.5)	157 (65.4)	204 (65.4)	69 (66.3)	
Information missing	4					
Mobility level before fracture						.272
Full or limited community	365 (49.4)	29 (45.3)	125 (52.1)	154 (49.4)	48 (46.2)	
Full or limited mobility indoors	352 (48.9)	32 (50.0)	110 (45.8)	154 (49.4)	56 (53.8)	
Unable to move	12 (1.7)	3 (4.7)	5 (2.1)	4 (1.2)	0	
Missing information	4					
Previous diagnosis of memory disorder						.010
Yes	237 (32.7)	24 (36.4)	79 (32.8)	114 (36.5)	20 (19.0)	
No	487 (67.3)	42 (63.6)	162 (67.2)	198 (63.5)	85 (81.0)	
Medications on admission						.290
<4	86 (11.9)	10 (15.1)	30 (12.4)	34 (10.9)	12 (11.4)	
4-10	467 (64.5)	45 (68.2)	158 (65.6)	205 (65.7)	59 (56.2)	
>10	171 (23.6)	11 (16.7)	53 (22.0)	73 (23.4)	34 (32.4)	
Hip fracture type						.589
Femoral neck fracture	427 (59.0)	36 (54.5)	141 (58.5)	179 (57.4)	71 (67.6)	
Pertrochanteric fracture	249 (34.4)	25 (37.9)	84 (34.9)	113 (36.5)	27 (25.7)	
Subtrochanteric fracture	48 (6.6)	5 (7.6)	16 (6.6)	20 (6.4)	7 (6.7)	
Need for blood transfusion						.457
No	418 (57.7)	37 (56.1)	130 (53.9)	189 (60.6)	62 (59.0)	
Yes	306 (42.3)	29 (43.9)	111 (46.1)	123 (39.4)	43 (41.0)	
Duration of surgery (minutes, SD)	80.4 (35.7)	79.5 (38.4)	79.5 (38.9)	78.8 (32.8)	87.8 (34.6)	.052

Patient characteristics grouped by surgical delay were compared using Kruskal-Wallis test for continuous variables not normally distributed and Pearson χ^2 test for categorical variables. A *P* value $\leq$.05 was considered statistically significant.

Cox regression models, where variables were entered simultaneously into the models, were built to investigate hazard ratios (HRs) for death 30 days and 365 days after hip fracture. Time to surgery, age, gender, living with somebody, previous living arrangements, previous diagnosis of memory disorder, number of regularly taken medications (both prescribed and over-the-counter medications) on admission, and hip fracture morphology represented covariates in the final model. Need for mobility aids before hip fracture and mobility level was not included because of a statistically significant association with prior living arrangements ($P < .05$). All statistical analyses were performed using IBM SPSS Statistics version 23.

Results

From the study population of 724, 514 (71%) were women and mean patient age was 84.1 (standard deviation: 7.1). In all, 427 (59%) patients had a femoral neck fracture, 249 (34%) had a pertrochanteric fracture, and 48 (7%) a subtrochanteric fracture. Mean timing of surgery was 32.3 hours (25%-75% percentile: 19.4-42.2) and 66 (9.1%) patients were operated on within 12 hours of admission, 241 (33.3%) at 12 to 24 hours,

Table 2. Multivariate Cox hazard Regression Model Stratified by 30- and 365-Day Survival.

	30-Day Survival			365-Day Survival		
	HR	(95% CI)	*P*	HR	(95% CI)	*P*
Age (years)	1.07	(1.03-1.11)	<.001	1.05	(1.03-1.08)	<.001
Sex						
Female	1.00			1.00		
Male	1.79	(1.11-2.88)	.017	1.57	(1.17-2.10)	.002
Delay to operation						
<12 hours	1.00			1.00		
12-24 hours	8.30	(1.13-61.14)	.038	1.75	(0.98-3.11)	.057
24-48 hours	7.21	(0.98-52.91)	.052	1.49	(0.84-2.63)	.169
>48 hours	11.75	(1.53-90.24)	.018	2.02	(1.08-3.80)	.029
Previous diagnosis of memory disorder						
No	1.00			1.00		
Yes	1.15	(.70-1.91)	.577	1.00	(.74-1.36)	.982
Medications on admission						
<4	1.00			1.00		
4-10	0.98	(0.43-2.21)	.960	2.17	(1.13-4.15)	.020
>10	1.42	(0.59-3.39)	.435	3.12	(1.58-6.17)	.001
Previous living arrangements						
Own home	1.00			1.00		
Own home with organized home care	0.88	(0.45-1.73)	.708	1.22	(0.82-1.80)	.329
Assisted living accommodation	1.68	(0.75-3.78)	.209	2.18	(1.35-3.51)	.001
Institutionalized	1.84	(0.94-3.62)	.076	2.16	(1.43-3.26)	<.001
Hip fracture type						
Femoral neck fracture	1.00			1.00		
Pertrochanteric fracture	1.15	(0.71-1.85)	.574	1.04	(0.78-1.39)	.804
Subtrochanteric fracture	0.78	(0.28-2.21)	.645	0.95	(0.54-1.66)	.848

Abbreviations: CI, confidence interval; HR, hazard ratio.

315 (43.1%) at 24 to 48 hours, and 105 (14.5%) after at least 48 hours.

Details of baseline patient characteristics and comparison of patients stratified by delay before surgery are shown in Table 1. Patient age and previous diagnosis of memory disorder differed across the surgical delay groups. Patients operated on later than 48 hours after admission were younger than the mean age ($P =$ .003) and had fewer diagnoses of memory disorder ($P = .010$).

Overall mortality was 29.1% (n = 211) at 365 days, of whom 76 (36.0%) died within 30 days and 175 (82.9%) within 180 days. Thirty- and 180-day mortality were 10.5% and 24.2%, respectively. A Cox regression model indicated statistically significant worse 30-day survival in patients operated on with a surgical delay of 12 to 24 hours (HR: 8.30; 95% CI: 1.13-61.4) and $\geq$48 hours (HR: 11.75; 95% CI: 1.53-90.2) compared to <12 hours surgical delay, whereas surgical delay of 24 to 48 hours (HR: 7.21; 95% CI: 0.98-52.9) showed a trend toward worse survival. The 30-day mortality for men was HR: 1.79 (95% CI: 1.11-2.88) compared to women, and mortality increased with every additional year of life (HR: 1.07; 95% CI: 1.03-1.11). Institutionalized living arrangements showed a trend toward worse 30-day survival (HR: 1.84; 95% CI: 0.94-3.62; Table 2 and Figure 1).

In the Cox hazard regression model describing 365-day survival, surgical delay of >48 hours (HR: 2.02; 95% CI: 1.08-3.80), age (HR: 1.05; 95% CI: 1.03-1.08), male gender (HR: 1.57; 95% CI: 1.17-2.10), 4 to 10 drugs on admission (HR: 2.17; 95% CI: 1.13-4.15) or $\geq$10 drugs on admission (HR: 3.12; 95% CI: 1.58-6.17) and impaired previous living

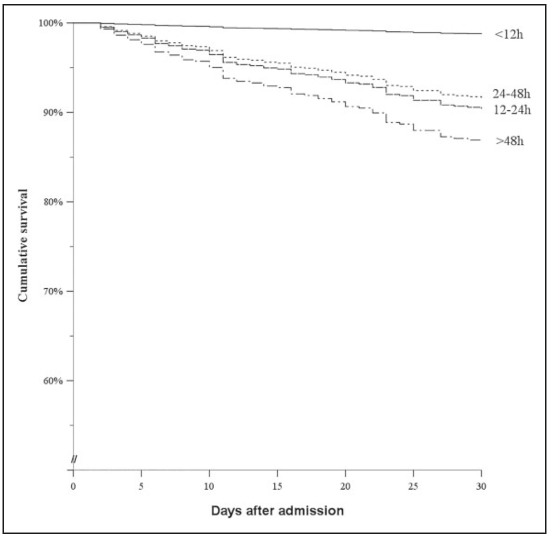

Figure 1. Cumulative 30-day survival stratified by the time delay to surgery.

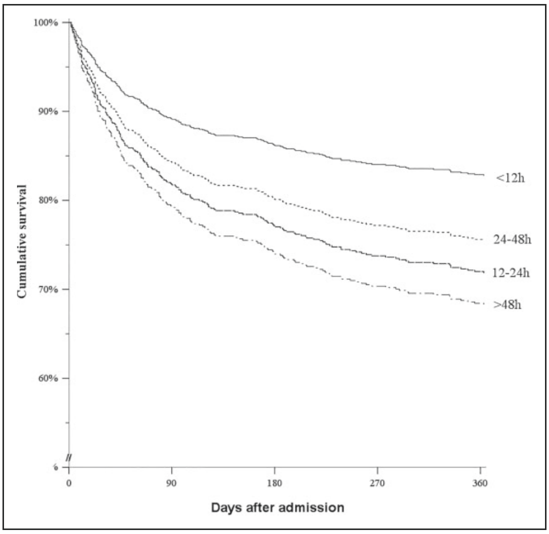

Figure 2. Cumulative 365-day survival stratified by the time delay to surgery.

arrangements were shown to represent independently significant factors for worse outcome (Table 2 and Figure 2).

We conducted another Cox hazard regression model including patients with ASA score 1 to 5, containing 859 patients. Increased risk for impaired 30-day survival was noticed in patients with surgical delay of 12 to 24 hours (HR: 7.95; 95% CI: 1.08-58.5) and $\geq$48 hours (HR: 10.7; 95% CI: 1.39-82.2), ASA score 4 to 5 (HR: 5.67; 95% CI: 1.29-25.0), male gender (HR: 1.78; 95% CI: 1.11-2.84), and every additional year of life (HR: 1.06; 95% CI: 1.02-1.10). Factors exacerbating worse 365-day survival included ASA score 3 (HR: 2.40; 95% CI: 1.16-4.98), ASA score 4 to 5 (HR: 4.31; 95% CI: 2.02-9.16), prior assisted living accommodation (HR: 2.04; 95% CI: 1.27-3.28), prior institutionalization (HR: 2.11; 95% CI: 1.41-3.16), 4 to 10 (HR: 2.50; 95% CI: 1.30-4.82) or >10 (HR: 3.35; 95% CI: 1.68-6.69) medications on admission, male gender (HR: 1.56; 95% CI: 1.17-2.07), and every additional year of life (HR: 1.04; 95% CI: 1.02-1.07).

Discussion

The main finding of the present study is that moderate- to high-risk hip fracture patients undergoing surgery within 12 hours of admission to the emergency department survived significantly better at 30 and 365 days. The effect of delay before surgery of more than 12 hours was the strongest factor affecting 30-day survival, and the impact of the timing of surgical treatment was even more significant than institutionalization prior to the injury. Furthermore, surgical delay also had an impact on long-term survival, although other factors, such as previous living arrangements and the number of medications taken before hip fracture, also had a more adverse effect on survival. The present study provides evidence corroborating previously reported controversial results concerning the effect of early surgery within 12 hours on survival.[5-10]

The favourable effect of early surgery on short-term survival may have to do with avoiding acute complications related to waiting for surgery. These include thromboembolic events, pressure sores, pneumonia, stroke, myocardial infarction, cardiac arrest, and sepsis.[11,15,20] Longer delay to surgery increases the risk of delirium, a common and serious complication among older hip fracture patients, especially among those with prefracture impaired cognition, with a potentially poor prognosis.[21,22] Conversely, delayed surgery after hip fracture may be advantageous for patients needing comprehensive stabilisation prior to anaesthesia. We assume that if patients survive the first month after hip fracture without acute complications, non-modifiable factors such as severe comorbidities will have more impact on long-term survival. This is supported by our findings that greater number of medications on admission and impaired living arrangements prior to injury have a more marked effect on worse long-term survival than surgical delay.

A Danish fracture database study including 3517 hip fracture patients concluded that surgical delay >12 hours significantly increased 30-day mortality and >24 hours delay increased the risk of 90-day mortality.[7] In that study, ASA score was the only factor describing comorbidity, and initially ASA grades 1 and 2 were detected more often in patients operated on within 12 hours. Bretherton and Parker published a prospective observation study on 6638 hip fracture patients and included ASA, mobility score, and Mini Mental Test score to describe patient comorbidity.[5] The conclusion was that patients undergoing surgery after 12 hours are 59% more likely to die within 30 days than are patients undergoing surgery within 12 hours. Interestingly, other thresholds they examined were not statistically significant, but earlier surgery was found to be beneficial. A third study supporting early surgery within 12 hours was conducted by Uzoigwe et al.[6] They studied the effect of surgical delay on in-hospital mortality in retrospective review from prospectively collected data of 1944 femoral neck fracture patients. ASA and patient's residence prior to the hip fracture described disease severity. The conclusion was that surgery within 12 hours significantly reduces risk of in-hospital mortality.

A register-based study on 3777 femoral neck fracture patients indicated that early surgery (<12 hours) was associated with a lower rate of mortality than in other patient groups, although the differences were not statistically significant.[9] It is noteworthy that detailed diseases or validated morbidity index were not reported. Smektala et al conducted a multicentre prospective observational study on 2916 patients aged 65 or more to research the effect of surgical timing on survival and postoperative complications.[10] Initially, patient demographics differed between surgical timing groups in terms of ASA classification, age, type of admission, and fracture type. More frequent postoperative complications were found in the group with more than 36 hours to surgery, but time to surgery did not affect mortality. A recent retrospective review of prospectively collected data included 1913 patients aged 60 or more indicated every hour of surgical delay increased the risk for 30-day mortality. However, when the analysis was conducted in 12-hour blocks, surgical delay of more than 24 hours was statistically significant in increasing 30-day mortality.

The higher ASA score from 3 to 5 is a very powerful indicator for impaired survival after hip fracture surgery. In our study, only 1.5% of 30-day mortality was seen in patients with ASA score 1 to 2 compared to 10.5% of 30-day mortality in patient with ASA score 3 to 5. Further, there may be a tendency to operate earlier on patients with a low ASA score because patients with at least one severe systemic disease (ASA score $\geq$ 3) may need more attention to medical optimization for anesthesia. This may markedly distort the final results when studying the effect of surgical delay on survival and other outcomes. Further, higher ASA score may have interactions with covariates in regression models, which may yield a corrupted model. Therefore, we suggest that excluding from the statistical analysis the healthiest (ASA 1-2) patients, whose short-term mortality is very low, may result in more reliable results overall.

An interesting finding of our study was that surgical intervention lasted longer in patients undergoing surgery >48 hours after admission. This may indicate that patients with complex hip fractures or in need of special instrumentation are less likely to be operated on outside office hours and the intervention may proceed later the next day. Moreover, patients needing oral anticoagulation prior to admission are exposed to longer delays before surgery, especially those receiving direct oral anticoagulants (DOACs).[23] In our study, hip fracture surgery was not conducted until 48 hours after the last administration of DOACs. In this study, no difference was shown in the need for blood transfusion during hospitalization between time delay groups. However, oral anticoagulants may have an unfavourable influence on bleeding. This may increase the duration of surgery.

Early surgery has a clear positive impact on several outcomes among hip fracture patients. Postoperatively less pain, shorter hospital stay, and fewer pressure ulcers have been reported in hip fracture patients undergoing surgery within 24 hours.[11,24] Shorter delay to surgery enables earlier mobilization, which in turn is likely to reduce the risk of developing delirium and pneumonia.[25] Surgical delay of more than 36 hours predisposes to diminished ability to return to independent living.[11] Further, more than 48 hours' surgical delay exposes hip fracture patients to the risk of pneumonia, stroke, myocardial infarction, sepsis, and septic shock.[20] However, controversial results and limited evidence are available on whether early surgery confers a survival benefit due to the nature of retrospective cohort or register studies.[5,9,10,13,24,26-28] Our study supports the benefit of early surgery within 12 hours of admission for short- and long-term survival.

This study has several limitations. First, patients who were operated on within 12 hours constituted a relatively small patient group compared to those subjected to other delays leading to large confidence intervals in the analyses. Second, at the beginning of the study, patients differed with regard to age and previous diagnosis of memory disorder. Patients who were operated on within 12 hours were older and had more prior diagnoses of memory disorder than did patients operated on 12 to 24 hours and >48 hours after admission, thus suggesting that patients in the reference group (operated on within 12 hours) were initially at greater risk for worse survival. On the other hand, this discrepancy in fact only strengthens our findings emphasizing the benefits of early surgery in these high-risk patients. Third, patients with ASA grade 1 or 2 were excluded from the study, which may affect generalizability to all hip fracture patients. However, it is noteworthy that our subanalysis containing patients with ASA score 1 to 5 did not indicate significantly different results. Finally, the reasons for delayed surgery such as the use of various anticoagulants were not registered, which may have caused bias in surgical timing. A major strength of this study was that initially there were no parameters favoring better survival for hip fracture patients operated on within 12 hours. Further, this study concerns all hip fracture types.

Conclusions

A delay in hip fracture surgery for more than 12 hours after admission is the most significant factor associated with impaired 30-day survival among patients with severe systemic disease (ASA $\geq$ 3). A delay before surgery of more than 48 hours has an adverse impact on 365-day survival, although unmodifiable patient-related factors are more important. In the future, a 12-hour threshold for surgical delay is recommended to include in studies exploring the effect of surgical delay on hip fracture patients. We suggest that hip fracture patients are operated on the same day or within 1 day of admission depending on modifiable patient risk factors. Even if the beneficial effects on survival are distinguishable, longer waiting before surgery exposes patients to prolonged pain and increased risk of acute complications.

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Declaration of Conflicting Interests

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