Turun yliopisto
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HIP FRACTURE PATIENTS' CARE AND PREDICTORS OF OUTCOMES DURING ORTHOGERIATRIC COLLABORATION

A Population Based Study

Hanna Pajulammi

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To Janne, Eevi and Martti

ABSTRACT

Hanna Pajulammi

HIP FRACTURE PATIENTS' CARE AND PREDICTORS OF OUTCOMES DURING ORHOGERIATRIC COLLABORATION: A POPULATION BASED STUDY

University of Turku, Faculty of Medicine, Department of Geriatrics, Doctoral Programme of Clinical Investigation, Seinäjoki Central Hospital

Annales Universitatis Turkuensis, Medica-Odontologica, 2017

The aim of this study was to identify more predictors of mortality and functional recovery in older hip fracture patients, explore the background of an effective orthogeriatric program and evaluate the quality-related changes in care during orthogeriatric collaboration.

This study was based on the data of hip fracture patients aged 65 years or older treated in Seinäjoki Central Hospital between 2007 and 2015 (n=1,756). Of older hip fracture patients, those previously able to walk outside unassisted or live without organized home care were found to be at greatest risk for declined mobility and in need of more supported living arrangements. Of the medical conditions, renal insufficiency beyond moderate or having more than three medications increased the risk of mortality after hip fracture. Of the care related actions, indwelling urinary catheter (IUC) removal while hospitalized was associated with decreased risk of decline in mobility level and living arrangements and 1-year mortality.

During the orthogeriatric collaboration, markedly more patients received comprehensive geriatric assessment (CGA), and for these patients, 1-month survival improved. With CGA, short-term mortality of high-risk patients with renal insufficiency, polypharmacy or cognitive disorder was reduced. Of the care procedures, adherence to the standardized care protocol on red blood cell transfusions and removal of the IUC was better when CGA was delivered. Surgery in <24h hours increased during orthogeriatric collaboration but independent of CGA. Also, general expertise in geriatric care improved as more IUCs were removed without geriatrician's involvement.

To decrease hip fracture –related mortality and improve the general quality of care, an orthogeriatric hip fracture program with standardized care protocol and a multidisciplinary team should be considered a routine care in hospitals providing acute surgical care for older hip fracture patients.

Keywords: hip fracture, mortality, functional recovery, orthogeriatric care, care quality

TIIVISTELMÄ

Hanna Pajulammi

LONKKAMURTUMAPOTILAIDEN HOITO JA HOITOTULOSTEN ENNUSTETEKIJÄT ORTOGERIATRISEN YHTEISTYÖN AIKANA: VÄESTÖPOHJAINEN TUTKIMUS

Turun yliopisto, Lääketieteellinen tiedekunta, Geriatria, Turun kliininen tohtoriohjelma, Seinäjoen keskussairaala

Annales Universitatis Turkuensis, Medica-Odontologica, 2017

Tutkimuksen tarkoituksena oli löytää lisää iäkkäiden lonkkamurtumapotilaiden kuolleisuuteen ja kuntoutumiseen liittyviä ennustetekijöitä, selvittää toimivan ortogeriatrisen hoitomallin taustatekijöitä sekä arvioida hoidon laadun muutoksia ortogeriatrisen yhteistyön aikana.

Tutkimuksen aineisto koostui Seinäjoen keskussairaalassa vuosina 2007-2015 hoidetuista yli 65-vuotiaista lonkkamurtumapotilaista (n=1756). Suurimmassa liikuntakyvyn laskun ja tuetumpaan asumismuotoon siirtymisen vaarassa olivat ne potilaat, jotka ennen lonkkamurtumaa olivat toimintakyvyltään parhaita kyeten liikkumaan ulkona ilman apua tai asumaan ilman kotihoidon palveluita. Lonkkamurtuman jälkeinen kuoleman riski oli suurempi niillä potilailla, joilla oli vähintään keskivaikea munuaisten vajaatoiminta tai enemmän kuin kolme lääkettä päivittäisessä käytössä. Hoitotoimenpiteistä virtsakatetrin poisto sairaalahoitojakson aikana oli yhteydessä pienempään toimintakyvyn menetykseen ja pienempään kuolleisuuteen.

Ortogeriatrisen yhteistyön aikana kokonaisvaltainen geriatrinen arviointi yleistyi ja geriatrin hoitamien potilaiden yhden kuukauden kuolleisuus oli pienempi kuin muilla potilailla. Kokonaisvaltaisen geriatrisen arvion kuolleisuutta alentava vaikutus tuli ilmi erityisesti potilailla, joilla oli munuaisten vajaatoiminta, monilääkitys tai muistisairaus. Myös hoitopolun kirjallisia ohjeita punasolujen siirrosta ja varhaisesta virtsakatetrin poistosta noudatettiin paremmin, kun geriatri osallistui hoitoon. Ortogeriatrisen yhteistyön aikana yhä useampi potilas leikattiin alle 24 tunnin kuluessa saapumisesta, mutta kehitys tapahtui ilman yhteyttä geriatriseen arvioon. Myös niillä potilailla, jotka eivät olleet geriatrin hoidossa, varhainen virtsakatetrin poisto tuli yleisemmäksi, mitä voidaan pitää geriatrisen hoidon osaamisen kehittymisen merkkinä.

Kuolleisuuden vähentämiseksi ja hoidon laadun kohentamiseksi lonkkamurtumapotilaita hoitavissa sairaaloissa tulisi harkita standardoidun ja moniammatillisen ortogeriatrisen lonkkamurtumaohjelman perustamista.

Avainsanat: lonkkamurtuma, kuolleisuus, toimintakyvyn palautuminen, ortogeriatrinen hoitotapa, hoidon laatu

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ABBREVIATIONS

ADL	Activities of daily living
ASA	American Society of Anesthesiologists
BMD	Bone mineral density
BMI	Body mass index
BZD-Z	Hypnotic benzodiazepines and z-hypnotics; midazolam, temazepam, nitrazepam, triazolam, zaleplon, zolpidem, zopiclon
CAM	Confusion assessment method
CGA	Comprehensive geriatric assessment
CI	Confidence interval
CKD-EPI	The Chronic Kidney Disease Epidemiology Collaboration
eGFR	Estimated glomerular filtration rate
fS-Ca-ion	Fasting sample for ionized calcium in serum
QALY	Quality-adjusted life-year
HFP	Hip fracture program
HR	Hazard ratio
IADL	Instrumental activities of daily living
IQR	Inter-quartile range
IUC	Indwelling urinary catheter
LOS	Length of stay
LTFC	Long-term facility of care
MMSE	Mini Mental State Exmination
MNA	Mini Nutritional Assessment
MNA-SF	Short form of the Mini Nutritional Assessment
NHFD	The National Hip Fracture Database
OR	Odds ratio
P-D-25OH	Plasma sample for 25-hydroxyvitamin D
RBC	Red blood cell
RCT	Randomized controlled trial
sCr	Serum creatinine
SD	Standard deviation
TUG	Timed Up and Go

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications, which are referred to throughout the thesis by their Roman numerals:

I Pajulammi HM, Pihlajamäki HK, Luukkaala TH, Nuotio MS (2015) Pre- and perioperative predictors of changes in mobility and living arrangements after hip fracture-A population-based study. Arch Gerontol Geriatr. 2015;61:182-189.

II Pajulammi HM, Luukkaala TH, Pihlajamäki HK, Nuotio MS (2016) Decreased glomerular filtration rate estimated by 2009 CKD-EPI equation predicts mortality in older hip fracture population Injury. 2016 Jul;47(7):1536-42

III Pajulammi HM, Pihlajamäki HK, Luukkaala TH, Jousmäki JJ, Jokipii PH, Nuotio MS (2017) The effect of an in-hospital comprehensive geriatric assessment on short-term mortality during orthogeriatric hip fracture program– which patients benefit the most? Geriatr Orthop Surg Rehabil. DOI: https://doi.org/10.1177/2151458517716516

IV Pajulammi HM, Pihlajamäki HK, Luukkaala TH, Jousmäki JJ, Nuotio MS (2017) Association of comprehensive geriatric assessment with quality-related care practices during implementation and development of an orthogeriatric hip fracture program. Eur Geriatr Med. DOI: http://dx.doi.org/10.1016/j.eurger.2017.06.002

1 INTRODUCTION

Hip fracture is the most serious common injury in older patients, and the consequences of hip fracture are considerable both to the injured individual and to society. Twenty-five percent of these patients die within one year of the injury (Hu et al. 2012) and the surviving patients report long-term impairment in functions such as walking, dressing, and shopping (Dyer et al. 2016). Also, for many older people, suffering a hip fracture ends the time of independent living (Dyer et al. 2016; National Institute of Health and Welfare 2016). Even after significant recovery, patients report a decline in their quality of life (Boonen et al. 2004), which in degree is comparable to severe neurological diseases (Griffin et al. 2015). In the European Union alone, the treatment of 600,000 hip fractures cost €19 billion (Hernlund et al. 2013).

The population of the world is ageing rapidly and as a result the number of hip fractures will increase in the future. Patients suffering hip fracture are typically old and frail and, with their multimorbidity and polypharmacy, their need for expert medical attention during care is evident. To meet the need for more comprehensive care for this patient group, a variety of co-managed models of care have been developed (Kammerlander et al. 2010). In an orthogeriatric care model both an orthopedic surgeon and a geriatrician contribute to treatment, accompanied by a multidisciplinary non-physician team.

In studies from other countries, the orthogeriatric care model has proven effective in reducing mortality (Grigoryan et al. 2014) and improving recovery (Prestmo et al. 2015). Yet, little is known about which of the elements of orthogeriatric care make it effective. To prepare for the inevitably increasing number of hip fracture patients, there is a need to learn more about the background of effective treatment in this heterogeneous patient population. Also, patients at greater risk for poorer outcomes need to better identified and their risk factors, if modifiable, carefully addressed.

This prospective and population based study was undertaken to identify more predictors of mortality and poor recovery, discover the effective elements of orthogeriatrics and investigate quality related factors of care during the orthogeriatric collaboration in our hospital. The study population was derived from the Seinäjoki Central Hospital hip fracture program and consists of patients treated for hip fracture between September 2007 and December 2015.

2 REVIEW OF THE LITERATURE

2.1 Epidemiology and costs of hip fractures

2.1.1 Global epidemiology of hip fractures

The world's population is ageing rapidly. It is estimated that the number of people aged 60 years or older will rise from 900 million to 2 billion between 2015 and 2050 (World Health Organization 2015). While most of this will occur in developing countries, the percentage of people aged 60 and over will exceed 25% in the USA and 30% in the majority of the European countries and Canada by 2050 (World Health Organization 2015). Adapting to this massive change in the demographics will challenge societies and particularly health care providers.

As a result of population ageing, the number of hip fractures will increase in the future, reaching an estimated global incidence of 4.5 million in 2050 (Gullberg et al. 1997). In Asia, Latin America, and Africa the absolute number of hip fractures is estimated to increase 520% over a 60-year period from 1990 to 2050 (Gullberg et al. 1997). During that time an entirely new population, the oldest old, will be present in many countries in these areas. Combining the effects of the large present population and the increase in life expectancy, 45% of all hip fractures will occur in Asia by 2050 (Gullberg et al. 1997). The increase in absolute numbers will undoubtedly also affect the western countries. The annual number of hip fracture cases is estimated to double in Sweden between 2002 and 2050 (Rosengren & Karlsson 2014), in Germany between 2010 and 2050 (Bleibler et al. 2013) and in Austria between 2015 and 2050 (Concin et al. 2016)

Globally the age-adjusted incidence of hip fractures varies between countries 10-fold for both men and women (Kanis et al. 2012). In Europe the highest age-adjusted incidence for men and women combined was found in Denmark (439/100,000), Norway (420) and Sweden (401) and lowest in Serbia (139), Croatia (157) and Spain (164) (Kanis et al. 2012). The highest reported incidence of hip fractures worldwide is in Oslo, Norway, where the age-adjusted incidence per 10,000 was 82.0 in women and 39.1 in men (Stoen et al. 2012). As the majority of hip fractures occurs indoors, the cold climate does not contribute to the high hip fracture incidence (Lofthus et al. 2001; Stoen et al. 2012). There has recently been a slight decrease in the overall incidence of hip fractures in many western countries. However, the decrease in incidence is mainly observed in women (Stevens & Rudd 2013; Stoen et al. 2012) and especially in institutionalized women (Guilley et al. 2008). The reason for the decline is not well understood but an educated guess includes better overall and bone health, decreased smoking and increase in vitamin D intake (Abrahamsen & Vestergaard 2010; Korhonen et al. 2013; Stoen et al. 2012).

2.1.2 Epidemiology of hip fractures in Finland

In Finland people aged 65 or over numbered 940,000 (17.5%) in 2010 and this is estimated to increase to 1,480,000 (25.6%) only in two decades by 2030 (Official Statistics of Finland 2015). The proportion of people aged 65 and over will moreover continue to increase after 2030, but at slower rate, and is estimated to reach 28.8% in 2060.

From the early 1970s until 1997, the hip fracture number and incidence in Finland rose sharply (Kannus et al. 1999). Thereafter the age-adjusted incidence has continuously declined from 516/100,000 in 1997 to 383/100,000 in 2010 in women and from 245/100,000 in 1997 to 211/100,000 in 2010 in men (Korhonen et al. 2013). The declining trend is, as reported elsewhere, clearer in women. If the incidence stabilized to the 2010 level, it was projected that the annual number of hip fractures would increase 1,8 fold from about 7,600 in 2010 to about 13,500 in 2030 (Korhonen et al. 2013). Even if the age-adjusted incidence continues to decline, the annual number of hip fractures will rise markedly as the large generations born after World War II reach the hip fracture age.

2.1.3 Cost of hip fractures

It was estimated in 2010, that there were 600,000 hip fractures in the European Union countries, costing €19 billion and additionally accounting for a loss of 137,000 quality-adjusted life-years (QALYs) (Hernlund et al. 2013). In Finland, the health care cost of the first year following hip fracture is €30,000 per patient (National Institute of Health and Welfare 2016) and over €20 million for the annual 7,600 fractures. The health care costs remain elevated for at least five years after hip fracture (Leslie et al. 2013), to which the occurrence of a second hip fracture (Leal et al. 2016) and moving to a long-term facility of care (LTFC) (Nikitovic et al. 2013) are major contributors. Of community-dwelling patients suffering their first hip fracture, 11% were permanently admitted to a LTFC (National Institute of Health and Welfare 2016) leading to an annual cost of €48,000 (Kapiainen et al. 2014) per patient per year.

2.2 Hip fracture patients

2.2.1 Demographics of hip fracture patients

The most notable risk factor for hip fracture is age (Wehren & Magaziner 2003). The rise in hip fracture rates in patients aged from 60 years to 85-90 years is exponential and the risk of hip fracture almost doubles for every 5-6 year period (Kim et al. 2012a). Increasing life expectancy and better health of the oldest old raise the mean age of hip fracture patients (Bergstrom et al. 2009) and it has been estimated that by 2031, 45% of hip fractures will occur in patients over 85 years old (Holt et al. 2009). Ageing of the hip fracture population is also seen in Finland: from 1992-1993 to 2002-2003, the fastest growing age group in both sexes were patients aged 85 and over (Lönnroos 2009). Also, between 1970 and 2010, the average age of hip fracture patients rose from 75 to 82 in women and 70 to 76 in men (Korhonen et al. 2013).

Of hip fracture patients, 75% are women (Formiga et al. 2007; Kim et al. 2012a). However, while the incidence in women has begun to decrease (Löfman et al. 2002; Stoen et al. 2012), in men the incidence is either stable (Stoen et al. 2012) or growing (Löfman et al. 2002) and thus, the ratio of genders is shifting.

The majority of hip fracture patients are community-dwelling but approximately a quarter of hip fracture patient live in an LTFC (Formiga et al. 2007; Ranhoff et al. 2010). When compared to the hip fracture patients living at home, LTFC residing patients are more likely to be male, have more comorbidities and lower functional level, have more medications in daily use (both total or psychoactive) and have more often uncorrected hearing or vision deficits (Formiga et al. 2007), thus their risk for complications, mortality, and poor recovery are higher.

2.2.2 Description of hip fracture patients

As their age would suggest, hip fracture patients suffer from chronic and often multiple co-morbidities, with 81% having at least three co-morbidities, 44% more than six comorbidities and only 2% no co-morbidities (Leslie et al. 2012). In age-matched controls, the corresponding figures are 66%, 27% and 8%. If classified according to the American Society of Anesthesiologists (ASA) score, 46% of patients have mild (ASA 2) and 50% severe (ASA 3) systemic disease (Ranhoff et al. 2010). Of the specific diseases, cognitive impairment affects two in five hip fracture patients (Seitz et al. 2011) and one in five has diagnosed memory disease (Formiga et al. 2007; Seitz et al. 2011). During the year preceding hip fracture, 75% of patients had been prescribed medication affecting nervous system, 58% cardiovascular medications, 28% respiratory medications and 41% antibiotics (Kannegaard et al. 2010). Of hip fracture patients 72% take more than three medications daily (Formiga et al. 2007).

The combinations of characteristics in hip fracture patients vary considerably, for example, regarding age, comorbidities, and functional status, thus hip fracture patients form a quite heterogeneous patient group (Penrod et al. 2007). Ranhoff et al. divided the patients roughly but practically into three groups (Ranhoff et al. 2010), where first group was community dwelling older adults who had fallen outdoors, accounting for 17% of patients. The patients in this group are more active and healthier that those falling indoors (Kelsey et al. 2010). The second group (59%) consisted of community-dwelling patients who had fallen indoors. Indoor falls are associated with more comorbidities and disabilities and less active lifestyle (Kelsey et al. 2010). The third group (24%) comprised patients from LTFCs. Although there are overlapping medical problems between the defined groups, the division also explains the need for an adjustable approach regarding the diversity among patients (Ranhoff et al. 2010).

2.3 Hip fracture pathophysiology and orthopedic principles

2.3.1 Hip fracture pathophysiology

According to the National Osteoporosis Foundation, a fragility fracture is any fracture caused by a fall from standing height or less. The most common fragility fractures are those of hips, vertebra and wrist, which together account for 60% of fragility fractures (Ensrud 2013). The lifetime risk of any fragility fracture is 40-50% in women and 13-22% in men (Johnell & Kanis 2005). The higher risk in women is the result of accumulation of the most important risk factors of fragility fractures: falls and osteoporosis.

When sustaining a hip fracture, a patient typically falls from standing height directly on the trochanter of the femur (Parkkari et al. 1999). At the time of the fall, the fracturing of the femur depends on complex combination fall-induced impact force and bone strength (Luo 2016). However, falling itself is the main independent risk factor for hip fractures.

2.3.1.1 Falls

One third of the population aged over 65 (Hausdorff et al. 2001) and 50% of those aged over 80 (Inouye et al. 2009) fall every year. Among people living in LTFCs, the rate is even higher (Rapp et al. 2012). Of those who fall, half will experience at least one more fall within a year (Peel 2011).

According to a meta-analysis describing 17 independent risk factors for falling, the main risk factor was a previous fall, which may be related to an up to 7-fold risk of falling (Tinetti & Kumar 2010). Other independent risk factors for falling in community dwelling older adults include, but are not limited to, age >80 and female gender (Tinetti & Kumar 2010). Even with no predisposing risk factors, risk of falling was 8% per year and the risk increased linearly with the number of risk factors to 78% with four or more risk factors (Tinetti et al. 1988).

The risk factors for falling can be classified into extrinsic, intrinsic or combined (Formiga et al. 2008). Intrinsic factors include the effects of physiological ageing (e.g. decline in muscle strength, reflex rapidity, height of stepping, vision or hearing), diseases (e.g. diabetes, osteoarthritis or stroke) and drugs (e.g. psychotropics, diuretics, antihypertensives). Extrinsic factors are “environmental” such as uneven or slippery surfaces, doorsteps, loose carpets or poor lighting. Combined risk factors include components from both extrinsic and intrinsic risk factors.

In 30-50% of falls, the most likely cause is “accidental” or environment-related (Rubenstein 2006). However, many falls categorized as accident-related also include intrinsic components, and the majority of falls are primarily caused by intrinsic factors of gait or balance disorders, dizziness or vertigo, drop attack, confusion, postural hypotension, visual disorder or syncope (Rubenstein 2006). Other specified causes include arthritis, acute illness, drugs, alcohol, pain, epilepsy, and falling from bed (Rubenstein 2006). The proportion of intrinsic or combined factors as the cause of the fall increases among people aged 80 or over (Peel 2011). In falls causing hip fractures, the sole extrinsic factors were the main cause of the fall in 48% of patients aged 65-79 years but 35% of patients aged over 90 years (Formiga et al. 2008).

2.3.1.2 Osteoporosis

The problem of falls in older people is not only about high incidence but also high susceptibility to injuries. Of older people’s falls, 40-60% are injurious and 5% cause fractures (Masud & Morris 2001). Only 1% of falls in older people lead to hip fracture (Ryynänen et al. 1991) but 98% of hip fractures are caused by a fall (Parkkari et al. 1999).

In osteoporosis the bone mass of the skeleton is reduced and the bone micro-architecture is deteriorated making the bones more fragile and susceptible to fractures. According to World Health Organization criteria, bone mineral density (BMD) 2.5 SD or more below the average BMD of young healthy adult represents osteoporosis and 1-2.5 SD below the average BMD of young healthy adult represents osteopenia (World Health Organization 1994). Osteoporosis prevalence increases with advancing age due to the physiological ageing of bone and the long-term effects of life-style factors (e.g. smoking), diseases (e.g. inflammatory bowel disease) and medication (e.g. steroids). Osteoporosis as measured in BMD is a significant risk factor for fractures and hip fractures (Leslie et al. 2012; Marshall et al. 1996). However, most of the hip fracture patients have BMD in normal or osteopenic range (Wainwright et al. 2005) and it has been estimated that fewer than one in three hip fractures are attributable to osteoporosis (Stone et al. 2003). Although osteoporosis significantly increases the risk for fractures, fracture risk may also be estimated fairly accurately without BMD and using only well-known clinical risk factors (Leslie et al. 2012).

2.3.1.3 Biomechanics of falling

Besides affecting the frequency of falling and incidence of osteoporosis, aging affects also the biomechanics of a fall. The control of lateral stability during stepping becomes more difficult in older age and this leads the direction of the fall to the side (Maki & McIlroy 2006). Also, in older adults the speed of the protective arm movement is slower (Maki & McIlroy 2006) and ability to arrest a fall weaker (Sran et al. 2010). Furthermore, the energy-absorption ability of soft tissues in the trochanter region decreases with age (Choi et al. 2015). Consequently, in falls leading to hip fracture, when compared to those not causing hip fracture, the fall was not successfully broken e.g. with an outstretched arm, and the direction of the fall was to the side with the greatest impact on the trochanter of the femur (Parkkari et al. 1999).

2.3.2 Orthopedic principles of hip fractures

2.3.2.1 Fracture types

Hip fracture is a general description for several types of fractures in the proximal part of the femur. The two most common types of fractures are femoral neck (also referred as cervical or intracapsular) fractures and trochanteric (including pertrochanteric and intertrochanteric fractures, also referred as extracapsular). The third but less common type of hip fracture is subtrochanteric fracture (Figure 1.).

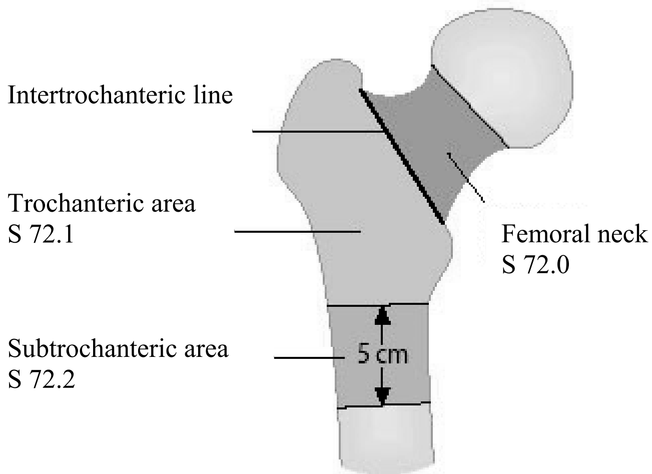

Figure 1 Classification and diagnostic codes (IDC-10) of fractures in the proximal femur adapted and modified from Current Care Guidelines of Hip Fractures (Working group appointed by the Finnish Medical Society Duodecim and the Finnish Orthopedic Association 2011).

Femoral neck and trochanteric fractures each account for approximately 45% (Löfman et al. 2002; Napoli et al. 2013) and subtrochanteric fractures for up to 10% (Napoli et al. 2013; Zuckerman 1996) of all hip fractures. There are signs that, as the demographics of hip fracture patients are changing, the distribution of fracture types is also changing, and the proportion of trochanteric fractures is increasing (Kim et al. 2012a). Patients with trochanteric fractures are older (Fox et al. 1999; Napoli et al. 2013) and have more comorbidities (Fox et al. 1999) than patients with femoral neck fractures. The subtrochanteric fracture risk profile is less certain but includes older age and diabetes (Napoli et al. 2013) and, in women, long-term bisphosphonate use (Schilcher et al. 2015). It should be noted that studies on subtrochanteric fractures are fewer than on other hip fracture types and, also, studies are conducted on study populations combining subtrochanteric hip fractures with distal shaft fractures (Napoli et al. 2013; Schilcher et al. 2015).

2.3.2.2 Surgical treatment and procedures

The choice of best treatment method depends on the anatomical location and pattern of the fracture and consideration for the patient's activity level, possible osteoarthritis, and comorbidities related to life expectancy.

According to a review article, the most common surgical procedures for different fracture types are as follows (Mears 2014):

- Femoral neck fracture
  - Undisplaced: internal fixation with screw(s)
  - Displaced:
    - Semiendoprothesis
    - Total endoprothesis for patients with high activity level or rheumatoid arthritis/osteoarthritis
- Trochanteric fracture
  - Stable fracture pattern: dynamic hip screw with side plate
  - Unstable fracture pattern: intramedullary hip screw
- Subtrochanteric fracture: intramedullary hip screw

Non-surgical treatment may be considered for severely co-morbid patients unlikely to survive any type of anesthesia or surgery. After 30 days, the mortality of conservatively treated patients was comparable to that in the surgical group and at one year, all surviving conservatively treated patients were able to move without pain and 55% to mobilize with walking aids (Gregory et al. 2010).

2.4 Outcomes of hip fractures

2.4.1 Mortality after hip fracture

Hip fracture mortality is high. According to a review and meta-analysis of 64,000 patients, mortality for in-hospital or one-month, three to six months, one year, two years and three to five years was 13.3%, 15.8%, 24.5%, 34.5% and 38.1%, respectively (Hu et al. 2012). There is considerable variation in hip fracture mortality between countries but the reason for this, for example differences in demographics or treatment methods, is not clear (Haleem et al. 2008). The hip fracture mortality figures in Finland in 2013 for one month, three months and one year were 5.7% (ranging from 1.4% to 9.4% between hospital districts), 11.9%

(2.9%-17.0%) and 18.4% (10.0%-24.5%) (National Institute of Health and Welfare 2016) with notable regional variation.

There is also persistent excess mortality related to hip fracture. When compared to controls of the same age, five to eightfold excess mortality has been reported during the first three months after the hip fracture (Abrahamsen et al. 2009b). The excess mortality decreases after one to two years but remains twofold even eight to ten years after hip fracture (Abrahamsen et al. 2009b; Katsoulis et al. 2017). In a long-term follow-up, the increase in mortality was not specifically related to any particular cause of death, but was seen in all major causes of death such as circulatory, respiratory, and digestive system disease, malignant neoplasm, and dementia (Panula et al. 2011).

2.4.2 Predictors of mortality

Many of the preoperative predictors for increased risk of mortality after hip fracture are well studied and a summary of two large meta-analyses is presented in Table 1.

Table 1 Summary of preoperative predictors for mortality after hip fracture. Adopted and modified from earlier publications (Hu et al. 2012; Smith et al. 2014).

Well-known predictors	**Moderate evidence predictors**
Advanced age	Intertrochanteric fracture (vs. femoral neck)
Male gender	Low serum albumin or malnutrition
LTFC residence	Low hemoglobin
Poor preoperative walking capacity	High serum creatinine
Poor preoperative ADL	Chronic renal disease
Higher ASA score	Chronic pulmonary disease
Multiple comorbidities	
Dementia or cognitive impairment	
Diabetes	
Cancer	
Cardiac disease	
Abnormal ECG	
Conflicting evidence	**No effect on mortality**
Low BMI	Education level (literate vs. illiterate)
Depression	
Ethnicity (Caucasian vs. non-Caucasian)	

LCFT=long-term facility of care, ADL=activities of daily living, ASA= American Society of Anesthesiologists, ECG=electrocardiogram, BMI=body mass index.

The International Society of Nephrology recommends using the 2009 Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation–based estimated glomerular filtration rate (eGFR) ($eGFR_{CDK\text{-}EPI}$) for assessing renal function in adults of all ages (Work Group of Kidney Disease - Improving Clinical Outcomes 2013). Notably, none of the studies in the Table 1 meta-analyses reported eGFR but used S-Cr or prefracture diagnosis of chronic renal insufficiency to assess patients' renal function. The only study that has used $eGFR_{CDK-EPI}$ in hip fracture patients found no association between renal function and mortality, but the study was very small with only 88 patients and the analysis was not adjusted for the well-known predictors of mortality (Lopez-Martinez et al. 2014). Polypharmacy is one of the predictors of interest in this study but it has been less studied in hip fracture patients and was not included in the meta-analyses above. Greater number of medications seems to increase long-term mortality in hip fracture patients (Gosch et al. 2014; Kannegaard et al. 2010) but these studies did not present risk stratification, as the patients were not classified according to number of medications.

To better address the prognosis of hip fracture patients coming from a population with an endless number of combinations of age, comorbidities, and "general fitness", frailty has recently been examined for predictive value after hip fracture. Frailty is a clinical state of increased vulnerability resulting from accumulated age-related physical and physiological deficit but is separated from chronological age itself. There are several definitions and indexes for frailty but Fried frailty phenotype comprising weight loss, physical inactivity, slow walking speed, low grip strength and exhaustion is the best known (Fried et al. 2001). Increased frailty has recently been demonstrated to independently predict mortality, also in older hip fracture patients (Dayama et al. 2016; Krishnan et al. 2014).

Whereas the list of preoperative predictors is extensive, fewer perioperative predictors of mortality are known and the evidence on these is more limited. One of the most studied preoperative predictors is delay from admission to surgery. It is well established, that > 48h delay from admission to surgery increases mortality in older hip fracture patients (Moja et al. 2012; Simunovic et al. 2010). However, according to more recent studies, shortening the delay under 24h decreases the mortality even more (Morrissey et al. 2017; Uzoigwe et al. 2013). Only a few other perioperative factors have been researched in relation to mortality and the evidence is not conclusive. According to a Cochrane review (Guay et al. 2016) and another large study of 7,585 patients (Brox et al. 2016), there is no difference in mortality if general or local anesthesia is used on hip fracture patients. The evidence for red blood cell (RBC) transfusions is conflicting as, according to a Cochrane review, liberal or restrictive red blood cell transfusion does not affect mortality among hip fracture patients (Brunskill et al. 2015) but in a more recent RCT a more liberal transfusion policy was beneficial in decreasing mortality for frailer subgroups such as patients living in LTFCs (Gregersen et al. 2015a). Also, an association between an indwelling urinary catheter still in place at discharge and increased 30-day mortality has been shown (Wald et al. 2005) but the evidence on hip fracture patients is limited to this one study.

Of the orthopedic surgeon related factors concerning the acute stay, the surgeon's level of experience seems to have predictive value. The mortality at various time points after hip fracture is lower if the orthopedic surgeon performes >15 hip fracture operations per year (Browne et al. 2009) or performs >25 total endoprothesis procedures per year (Ames et al. 2010). If a trainee operates without the supervision of a scrubbed-in consultant, the patient's odds of dying within 6 months was 80% higher (Khunda et al. 2013). The evidence on the effect of hospital volume on mortality is inconsistent (Browne et al. 2009; Kristensen et al. 2014). However, the study by Kristensen et al is from the "post-centralization" era and the categorization of hospital volumes more up to date (< 152 per year, 152-351 per year, >351 per year). In their study, 30-day mortality was higher in the high-volume hospitals.

2.4.3 Recovery after hip fracture

The impact of hip fracture on the patients' health and functioning abilities is heavy as recovery is slow and often incomplete. In the studies examining multiple aspects of recovery, a partly overlapping variety of indicators, classifications, time-points and casemix of patients has been used.

In a large study of 16,000 patients, of those able to walk without aid or assistance before the fracture, 18% had regained their prefracture status, 50% needed an aid, 10% needed assistance and 6% could not walk four months after the fracture (Holt et al. 2008b). In another study, 52% of patients had still not regained their prefracture mobility level in 12-month follow-up and in a subgroup of patients mobile without aid only 40% had regained their prefracture status (Vochteloo et al. 2013b).

At three months after hip fracture, prefracture ADL level was regained by 71% of community dwelling and by only 22% of LTFC residing hip fracture patients (Beaupre et al. 2007). More than half of prefracture independent patients did not regain their previous state in one year in ordinary daily actions of climbing 5 stairs, walking 1 block, getting places within walking distance and housecleaning but more than half had recovered independency in getting into a car, taking a shower and putting on socks, shoes and pants (Magaziner et al. 2000). Even after two years, 51% of hip fracture patients had not regained their prefracture status in ADL functions and 45% in IADL functions, which represented substantially larger functional deteoriation than in patients of same age without a hip fracture (Bentler et al. 2009). When the patients in the most fragile subgroups are examined separately, the consequences of hip fracture are devastating. Of the patients living in LTFCs, only 20% both survive and regain their prefracture functions (Neuman et al. 2014).

According to two reviews, most of the recovery both in mobility and daily functions was achieved within six months after hip fracture (Bertram et al. 2011; Dyer et al. 2016), which suggests that these hip fracture-related disabilities may be largely permanent.

In a Scottish study of 16,000 patients, 35% of patients living prefracture in their own home had not been able to return there four months after the fracture (Holt et al. 2008b). In Canada, 24% of prefracture community-dwelling patients had moved to a LTFC one year after hip fracture (Morin et al. 2012). In Germany, the crude institutionalization rate after hip fracture was 12% but varied by age from 3.6% in patients aged 65-69 years old to 35% in patients 95 years or older (Rapp et al. 2015). Compared to the institutionalization-rate of home-dwelling patients mentioned above, 29% in Finland (Rissanen et al. 2002) seems high. However, the patients in the Finnish study were enrolled in 1998-1999 and secular changes in both hip fracture care and rehabilitation and in the living arrangements of older people have occurred since then. According to the most recent register data from 2011-2013, 11% of patients previously living at home were permanently admitted to an LTFC (National Institute of Health and Welfare 2016).

Suffering a hip fracture also affects the quality of life. When compared to age-matched controls without hip fracture, the quality of life is substantially worse even after significant recovery (Boonen et al. 2004). The deterioration in the quality of life does not regain prefracture level within one year, and the severity of it is comparable to the deterioration caused by neurological conditions such as Parkinson's disease and multiple sclerosis (Griffin et al. 2015).

2.4.4 Predictors of recovery

A review article reports several predictors of poorer functional and/or mobility outcome including higher age, male sex, trochanteric or subtrochanteric fracture (vs. femoral neck), impaired cognitive function, existing co-morbidities, and lower prefracture functioning (Kristensen 2011). Even though older age is a risk factor for survival and satisfactory recovery after hip fracture, 40% of patients aged over 90 years living prefracture at home could return home, and there was no difference between these and younger patients in regaining prefracture mobility level (Vochteloo et al. 2013a). If age does not provide accurate enough prognosis, frailty may be useful not only in predicting mortality but also recovery (Krishnan et al. 2014). Also, type of fracture, trochanteric or subtrochanteric, may not be an undisputed predictor as there is evidence to suggest that the result of the recovery one year after the fracture is comparable but achieved more slowly than in femoral neck patients (Fox et al. 1999). Unsurprisingly, lower functional level at discharge or living in an LTFC at the time of the fracture has also been connected to poorer recovery after hip fractures (Haentjens et al. 2005). The risk factors for the need to move to more supported living arrangements are to a great extent similar to the risk factors of compromised functional recovery (Martinez-Reig et al. 2012; Parker & Palmer 1995).

Known perioperative or modifiable predictors of recovery are fewer and the results of the studies either contradictory or negative. In one study, shorter delay to surgery was associated with the ability to return to independent living (Al-Ani et al. 2008), but did not correlate with walking ability at six months (Kim et al. 2012b). Having a more liberal or more restricted RBC policy had no effect on recovery after hip fracture (Brunskill et al. 2015). However, a more liberal RBC transfusion policy resulted in greater ADL recovery in frail hip fracture patients and ADL recovery was furthermore associated with better overall quality of life (Gregersen et al. 2015b). Of the functional outcomes, prompt postoperative catheter removal has been associated with greater activity level one year after hip fracture (Sorbye & Grue 2013) and regaining walking ability during hospitalization for hip fracture (Brown et al. 2006).

2.4.5 Complications and readmissions

Reflecting their vulnerability and the seriousness of the injury, as many as half of the older hip fracture patients suffered from complications during hospitalization (Leung et al. 2011; Vidan et al. 2005). The most common groups of in-hospital complications are infections (pneumonia, urinary tract infection, wound infection), cardiovascular problems (acute myocardial infarction, heart failure, arrhythmias, anemia), delirium/confusion, pressure ulcers and deep vein thrombosis (Leung et al. 2011; Neuman et al. 2009; Vidan et al. 2005). In patients 85 years or older, pneumonia, acute myocardial infraction, acute renal failure, and deep vein thrombosis were more common than in younger patients, but the frequencies of cerebrovascular events or pulmonary embolisms did not differ (Jameson et al. 2012).

The rates of readmission to hospital are 5%-12% within 30-days (Nordström et al. 2016; Stenvall et al. 2007) and 12%-30% within 4 months (Deschodt et al. 2011; Prestmo et al. 2015). The predictive factors for readmission are similar to those of poor survival and functional recovery, including older age, male gender, comorbidities, dependency in daily living and discharge destination (Basques et al. 2015). 10-20% of the reasons for readmissions are surgical and of the medical reasons pneumonia, cardiovascular problems (heart failure, arrhythmias, acute myocardial infraction), acute renal failure and general deterioration are the most common (Buecking et al. 2013; Khan et al. 2012)

The most common surgical reasons for readmission are periprosthetic fracture, aseptic loosening of the prosthesis, unexplained pain and deep infection. It is not clear if a routine orthopedic follow-up visit would be useful in detecting these complications earlier (Chaplin et al. 2013). Of the surgical complications, deep wound infection is the most feared. Of the hip fracture patients treated with hemiarthroplasty, 6% were diagnosed with early prosthesis joint infection, and their overall 1-year mortality almost doubled to 41% and was 71% if the infection treatment was not successful (Guren et al. 2017). After primary hip fracture surgery, the reoperation rate is 3-15% and depends on the type of fracture and primary operation (Broderick et al. 2013, Gjertsen et al. 2012).

2.5 Orthogeriatrics

The role of the geriatrician in the care of older hip fracture patients was first described in the UK in the 1960s. The first reported models of orthogeriatric care outside of Great Britain were published in Australia in the 1980s and in USA and Europe in the 1990s. Evidence on the benefits of orthogeriatrics emerged enough for the Blue Book of the British Orthopaedic Association and British Geriatric Society to be published in 2003 and updated in 2007 (British Orthopaedic Association and British Geriatrics Society 2007). This first detailed guideline in orthogeriatrics summarized the best clinical practice and available evidence, and set out standards for the care of older patients with fragility fractures including an orthogeriatric care model as one of them. Today, orthogeriatric management of hip fracture patients is increasingly becoming standard care in many countries and locations around the world.

2.5.1 Components of orthogeriatric care

2.5.1.1 Staff

Of the doctors, an orthopedic surgeon and a geriatrician share the daily care of hip fracture patients and including an anesthesiologist a consultant and a member of the team designing the care protocol is common. The rationale for including a geriatrician in the care of hip fracture patients is indisputable. By definition, a geriatrician is a physician trained to meet the unique healthcare needs of older adults (European Union of Medical Specialists - Geriatric Medicine). Patients with hip fracture are mostly very vulnerable and, thus, at the core of geriatric practice (Warshaw et al. 2008). Hip fracture patients are also a very heterogeneous group (Penrod et al. 2007; Ranhoff et al. 2010), and the care has to be tailored to provide the most beneficial care and rehabilitation for each individual. Complexity of the patients is well known and, in addition to the surgical care crucial to most patients, expert medical attention is needed. In the study of possibly preventable in-hospital mortality among hip fracture patients, the errors contributing to death differed slightly between specialties (Tarrant et al. 2014) pointing out the importance of combining cross-disciplinary expertise for the benefit of the patient. Also, two of the biggest subgroups in hip fracture patients are those with dementia and cognitive disorders, amounting respectively to 19% and 42% of hip fracture patients (Seitz et al. 2011). Dementia is one of the so-called giants in geriatrics and in hip fracture patients it is a known risk factor for poor prognosis of survival (Hu et al. 2012) and recovery (Kristensen 2011) and may limit access to rehabilitation (McFarlane et al. 2015; Seitz et al. 2016). Their prognosis after hip fracture may, however, be improved by multidisciplinary geriatric rehabilitation (Huusko et al. 2000). As more than every third hip fracture patient has cognitive impairment, a geriatric expertise is crucial.

Multidisciplinarity is fundamental in orthogeriatric care. The core of the orthogeriatric team are a geriatrician and an orthopedic surgeon but the compositions of non-medical members of orthogeriatric teams vary and may include geriatric nurses, physiotherapists, occupational therapists, pharmacists, social workers and clinical nutritionists dedicated and trained to care for the older hip fracture patients. The background of the non-medical staff may vary according to traditions, availability, and resourcing and the suitable composition considering the task is decided locally.

2.5.1.2 Standardized protocol

Orthogeriatric care models include a standardized protocol relying on clinically judged best practice and evidence where available. Protocols often are extensive and detailed written instructions for care addressing every step of care from admission to discharge. The protocols differ slightly depending on local resources and traditions and a synopsis of three orthogeriatric protocols is presented in Table 2.

Table 2 An example of a written orthogeriatric care protocol. Adapted and modified from existing publications (Friedman et al. 2008; Martinez-Reig et al. 2012; Ranhoff et al. 2010).

Preoperative care	Delay from admission to surgery <48h Set of preoperative laboratory tests Pain control with standard regimen Clinical examination (fluid balance, cardiovascular stability, other trauma etc.) Antibiotic and venous thromboembolism prophylaxis
Postoperative care	
Geriatric assessment	Assessment of prefracture ADL, cognitive function, need of assistance in care, general health Clinical examination with measurements of blood pressure and oxygen saturation Medications evaluation and adjustment Fluid balance and blood results monitoring
Prevention of complications	Systematic prevention of delirium, falls, thromboembolism, nosocomial infections, pressure sores and wound infections Removal of IUC within 24h after surgery Screening for urinary retention by bladder scans Prevention of constipation RBC transfusion at specific hemoglobin levels Systematic pain control
Nutrition	Preoperative oral liquid supplements to all patients Energy-dense meals Nutritious state assessment Additional nutritious supplements as needed
Rehabilitation	Mobilization on first postoperative day Daily ADL and mobility training with nursing staff Training with physiotherapist Encouragement to be independent
Future fracture prevention	Fall assessment and multifactorial intervention Assessment of bone health and osteoporosis treatment (calcium, vitamin D, bisphosphonates)

ADL=activities of daily living, IUC=indwelling urinary catheter, RBC=red blood cell

2.5.2 Orthogeriatric care models

Orthogeriatric service can be organized in many ways and several orthogeriatric or co-managed care models have been developed. They have been described as follows by several authors (Kammerlander et al. 2010; Sabharwal & Wilson 2015):

1. Patients are treated on an orthopedic ward and geriatric consultation is available on request.

2. Patients are treated on an orthopedic ward and geriatric consultation is daily and consistent. The responsibility, however, is not shared but rests solely with the orthopedic surgeon.

3. Patients are treated on a geriatric or rehabilitative ward either from admission or immediately post-operation until discharge and the role of the orthopedic surgeon is consultative. In this model, the responsibility rests with a geriatrician.

4. Patients are treated on an orthopedic ward but an orthopedic surgeon and a geriatrician manage the patients jointly and a multidisciplinary team is integrated into the care. In this model the orthopedic surgeon and a geriatrician share the responsibility for the patients.

The considerable variation in the degree of implementation and thoroughness and the degree of integration of disciplines in the models applied in real life circumstances makes the comparison of models challenging, and none of the models has been proven to be optimal (Grigoryan et al. 2014). To measure and compare the outcomes of different models, a standard set of objective and patient-reported outcome parameters has been identified (Liem et al. 2013).

2.5.3 Effects of orthogeriatric care on mortality

An overview of the results of the studies on the effect of orthogeriatric care on mortality is presented in Table 3. To minimize the effect of the secular changes in hip fracture care and management, only studies with patient enrollment beginning during the past 20 years (since January 1997) were included in the table.

In the largest (n= 319) of the randomized controlled trials on the effect of orthogeriatric care on mortality, a significant decrease in in-hospital mortality was demonstrated in the intervention group vs. the control group, the rates being 0.6% vs. 5.5%, respectively. In the two RCTs available, a decreasing trend in one-year mortality was demonstrated (from 25.3% to 18.9% and from 18% to 16%) but neither of them reached statistical significance (Stenvall et al. 2007; Vidan et al. 2005).

In the real-life studies presented in Table 3, the trend in the mortality rates is decreasing in almost all of the studies, including all time-points. However, in many of the studies the number of participants is small and statistical significance is not reached even when the difference between groups is clinically meaningful. A recognized challenge in the comparison of the results of different studies is the wide variation in the contents and description of orthogeriatric care programs. A non-significant increase in mortality was seen in two studies. In the study by Marsland et al the after-group receiving orthogeriatric care had markedly higher incidence of prefracture comorbidities, which was thought to contribute to the result (Marsland & Chadwick 2010). In the study by Gregersen et al, the 23% of patients admitted from LTFCs were excluded from the intervention but were included in the analysis (Gregersen et al. 2012). In a subgroup analysis, the three-month mortality in patients from LTFCs actually increased significantly, which is likely to affect the result of mortality analysis of the whole study population.

In addition, not only establishing and implementing an orthogeriatric program, but also intensifying an existing program may reduce 30-day (Hawley et al. 2016; Neuburger et al. 2016) and one-year (Hawley et al. 2016) mortality in older hip fracture patients. In the study by Neuburger et al, the increase of orthogeriatrician hours per patient by 2.5 hours (from 1.5 to 4.0 hours) was estimated to have potential to prevent 200 deaths annually if applied across the UK.

According to individual studies without comparison analysis, it seems that "light-weight" orthogeriatric models, such as one-time consultation by a geriatrician or written clinical instructions without a dedicated unit or a geriatrician's/physician's involvement do not make an impact on mortality (Deschodt et al. 2011; Neuman et al. 2009). However, in one study, implementation of a written hip fracture protocol reduced one-year mortality in the subgroup of community-dwelling patients (Pedersen et al. 2008).

Some of the co-managed hip fracture programs do not involve a geriatrician but the medical expertise is brought to the team through hospitalists or internists. These programs have not succeeded in decreasing mortality even though many other outcomes, such as time to surgery and delivering bone health assessment, have improved (Lau et al. 2013; Soong et al. 2016; Suhm et al. 2014). Interestingly, however, by implementing nurse-led fracture liaison services, mortality was decreased in 40% of the hospitals in the study (Hawley et al. 2016).

Table 3 Summary of studies on the effect of orthogeriatric care on mortality.

Reference, year, location	N	Setting and intervention	In-hospital mortality	SS	1-month mortality	SS	3-6-month mortality	SS	1-year mortality	SS
Randomized controlled studies										
Vidan et al., 2005, Spain	319	single center, MOT vs. usual care, both on orthopedic ward	0.6% vs. 5.5%	yes	-	-	-	-	19% vs. 25%	no
Stenvall et al., 2007, Sweden	199	single center, orthogeriatric unit vs. orthopedic ward	NR	no	-	-	NR	no	16% vs. 18%	no
Real-life studies										
Friedman et al., 2009, USA	314	multicenter, orthogeriatric unit vs. orthopedic ward	1.6% vs. 2.5%	no	-	-	-	-	-	-
Cogan et al., 2010, Ireland	201	before and after, MOT vs. usual care, both on orthopedic ward	8% vs. 20%	NR	-	-	-	-	43% vs. 45%	NR
Marsland et al., 2010, UK	206	before and after, MOT vs. usual care, both on orthopedic ward	-	-	8.9% vs. 8.6%	no	22% vs. 15%	no	-	-
Adunsky et al., 2011, Israel	3114	single center, orthogeriatric unit vs. orthopedic ward	-	-	1.9% vs. 3.0%	no	6.5% vs. 8.1%	no	15% vs. 17%	yes
Leung et al., 2011, Hong Kong	548	before and after, MOT vs. usual care, both on orthopedic ward	-	-	1.8% vs. 5.2%	yes	4.7% vs. 9.3%	yes	12% vs. 20%	yes
Gregersen et al., 2012, Denmark	495	before and after, MOT vs. usual care, both on orthopedic ward	8% vs. 6%	no	-	-	16% vs. 18%	no	-	-
Biber et al., 2013, Germany	283	before and after, orthogeriatric unit vs. orthopedic ward	4.4% vs. 5.9%	no	-	-	-	-	-	-

Boddaert et al., 2014, France	334	before and after, orthogeriatric unit vs. orthopedic ward	3% vs. 8%	no	-	-	NR	yes	-	-
Flikweert et al., 2014, Netherlands	401	before and after, MOT vs. usual care, both on nursing ward	2% vs. 6%	yes	5% vs. 9%	no	-	-	-	-
Henderson et al., 2017, Ireland	454	before and after, MOT vs. usual care, both on orthopedic ward	1.9% vs. 4.4%	no	-	-	-	-	9.7% vs. 19%	yes
Register-based studies										
Kristensen et al., 2016, Denmark	11 461	multicenter, orthogeriatric unit vs. orthopedic ward	-	-	9.4% vs. 12%	yes	-	-	-	-
Nordström et al., 2016, Sweden	89 301	multicenter, geriatric ward vs. orthopedic ward	-	-	7.1% vs. 7.4%	yes	-	-	-	-

SS=statistically significant, MOT=multidisciplinary orthogeriatric team with a geriatrician and non-physician staff, NR= not reported, - = not studied

2.5.4 Effects of orthogeriatric care on functional recovery

Some of the most convincing evidence on the effect of orthogeriatric management of hip fractures on functional recovery was published in The Lancet in 2015. In this RCT, the prefracture home-dwelling patients treated on an geriatric ward improved in mobility, activities of daily living, quality of life, and more patients (25% vs. 11%) could also be discharged directly home when compared to usual care on an orthopedic trauma ward (Prestmo et al. 2015). The mean length of hospital stay in the intervention group was only 12.6 days, but the positive effect on functional recovery lasted until the end of follow-up (12 months). Another RCT with continued orthogeriatric rehabilitation after acute care reported significant improvements in regaining independence in indoor walking, ADL functions, bathing, and continence, which lasted for the whole of the 12 month-follow up (Stenvall et al. 2007). Mean length of stay (LOS) was lengthy 30 days, yet 10 days shorter than in the control group with poorer outcomes. However, despite the improvements in functional recovery, the proportions of patients still living at home one year after hip fracture were not affected by comprehensive geriatric care (Prestmo et al. 2015; Stenvall et al. 2007). In the RCT by Vidan et al. the intervention was less intensive and no difference in long-term functional recovery was achieved (Vidan et al. 2005).

Implementation of an orthogeriatric program in real-life circumstances showed increased independence in ADL functions and the effect lasted until the end of 12-month follow-up (Leung et al. 2011). Also, postoperative care in a dedicated geriatric unit resulted in more patients rehabilitating to having no walking disabilities and fewer patients were non-mobile, but these results were not long-term (Boddaert et al. 2014). In a nurse-led orthogeriatric program the benefits on functional recovery were almost negligible even though LOS increased by seven days (Roberts et al. 2004).

2.5.5 Effects of orthogeriatric care on other outcomes

Orthogeriatric management improves numerous outcomes other than mortality and functioning. In many studies time to surgery has been successfully shortened through implementation of an orthogeriatric program (Biber et al. 2013; Patel et al. 2013). Also, statistically significant reductions in the incidence of complications such as post-operative infections, venous thromboembolism, cardiac complications, deliriums, falls, pressure sores have been achieved (Neuman et al. 2009; Patel et al. 2013; Pedersen et al. 2008; Stenvall et al. 2007; Vidan et al. 2005). In orthogeriatric care more patients received bone protection medication (Kristensen et al. 2016; Patel et al. 2013) and a rehabilitation plan

(Kristensen et al. 2016) and more comorbidities were newly diagnosed (Leung et al. 2011; Nordström et al. 2016). Despite the improvements in complication rates, the evidence on decreasing readmissions by taking a comprehensive orthogeriatric approach is inconsistent (Deschodt et al. 2011; Nordström et al. 2016; Prestmo et al. 2015; Stenvall et al. 2007).

Length of stay in orthogeriatric care may be similar (Kristensen et al. 2016; Vidan et al. 2005), increased (Prestmo et al. 2015) or decreased (Biber et al. 2013; Collinge et al. 2013; Leung et al. 2011; Stenvall et al. 2007) when compared to the traditional care. Even though the decrease in LOS with no impact on in-hospital mortality is sometimes pointed out as a positive result (Biber et al. 2013), each one-day reduction in LOS has been shown to increase 30-day mortality 8-16% for patients with LOS under 10 days (Nordström et al. 2015). Furthermore, in-hospital mortality may even increase, if surgery is rushed while aiming at shorter LOS (Collinge et al. 2013). LOS is among the most difficult parameters to compare between countries and health care systems (Liem et al. 2013) and, thus, generally applicable optimal LOS is nearly impossible to determine.

The adverse psychological effect of suffering a hip fracture may also be reduced in comprehensive care as fear of falling was decreased and quality of life increased for patients treated on a geriatric ward (Prestmo et al. 2015). The orthogeriatric care model was also well-accepted among staff; 91% of the doctors and 84% of other health care providers believed the quality of care had improved and preferred the improved orthogeriatric model over the previous model (Bhattacharyya et al. 2013).

2.5.6 Financial costs of orthogeriatric care

Due to the variations in actual costs, treatment patterns, and post-discharge options available for older hip fracture patients, generalization of costing analysis studies between countries is difficult. In absolute costs, orthogeriatric care has been found to be either more expensive (Prestmo et al. 2015), less expensive (Ginsberg et al. 2013) or both in the same study depending on the organization of the model (Swart et al. 2016). The financial aspect in most studies has been evaluated concerning both actual costs and cost-effectiveness (improvements in outcomes worth the additional expenses) (Ginsberg et al. 2013; Prestmo et al. 2015; Swart et al. 2016) and the time-range in the studies varies from covering the index stay in hospital (Swart et al. 2016) to including mainly institutional initial rehabilitation (Ginsberg et al. 2013) to all medical expenses during the first year after hip fracture (Prestmo et al. 2015).

According to an economic analysis from the US, co-management with a full-time team (physician, physical therapist, social worker) was more cost-effective if the annual case volume exceeded 54 and cost saving if the case volume exceeded 318 (Swart et al. 2016). In the same study, with part-time staff accounted only according to the number of hip fractures, each QALY achieved was USD 2300 cheaper than in traditional care.

The treatment cost and outcomes for over 3,000 patients from a real-life setting in Israel were analyzed (Ginsberg et al. 2013). The care in the comprehensive orthogeriatric model consumed 23% less resources and concurrently avoided 0.23 disability-adjusted life-years per patient. In the study in question, LOS in the orthogeriatric care group was 30 days compared to 44 days (orthopedic ward + rehabilitation ward) in the traditional care group. Major cost savings have also been associated with a dramatic decrease in LOS in a Canadian before-and-after study (Soong et al. 2016).

In a randomized setting in Norway, comprehensive geriatric care in a specialized orthogeriatric unit was more expensive during the index stay. However, as the post-discharge costs were higher in traditional orthopedic care, the total cost per patient for the first 12 months after hip fracture was 5000€ higher in the traditional care (Prestmo et al. 2015). In this study, when the costs were combined with the decreased mortality and better quality of life achieved, orthogeriatric care was more cost-effective than traditional care.

In the Finnish health care system the mean LOS of the acute hospitalization for hip fracture before discharge to a health-care center ward for rehabilitation is only 4-5 days (National Institute of Health and Welfare 2017). Most of the cost analysis studies are from countries in which either the initial or entire rehabilitation is in a hospital setting, thus LOS is markedly longer and the result cannot directly to be applied to the Finnish health care system. There are no Finnish studies on the costs of orthogeriatric acute care.

2.6 Comprehensive geriatric assessment

Comprehensive geriatric assessment (CGA) is one of the most important tools in the modern geriatric care. It is as a defined “multidimensional interdisciplinary diagnostic process focused on determining a frail older person’s medical, psychological and functional capability in order to develop a coordinated and integrated plan for treatment and long-term follow-up” (Stuck et al. 1993). CGA is therefore both a diagnostic and therapeutic process.

In general, there are two models of inpatient CGA (Stuck et al. 1993). In the first model, the patient is located in a geriatric evaluation and management unit and, in addition to the multidisciplinary assessment and intervention, day-to-day care is provided by experienced geriatric staff. In the second model the multidisciplinary geriatric team visits the patients on the ward they are located providing consultation and recommendations for the use of the doctor responsible for the patient. According to a Cochrane review, receiving inpatient CGA increases the odds of the older patient being alive and living at home after an unplanned hospitalization (Ellis et al. 2011). In their analysis, the number needed to treat was 17 to avoid one unnecessary death or institutionalization up to a follow-up time of six months, when compared to traditional medical care. The majority of the positive effects in the review, however, came from the CGA ward studies. The partial implementation of the recommendations made by a CGA team without shared responsibility for care is a recognized challenge and also suspected of negatively affecting the outcomes (Deschodt et al. 2011).

An orthogeriatric care model is practically a combination of surgical care and CGA (De Rui et al. 2013). When applied to the care of hip fracture patients, CGA is performed to minimize the risk in the surgical procedure, prevent post-surgery complications and optimize the conditions in the rehabilitative process (De Rui et al. 2013). Firstly, the assessment of pre-operative health, identification, and stabilization of possible overriding diseases, promoting early surgery and instructions for adequate pain management and nutritional support aim at reducing the surgical risk. Secondly, to reduce mortality and prevent cognitive and functional decline in the post-operative phase, clinical stabilization, early recognition and management of complications, and early mobilization are crucial procedures. Thirdly, the discharge plan from acute hospitalization is created and includes a falls risk assessment and plans for bone quality improvement and tailored rehabilitation.

2.7 Hip fracture registers

Clinical hip fracture registries have been established to address and manage the current global hip fracture epidemic. The first national hip fracture registry was established in Sweden in 1988, and has served as a model for other databases. The Swedish Rikshöft records data on the patient, treatment, functional and rehabilitation outcome (Rikshöft). The largest hip fracture audit in the world is the National Hip Fracture Database (NHFD) in the UK (The National Hip Fracture Database). It was established in 2007 and currently holds 525,000 hip fracture cases. In addition to the casemix information, the NHFD includes data on the following issues:

- Anesthesia: the type of anesthesia
- Best Practice: achievement of a collection of standards on best practice care of patients with hip fracture
- Length of stay: acute ward and rehabilitation in hospital
- Overall performance: time from admission to surgery and 30-day mortality
- Patient safety: incidence of fractures sustained in hospital, pressure ulcers and re-operations
- Surgery: the type of procedure for each fracture

In the UK healthcare system the audit data is used not only for benchmarking but governmental funding of hospitals for the care of hip fracture patients depends on their performance on specifically defined care quality measures recorded in the data. Also, the detailed reports of audit data are freely available to the public. Since the launch of the database in 2007, substantial improvements in the care and survival of older hip fracture patients have been achieved (Neuburger et al. 2015).

3 AIMS OF THE STUDY

The overall aim of the present study was to examine the effect of an orthogeriatric collaboration and CGA on mortality and quality of care, and to identify predictors of mortality and functional recovery in older hip fracture patients.

The specific aims of the study were the following:

1. to identify patient- and care-related predictors of decline in mobility level and the need for more supported living arrangements one year after hip fracture (I),
2. to examine renal insufficiency, polypharmacy and prompt IUC removal as predictors of mortality one year after hip fracture (II),
3. to examine the effect of an association of in-hospital CGA with patient-related factors on one-month (III) and four-month mortality.
4. to evaluate changes in quality-related care practices and their association with CGA during the implementation and development of an orthogeriatric hip fracture program 2007-2015 (IV).

4 MATERIALS AND METHODS

4.1 Study population

The data for this study was drawn from the database established at the initiation of orthogeriatric collaboration in Seinäjoki Central Hospital.

The data was prospectively collected in Seinäjoki Central Hospital beginning on September 1, 2007, and includes all hip fracture patients aged 65 or over suffering their first hip fracture during the follow-up period. Pathologic and periprosthetic fractures were excluded from the data collection. The Hospital District of Southern Ostrobothnia has a population of 199,000 and Seinäjoki Central Hospital is the only hospital providing acute surgical care in this area and, thus, the data is population based.

The study populations (I, II-III, IV) were retrieved from the same database but differed in size between studies. The difference in study populations concurs with the time elapsing and the progress of the current study.

4.2 Study design

A hip fracture program (HFP) was initiated in Seinäjoki Central Hospital in 2007 with the goal of improving the quality of hip fracture care through standardized treatment guidelines. The care model of the HFP was first generated by a group of doctors only including an orthopedic surgeon, a geriatrician and an anesthesiologist. Before the beginning of any intervention, a database adapted and modified from the NHFD in UK was established. The database includes demographic, surgical, medical, functional, social, and outcome measures and data was collected during hospitalization and at one-month, four-months, one-year, and two-years.

The development of the Seinäjoki Central Hospital HFP has taken place gradually. The data collection begun on September 1, 2007. The first intervention was, as directed in the 2006 edition of the Finnish Current Care Guidelines for hip fractures, an initiation of 1000mg calcium and 20ug vitamin D for all hip fracture patients without hypercalcemia. In 2008, geriatrician-led interdisciplinary rounds 1-3 times per week began on the orthopedic wards with a team of a geriatrician (or resident), a nurse from the orthopedic ward and a physiotherapist.

In 2009, a multidisciplinary orthogeriatric committee was established including doctors from geriatrics, anesthesia, and orthopedic surgery; nurses from the orthopedic ward; and physiotherapists. Other experts, such as nutritionists, are consulted if needed. In its first year, the orthogeriatric committee generated a written HFP with a standardized set of orders for hip fracture patients' hospital stay. As a part of that, the hip fracture patients were centralized from two to one orthopedic ward only and the interdisciplinary rounds began to take place on all weekdays. In 2009, the HFP stabilized from being a project to a permanent model of care.

In 2010 the HFP continued to expand. To assess the incidence of delirium, Confusion Assessment Method (CAM) was included in the program. A designated orthogeriatric nurse was appointed to the orthopedic ward to co-ordinate the service and regular education sessions for the orthopedic ward staff were initiated. At this point, frequent hypercalcemia was observed in the follow-up CGA in geriatrics outpatient clinic from four to six months after the hip fracture (Nuotio et al. 2011). As a result, assessment of dietary calcium consumed was added to the HFP, and thereafter the dosage of calcium and vitamin D were based on dietary intake and levels of calcium (fS-Ca-ion) and vitamin D (P-D-25OH).

In 2011, special attention was paid to the nutrition of hip fracture patients. Nutritional assessment according to the Mini Nutritional Assessment (MNA) and meal consumption monitoring were added to the program. Meals rich in protein and energy replaced the regular meals for hip fracture patients and nutritional supplements were also added to the pre- and postoperative plan. Beginning in 2012 patients suffering from periprosthetic fractures were also included in the multidisciplinary rounds (but not in data collection). In 2012, a lean model (Kates 2014) was introduced in hip fracture surgery and it became effective in 2013.

In 2013 the written instructions of the HFP were updated to include extensive instructions on pre-, peri-, postoperative, and surgical care as well as the CGA, discharge criteria, and recommendations for post-discharge care (Table 4, Table 5). A second update of the instructions of the HFP was completed in 2017.

Table 4 Summary of current components of Seinäjoki Central HFP for all hip fracture patients. (Modified from original publication III.)

Standardized and detailed set of orders on

- Examining and imaging
- Pain management
- Fluid balance and nutritional care with supplements
- Type of anesthesia (mainly spinal)
- Surgical care for different fracture types
- Delirium prevention and management
- Oxygen therapy
- Erythrocyte transfusion thresholds of hemoglobin
- Urinary catheterization practices (removed on 1. postoperative day)
- Mobilizing and physiotherapy
- Deep venous thrombosis prophylaxis

Pre-round interview by a geriatric hip fracture nurse

- Living arrangements and the level of assistance needed before the fracture
- Mobility level and walking aids before the fracture
- Diagnosis of a memory disease or any concern of cognitive decline (prefracture Mini-Mental Status Examination score, if available)
- Detailed information of circumstances of the fall
- Mini Nutritional Assessment, estimated height, weight and body mass index
- Calcium intake (dietary and supplements) and vitamin D supplementation
- Consent for data collection

Discharge criteria

- Stable hemodynamics (oxygen saturation, pulse and blood pressure, cardiac rhythm)
- Hemoglobin > 90 g/l (>100 g/l if severe cardiac condition)
- Urinary catheter removed
- Pain under control
- Patient mobilized
- Medications updated to the outpatient file
- If treated for infection, declining CRP and fever
- 2^{nd} or later postoperative day
- No discharge of a patient with immediate poor prognosis

Follow-up visits

- Orthopedic surgeon
    - Total endoprothesis: at 3 months radiographs and visit to the orthopedic outpatient clinic
    - Semiendoprothesis: no routine follow-up (arranged if needed)
    - Osteosynthesis (with dynamic hip screw or intramedullary nail): at 6-8 weeks radiographs and visit at primary health care outpatient clinic followed by routine scrutiny of results by an orthopedic surgeon
- Geriatrician
    - Follow-up visit to the geriatric outpatient clinic for all patients at 3-4 months

Table 5 Components of CGA (when available). (Original publication III. Reprinted with permission from SAGE Publishing.)

Interdisciplinary orthogeriatric ward rounds on weekdays

- Staff: geriatrician (or a resident), orthopedic hip fracture nurse, physiotherapist
- Encouragement and motivation of the patient
- Check-up on the adherence to standardized orders of care protocol
- Early detection and treatment of complications
- Patient examination: orthostatic blood pressure test, oxygen saturation, orientation, auscultation of cardiac and pulmonary sounds, any additional examination as needed, evaluation of mobility
- Mobilizing the patient
- Setting the goal for rehabilitation
- Careful evaluation and adjustment of medications
- Evaluation of calcium and vitamin D intake and supplements
- Orders on examinations needed after discharge (for example, on memory disorder and osteoporosis)

Instructions and suggestions to discharge destination

- Objectives of treatment and rehabilitation
- Physical status at discharge
- General instructions on mobilizing (including active walking exercises, encouragement towards independency)
- Nutritional plan including supplements
- Medications plan and instructions on discontinuation of opiate pain medications
- Planned examinations and follow-ups after discharge
- Separate discharge documents from all disciplines (geriatrician, orthopedic, nurse, physiotherapist)

The care model is integrated and entails shared care: patients are on an orthopedic ward, but the responsibility for the care of the patient is shared between the orthopedic surgeon and the geriatrician. The orthopedic surgeon sees the patient daily and the geriatrician on weekdays, and both services write their own orders. Due to the shortage of geriatricians, multidisciplinary rounds are not always feasible, and in such cases the responsibility for the patient rests solely with the orthopedic surgeon. Interruptions in the availability of geriatric service enabled the formation of the study groups. If a geriatrician was available, all patients were treated alike and received a CGA.

The HFP was developed and implemented in a real-life setting with minimal addition of resources. The comprehensiveness of the program and the skills and commitment of the staff gradually improved, leading to the present model in which the emphasis is on detailed, individually adjusted, and multidisciplinary care throughout and after hospitalization.

4.3 Data collection

After admission to the orthopedic ward, the eligible patients were identified through their diagnostic codes (ICD-10) of S72.0 (femoral neck fracture), S72.1 (trochanteric fracture) and S72.2 (subtrochanteric fracture). During hospitalization the patients' medical records and structured interviews conducted by a geriatric nurse with the patient or caregiver were used to collect data on patients. Also, if applicable, the place of residence was contacted by phone for missing information.

The patient-related data used in the present study include age, sex, fracture type, ASA score, BMI, on-admission serum creatinine, regularly taken medications (included both prescribed and over-the-counter medications), regular or as needed use of hypnotic benzodiazepines and z-hypnotics (BZD-Z; midazolam, temazepam, nitrazepam, triazolam, zaleplon, zolpidem, zopiclon), prefracture diagnosis of memory disorder, prefracture mobility level, and living arrangements. The care-related data used in the present study include the length of delay from admission to surgery, transfusion or non-transfusion of RBCs, removal or non-removal of IUC, delivery or non-delivery of CGA, and LOS.

Data on regularly taken medications, prefracture mobility level and living arrangements was categorized simultaneously with collection. The number of regularly taken medications was categorized into three classes of less than 4, 4 to 10, and more than 10. Mobility was categorized into four levels: outdoors unassisted (with or without walking aid), indoors unassisted (with or without walking aid), assisted by another person only and unable to walk. Living arrangements were categorized into four levels: home without organized homecare, home with organized homecare, assisted living accommodation (no night-time staff) and institution (nursing staff present at all times). The categorization of mobility and living arrangements were adopted and modified from NHFD. As presented to hospital with hip fracture, testing of mobility or functional abilities was not possible, and we relied on information acquired by the interview.

The same geriatric nurse contacted the patients or their caregivers to obtain follow-up data on mobility level and living arrangements one year after hip fracture. The dates of death were provided by the National Population Register Center and extracted from the electronic patient files of the hospital. There were no losses to mortality follow-up.

The data was collected and saved by two specifically trained nurses.

4.4 Study methods and patients

4.4.1 General

The patient-related variables retrieved from the database and used in the studies (I-IV) are age, sex, ASA score, prefracture diagnosis of memory disorder, prefracture mobility level and prefracture living arrangements. BMI was used in I-II, fracture type in I-III, number of regularly taken medications in II-III and regular or as-needed use of hypnotic benzodiazepines and z-hypnotics (BZD-Z; midazolam, temazepam, nitrazepam, triazolam, zaleplon, zolpidem, zopiclon) in III.

eGFR according to the CKD-EPI ($eGFR_{CDK-EPI}$) (II-III) was calculated from the first available sCr (enzymatic assay) on admission (Table 6). The results were categorized into four groups: ≥ 60 ml/min/1.73m^2 (normal to mildly decreased eGFR), 45-59 ml/min/1.73m^2 (mildly to moderately decreased eGFR), 30-44 ml/min/1.73m^2 (moderately to severely decreased eGFR) and < 30 ml/min/1.73m^2 (severely decreased eGFR or kidney failure).

Table 6 The 2009 Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation for estimating glomerulus filtration rate (GFR) expressed for sex and serum creatinine (SCr) in μmol/L. (Original publication II. Reprinted with permission from Elsevier.)

Sex	Serum creatinine, SCr μmol/L	Equation
Female	≤ 61.9	$GFR = 144 \times (SCr/61.9)^{-0.329} \times (0.993)^{Age}$
Female	> 61.9	$GFR = 144 \times (SCr/61.9)^{-1.209} \times (0.993)^{Age}$
Male	≤ 79.6	$GFR = 141 \times (SCr/79.6)^{-0.411} \times (0.993)^{Age}$
Male	> 79.6	$GFR = 141 \times (SCr/79.6)^{-1.209} \times (0.993)^{Age}$

The care-related variables used in the studies are delay from admission to surgery (I-IV), removal of urinary catheter during hospitalization (I-IV), delivering CGA during the acute hospitalization (III-IV) and transfusion of RBCs (IV).

The categorization of the patient- and care-related variables is seen in Tables 8-14 in Results.

4.4.2 Study I

Study I included 1,027 consecutive patients between September 2007 and November 2012. Of these, 10 patients (1.0%) refused to participate in the study and 259 (25%) died during the first year. After excluding the patients who were unable to walk prefracture (n=23) and those with missing information on the outcome (n=124), 611 patients were eligible for inclusion in the mobility analysis. After excluding the patients who were institutionalized prefracture (n=112) or those with missing information on the outcome (n=94), 552 patients were eligible for inclusion in the mobility analysis.

Of the outcome variables, prefracture mobility level was originally categorized as ability to walk outdoors unassisted, ability to walk indoors unassisted (in the original article I labeled “outdoors assisted”), ability to walk assisted only (in the original article I labeled “ability to walk assisted but only indoors”) or unable to walk. For analyses of changes in living arrangements, the prefracture mobility level was dichotomized to walking unassisted (with or without walking aid) or assisted by another person.

Living arrangements were originally categorized as living independently in own home, living in own home with help organized home care, living in assisted living accommodation, and living in an institution. For the analyses of the change in mobility from the prefracture level, living arrangements were dichotomized to living at home or elsewhere than home.

The outcome was measured in change in the mobility level and living arrangements one year after hip fracture: declined vs. same or improved mobility level and more supported vs. same or less supported living arrangements.

4.4.3 Study II

Study II included 1,445 consecutive patients between September 2007 and August 2014. Of these, 20 patients (1.4%) refused to participate in the study. The one-year mortality analyses were performed separately for $eGFR_{CDK\text{-}EPI}$ (n=1,388), removal of urinary catheter (n=1,374) and number of medications (n=1,424), after excluding patients with missing information on the index variable (n=37, n=51 and n=1, respectively). The outcome was mortality one year after hip fracture.

4.4.4 Study III

The study population in III is the same as in II. After excluding only those patients who refused to participate, the analysis included 1,425 patients. In the original article the outcome was mortality one month after hip fracture but the thesis also presents the results for four-month mortality.

4.4.5 Study IV

The study population in IV included 1,756 consecutive patients between September 2007 and December 2015. Of these, 37 patients (2.1%) declined to participate in the study. After exclusion of patients with missing information regarding any of the outcome variables (n=75), the analysis was performed for 1,644 patients. Follow-up time was modeled both as continuous and as categorized for two time groups, the years 2007-2011 and 2012-2015. The division was made according to years with approximately the same number of patients in the two groups. The main outcome was the effect of CGA on occurrence of quality-related factors of care.

4.5 Statistical analysis

Baseline differences between groups were analyzed using Mann-Whitney test, Pearson chi-Square test, or Fisher's exact test (I-IV). Adjusted analyses were performed by logistic regression analysis or Cox proportional hazards model, and the specific features of studies will be discussed in more detail below.

Study I. Multivariate analyses were performed by logistic regression analysis using each of the variables as independent variables and changes in the mobility level or living arrangements after the fracture at one-year follow-up as the dependent variables. The results are presented as odds ratios (ORs) with 95% confidence intervals (CIs).

Study II. Age- and sex-adjusted (Model 1) and multivariate (Models 2 and 3) analyses were performed using the Cox proportional hazards model. Model 2 was adjusted for age, sex, ASA score, prefracture diagnosis of memory disorder, delay to surgery and prefracture mobility level, and living arrangements. Model 3 was adjusted not only for the factors in Model 2, but also for BMI, fracture type, $eGFR_{CDK\text{-}EPI}$, removal of urinary catheter during hospitalization and number of regularly taken medications. The results are presented as hazard ratios (HRs) with 95% CIs.

Study III. One-month and four-month mortality were analyzed by age- and sex-adjusted Cox proportional hazards models. Also, age and sex adjusted analyses of the association of receiving vs. not receiving CGA with mortality separately in each group of the patient-related factors were performed using the Cox proportional hazards model. The results of the Cox models are presented as HRs with 95% CIs.

Study IV. Associations of CGA and time were analyzed using logistic regression models. First, unadjusted CGA and follow-up time were analyzed separately (Model 1). Follow-up time was modeled both as continuous and as categorized for two time-groups, the years 2007-2011 and 2012-2015. Second, CGA and time were modeled together without and with their interaction unadjusted (Model 2). Third, the analyses in Model 2 were adjusted for age, sex, ASA score, prefracture diagnosis of memory disorder, prefracture mobility level and living arrangements (Model 3). The results are presented as ORs with 95% CIs.

Statistical analyses were performed using SPSS Statistics software versions 20.0 for Windows, 23.0 for Windows or 23.0 for Mac (IBM SPSS: IBM Corp, Armonk, NY). P values of less than 0.05 were considered significant.

4.6 Ethical considerations

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

5 RESULTS

5.1 Predictors of changes in mobility and living arrangements one year after hip fracture (I)

5.1.1 Predictors of declined mobility level

Of the 611 patients eligible for the mobility analysis, 232 patients (38%) had declined in their mobility level one year after hip fracture. The changes in the different categories of mobility level of the whole study population during the one-year follow up are presented in Figure 2. The distribution of variables and unadjusted analysis of difference between groups is presented in Table 7.

In the multivariate logistic regression analysis, older age (OR=1.06, 95% CI 1.02-1.09), prefracture diagnosis of a memory disorder (OR=1.89, 95% CI 1.19-3.00) and not living in own home (OR=2.14, 95% CI 1.33-3.44) were associated with declined mobility level one year after hip fracture. Prefracture mobility level of walking indoors unassisted (OR=0.47, 95% CI 0.30-0.75) or assisted only (OR=0.25, 95% CI 0.09-0.72) were associated with maintaining the same level of mobility when categorized into four levels. Also, having IUC removed during the acute hospital stay (OR=0.45, 95% CI 0.29-0.70) was independently associated with maintaining or improving mobility level one year after hip fracture.

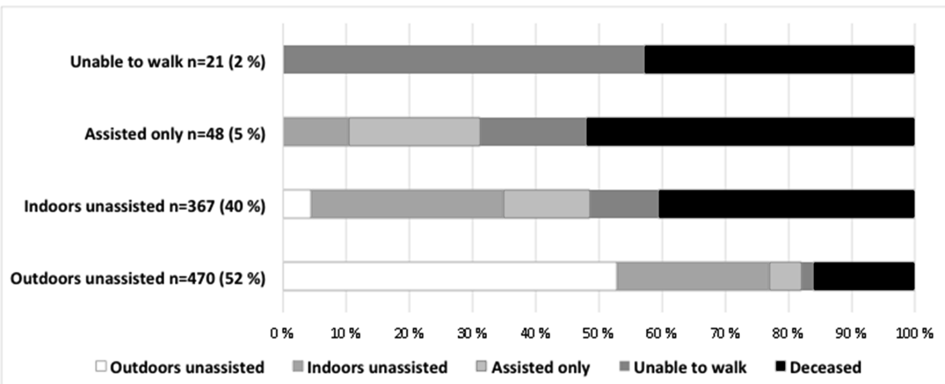

Figure 2 Changes in mobility level one year after hip fracture (n=906, 89% of the study population). Modified from original publication I.

Table 7 Distribution of the variables according to changes in mobility one year after hip fracture (n=611). The data for the number of regularly taken medications is previously unpublished. Modified from original publication I.

	Mobility level 1 year after hip fracture				
	Same or better		Declined		
	n=379		n=232		p
Preoperative variables					
Sex, n (%)					.300
Men	87	(23)	45	(19)	
Women	292	(77)	187	(81)	
Age, Median (IQR, Range)	82.0	(77-86, 65-96)	85.0	(79-88, 68-105)	<.001
BMI, n (%)					.280
23-28	180	(48)	102	(44)	
<23	83	(22)	64	(28)	
>28	116	(31)	66	(28)	
ASA score, n (%)					.082
1-2	56	(15)	20	(9)	
3	247	(65)	162	(70)	
4-5	76	(20)	50	(22)	
Number of regularly taken medications, n (%)					.166
<4	86	(23)	41	(18)	
4-10	244	(64)	151	(65)	
>10	49	(13)	40	(17)	
Diagnosis of memory disorder, n (%)					<.001
No	314	(83)	160	(69)	
Yes	65	(17)	72	(31)	
Mobility level, n (%)					.571
Outdoors unassisted	242	(64)	139	(60)	
Indoors unassisted	123	(33)	85	(37)	
Assisted only	14	(4)	8	(3)	
Living arrangements, n (%)					<.001
Home	300	(79)	148	(64)	
Other than home	75	(20)	83	(36)	
Fracture type, n (%)					
Neck of femur	256	(68)	132	(57)	.016
Intertrochanteric	102	(27)	88	(38)	
Subtrochanteric	21	(6)	12	(5)	
Perioperative variables					
Delay to surgery, n (%)					.073
<24 h	167	(44)	91	(39)	
24-47 h	147	(39)	111	(48)	
>47 h	65	(17)	30	(13)	
Urinary catheter removed during hospital stay, n (%)					<.001
No	229	(60)	186	(80)	
Yes	148	(39)	46	(20)	

Missing values are not shown, but were tested and included in the percentages. ASA=American Society of Anesthesiologists, BMI=body mass index, IQR=interquartile range. Differences between groups were analyzed using Mann-Whitney test or Pearson's chi-square test or Fisher's exact test.

5.1.2 Predictors of the need for more supported living arrangements

Of the 552 patients eligible for the living arrangements analysis, 230 (41%) had moved to more supported living accommodation one year after hip fracture. The changes in the different categories of living arrangements of the whole study population during the one-year follow up are shown in Figure 3. The distribution of variables and unadjusted analysis of differences between groups are shown in Table 8.

In the multivariate logistic regression analysis, an ASA score of 3 (OR=3.58, 95% CI 1.79-7.17) or 4-5 (OR=2.35, 95% CI 1.05-5.26), prefracture diagnosis of memory disorder (OR=2.77, 95% CI 1.64-4.69), prefracture need for assistance in mobilizing (OR=2.74, 95% CI 1.70-4.41) were independently associated with moving to more supported living accommodation one year after hip fracture. Also, living in assisted living accommodation before the fracture (OR=0.23, 95% CI 0.12-0.44) and having IUC removed during the acute hospital stay (OR=0.49, 95% CI 0.31-0.77) were associated with maintaining or improving the prefracture living arrangements.

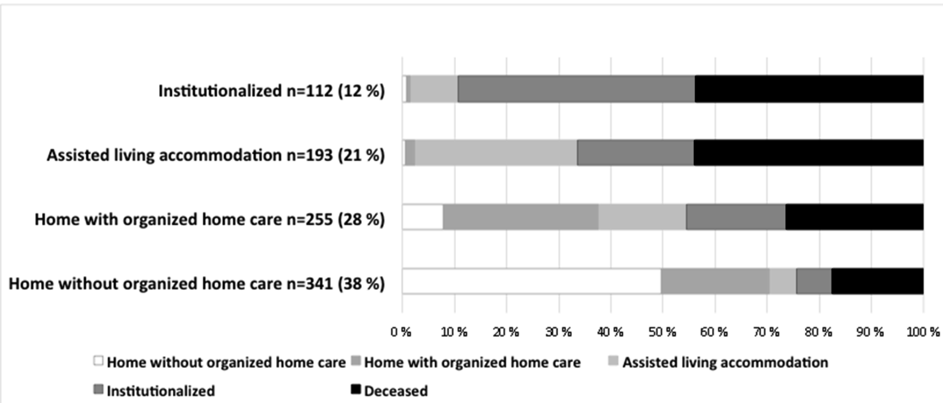

Figure 3 Changes in living arrangements one year after hip fracture (n=901, 89% of the study population). Modified from original publication I.

Table 8 Distribution of the variables according to changes of living arrangements one year after hip fracture (n=552). The data for the number of regularly taken medications is previously unpublished. Modified from original publication I.

	Living arrangements 1 year after hip fracture				
	Same or better		More supported		
	n=322		n=230		p
Preoperative variables					
Sex, n (%)					.007
Men	86	(27)	39	(17)	
Women	236	(73)	191	(83)	
Age, Median (IQR, Range)	81.0	(76-86, 65-98)	84.0	(78-88, 65-105)	<.001
BMI, n (%)					.322
23-28	148	(46)	102	(44)	
<23	71	(22)	63	(27)	
>28	103	(32)	65	(28)	
ASA score, n (%)					<.001
1-2	65	(20)	12	(27)	
3	199	(62)	176	(77)	
4-5	58	(18)	42	(18)	
Number of regularly taken medications, n (%)					.386
<4	79	(25)	45	(20)	
4-10	198	(62)	151	(66)	
>10	45	(14)	34	(15)	
Diagnosis of memory disorder, n (%)					
No	283	(88)	164	(71)	<.001
Yes	39	(12)	66	(29)	
Mobility level, n (%)					<.001
Unassisted	250	(78)	122	(53)	
Assisted	72	(22)	108	(47)	
Living arrangements, n (%)					.221
Home without organized home care	164	(51)	106	(46)	
Home with organized home care	95	(30)	84	(37)	
Assisted living accommodation	63	(20)	40	(17)	
Fracture type, n (%)					.604
Neck of femur	206	(64)	150	(65)	
Intertrochanteric	99	(31)	72	(31)	
Subtrochanteric	17	(5)	8	(4)	
Perioperative variables					
Delay to surgery, n (%)					.297
<24 h	144	(45)	90	(39)	
24-47 h	126	(39)	105	(46)	
>47 h	52	(16)	35	(15)	
Urinary catheter removed during hospital stay, n (%)					<.001
No	183	(57)	182	(79)	
Yes	137	(43)	47	(20)	

Missing values are not shown, but were tested and included in the percentages. ASA=American Society of Anesthesiologists, BMI=body mass index, IQR=interquartile range. Differences between groups were analyzed using Mann-Whitney test or Pearson's chi-square test or Fisher's exact test.

5.2 Predictors of mortality one year after hip fracture (II)

Data on 1,425 patients were available. Of the 1,425 patients, 390 (27%) died within one year of the fracture. The median duration of acute hospital stay was six days (IQR 5-7, range 1-37). Distribution of the variables at baseline and according to survival status one year after hip fracture is shown in Table 9.

5.2.1 eGFR$_{CDK\text{-}EPI}$

Of the 1,425 patients, 567 (40%) had renal insufficiency on admission and in 280 (20%) patients the insufficiency was at least moderate.

In the age and sex adjusted Cox regression analysis (Model 1), when compared to eGFR$_{CDK\text{-}EPI}$ 60 ml/min/1.73m^2 or more, eGFR$_{CDK\text{-}EPI}$ 45-59 ml/min/1.73m^2 (HR 1.39, 95% CI 1.07-1.81), 30-44 ml/min/1.73m^2 (HR 1.93, 95% CI 1.47-2.53) and < 30 ml/min/1.73m^2 (HR 2.74, 95% CI 1.96-3.83) were associated with increased risk of mortality. The association of eGFR$_{CDK\text{-}EPI}$ under 45 ml/min/1.73m^2 and one-year mortality persisted after adjusting for the well-known predictors (Model 2) (30-44 ml/min/1.73m^2 HR 2.05, 95% CI 1.55-2.71, < 30 ml/min/1.73m^2 HR 2.50, 95% CI 1.78-3.51) and also in the final multivariate analysis (Model 3) (30-44 ml/min/1.73m^2 HR 1.91, 95% CI 1.44-2.52, < 30 ml/min/1.73m^2 HR 1.95, 95% CI 1.36-2.78) (Figure 4).

5.2.2 Urinary catheter removal during hospitalization

Of the 1,425 patients, 526 (37%) had their urinary catheter removed during hospitalization. The non-removal of the urinary catheter during hospitalization was significantly associated with increased risk of one-year mortality in Model 1 (HR 1.81, 95% CI 1.42-2.31), Model 2 (HR 1.35, 95% CI 1.05-1.74) and Model 3 (HR 1.45, 95% CI 1.12-1.88) (Figure 4).

5.2.3 Number of regularly taken medications

Of the 1,425 patients, 1,177 (83%) were taking ≥ 4 and 261 (18%) > 10 medications regularly before the hip fracture.

Taking 4-10 (Model 1 HR 2.88, 95% CI 1.91-4.34, Model 2 HR 2.02, 95% CI 1.32-3.09, Model 3 HR 1.81, 95% CI 1.78-2.79) or > 10 (Model 1 HR 4.28, 95% CI 2.76-6.63, Model 2 HR 2.53, 95% CI 1.59-4.02, Model 3 HR 2.21, 95% CI 1.38-3.54) medications in regular use, when compared to taking < 4, was significantly associated with increased risk of one-year mortality (Figure 4).

Table 9 Distribution of the variables at baseline and according to survival status one year after hip fracture (n=1,425). (Original publication II. Reprinted with permission from Elsevier.)

	Baseline		One year after hip fracture				
			Alive		Deceased		p
	n=1425		n=1035		n=390		
Age, median (IQR, range)	84	(78-88, 65-105)	83	(77-87, 65-105)	86	(82-91, 65-103)	<0.001
Sex, n(%)							<0.001
Women	1062	(75)	804	(78)	258	(66)	
Men	363	(25)	231	(22)	132	(34)	
BMI, n(%)							<0.001
23-28	594	(42)	445	(43)	149	(38)	
<23	397	(28)	269	(26)	128	(33)	
>28	387	(27)	305	(30)	82	(21)	
ASA score, n(%)							<0.001
1-2	170	(12)	155	(15)	15	(4)	
3	877	(62)	677	(65)	200	(51)	
4-5	354	(25)	195	(19)	159	(41)	
Number of regularly taken medications, n(%)							<0.001
< 4	247	(17)	222	(21)	25	(6)	
4-10	916	(64)	656	(63)	260	(67)	
> 10	261	(18)	157	(15)	104	(27)	
Diagnosis of memory disorder, n(%)							0.001
No	1038	(73)	779	(75)	259	(66)	
Yes	379	(27)	254	(25)	125	(32)	
$eGFR_{CKD-EPI}$, n(%)							0.001
> 60 ml/min/1.73m^2	821	(58)	653	(63)	168	(43)	
45-59 ml/min/1.73m^2	287	(20)	201	(19)	86	(22)	
30-44 ml/min/1.73m^2	193	(14)	112	(11)	81	(21)	
< 30 ml/min/1.73m^2	87	(6)	43	(4)	44	(11)	

Mobility level, n(%)							<0.001
Outdoors unassisted	743	(52)	629	(61)	114	(29)	
Indoors unassisted	578	(42)	352	(34)	226	(58)	
Assisted only	69	(5)	36	(4)	33	(9)	
Unable to walk	25	(2)	16	(2)	9	(2)	
Living arrangements, n(%)							<0.001
Home	565	(40)	477	(46)	88	(23)	
Home with organized homecare	399	(28)	304	(29)	95	(24)	
Assisted living accommodation	237	(17)	130	(13)	107	(27)	
Institutionalized	213	(15)	118	(11)	95	(24)	
Fracture type, n(%)							0.036
Neck of femur	886	(62)	664	(64)	222	(57)	
Intertrochanteric	458	(32)	317	(31)	141	(36)	
Subtrochanteric	80	(6)	53	(5)	27	(7)	
Delay from admission to surgery, n(%)							<0.001
<24 h	560	(39)	430	(42)	130	(33)	
24-47 h	609	(43)	443	(43)	166	(43)	
>47 h	231	(16)	155	(15)	76	(20)	
Urinary catheter removed during hospital stay, n(%)							<0.001
Yes	526	(37)	437	(42)	89	(23)	
No	848	(60)	590	(57)	258	(66)	

Missing values not shown, but were tested and included in the percentages. ASA=American Society of Anesthesiologists, BMI=body mass index, IQR=interquartile range, $eGFR_{CKD\text{-}EPI}$ = estimated glomerular filtration rate by 2009 Chronic Kidney Disease Epidemiology Collaboration equation. Differences between alive and deceased were analyzed using Mann-Whitney test or Pearson's chi-square test or Fisher's exact test.

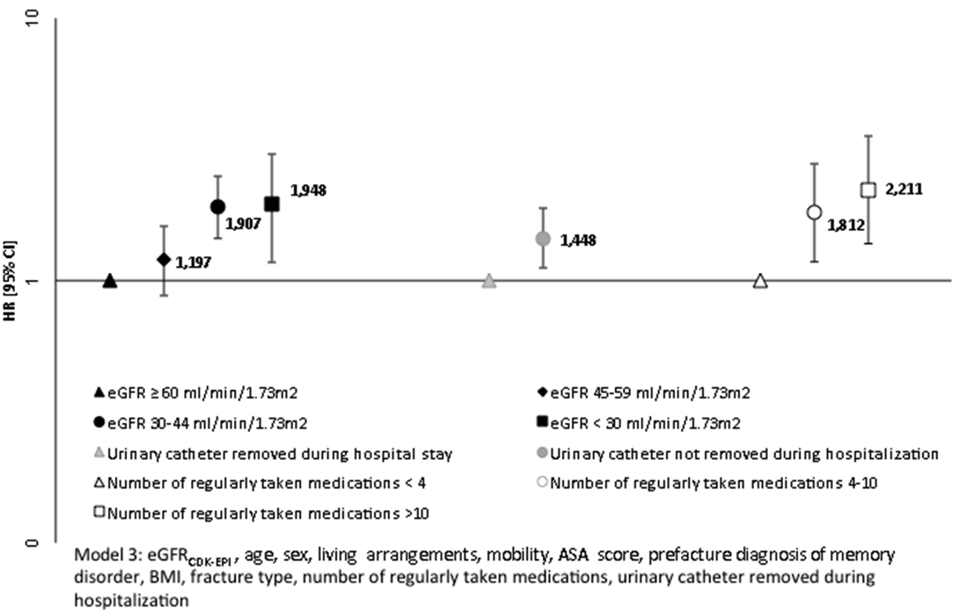

Figure 4 Hazard ratio (95% CI) of one-year mortality according to $eGFR_{CDK\text{-}EPI}$, removal of the urinary catheter during hospitalization and number of regularly taken medications (Model 3). Modified from original publication II.

For the complete results of the models, please see Supplementary Tables 1-3 in the Appendices.

5.3 Association of in-hospital CGA with one-month and four-month hip fracture mortality (III)

Data on 1,425 hip fracture patients were available. The median age was 84 years (IQR 78-88, range 65-104) and the median length of stay was six days (IQR 5-7, range 1-37). Distribution of the variables at baseline is shown in Table 9 (II).

5.3.1 Comprehensive geriatric assessment

Of the 1,425 patients, 886 (62%) received CGA during hospitalization. The patients receiving CGA while hospitalized, compared to those who did not, more likely had an ASA score of 1-3 (p=0.002) and lived at home or in an institution (p=0.002). Age, sex, number of regularly taken medications, use of BZD-Zs, diagnosis of memory disorder, $eGFR_{CKD-EPI}$, prefracture mobility level, or fracture type did not differ significantly different between the two groups.

5.3.2 Age- and sex-adjusted mortality at one month and four months

Of the 1,425 patients, 36 (3%) patients died during acute hospitalization, 140 (10%) within one month, and 281 (20%) within four months of hip fracture. Of the patients receiving CGA compared to those who did not, 8.5% vs.12.0% died within one month (p= 0.028) and 18.6% vs. 21.5% (p=0.192) within four months of the hip fracture.

In the age and sex adjusted Cox regression analysis patients with older age, higher ASA score, greater number of medications in regular use, having a diagnosis of memory disease, lower $eGFR_{CKD-EPI}$, living in more supported living accommodation, having lower mobility class and male sex had a greater likelihood of dying within one month and four months of the hip fracture (Table 10). The patients receiving CGA were significantly more likely to survive at one month after the hip fracture than those not receiving CGA (Table 10).

The data on four-month mortality has not been previously published.

5.3.3 Age- and sex-adjusted analyses of the association of patient-related factors with the effect of CGA on mortality

In the age- and sex-adjusted Cox proportional hazards model, CGA was significantly associated with decreased risk of one-month and four-month mortality in patients 80-89 years of age, female sex, having ASA score 1-3, using regular or as-needed BZD-Zs, having a diagnosis of memory disease, having $eGFR_{CKD-EPI}$ < 30 ml/min/1.73 m^2, living in assisted living accommodation, or having the fracture in the neck of the femur (Table 11). Also, CGA was associated with a decreased risk of one-month mortality in patients taking four to ten medications daily and having $eGFR_{CKD-EPI}$ 45-59 ml/min/1.73 m^2 (Table 11).

The data on four-month mortality has not previously been published.

Table 10 Distribution and associations of the patient-related factors and comprehensive geriatric assessment according to one-month and four-month mortality (n=1,425). The data on four-month mortality has not previously been published. Modified from original publication III.

	1-month mortality						4-month mortality					
	Alive n=1285		Deceased n=140		Age- and sex adjusted		Alive n=1144		Deceased n=281		Age- and sex adjusted	
	n	(%)	n	(%)	HR	(95% CI)	n	(%)	n	(%)	HR	(95% CI)
Age												
65-79	389	(30)	21	(15)	1.00		368	(32)	42	(15)	1.00	
80-89	683	(53)	76	(54)	2.21	(1.36-3.59)	612	(54)	147	(52)	2.15	(1.52-3.04)
90 or over	213	(17)	43	(31)	3.87	(2.28-6.55)	164	(14)	92	(33)	4.42	(3.06-6.39)
Sex												
Women	970	(76)	92	(66)	1.00		869	(76)	193	(69)	1.00	
Men	315	(25)	48	(34)	1.80	(1.26-2.45)	275	(24)	88	(31)	1.61	(1.25-2.08)
ASA score												
1-3	983	(77)	64	(46)	1.00		900	(78)	147	(52)	1.00	
4-5	290	(23)	64	(46)	2.75	(1.94-3.91)	235	(21)	119	(42)	2.34	(1.83-3.00)
Number of regularly taken medications												
< 4	236	(18)	11	(8)	1.00		231	(20)	16	(6)	1.00	
4-10	832	(65)	84	(60)	1.94	(1.03-3.63)	732	(64)	184	(66)	3.06	(1.83-5.10)
> 10	217	(17)	44	(32)	3.67	(1.89-7.12)	181	(16)	80	(29)	4.97	(2.90-8.51)
BZD-Z												
No	937	(73)	96	(69)	1.00		837	(73)	196	(70)	1.00	
Yes	348	(27)	43	(31)	1.09	(0.76-1.56)	307	(27)	84	(30)	1.03	(0.80-1.33)
Diagnosis of memory disorder												
No	952	(74)	86	(61)	1.00		854	(75)	184	(66)	1.00	
Yes	330	(26)	49	(35)	1.55	(1.09-2.20)	288	(25)	91	(32)	1.38	(1.08-1.78)
$eGFR_{CKD\text{-}EPI}$												
> 60 ml/min/1.73m^2	766	(60)	55	(39)	1.00		709	(62)	112	(40)	1.00	
45-59 ml/min/1.73m^2	252	(20)	35	(25)	1.69	(1.10-2.59)	221	(19)	66	(24)	1.57	(1.16-2.14)
30-44 ml/min/1.73m^2	164	(13)	29	(21)	1.93	(1.22-3.07)	130	(11)	63	(22)	2.14	(1.55-2.94)
< 30 ml/min/1.73m^2	69	(5)	18	(13)	2.99	(1.75-5.12)	52	(5)	35	(13)	3.09	(2.11-4.53)

	1-month mortality						4-month mortality					
	Alive n=1285		Deceased n=140		Age- and sex adjusted		Alive n=1144		Deceased n=281		Age- and sex adjusted	
	n	(%)	n	(%)	HR	(95% CI)	n	(%)	n	(%)	HR	(95% CI)
Mobility level												
Outdoors unassisted	718	(56)	25	(18)	1.00		675	(59)	68	(24)	1.00	
Indoors unassisted	486	(38)	91	(65)	4.63	(2.95-7.28)	398	(35)	179	(64)	3.50	(2.62-4.66)
Assisted only	58	(5)	12	(9)	4.77	(2.38-9.59)	50	(4)	20	(7)	2.97	(1.79-4.91)
Unable to walk	21	(2)	4	(3)	4.04	(1.40-11.7)	19	(2)	6	(2)	2.43	(1.05-5.61)
Living arrangements												
Home	543	(42)	22	(16)	1.00		510	(45)	55	(20)	1.00	
Home with organized homecare	369	(29)	30	(21)	1.79	(1.02-3.14)	331	(29)	68	(24)	1.60	(1.11-2.29)
Assisted living accommodation	197	(15)	40	(29)	3.97	(2.31-6.81)	156	(14)	81	(29)	3.22	(2.25-4.60)
Institutionalized	169	(13)	44	(31)	5.08	(2.98-8.65)	141	(12)	72	(26)	3.39	(2.35-4.88)
Fracture type												
Neck of femur	800	(62)	86	(61)	1.00		725	(63)	161	(57)	1.00	
Intertrochanteric	410	(32)	48	(34)	0.99	(0.69-1.41)	359	(31)	99	(35)	1.09	(0.84-1.40)
Subtrochanteric	74	(6)	6	(4)	0.65	(0.28-1.49)	59	(5)	21	(8)	1.23	(0.78-1.94)
Comprehensive Geriatric Assessment												
No	474	(37)	65	(46)	1.00		423	(37)	116	(41)	1.00	
Yes	811	(63)	75	(54)	0.63	(0.45-0.87)	721	(63)	165	(59)	0.77	(0.61-0.98)

Missing values are not shown, but were tested and included in the percentages, ASA=American Society of Anesthesiologists, BZD-Z =hypnotic benzodiazepines and z-hypnotics (midazolam, temazepam, nitrazepam, triazolam, zaleplon, zolpidem, zopiclon), $eGFR_{CKD-EPI}$ =estimated glomerular filtration rate calculated by the Chronic Kidney Disease Epidemiology Collaboration equation. Associations with mortality were tested by Cox hazard regression models showing results by hazard ratios (HR) and 95% confidence intervals (CI).

Table 11 Age- and sex-adjusted effect of in-hospital geriatric assessment (total n=1,425, geriatric assessment n=886, no geriatric assessment n=539) on mortality one month and four months after hip fracture in the groups of patient-related factors. The data on four-month mortality has not previously been published. Modified from original publication III.

	Total	Mortality ratio at 1 month comparing groups of CGA vs. non-CGA (total deaths n=140)				Mortality ratio at 4 months comparing groups of CGA vs. non-CGA (total deaths n=281)			
	n	deaths n	(%)	HR	(95% CI)	deaths n	(%)	HR	(95% CI)
Age									
65-79	410	21	(5.1)	0.74	(0.31-1.75)	42	(10.0)	0.88	(0.48-1.62)
80-89	759	76	(10.0)	**0.46**	**(0.29-0.73)**	147	(19.4)	**0.58**	**(0.42-0.80)**
90 or over	256	43	(16.8)	0.98	(0.52-1.85)	92	(35.9)	1.20	(0.76-1.89)
Sex									
Women	1062	92	(8.7)	**0.57**	**(0.38-0.86)**	193	(18.2)	**0.75**	**(0.56-0.998)**
Men	363	48	(13.2)	0.76	(0.42-1.34)	88	(24.2)	0.83	(0.54-1.27)
ASA									
1-3	1047	64	(6.1)	**0.60**	**(0.37-0.99)**	147	(14.0)	**0.71**	**(0.51-0.99)**
4-5	354	64	(18.1)	0.86	(0.53-1.42)	119	(33.6)	1.07	(0.74-1.55)
Number of regularly taken medications									
< 4	247	11	(4.5)	0.58	(0.17-1.96)	16	(6.5)	0.67	(0.25-1.84)
4-10	916	84	(9.2)	**0.59**	**(0.38-0.91)**	184	(20.1)	**0.77**	**(0.57-1.04)**
> 10	261	44	(16.9)	**0.58**	**(0.32-1.06)**	80	(30.7)	**0.66**	**(0.42-1.03)**
BZD-Z									
No	1033	97	(9.4)	0.75	(0.50-1.13)	197	(19.1)	0.83	(0.62-1.11)
Yes	391	43	(11.0)	**0.38**	**(0.21-0.73)**	84	(21.5)	**0.64**	**(0.42-0.99)**
Diagnosis of memory disorder									
No	1038	86	(8.3)	0.70	(0.46-1.07)	184	(17.7)	0.91	(0.68-1.23)
Yes	379	49	(12.9)	**0.50**	**(0.29-0.88)**	91	(24.0)	**0.55**	**(0.36-0.84)**

		Mortality ratio at 1 month comparing groups of CGA vs. non-CGA (total deaths n=140)				Mortality ratio at 4 months comparing groups of CGA vs. non-CGA (total deaths n=281)			
$eGFR_{CKD-EPI}$									
> 60 ml/min/1.73m^2	821	55	(6.7)	0.73	(0.43-1.24)	112	(13.6)	**0.72**	**(0.50-1.04)**
45-59 ml/min/1.73m^2	287	35	(12.2)	**0.46**	**(0.24-0.90)**	66	(23.0)	0.81	(0.49-1.35)
30-44 ml/min/1.73m^2	193	29	(15.0)	0.79	(0.36-1.72)	63	(32.6)	0.96	(0.56-1.65)
< 30 ml/min/1.73m^2	87	18	(20.7)	**0.28**	**(0.10-0.76)**	35	(40.2)	**0.39**	**(0.19-0.78)**
Mobility level									
Outdoors unassisted	743	25	(3.4)	0.52	(0.24-1.14)	68	(9.2)	0.95	(0.58-1.56)
Indoors unassisted	557	91	(16.3)	0.75	(0.49-1.14)	179	(32.1)	0.79	(0.59-1.07)
Assisted only	70	12	(17.1)	0.77	(0.24-2.42)	20	(28.6)	0.79	(0.32-1.93)
Unable to walk	25	4	(16.0)	2.32	(0.10-53.4)	6	(24.0)	1.62	(0.10-25.2)
Living arrangements									
Home	565	22	(3.9)	0.75	(0.32-1.75)	55	(9.7)	0.90	(0.52-1.56)
Home with organized homecare	399	30	(7.5)	0.81	(0.39-1.69)	68	(17.0)	0.83	(0.51-1.34)
Assisted living accommodation	237	40	(16.9)	**0.40**	**(0.21-0.76)**	81	(34.2)	**0.62**	**(0.40-0.96)**
Institutionalized	213	44	(20.7)	0.73	(0.39-1.37)	72	(33.8)	0.89	(0.53-1.49)
Fracture type									
Neck of femur	886	86	(9.7)	**0.44**	**(0.29-0.68)**	161	(18.2)	**0.68**	**(0.49-0.93)**
Intertrochanteric	458	48	(10.5)	1.20	(0.65-2.21)	99	(21.6)	0.93	(0.62-1.40)
Subtrochanteric	80	6	(7.5)	0.50	(0.10-2.48)	21	(26.3)	0.82	(0.64-1.98)

BMI=body mass index, ASA=American Society of Anesthesiologists, BZD-Z =hypnotic benzodiazepines and z-hypnotics (midazolam, temazepam, nitrazepam, triazolam, zaleplon, zolpidem, zopiclon), $eGFR_{CKD-EPI}$ =estimated glomerular filtration rate calculated by the Chronic Kidney Disease Epidemiology Collaboration equation. Statistically significant p-values (p<.10) are **bolded.**

5.4 Association of in-hospital CGA with quality-related care practices during the implementation and development of the orthogeriatric HFP (IV)

Data were available for 1,644 hip fracture patients (Table 12). The distribution of basic patient characteristics and quality related care factors in the study population and according to bivariate time factor are shown in Table 12. The median length of hospitalization was six days (IQR 5-7, range 1-37). Of the 1,644 patients, 1,072 (65%) received CGA. There was no difference in the basic patient characteristics of patients receiving CGA while hospitalized from those who did not receive CGA. Patients receiving CGA were more likely to have received RBC transfusions (p=0.011) and to have had their IUC removed during acute hospitalization (p<0.001).

The overall trends in the quality-related care practices during the orthogeriatric collaboration are shown in Figure 5.

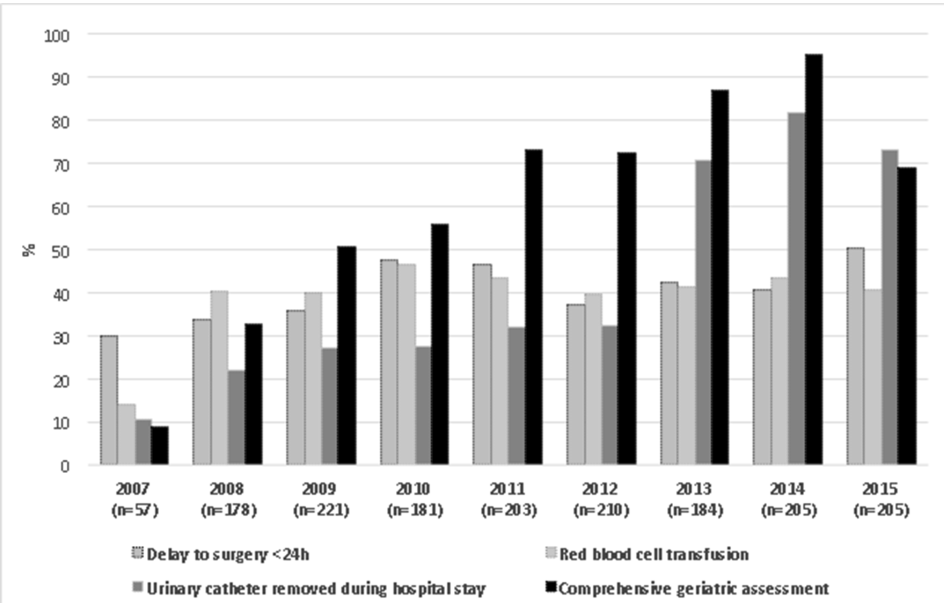

Figure 5 Trends in the quality-related care practices during orthogeriatric collaboration. Modified from original publication (IV).

Table 12 Distribution of the variables according to the bivariate time-factor (n=1,644). Modified from original publication (IV).

	Total	Time		
		2007-2011	2012-2015	p
	n=1644	n=841	n=803	
Age, median (IQR, range)	84 (78-88, 65-105)	84 (78-88, 65-105)	84 (78-88, 65-104)	0.968
Sex, n(%)				0.014
Women	1218 (74)	645 (77)	573 (71)	
Men	426 (26)	196 (23)	230 (29)	
ASA score, n(%)				<0.001
1-3	1242 (76)	612 (73)	630 (79)	
4-5	393 (24)	228 (27)	165 (21)	
Diagnosis of memory disorder, n(%)				0.006
No	1195 (73)	631 (75)	564 (70)	
Yes	445 (27)	206 (25)	239 (30)	
Mobility level, n(%)				0.901
Independently	1530 (93)	784 (93)	746 (93)	
Assisted only	109 (7)	55 (7)	54 (7)	
Living arrangements, n(%)				0.001
Home	1146 (70)	561 (67)	585 (73)	
Other than home	490 (30)	272 (32)	218 (27)	
Delay from admission to surgery, n(%)				0.190
<24 h	687 (42)	338 (40)	349 (44)	
24-47 h	686 (42)	352 (42)	334 (42)	
>47 h	271 (17)	151 (18)	120 (15)	
RBC transfusion, n(%)				0.783
Yes	670 (41)	340 (40)	330 (40)	
No	974 (59)	501 (60)	473 (60)	
Urinary catheter removed during acute hospitalization, n(%)				<0.001
Yes	734 (45)	220 (26)	514 (64)	
No	909 (55)	621 (74)	288 (36)	
CGA				<0.001
Yes	1072 (65)	425 (50)	647 (81)	
No	572 (35)	416 (50)	156 (19)	

Missing values not shown, but were tested and included in the percentages. IQR=interquartile range, ASA=American Society of Anesthesiologists, RBC=red blood cell. Statistical significant p-values (p<.05) presented in bold face. Differences between groups were analyzed using Mann-Whitney test or Pearson's chi-square test or Fisher's exact test.

Table 13 Effect of comprehensive geriatric assessment (CGA), time, and interaction with quality-related care practices during orthogeriatric collaboration (n=1,644). (Original publication IV. Reprinted with permission from Elsevier Masson SAS)

		Delay to surgery <24h		Transfusion of red blood cells		Removal of urinary catheter during hospital stay	
	N	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
MODEL 1							
CGA							
No	572	1.00		1.00		1.00	
Yes	1072	1.00	(0.81-1.23)	**1.32**	**(1.07-1.62)**	**2.98**	**(2.39-3.71)**
Time (continuous)	1644	**1.06**	**(1.02-1.11)**	1.03	(0.99-1.08)	**1.51**	**(1.43-1.58)**
Time (bivariate)							
2007-2011	839	1.00		1.00		1.00	
2012-2015	805	1.12	(0.92-1.36)	1.04	(0.85-1.26)	**5.00**	**(4.05-6.17)**
MODEL 2							
Without interaction							
CGA							
No	572	1.00		1.00		1.00	
Yes	1072	0.96	(0.77-1.19)	**1.34**	**(1.07-1.67)**	**2.01**	**(1.59-2.55)**
Time							
2007-2011	839	1.00		1.00		1.00	
2012-2015	805	1.13	(0.92-1.39)	0.95	(0.77-1.17)	**4.20**	**(3.38-5.22)**
With interaction							
No CGA 2007-2011	416	1.00		1.00		1.00	
CGA 2007-2011	423	0.96	(0.73-1.27)	**1.32**	**(1.003-1.74)**	**1.69**	**(1.24-2.31)**
No CGA 2012-2015	156	1.14	(0.79-1.66)	0.93	(0.63-1.36)	**3.20**	**(2.16-4.73)**
CGA 2012-2015	649	1.09	(0.84-1.39)	1.27	(0.98-1.63)	**8.02**	**(6.01-10.7)**

	N	Delay to surgery <24h		Transfusion of red blood cells		Removal of urinary catheter during hospital stay	
		OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
MODEL 3							
Without interaction							
CGA							
No	572	1.00		1.00		1.00	
Yes	1072	0.96	(0.77-1.20)	**1.33**	**(1.06-1.66)**	**2.18**	**(1.70-2.79)**
Time							
2007-2011	839	1.00		1.00		1.00	
2012-2015	805	1.12	(0.90-1.38)	1.00	(0.81-1.24)	**4.83**	**(3.81-6.13)**
With interaction							
No CGA 2007-2011	416	1.00		1.00		1.00	
CGA 2007-2011	423	0.95	(0.72-1.26)	1.27	(0.96-1.68)	**1.84**	**(1.32-2.55)**
No CGA 2012-2015	156	1.09	(0.75-1.59)	0.92	(0.62-1.36)	**3.69**	**(2.43-5.61)**
CGA 2012-2015	649	1.07	(0.83-1.38)	**1.32**	**(1.02-1.71)**	**10.0**	**(7.34-13.7)**

Model 1: Crude effect of CGA OR time separately in the model.
Model 2: Crude effect of CGA AND time together in the model.
Model 3: Effect of geriatric assessment AND time as adjusted by age, sex, American Society of Anesthesiologists score, diagnosis of memory disorder, and prefracture living arrangements and mobility level.
Statistically significant p-values <0.05 are presented in bold face.

5.4.1 Crude changes in the occurrence of CGA, delay from admission to surgery <24 h, RBC transfusions, and IUC removal before discharge

Since beginning the HFP, frequency of performing CGA increased (OR 1.43, 95% CI 1.36-1.50). Delay from admission to surgery less than 24 h and IUC removal before discharge also became more common, while the increase in RBC transfusions did not reach statistical significance (Table 13, Model 1). Performing of CGA was associated with prompt IUC removal and RBC transfusions, but did not affect delay to surgery (Table 13).

5.4.2 Adjusted analysis of CGA and quality-related factors during eight-year follow-up

IUC removals increased with time and effect of CGA (OR 10.0, 95% CI 7.34-13.7), but CGA increased RBC transfusions without time-effect (OR 1.32, 95% CI 1.02-1.71). Neither CGA nor time affected delay to surgery (OR 1.07, 95% CI 0.83-1.38) (Table 13, Model 3).

6 DISCUSSION

When the care of and responsibility for older hip fracture patients, one the most vulnerable group of patients in hospitals worldwide, is shared between an orthopedic surgeon and a geriatrician, lives are saved. Daily input from a geriatrician through interdisciplinary ward rounds and CGA not only improved the quality of care but also decreased one-month mortality. This study also revealed new information on the background components of effective orthogeriatric care.

Although inventing, implementing, and practising orthogeriatric care for hip fracture patients is to a great extent a multidisciplinary joint effort, the results demonstrate the need for and applicability of a geriatrician's participation in older hip fracture patients' care in the Finnish health care system. Also, this is the first large population-based study on predictors of mortality and functional recovery in Finnish hip fracture patients. In addition to the new information on the predictors for mortality and outcomes of recovery, the well-known predictors are now confirmed in Finnish hip fracture patients and the health care system.

The patient-related predictive factors are here discussed as modifiable and non-modifiable patient-related factors. The division serves to make clear the difference between conditions that are targets for active treatment and those to be considered and taken into account in individually tailored care and rehabilitation. Also, the division adds to the understandability and applicability of the results if orthogeriatric care is introduced for the first time. The care-related predictive factors are parts of the general instructions in the written orders of the HFP.

6.1 Patient-related predictors of outcomes (I, II, III)

6.1.1 Modifiable patient-related factors

Renal insufficiency beyond $eGFR_{CDK\text{-}EPI} < 45ml/min/1{,}73m^2$ is a clear predictor of increased risk of mortality after hip fracture, both short-term (III) and long-term (II). While others have demonstrated this with sCr or eGFR calculated with the widely used MDRD equation (Khan et al. 2013; Nitsch et al. 2009; Singh Mangat et al. 2008), this is the first large study on hip fracture-patient mortality to use the International Society of Nephrology Studies recommended CKD-EPI-equation for the calculation of eGFR. In a large meta-analysis of 1.1 million people $eGFR_{CDK\text{-}EPI}$, when compared to $eGFR_{MDRD}$, classified fewer individuals as having chronic kidney disease ($eGFR < 60ml/min/1{,}73m^2$) and yields a more accurate risk stratification for mortality and end-stage renal disease (Matsushita et al. 2012). In our results the hazard ratios for the groups of $eGFR_{CDK\text{-}EPI}$ 30-44ml/min/1,73m^2 and $eGFR_{CDK\text{-}EPI}$ <30ml/min/1,73m^2 are very close, and thus $eGFR_{CDK\text{-}EPI}$ < 45ml/min/1,73m^2 provides justification for clinical decision-making.

Taking more than 10 medications daily increases the risk of mortality both short-term (III) and long-term (II) and the risk of death is over more than doubled (HR 2.2) at one year after hip fracture. Alarmingly, taking four to ten medications daily clearly also increases the risk of mortality after hip fracture, yet slightly less (HR 1.8). In surviving patients, polypharmacy did not have an independent effect on mobility level or living arrangements (I), which yet again, calls for an optimistic care and rehabilitation plan from the beginning. In a Danish register-based study on polypharmacy and mortality in hip fracture patients greater number of medications did indeed increase mortality but no threshold number for increased risk was sought (Kannegaard et al. 2010). In another study focusing on inappropriate medications in older hip fracture patients, the total number of prescription medications in the survivor group was 6.7 and in the non-survivor group 7.6 (Gosch et al. 2014), and this difference is too small to serve as a useful clinical alert. In our data, the patients taking more than three medications daily were in the majority (83%) of the patients. The very common situation of a patient having more than three medications on a daily list should alert the physician to the chronic conditions related to the medications (Gosch et al. 2014; Lehnert et al. 2011).

Of hip fracture patients, 24-28% are underweight, having BMI < 23kg/m^2. Being underweight increases the risk of one-year mortality (II, Supplementary tables 1-3 in Appendices) but has no effect on mobility level or living arrangements one year after the hip fracture (I). Two reviews of predictors of hip fracture mortality used BMI as a marker for nutrition state and in these the results were ambivalent: low BMI either did not predict (Smith et al. 2014) or moderately predicted (Hu et al. 2012) mortality after hip fracture. A more accurate assessment of the nutrition state according to the short form of the MNA (MNA-SF), but not the use of BMI alone, has been recommended for consideration when diagnosing malnutrition in hip fracture patients (Bell et al. 2014). However, Bell et al. used a diagnostic limit of <18.5 kg/m^2 for BMI but using a higher threshold of <23 kg/m^2 may be equally effective in identifying malnourished older hospital patients (Ranhoff et al. 2005). In the Seinäjoki HFP, MNA-SF was included only from 2010, and therefore could not be used in the present study. Another study from the Seinäjoki database, however, included only patients with data on MNA-SF and associated malnutrition at baseline with increased risk of mortality, malnutrition, and risk of malnutrition with increased risk of institutionalization and risk of malnutrition with increased risk of declined mobility four months after hip fracture (Nuotio et al. 2016b).

6.1.2 Non-modifiable patient-related factors

In this study, those hip fracture patients who before the fracture were able to walk outside unassisted or live without organized home care experienced the greatest changes in mobility level and living arrangements one year after hip fracture (I). Only half of those patients being able to walk unassisted outdoors before the fracture were both alive and had succeeded in regaining their walking ability one year after hip fracture. Also, half of the patients living without organized home care before the fracture had been able to return to independent living one year after the hip fracture. This is alarming, as these patients should have the greatest potential for functional recovery (Beaupre et al. 2007; Kristensen 2011). Within the scope and study design of the current study, the reason for this remains unclear. In our data, the acute hospital stay being six days is longer than LOS for hip fracture in other Finnish hospitals (in 2015 average LOS 4.5 days, mean 5 days, range 3-10 days) (National Institute of Health and Welfare 2017). However, as the statistics provided by the National Institute of Health and Welfare do not include patients living in institutions or patients suffering their second hip fracture within ten years, the difference is logical. After the relatively short hospital stay, patients are discharged to local health care centers in which the rehabilitation resources vary (Nuotio et al. 2016a). Also, due to the downsizing of available beds in all parts of the health care (hospital wards, wards in health care center and LTFCs) (Mikkola et al. 2015), the pressure to discharge the patient home too soon may be high. For previously independent patients, the rehabilitation may have proceeded swiftly enough for them to cope at home but to achieve the goal of full recovery or independence, too much of the work and responsibility is left to the patient. However, if a home-based rehabilitation program follows the institutional rehabilitation provided by the health care center, restoring mobility is significantly improved even if compared to the prefracture level (Salpakoski et al. 2014). Thus, the existing coping abilities or independence should not be seen as affording a possibility for early discharge, but as an alert to what the patient has to lose if rehabilitation is not carried out to the fullest extent. Although there is a growing interest in home-based rehabilitation in our area, systematic programs for hip fracture patients are practically non-existent.

Patients living in assisted living accommodation or an institution or needing assistance in moving are at higher risk of mortality at one month, four months and one year (Tables 1-3 in Appendices) which concurs with previous results (Hu et al. 2012; Smith et al. 2014). Also, living elsewhere than home predisposes to decline in mobility level one year after hip fracture. This may reflect the recovery capacity of the patients (Neuman et al. 2014) but also the rehabilitative resources available to them. For patients already needing assistance in moving before the fracture, suffering a hip fracture extends the need for assistance to other aspects of life and the need for more supported living arrangements is established.

Older age is a well-known risk factor for increased risk of mortality (Hu et al. 2012; Smith et al. 2014) after hip fracture both short-term and long-term and also has a negative impact on overall recovery (Kristensen 2011). Even though this characteristic is fixed, it should not be thought to predetermine the outcome but should be taken more actively into account. As the mean age of hip fracture patients is increasing (Bergstrom et al. 2009), it is vital to understand that not all "aged" are the same and they, too, have recovery potential. Of patients 90 years or older, as many as half of those who before the fracture had lived in their own homes could return there (Vochteloo et al. 2013a).

As is already well documented, the risk of mortality after hip fracture is higher for men (Hu et al. 2012; Smith et al. 2014) but for those who survive gender has little or no effect on the results of recovery (Kristensen 2011). In addition to being older than before, the hip fracture patients are nowadays more often male (Löfman et al. 2002). As their prognosis is known to be poorer, men should be treated as high-risk patients. However, improving survival for male hip fracture patients may be challenging as discussed in more detail in Chapter 6.4.

In our data 27% of patients had diagnosed memory disorder prior to the fracture. Memory disorder is a risk factor for increased risk of mortality (III) and decline in mobility level and living arrangements at one year (I), as is already known (Hu et al. 2012; Kristensen 2011; Smith et al. 2014). In the adjusted analyses of the present study, however, memory disorder increased only one-month and four-month (III) but not one-year risk of mortality (II, Supplementary Tables 1-3 in Appendices). Even though not reaching statistical significance at one year, the mortality of patients with a diagnosis of memory disorder, when compared to patients with no such diagnosis, was 32% higher (25% vs. 33%) one year after hip fracture. The result of the incomplete functional recovery is not new but could be avoided to some extent as cognitively impaired hip fracture patients do benefit from multidisciplinary geriatric rehabilitation (Huusko et al. 2000). Hence it is likely, as physical rehabilitation specifically designed for cognitively impaired patients is non-existent in our hospital district, that the patients with memory disorder are not provided with the conditions and duration of rehabilitation that they would need.

Fracture type in this study was not associated with mortality or mobility or living arrangements outcomes. Even though a review article with a large data concluded that fracture type is not independently associated with long-term patient-related outcomes (Butler et al. 2011), both femoral neck (Smith et al. 2014) and trochanteric (Hu et al. 2012) fracture have been associated with increased risk of mortality and trochanteric fracture with compromised (Kristensen 2011) or at least delayed (Fox et al. 1999) functional recovery. As the proportion of trochanteric fractures is rising (Kim et al. 2012a) it is important to remember that besides being older and having more comorbidities than femoral neck patients (Fox et al. 1999), patients with trochanteric fracture may need a longer time to rehabilitate.

ASA score in this study was used to assess general health (Bjorgul et al. 2010; Sankar et al. 2014) and was mainly used for adjustment purposes. Poorer general health is associated with poorer outcomes in hip fracture patients (Hu et al. 2012; Kristensen 2011; Smith et al. 2014), which was also seen in our results. According to the results of the studies, ASA 4-5 predicts mortality at all three time-points (II, III) and ASA 3 or ASA 4-5 was associated with increased need for more supported living arrangements one year after hip fracture (I).

6.2 Care-related predictors of outcomes (I, II, III)

6.2.1 CGA

This study succeeded in demonstrating the clinical significance of a geriatrician's input in the acute care of older hip fracture patients as the one-month mortality was less among patients who received CGA during hospitalization for hip fracture (III). This is the first study to show the effectiveness of orthogeriatric acute care in reducing mortality in the Finnish health care setting and the result is similar to other comprehensive and interdisciplinary real-life hip fracture programs in other countries (Adunsky et al. 2011; Hawley et al. 2016; Kristensen et al. 2016; Leung et al. 2011). The effect of decreased risk of mortality was seen in the age- and sex-adjusted analysis of the entire study population without excluding patients with well-known predictors for high mortality. Furthermore, it is noteworthy, that the patients in the group used for comparison (38% of the patients) were treated according to the written instructions of the HFP, and thus received intervention at some level. This is in concordance with the findings that evidence-based clinical pathways without a multidisciplinary team (Neuman et al. 2009) or shared responsibility (Deschodt et al. 2011) do not affect mortality. In the present study, the effect of CGA while hospitalized for hip fracture was seen in one-month mortality, and a clear trend, albeit statistically non-significant, was also noted in the effect of CGA on four-month mortality. In Sweden, LOS of 10 days was found to be the threshold under which each one-day reduction in LOS increased 30-day mortality by 8-16% (Nordström et al. 2015). It may be, that our intervention with mean LOS of six days is too short to achieve a significant reduction in mortality at the time point of four months.

6.2.2 Delay from admission to surgery

The association of the delay from admission to surgery > 47h with increased risk of mortality is consistent with previous findings (Moja et al. 2012; Simunovic et al. 2010). In the UK 38% of the reasons for not operating in <36h were due to being medically unfit (Royal College of Physicians) and it may be rationally questioned if the reason for the delay is also to some extent prognostic. Interestingly, however, the only risk factor for delay exceeding 36h was hyponatremia, yet this was not associated with mortality (Aqil et al. 2016). While pre-operative physiological stabilization is sometimes necessary, the time used on it should be considered carefully and pragmatically: every hour of delay beyond 24 hours increases the risk of mortality but the benefits of ultra early (<12h) surgery are unclear (Morrissey et al. 2017; Uzoigwe et al. 2013). The effect of early surgery on functional recovery has been studied less and the results are inconclusive. Shorter surgical delay has been associated with better ability to return to independent living (Al-Ani et al. 2008) but was not associated with walking ability six months after hip fracture (Kim et al. 2012b). In the present study, timing of surgery had no effect on mobility level or living arrangements one year after hip fracture.

6.2.3 IUC removal during hospitalization

In this study prompt removal of IUC was associated with decreased risk of mortality (II) and with lower risk of declined mobility level and the need for more supported living arrangements (I). This is the first time prolonged IUC use has been associated with increased risk of long-term mortality and declined functional recovery in hip fracture patients. The only study so far on prolonged IUC use in hip fracture patients in relation to mortality found an association between being discharged with a catheter and increased 30-day mortality (Wald et al. 2005). While the direction of causality cannot be explored in the present study design, prolonged catheterization being the cause for the poorer outcomes may be discussed in light of the findings of earlier studies. Catheterization itself causes UTI (Hooton et al. 2010) and if prolonged beyond six days (the mean LOS in our study), the risk for UTI is up to 7-fold (Maki & Tambyah 2001). Both catheterization itself and UTI are linked to prolonged hospitalization (Holroyd-Leduc et al. 2007; Kamel 2005) and delirium (Kamel 2005; Ranhoff et al. 2006). Also, an IUC may be seen as physical restraint and a barrier to mobilization (Brown et al. 2007). Consistently, it has been demonstrated that, in the older patients, the absence of the catheter is conducive to regaining walking ability during hospitalization (Brown et al. 2006) and results in less long-term functional decline and fewer new admissions to LTFCs (Bootsma et al. 2013). In addition, based on clinical experience, patients with an indication to be discharged with IUC, for example, in order to monitor urine output in severely ill patients, are very few, and the proportion of these patients is not likely to explain the adverse result of the entire patient population discharged with IUC still in place. Regardless of the causality not examined in the current study, our results underline the importance of adhering to the clinical instructions on prompt postoperative IUC removal.

6.3 Improvements in quality of care in orthogeriatric collaboration (IV)

6.3.1 Delivering CGA for older hip fracture patients

One of the main goals in developing the HFP was achieved as the delivery of CGA increased markedly, from 9% in 2007 to 69% in 2015. Providing multidisciplinary orthogeriatric care for all patients was almost achieved in 2014 with 95% coverage, but occasional lack of geriatricians affected the availability of the service in Seinäjoki Central Hospital. However, sharing the care of hip fracture patients on an orthopedic ward is an excellent way to provide the service for as many patients as possible given that the number of geriatricians working in hospital environments in Finland is very low. The general target of equality in care was also achieved as none of the patient-related factors discriminated the availability of CGA and the effect of the involvement of a geriatrician remained after adjusting for patient-related factors.

6.3.2 Delay from admission to surgery

In Seinäjoki Central Hospital, the aim to shorten the delay from admission to surgery was achieved as the percentage of patients operated on within 24 hours increased during the orthogeriatric collaboration, from 30% in 2007 to 52% in 2015. In the data updated after the follow-up of the present study, the proportion of patients operated on within 24 hours after admission has increased to over 60%. The benefits of short surgical delay are strongly evidence-based and this aim is a common part of successful programs targeting quality improvements in hip fracture care (Ciaschi et al. 2011; Collinge et al. 2013; Lau et al. 2013; Soong et al. 2016). Smoothing the patient's path from arrival at the emergency room to undergoing surgery requires, after ascertaining the relevance of the matter, process or lean thinking in which every part of the path is scrutinized and trimmed (Kates 2014). Thus the delay to surgery is an important quality indicator of the orthopedic surgeon-led process of hip fracture care. The lean model in hip fracture surgery in our hospital came into effect in 2013, thus the significant change could only be seen in the analysis with time as a continuous factor but not in the 2007-2011 vs. 2012-2015 analysis. The increase in the proportion of patients undergoing surgery in <24 h was independent of the geriatrician's involvement, which highlights the necessity of the effort from both specialties in improving the care of patients with hip fracture.

6.3.3 RBC transfusions

In the present study, RBC transfusion while hospitalized for hip fracture was associated with receiving CGA. The thresholds (90 g/l and 100 g/l if severe cardiac condition) are clearly stipulated in the set of instructions, but in our experience, the actual threshold used in clinical decision-making is lower when patients are treated by an orthopedic surgeon only, and this could affect the result. When the optimal RBC transfusion threshold for hip fracture patients is not known, it may be questioned if more RBC transfusions is a valid indicator for better quality of care. A Cochrane review of RBC transfusions for patients undergoing hip fracture surgery concluded that liberal or restrictive policies do not differ with respect to mortality or recovery. The review does not, however, include results from a more recently conducted RCT by Gregersen et al. In their results, a more liberal (113g/l vs. 97g/l) RBC transfusion policy decreased 90-day mortality among patients living in LTFCs but not among those living in less supported sheltered housing (Gregersen et al. 2015a). In the same frail population, the RBC transfusion policy did not affect quality of life but the more liberal policy improved ADL recovery for patients with at least moderate cognitive ability (Gregersen et al. 2015b). Furthermore, there were fewer cases of delirium in the more liberal policy group (Blandfort et al. 2016). In a recent review, the use of a more liberal RBC transfusion policy is recommended in order to prevent acute coronary syndromes in patients with cardiovascular disease (Docherty et al. 2016). As often in geriatrics, it may be concluded that quality of care in the matter of RBC transfusions lies within the individual consideration of multiple aspects. In our model, the time reserved for CGA allows for thorough evaluation of the hemodynamics, oxygen saturation, pre-fracture hemoglobin level, and possible symptoms of anemia and/or ischemic heart disease, etc. We believe the observed association between CGA and RBC transfusion is, in addition to adhering to the instructions, the result of more careful and individual medical assessment of the patients by a geriatrician.

6.3.4 IUC removal during hospitalization

One of the most remarkable advances during the orthogeriatric collaboration was the dramatic increase in IUC removals before discharge. Compared to traditional care at the beginning of the orthogeriatric HFP, prompt IUC removal increased 10-fold. According to Meddings et al. removal of an IUC requires 1) recognition that an IUC is still in place, 2) recognition that it is no longer needed, 3) a physician's instruction for the IUC to be removed, and 4) a nurse to remove the catheter (Meddings et al. 2014). During the years of orthogeriatric collaboration, we have focused on all four steps through continuous education in best practices and encouragement to adhere to the written instructions of the care protocol. The awareness in 1), 2), and 4) are increased by including the simple instruction on removing of the IUC routinely on the first postoperative day. Step 3) has practically been overridden as nurses are encouraged to proceed using their own judgment. Although IUCs are still removed more often promptly under the care of a geriatrician, IUCs were more promptly removed even without a geriatrician's involvement during the last half of the follow-up, which is an encouraging sign of learning and growing of expertise for the entire team.

6.4 Association of CGA with mortality in groups of patient-related factors (III)

The beneficial effect of CGA on short-term mortality as a part of the HFP was seen in the total study population receiving CGA. More importantly, part of the effect was derived specifically from certain patient-related conditions, which will help in understanding the complicated relationship between optimal hip fracture care and the heterogeneous group of patients. The background components of effective orthogeriatric care are still largely unclear (Chen & Hung 2015). Improved quality of care is likely part of the explanation (Kristensen et al. 2016) but the characteristics of the patients with favorable survival response to the multidisciplinary care in an every-day care setting have not previously been explored. We found several patient characteristics, some of which are medically modifiable, that could explain the protective effect of in-hospital CGA on short-term mortality.

6.4.1 Potentially modifiable patient-related factors

In the present study the risk of short-term mortality among hip fracture patients taking four to ten medications daily decreased significantly when CGA was performed while they were hospitalized for hip fracture. This was also seen in patients using BZD-Zs. Medications management calls for involvement and expertise as only 9.6% of hip fracture patients had neither inappropriate or underprescribed efficacious medications in their lists (Gosch et al. 2014). Nevertheless, as polypharmacy (Gosch et al. 2014; Lehnert et al. 2011) and use of BZD-Z (Cheng et al. 2008) are related to underlying comorbidities and undertreatment is to be avoided, the goal of medications management cannot be any absolute number. Yet the findings that the number of fall-risk increasing drugs increases (Kragh et al. 2011) and polypharmacy even doubles (Kaukonen et al. 2011) after hip fracture are indeed worrying. In improving the appropriateness of medication in older patients, intervention by a multidisciplinary geriatric team has been found to be the most effective (Kaur et al. 2009).

The importance of medications and other medical management is highlighted in patients with renal insufficiency. In these patients, adverse drug reactions are more common (Jones & Bhandari 2013) and polypharmacy actually increases the risk for mortality (Bowling et al. 2014). Low eGFR on admission may be a sign of physiological, acute (Rosner 2013) or acute-on-chronic (White et al. 2009) renal dysfunction. If eGFR is low on admission, especially in patients with previously higher eGFR, carefully balanced preoperative medication and fluid therapy are needed to minimize acute renal dysfunction, which in hip fracture patients leads to increased complications and mortality (Bennet et al. 2010). Encouragingly, in our results, the patients with on-admission $eGFR_{CDK\text{-}EPI}$ <30ml/min/1,73m^2 clearly benefited from more thorough medical care as their survival improved with CGA.

6.4.2 Patient-related factors to be taken into consideration without modification

In this study patients aged 80-89 years benefited from the CGA in relation to mortality, whereas younger (65-79 years) or older (90 years or older) patients did not. In two meta-analyses, the critical age for predicting higher mortality was 80 years (Hu et al. 2012) or 85 years (Smith et al. 2014). However, there is a growing body of evidence that comorbidity rather than age itself is the decisive factor for survival even in the patients aged 90 or over (Eschbach et al. 2013; Lin et al. 2015; Liu et al. 2015). According to our analysis not adjusted for comorbidities, the critical age for surviving hip fracture under comprehensive geriatric care may be set at 90 years.

For women, receiving CGA was beneficial in relation to short-time mortality but for men the mortality did not decrease. It is known that male sex itself is an independent risk factor for higher mortality (Hu et al. 2012; Smith et al. 2014). The gender difference in mortality may, despite being younger at the time of the fracture, be due to being in poorer health prior to the fracture (Holt et al. 2008a). In a small, retrospective study on male hip fracture patients, comprehensive care reduced in-hospital complications but had no effect on mortality (Dy et al. 2011). The findings imply that older men require specific attention regarding hip fracture care. It may, however, be that for the frail males, suffering a hip fracture is another incident in the end-of life cascade, and reducing their mortality is beyond the scope of the approximately six-day intervention in our study.

Our results suggest that for the patients with dementia the high risk of hip fracture related mortality (Hu et al. 2012; Smith et al. 2014) may be reduced by CGA. There are no studies on the effect of multidisciplinary orthogeriatric acute care on the mortality of hip fracture patients with dementia. As the care of patients with dementia, with or without hip fracture, is at the very core of the geriatrician's expertise, the result is logical. A single diagnosis or a memory test score does not determine the geriatrician's view of a patient; the focus is on the patient's remaining resources. To utilize those through correct acute care decisions and an appropriately tailored rehabilitation plan, multidisciplinary care is necessary. Although here presented as an unmodifiable factor, an existing memory disorder may to some extent to be modifiable. Under the care of a geriatrician, the choices and doses for medications to treat memory disorder or its symptoms may be evaluated and adjusted to achieve optimal care for each patient.

Patients living in assisted-living accommodations are too frail to survive at home, but well enough to avoid care in an institution. In our study this patient group benefited greatly from CGA with regard to mortality. Also, in this study, patients with femoral neck fracture benefited from CGA in relation to short-term mortality. Consequently, patients sustaining other types of fracture are older, have more comorbidities, and a higher risk of mortality (Fox et al. 1999), which may determine their prognosis beyond the effects of a CGA.

6.4.3 Remarks on patients whose risk of mortality was not improved by CGA

The orthogeriatric approach for younger and fitter patients had no effect on short-time mortality. The younger patients were less frail (Krishnan et al. 2014; Penrod et al. 2007) and more likely to survive hip fracture regardless of the CGA. Rehabilitation-wise, however, community-dwelling younger patients with high pre-fracture IADL benefit from comprehensive orthogeriatric care and rehabilitation most of all (Prestmo et al. 2016). In the study by Prestmo et al. high-quality orthogeriatric care lasting only 13 days, more than doubled the number of patients (from 11% to 25%) discharged direct to their own homes and the functional and quality-of-life improvements lasted to the end of the one-year follow-up (Prestmo et al. 2015). Thus, for the patients who in our study experienced the greatest losses in their functional abilities, a longer orthogeriatric intervention might be rational not for surviving but for recovering sufficiently to be able to continue living independently.

At the other extreme, the oldest and frailest hip fracture patients with the poorest prognoses, or ASA score 4-5, did not either benefit from CGA in relation to mortality. In this patient group, mortality may to some extent be an inappropriate outcome to measure since reducing mortality at the expense of a disabled and dependent outcome may not be considered the optimal goal of treatment. These patients, however, are at the core of the geriatric expertise (Warshaw et al. 2008) and for them, the enhanced quality of care provided by the means of CGA is to be valued equally.

6.5 Strengths and limitations of the study

This study is based on the population of the geographically defined catchment area of the Hospital District of Southern Ostrobothnia. All hip fracture patients aged 65 or over sustaining their first hip fracture during the follow-up period were enrolled in the study beginning on September 1, 2007, and the exclusion criteria only included periprosthetic and pathologic fractures. Also, the older population in Finland is quite homogeneous and the ethnic diversity, for example, is very small. On the other hand, the study population represents only 3.5% of the total population of Finland which may limit the generalization of the results.

Data was prospectively collected in Seinäjoki Central Hospital, which is the only hospital providing acute surgical care for patients in the hospital district. The information was collected from the patients, original patient records, and by phone calls to caregivers or places of residence. Very few patients declined to participate and the participation rate was as high as 98%. The data was collected almost entirely by one person, whose personal characteristic of thoroughness and carefulness add to the quality of the data used in the study. The dates of death were provided by the National Population Register Center and extracted from the electronic patient files of the hospital. Only two patients had moved outside of the hospital district but both were reached by phone so there were no losses to mortality follow-up.

The data used in the present study was collected on patients sustaining their hip fractures between September 1, 2007, and December 31, 2015. This allowed the number of patients in the study to grow large but at the same time exposed the data to the secular changes that occurring in hip fracture care in general and in the

Finnish health care system during those years. The secular changes may impair the reliability of the results but are an inevitable part of long-term real-life studies. In recent years housing of the frailest older citizens in Finland has shifted from institutional living to assisted living accommodation and to remaining in their own homes. To minimize the effect of this on the results, we used the decline from less supported living arrangements to more supported living arrangements rather than percentages of each type of housing to measure the need for a more supported living environment. Also, even though the official nomenclature for housing units has changed, the classification used in this study was based on the services available in the unit. In the study living arrangements was used as an indirect measurement for functional ability but using a validated functional evaluation would have added to the weight of the thesis.

The classification of factors for the analysis may in part be criticized. The exact number of medications was not registered but the patients were classified directly into groups. The division of the middle group of taking four to ten daily medications would have provided more detailed information on risk stratification related to polypharmacy. The mobility classification is crude and does not cover, for example, ease of movement: before the fracture the patient may have used a walking aid without pain and with satisfactory walking speed and after hip fracture these may have changed but with no change in the classification. A more detailed and both patient and proxy validated questionnaire on the patients' mobility might have yielded more accurate results. However, the measures selected for mobility and functional decline correlate with standardized measures of PADL, IADL and Timed Up and Go (TUG) at the later follow-up visit to the outpatient clinic (Nuotio & Luukkaala 2016c).

Also, the weight used for the calculation of BMI was retrieved from the patients' medical record or estimated if no recent weighting result was available.

Memory disorder was not an exclusion criterion, thereby increasing the generalizability of the results and was recorded as having or not having a prefracture diagnosis of memory disorder. We believe it is not reliable to perform memory testing on patients while hospitalized for hip fracture as the result could be affected by confounding factors such as delirium or narcotic analgesics. Therefore it is possible that the classification of cognitive health was not accurate, and in fact, of the patients not having a diagnosis of memory disorder, more than half scored 5-24 on the Mini Mental State Examination (MMSE) 4-6 months later (Nuotio & Luukkaala 2016c). Nevertheless, the prevalence of diagnosed dementia in our study was 27%, which is close to the prevalence of 28% calculated in a review article on dementia in hip fracture patients (Hebert-Davies et al. 2012). Du to not testing the patients while hospitalized, we were also unable to classify the patients according to grade of dementia.

The study data was collected prospectively but the analyses and part of the hypothesis setting were conducted retrospectively. Therefore some of the data that would have been useful and added to the weight of the results, such as values of hemoglobin for RBC transfusion and exact duration of urinary catheterization, were not recorded. The incidence of delirium measured by CAM and nutritional assessment by the MNA were added to the assessment in recent years of the program and could not be included in the analyses.

Also, diagnoses of specific diseases or indexes designed for comorbid conditions were not included in the data collection but ASA score was used to adjust for general health. Although criticized for inadequate inter-rater consistency (Mak et al. 2002), ASA score has been found to correlate fairly well with the Charlson Comorbidity Index (Sankar et al. 2014) and to be a fairly reliable comorbidity index in hip fracture patients (Bjorgul et al. 2010).

The patient-related factors differ somewhat between the studies. Renal insufficiency and polypharmacy were only studied for mortality, but their predictive value for the results of recovery, here mobility and living arrangements, would have added to the weight of the thesis.

7 CONCLUSIONS

Among older hip fracture patients, risk for declined mobility is greatest in those patients who are able to walk unassisted outdoors before the fracture. The risk for needing more supported living arrangements is greatest for patients living in their own homes without organized homecare (I). In these patients, regaining their prefracture mobility level and, more importantly, the ability to continue living independently in their own homes is essential for the individual, and also for reducing financial costs. Rehabilitation should be designed and resourced not only to aim at but also to achieve these goals.

Renal insufficiency beyond $eGFR_{CDK\text{-}EPI} < 45ml/min/1{,}73m^2$ or having more than three daily medications increased the risk of mortality after hip fracture, both short-term (III) and long-term (II). By delivering CGA, however, risk of mortality of the high-risk patients with renal insufficiency, polypharmacy or cognitive disorder could be decreased (III). It may be concluded that careful medical evaluation of older hip fracture patients is at the core of improving their care and outcomes.

IUC removal while hospitalized for hip fracture is associated with decreased risk of decline in mobility level and living arrangements (I) and mortality (II) one year after hip fracture. While the direction of causality was not addressed, the result underlines the importance of following the guidelines on prompt postoperative IUC removal.

Implementing and developing a comprehensive orthogeriatric care model for hip fracture patients improves quality of care (IV). Markedly more patients receive CGA and CGA increased adherence to the written instructions of the HFP on prompt IUC removal and RBC transfusions. Also, expertise in geriatric care was increased among other than geriatric staff, as the prompt removal of IUCs was more frequent during the latter half of the follow-up time, even without geriatrician’s involvement. The promptness of surgery improved during the orthogeriatric collaboration but independent of CGA.

Even in the presence of standardized and thorough instructions, delivering CGA decreased the risk of one-month mortality among older hip fracture patients (III). For younger and fitter or older and frailer patients CGA did not affect mortality but between the extremes of low-risk and high-risk patients is a large group of patients whose lives can be saved by means of CGA and, to prevent early mortality, CGA should be available to all hip fracture patients

8 FUTURE CONSIDERATIONS

Nationwide, orthogeriatric care during acute hospitalization is currently rare and, where it exists, vulnerable. As the scientific knowledge of how to best treat older hip fracture patients is vast and sound, and now proven in our local health care setting, an orthogeriatric care model should be in use in all units providing hip fracture care. The imminent reform of the Finnish social and health care system offers us a tremendous opportunity to upgrade hip fracture care in Finland to correlate with current evidence considering both acute and rehabilitative care. In larger units with adequately staffing by geriatric specialists and trainees, also the continuity in care and education will be better ensured.

8.1 Acute care

Every unit providing surgical care for older hip fracture patients needs to have a full orthogeriatric staff and an orthogeriatric care plan including detailed written instructions for treatment covering the entire care pathway. After the centralization of acute surgical care of hip fracture patients (Haapiainen & Virolainen 2016) is impelmented, every unit providing hip fracture surgery will be large enough to provide a geriatrician-led orthogeriatric unit. In this model, the patient is in an orthogeriatric unit for the entire stay, from possible preoperative care until discharged. The responsibility for the patient is shared between an orthopedic surgeon and a geriatrician until, for example, the first postoperative day, after which full responsibility is assumed by a geriatrician. The non-physician staff should be geriatricly oriented, and experienced in both acute care and rehabilitation.

The size of the unit should be designed to cover all patients with first hip fracture, periprosthetic fractures, distal femoral fractures and possibly also other surgically treated fragility fractures. The near future increase in the number of hip fracture patients should be considered in advance.

The number of geriatricians in Finland is approximately 300 and the tradition of geriatricians working in primary care is strong. Therefore, with less than 10% of geriatricians working in acute hospital environments, “hospital geriatrics” is currently undeveloped. In hospitals with small geriatrics departments, the model presented in the thesis is a viable option. The shared responsibility model requires flexibility on the part of the orthopedic staff to step up and take full responsibility whenever a geriatrician is not available for the ward rounds and to conduct a CGA. To support all members of the team, the written hip fracture care protocol should be a firmly established routine and the best care the easiest choice also in the absence of a geriatrician.

8.2 Rehabilitation

The rehabilitation currently organized in local health care centers is decidedly and impractically multipolar and the number of cases in all units is not sufficient for all team members to increase their expertise. Furthermore, the distance from the acute hospital and variation in acute services in the current discharge locations exposes patients to unequal treatment and care. According to a report published by the Finnish Ministry of Social Affairs and Health, the rehabilitation of hip fracture patients should take place in specialized geriatric rehabilitation units in close proximity to the acute operative unit and other acute hospital services (Huusko 2017).

The current evidence suggests that the initial rehabilitation for selected patients should also take place in a hospital-based orthogeriatric unit (Prestmo et al. 2015). Therefore, the initial rehabilitation should be designed to continue in the acute orthogeriatric unit for patients aiming at discharge directly home within 1-2 weeks from the fracture. The patients anticipated to need longer rehabilitation or continued rehabilitation after discharge from acute hospital care should be treated in a centralized geriatric rehabilitation unit with experience and knowledge of the details of geriatric trauma patient rehabilitation and easy access to acute services of a hospital if needed. In many of the present hospital districts the optimal location would be a primary care ward located near the acute hospital. If the patient is already residing in a LTFC, the rehabilitation may take place in the original residence, the patient is recommended to be transferred back after the discharge criteria from acute hospital care are fulfilled.

The re-organizing the rehabilitation will inevitably increase hospital LOS on the initial stay. While the patient-related goals of improving hip fracture care are easy to set for achieving better results in a variety of outcomes, the organization-related goal of efficacy should be considered carefully and without sub-optimizing if aiming, for example, at lower costs through shorter LOS.

8.3 Management and leadership

The transition from traditional orthopedic care to comprehensive orthogeriatric care involves not only the geriatrician but also doctors from other specialties and members of the multidisciplinary team. Basu et al present the following elements for the successful implementation of an orthogeriatric program (Basu et al. 2016):

- Program leadership from an orthopedic surgeon and a geriatrician
- Medical co-management
- Standardized order sets and protocols
- Collegial relationships of team members
- Early surgical intervention
- Strategy for continuous quality improvement

Lack of leadership, especially on part of the the geriatrician, has been seen as the biggest barrier in implementation of an orthogeriatric program, and well-respected orthopedic surgeon "champion" and geriatric "champion" should be selected to lead the change (Kates et al. 2012).

To ensure the continuous communication and dynamic decision-making vital to the successful implementation and development of the orthogeriatric care model, an orthogeriatric committee should be established. Regular meetings of the committee including at minimum a geriatrician, an orthopedic surgeon, an orthogeriatric nurse and physiotherapist should be responsible for

- Problem solving of impracticalities identified in the daily work
- Monitoring and evaluating performance
- Training of staff from all disciplines
- Updating the standardized clinical instructions using an extended composition of the committee with the addition of an anesthesiologist and a dietitian

8.4 Hip fracture register

By implementing an evidence-based quality register and allowing and accepting detailed benchmarking it is possible to facilitate improvements in clinical care and cost-effectiveness (Patel et al. 2013). Due to the narrow composition of variables and considerable delays in publishing the data, the current PERFECT -registry of the National Institute of Health and Welfare in its present form is not useful or agile enough to provide information for the real-time evaluation of performance in hip fracture care. Therefore a national hip fracture registry with rapid data publishing not only on patient-related information and outcomes but also on quality indicators, including the existence of HFP and geriatric multidisciplinary teams as well as coverage of CGA, should be established. The Finnish Arthroplasty

Register for elective hip and knee arthroplasties was modernized into a web-based, open access service in 2015 and in the preface of the ENDOnet, the need for a similar register for hip fracture patients is recognized (Finnish Arthroplasty Register 2017).

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APPENDICES

Supplementary Table 1. Models of 1-year survival according to $eGFR_{CKD\text{-}EPI}$ (n=1388). Reprinted with permission from Elsevier.

			Survival 1 year after hip fracture					
			Model 1		**Model 2**		**Model 3**	
	n	(%)	HR	95% CI	HR	95% CI	HR	95% CI
$eGFR_{CKD\text{-}EPI}$								
> 60 ml/min/1.73m^2	821	(59)	1.00		1.00		1.00	
45-59 ml/min/1.73m^2	287	(21)	**1.39**	**1.07-1.81**	1.29	0.96-1.69	1.20	0.91-1.57
30-44 ml/min/1.73m^2	193	(14)	**1.93**	**1.47-2.53**	**2.05**	**1.55-2.71**	**1.91**	**1.44-2.52**
< 30 ml/min/1.73m^2	87	(6)	**2.74**	**1.96-3.83**	**2.50**	**1.78-3.51**	**1.95**	**1.36-2.78**
Age *median* (IQR, range)	84.0	(79-88, 65-105)	**1.07**	**1.05-1.08**	**1.03**	**1.01-1.05**	**1.04**	**1.02-1.06**
Sex								
Women	1040	(75)	1.00		1.00		1.00	
Men	384	(25)	**1.91**	**1.54-2.37**	**2.09**	**1.67-2.61**	**1.98**	**1.58-2.50**
ASA score								
1-2	167	(12)			1.00		1.00	
3	856	(62)			**2.09**	**1.21-3.61**	1.68	0.96-2.94
4-5	344	(25)			**3.40**	**1.94-5.97**	**2.60**	**1.46-4.63**
Diagnosis of memory disorder								
No	1009	(73)			1.00		1.00	
Yes	372	(27)			0.95	0.75-1.22	0.97	0.76-1.24
Mobility level								
Outdoors unassisted	725	(52)			1.00		1.00	
Indoors unassisted	565	(41)			**1.86**	**1.42-2.45**	**1.93**	**1.46-2.56**
Indoors assisted	65	(5)			**1.78**	**1.14-2.79**	**1.84**	**1.16-2.91**
Unable to walk	23	(2)			1.03	0.47-2.26	0.65	0.29-1.45

Living arrangements						
Home	547	(39)	1.00		1.00	
Home with organized homecare	393	(28)	1.08	0.79-1.47	1.01	0.73-1.38
Assisted living accommodation	232	(17)	**1.83**	**1.31-2.56**	**1.56**	**1.11-2.18**
Institutionalized	205	(15)	**1.96**	**1.36-2.82**	**1.69**	**1.17-2.44**
Delay from admission to surgery						
<24 h	545	(39)	1.00		1.00	
24-47 h	596	(43)	1.09	0.86-1.37	1.17	0.92-1.49
>47 h	224	(16)	1.26	0.93-1.70	**1.40**	**1.03-1.91**
Fracture type						
Neck of femur	859	(62)			1.00	
Intertrochanteric	450	(32)			1.14	0.91-1.42
Subtrochanteric	78	(6)			1.29	0.84-1.97
BMI						
23-28	580	(42)			1.00	
<23	383	(28)			**1.33**	**1.03-1.71**
>28	380	(27)			0.89	0.67-1.18
Number of regularly taken medications						
< 4	240	(17)			1.00	
4-10	893	(64)			**1.76**	**1.14-2.72**
> 10	254	(18)			**2.11**	**1.32-3.38**
Urinary catheter removed during hospital stay						
Yes	508	(37)			1.00	
No	830	(60)			**1.33**	**1.03-1.72**

Missing values not shown, but were tested and included in the percentages. ASA=American Society of Anesthesiologists, BMI=body mass index, $eGFR_{CKD-EPI}$=estimated glomerular filtration rate by 2009 Chronic Kidney Disease Epidemiology Collaboration equation. Statistically significant p-values ($p<.05$) are presented in bold face. Analyses were performed with Cox regression models, results shown by hazard ratios with 95% confidence intervals

Supplementary Table 2. Models of 1-year survival according to removal of urinary catheter before discharge (n=1374). Reprinted with permission from Elsevier.

			Survival 1 year after hip fracture					
			Model 1		**Model 2**		**Model 3**	
	n	(%)	HR	95% CI	HR	95% CI	HR	95% CI
Urinary catheter removed during hospital stay								
Yes	526	(38)	1.00		1.00		1.00	
No	848	(62)	**1.81**	**1.42-2.31**	**1.35**	**1.05-1.74**	**1.45**	**1.12-1.89**
Age *median* (IQR, range)	84.0	(78-88, 65-105)	**1.07**	**1.05-1.09**	**1.04**	**1.02-1.06**	**1.03**	**1.01-1.05**
Sex								
Women	1030	(75)	1.00		1.00		1.00	
Men	344	(25)	**1.99**	**1.59-2.31**	**2.12**	**1.68-2.68**	**2.10**	**1.67-2.67**
ASA score								
1-2	168	(12)			1.00		1.00	
3	856	(62)			1.69	0.99-2.89	1.63	0.93-2.84
4-5	337	(25)			**2.90**	**1.68-5.06**	**2.46**	**1.39-4.37**
Diagnosis of memory disorder								
No	1004	(73)			1.00		1.00	
Yes	366	(27)			0.96	0.74-1.23	0.93	0.72-1.21
Mobility level								
Outdoors unassisted	728	(53)			1.00		1.00	
Indoors unassisted	552	(40)			**1.84**	**1.40-2.44**	**1.68**	**1.26-2.24**
Indoors assisted	66	(5)			**1.61**	**1.01-2.57**	**1.77**	**1.1-2.86**
Unable to walk	24	(2)			1.33	0.63-2.83	1.11	0.49-2.51
Living arrangements								
Home	554	(40)			1.00		1.00	
Home with organized homecare	391	(29)			1.11	0.81-1.52	1.05	0.75-1.45
Assisted living accommodation	223	(16)			**1.76**	**1.25-2.48**	**1.71**	**1.20-2.43**
Institutionalized	198	(14)			**1.78**	**1.23-2.58**	**1.64**	**1.11-2.43**

Delay from admission to surgery						
<24 h	543	(40)	1.00		1.00	
24-47 h	592	(43)	1.04	0.81-1.32	1.05	0.82-1.35
>47 h	226	(16)	1.25	0.92-1.70	1.23	0.99-1.67
Fracture type						
Neck of femur	853	(62)			1.00	
Intertrochanteric	444	(32)			1.16	0.92-1.47
Subtrochanteric	76	(6)			1.49	0.96-2.31
BMI						
23-28	575	(42)			1.00	
<23	381	(28)			**1.36**	**1.04-1.77**
>28	377	(27)			0.89	0.66-1.19
$eGFR_{CKD-EPI}$						
> 60 ml/min/1.73m^2	803	(58)			1.00	
45-59 ml/min/1.73m^2	271	(20)			1.20	0.90-1.61
30-44 ml/min/1.73m^2	186	(14)			**2.10**	**1.56-2.82**
< 30 ml/min/1.73m^2	78	(6)			**2.77**	**1.91-4.01**
Number of regularly taken medications						
< 4	243	(18)			1.00	
4-10	885	(64)			**1.81**	**1.14-2.86**
> 10	246	(18)			**2.03**	**1.23-3.34**

Missing values not shown, but were tested and included in the percentages. ASA=American Society of Anesthesiologists, BMI=body mass index, $eGFR_{CKD-EPI}$=estimated glomerular filtration rate by 2009 Chronic Kidney Disease Epidemiology Collaboration equation. Statistically significant p-values ($p<.05$) are presented in bold face. Analyses were performed with Cox regression models, results shown by hazard ratios with 95% confidence intervals.

Supplementary Table 3. Models of 1-year survival according to number of regularly taken medications (n=1424). Reprinted with permission from Elsevier.

			Survival 1 year after hip fracture					
			Model 1		**Model 2**		**Model 3**	
	n	(%)	HR	95% CI	HR	95% CI	HR	95% CI
Number of regularly taken medications								
< 4	247	(17)	1.00		1.00		1.00	
4-10	916	(64)	**2.88**	**1.91-2.20**	**2.02**	**1.32-3.09**	**1.81**	**1.18-2.79**
> 10	261	(18)	**4.28**	**2.76-6.63**	**2.53**	**1.59-4.02**	**2.21**	**1.38-3.54**
Age *median* (IQR, range)	84.0	(79-88, 65-105)	**1.07**	**1.06-1.09**	**1.05**	**1.03-1.06**	**1.04**	**1.02-1.06**
Sex								
Women	1062	(75)	1.00		1.00		1.00	
Men	362	(25)	**1.78**	**1.44-2.20**	**1.95**	**1.57-2.43**	**2.00**	**1.60-2.51**
ASA score								
1-2	170	(12)			1.00		1.00	
3	876	(62)			1.66	0.97-2.83	1.60	0.93-2.74
4-5	354	(25)			**2.70**	**1.56-4.69**	**2.52**	**1.44-4.40**
Diagnosis of memory disorder								
No	1038	(73)			1.00		1.00	
Yes	379	(27)			0.97	0.76-1.23	0.98	0.77-1.25
Mobility level								
Outdoors unassisted	743	(52)			1.00		1.00	
Indoors unassisted	577	(41)			**1.82**	**1.39-2.38**	**1.95**	**1.48-2.57**
Indoors assisted	70	(5)			**1.56**	**1.00-2.43**	**1.81**	**1.15-2.83**
Unable to walk	25	(2)			0.86	0.40-1.83	0.67	0.31-1.44
Living arrangements								
Home	565	(40)			1.00		1.00	
Home with organized homecare	399	(28)			1.01	0.74-1.37	0.97	0.71-1.32
Assisted living accommodation	237	(17)			**1.60**	**1.15-2.22**	**1.50**	**1.08-2.09**
Institutionalized	213	(15)			**1.67**	**1.17-2.37**	**1.58**	**1.10-2.26**

Delay from admission to surgery								
<24 h	560	(39)			1.00		1.00	
24-47 h	609	(43)			1.06	0.84-1.33	1.14	0.90-1.45
>47 h	230	(16)			1.21	0.90-1.63	**1.36**	**1.00-1.84**
Fracture type								
Neck of femur	885	(62)					1.00	
Intertrochanteric	458	(32)					1.14	0.91-1.42
Subtrochanteric	80	(6)					1.19	0.78-1.82
BMI								
23-28	593	(42)					1.00	
<23	397	(30)					**1.36**	**1.06-1.74**
>28	387	(27)					0.87	0.66-1.15
$eGFR_{CKD-EPI}$								
> 60 ml/min/1.73m^2	820	(58)	1.00		1.00		1.00	
45-59 ml/min/1.73m^2	287	(20)	**1.39**	**1.07-1.81**	1.29	0.96-1.69	1.21	0.92-1.58
30-44 ml/min/1.73m^2	193	(14)	**1.93**	**1.47-2.53**	**2.05**	**1.55-2.71**	**1.92**	**1.45-2.53**
< 30 ml/min/1.73m^2	87	(6)	**2.74**	**1.96-3.83**	**2.50**	**1.78-3.51**	**1.93**	**1.35-2.75**
Urinary catheter removed during hospital stay								
Yes	526	(37)					1.00	
No	848	(60)					**1.29**	**1.00-1.66**

Missing values not shown, but were tested and included in the percentages. ASA=American Society of Anesthesiologists, BMI=body mass index, $eGFR_{CKD-EPI}$=estimated glomerular filtration rate by 2009 Chronic Kidney Disease Epidemiology Collaboration equation. Statistically significant p-values ($p<.05$) are presented in bold face. Analyses were performed with Cox regression models, results shown by hazard ratios with 95% confidence intervals.

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