PUBLICATIONS OF
THE UNIVERSITY OF EASTERN FINLAND

**Dissertations in Health Sciences**

UNIVERSITY OF EASTERN FINLAND

**TERO YLI-KYYNY**

# OUTCOMES OF HIP FRACTURE SURGERY

# OUTCOMES OF HIP FRACTURE SURGERY

Tero Yli-Kyyny

# OUTCOMES OF HIP FRACTURE SURGERY

To be presented by permission of the Faculty of Health Sciences,
University of Eastern Finland for public examination in Auditorium 2,
Kuopio University Hospital Kuopio on june 3rd, 2022, at 12 o'clock noon

Publications of the University of Eastern Finland
Dissertations in Health Sciences
No 682

Department of Surgery, Institute of Clinical Medicine
Faculty of Health Sciences
University of Eastern Finland, Kuopio
2022

PunaMusta Oy
Joensuu, 2022
Distributor: University of Eastern Finland
Kuopio Campus Library

ISBN: 978-952-61-4532-7 (print/nid.)
ISBN: 978-952-61-4533-4 (PDF)
ISSNL: 1798-5706
ISSN: 1798-5706
ISSN: 1798-5714 (PDF)

Author's address: Musculoskeletal Research Unit, Institute of Clinical Medicine, Faculty of Health Sciences
University of Eastern Finland
KUOPIO
FINLAND

Doctoral programme: Clinical Medicine

Supervisors: Professor Heikki Kröger, M.D. Ph.D.
Department of Orthopaedics, Traumatology and Hand Surgery, Kuopio University Hospital and Kuopio Musculoskeletal Research Unit, Department of Surgery, Institute of Clinical Medicine, Faculty of Health Sciences
University of Eastern Finland
KUOPIO
FINLAND

Professor Reijo Sund, D.Soc.Sc.
Musculoskeletal Research Unit, Institute of Clinical Medicine, Faculty of Health Sciences
University of Eastern Finland
KUOPIO
FINLAND

Reviewers: Docent Pekka Hyvönen, M.D., Ph.D.
Department of Orthopaedic Surgery
University of Oulu
OULU
FINLAND

Professor Ville Mattila, M.D., Ph.D.
Department of Orthopedics and Traumatology
Tampere University Hospital and Tampere University
TAMPERE
FINLAND

Opponent: Docent Jan Lindahl, M.D., Ph.D.
Department of Orthopedics and Traumatology
Helsinki University Hospital
University of Helsinki
HELSINKI
FINLAND

Yli-Kyyny Tero
Outcomes of surgical treatment for proximal femoral fractures
Kuopio: University of Eastern Finland
Publications of the University of Eastern Finland
Dissertations in Health Sciences 682. 2022, 142 p.
ISBN: 978-952-61-4532-7 (print)
ISSNL: 1798-5706
ISSN: 1798-5706
ISBN: 978-952-61-4533-4 (PDF)
ISSN: 1798-5714 (PDF)

## ABSTRACT

The most common type of femoral fracture that requires surgery is the proximal femoral fracture. As a result, their importance to the healthcare system is enormous. After a successful surgical intervention for a proximal femoral fracture, the patient may be able to return to their previous level of physical activity. However, because patients with hip fractures are often frail, proximal femoral fractures and their treatment can result in severe disability or even death. They can be treated surgically in a variety of ways. Methods can be divided into various prosthetic replacements for the hip joint and various options for osteosynthesis of the fracture.

The primary goal of this doctoral dissertation was to investigate the effects of various treatment options on the outcome of hip fractures (I-IV). The goals were to investigate the effect of hip hemiendoprosthesis fixation (cemented or uncemented) on the outcome and postoperative complications (II and III), as well as the outcomes and postoperative complications after surgery for intertrochanteric proximal femoral fractures (I) and the occurrence of complications after surgery for proximal femoral fractures (IV). Three of the studies (I,III and IV) used data from the national registry data (PERFECT database).

Uncemented hip hemiendoprosthesis fixation was found to not affect mortality after hip fracture surgery when compared to cemented fixation.

At one week, cemented hemiarthroplasty (HA) had a mortality rate of 3.9 percent, while uncemented HA had a mortality rate of 3.4 percent (*P*=0.09). One-year mortality was also comparable to cemented HA (26%) and uncemented HA (27%) (*P*=0.1). Hemiarthroplasty without cement was linked to more complications (I and III). When it comes to the treatment of pertrochanteric fractures, newer and more expensive intramedullary (IM) implants are no better than extramedullary (EM) implants. IM implants had a higher one-year mortality rate than EM implants (26.6 percent vs. 24.9 percent; *P*=0.011). In the first year after IM implants, new hip or thigh operations were also more common (11.1 percent vs 8.9 percent; *P*=0.0001) (II). Several comorbidities, such as Parkinson's disease, alcoholism, pre-existing osteoarthritis, or rheumatoid disease, have been linked to an increased risk of complications. Increased re-admission risk was also associated with operative delay to surgery and the use of total hip arthroplasty (THA) for surgical treatment (IV).

In conclusion, this thesis showed that surgical methods for hip fractures have different outcomes. For femoral neck fractures, cemented hemiarthroplasty (HA) seems to be a more reliable alternative than osteosynthesis, uncemented HA, or THA when trying to avoid complications and achieve a favorable outcome for the patient. For pertrochanteric fractures, EM implants seem to yield comparable, or even better, results than more expensive IM implants. It was found that certain comorbidities and treatment decisions are associated with more complications after hip fracture surgery. To conclude, there are possibilities to improve outcomes after hip fracture surgery and these include choosing the correct surgical method for the patients and recognizing patients’ comorbidities that may affect the outcome.

**Keywords**: Hip fracture, outcome, register study, hip arthroplasty, complications

Yli-Kyyny, Tero
Outcomes of hip fracture surgery
Kuopio: Itä-Suomen yliopisto
Publications of the University of Eastern Finland
Dissertations in Health Sciences 682. 2022, 142 s.
ISBN: 978-952-61-4532-7 (nid.)
ISSNL: 1798-5706
ISSN: 1798-5706
ISBN: 978-952-61-4533-4 (PDF)
ISSN: 1798-5714 (PDF)

## TIIVISTELMÄ

Lonkkamurtumat ovat yleisimpiä leikkaushoitoa vaativia murtumia. Tästä johtuen niiden merkitys on suuri myös terveydenhuollon palvelujärjestelmälle. Onnistunut leikkaushoito ja kuntoutus voivat palauttaa potilaan toimintakyvyn murtumaa edeltäneelle tasolle. Toisaalta hoidon komplisoituminen voi johtaa merkittävään toiminnanvajaukseen tai jopa kuolemaan. Lonkkamurtumia voidaan hoitaa lukuisille leikkausmenetelmillä. Nämä voidaan jakaa kahtia erilaisiin tekonivelratkaisuihin ja murtuman luutumiseen tähtääviin menetelmiin.

Tämän väitöskirjatyön päätavoitteena oli tutkia erilaisten hoitomenetelmien vaikutusta lonkkamurtuman hoitotulokseen (osatyöt I-IV). Kahdessa osatyössä (II ja III) tutkittiin puolitekonivelen kiinnitysmenetelmän (sementillinen tai sementitön) vaikutusta hoitotulokseen tai komplikaatioiden esiintyvyyteen. Yhdessä osatyössä (I) selvitettiin pertrokanteeristen lonkkamurtumien hoitotuloksia ja yhdessä osatyössä (IV) lonkkamurtumien kirurgiseen liittyviä komplikaatioita. Kolme osatöistä (I, III ja IV) perustuivat kansalliseen PERFECT-rekisteriaineistoon.

Väitöskirjatyössä selvisi että sementitön puolitekonivel ei johda alhaisempaan kuolleisuuteen lonkkamurtumakirurgian jälkeen. Kuolleisuus yhden viikon kohdalla oli 3.9% sementillistä tekoniveltä käytettäessä ja 3.4% sementitöntä tekoniveltä käytettäessä. Ero ei ollut tilastollisesti merkitsevä (p=0.09). Myös yhden vuoden kuolleisuus oli sama sementillistä tekoniveltä käytettäessä (26%) ja sementitöntä tekoniveltä käytettäessä (27%; p=0.1). Osatöissä I ja III selvisi että sementittömän tekonivelen käyttöön liittyy enemmän sairaalahoitoa vaativia komplikaatioita. Osatyössä II selvisi että uudemmat ja kalliimmat intramedullaariset implantit eivät paranna pertrokanteeristen lonkkamurtumien hoitotuloksia extramedullaarisiin implantteihin verrattuna. Yhden vuoden kuolleisuus oli intramedullaarisia implantteja käytettäessä korkeampi (26.6% vrt 24.9%; p=0.011). Uusintaleikkauksia jouduttiin suorittamaan enemmän intramedullaarisia implantteja käytettäessä (11.1% vrt 8.9%; p<0.0001). Osatyössä IV selvisi että liitännäissairaudet kuten Parkinsonin tauti, alkoholiriippuvuus, aiempi nivelrikko tai reumasairaudet lisäävät lonkkamurtumapotilaan riskiä sairaalahoitoa vaativille komplikaatioille. Kyseiset komplikaatiot olivat myös tavallisempia jos lonkkamurtuman hoito viivästyi tai jos hoitomenetelmänä käytettiin kokotekoniveltä.

Tämä väitöskirja osoitti että erilaisilla kirurgisilla hoitomenetelmillä on vaikutus lonkkamurtuman hoitotuloksiin. Reisiluun kaulan murtumia hoidettaessa sementillinen puolitekonivel vaikuttaa luotettavimmalta vaihtoehdolta, erityisesti jos tavoitteena on välttää hoitoon liittyviä komplikaatioita. Pertrokanteerisia murtumia hoidettaessa extramedullaarisilla implanteilla saavutetaan vähintään yhtä hyviä tuloksia kuin kalliimmilla intramedullaarisilla implanteilla. Yhteenvetona voidaan todeta että lonkkamurtumien hoitotuloksien optimointi ja komplikaatioiden välttäminen on mahdollista erityisesti oikealla hoitomenetelmän valinnalla ja potilaiden liitännäissairauksia tunnistamalla.

**Avainsanat**: Lonkkamurtuma, rekisteritutkimus, leikkaushoito, tekonivelleikkaus, komplikaatio

# ACKNOWLEDGEMENTS

This thesis study was carried out in the Department of Orthopaedics, Traumatology and Hand Surgery, Kuopio University Hospital and Kuopio Musculoskeletal Research Unit, Department of Surgery, Institute of Clinical Medicine, Faculty of Health Sciences, University of Eastern Finland. The financial support for this study has come from Finnish Orthopaedic Research Foundation and from Kuopio University Hospital EVO- and VTR-grants.

I want to express my deepest gratitude to my primary supervisor, Professor Heikki Kröger. This thesis project around hip fractures was started more than ten years ago and has included some periods when reaching the goal has been more than uncertain. Without your enduring support and push this race would have ended up as "DNF".

I also want to sincerely thank Professor Reijo Sund for being my other supervisor in this project. Your expertise in the field of register studies is truly amazing and our discussions have been very inspiring to me. Your knowledge of statistics was also invaluable for this project. I have been priviledged to enjoy for your teachings in these fields.

In the beginning of this thesis project, I benefited from a suberb team planning this combination of studies. Thank you, Docent Jukka Kettunen, Docent Hannu Miettinen and Professor Jari Salo for this. I also want to thank you all three for being important teachers for me in the field of clinical orthopaedics. Professor Salo was a distinguished teacher in the very years of my M.D. studies in Helsinki University while Docent Kettunen and Docent Miettinen provided me outstanding training when I was a registrar in Kuopio University Hospital.

I owe my sincere thanks to the reviewers of this thesis, Docent Pekka Hyvönen from University of Oulu and Professor Ville Mattila from Tampere University. I am thankful for your invaluable remarks and swift reviewing process.

I have had a great pleasure to have outstanding co-authors in the substudies of this thesis. I owe my gratitude to Mikko Heinänen, Merja

Juntunen, Antti Malmivaara, Johanna Ojanperä and Petri Venesmaa. Thank you for a fruitful collaboration.

During this thesis I have practiced clinical orthopaedics both as a registrar and as a consultant. I have been fortunate to have so many wonderful colleagues as teachers and workmates in several hospitals. In Kuopio University Hospital I want specially to thank my close colleagues from “Tarina Unit”. Thank you Antti Joukainen, Tommi Kääriäinen and Janne Sahlman for those unforgettable moments at workplace and outside. I also want to thank my first tutor during my surgical training, Heikki Ahtola, who ended up to be also my father-in-law.

In 2014 I worked 6 months as a clinical fellow in Royal Infirmary of Edinburgh. During that time it was eye-opening to see orthopedic practice and treatment of hip fractures outside Finland. I specially want to thank Mr Gary Keenan, my guiding consultant there.

Five years ago I decided to switch my clinical practice and work from Kuopio University Hospital to Mehiläinen. The decision was not easy but I have not regretted. I have been very priviledged to learn many fascinating aspects and new things about function of privately funded enterprise. From Mehiläinen I have acquired many new workmates with so much talent in various fields. There also is a saying: ‘Sweating together is sticking together’. Thank you Johanna Asklöf, Iiro Heikkilä, Anne Karttunen, Mikko Kirjavainen, Kaisla Lahdensuo and Andreas Taalas, I believe that our sweaty journey will reach new levels in future.

There is a saying that ultrarunners do it longer. Maybe that is why this thesis project has lasted quite a few years. As an offset to clinical work and research, I have found great pleasure in practicing endurance sports. In this regard I have enjoyed great camaraderie with many colleagues and friends. In this regard I want to express my thanks for enduring friendship to Stepani Bendel, Mikko Joensuu and Marko Nyyssönen.

I also want to thank our family friends and relatives. “Hepsankeikat”, I know that you know who you are and how important you have been to me.

I was born in Helsinki in 1976 and spent first 20 years of my life in Vuosaari. I want to express my gratitude to my parents who grew my up and my little sister, Outi, with whom I grew up having a happy childhood.

As I have pointed out few times, this thesis project has lasted quite some time. During these years I have seen the growth of my three wonderful children, Urho, Vilho and Iida from tiny babies to almost adults (or so it seems). I am so proud of you and sure that you all will be so successful in your lives, whatever your futures will be.

And last but definitively not least, I want to thank my loving wife Saara. With you we have lived through the busy rush years of our lives. I am so thankful that I have had you by me. With you I hope to see many more happy years to come. I love you.

Kuopio, April 2022.
Tero Yli-Kyyny

# LIST OF ORIGINAL PUBLICATIONS

This dissertation is based on the following original publications:

I Yli-Kyyny T, Sund R, Juntunen M, Salo J, Kröger H. Extra- and intramedullary implants for the treatment of pertrochanteric fractures – results from a Finnish National Database Study of 14,915 patients. Injury 43:2156-2160, 2012.

II Yli-Kyyny T, Ojanperä J, Venesmaa P, Kettunen J, Miettinen H, Salo J, Kröger H. Perioperative complications after cemented or uncemented hemiarthroplasty in hip fracture patients. Scand J Surg 102:124-8, 2013.

III Yli-Kyyny T, Sund R, Heinänen M, Venesmaa P, Kröger H. Cemented or uncemented hemiarthroplasty for the treatment of femoral neck fractures? Acta Orthop 85:49-53, 2014.

IV Yli-Kyyny T, Sund R, Heinänen M, Malmivaara A, Kröger H. Risk factors for early readmission due to surgical complications after treatment of proximal femoral fractures – A Finnish National Database Study of 68,800 patients. Injury 50:403-408, 2019.

The publications were adapted with the permission of the copyright owners.

# CONTENTS

# ABBREVIATIONS

| | |
|---|---|
| BMD | Bone Mineral Density |
| BCIS | Bone Cement Implantation Syndrome |
| CMN | Cephalomedullary nail |
| DNF | Did Not Finish |
| DVT | Deep Venous Thrombosis |
| EM | Extramedullary |
| FNF | Femoral Neck Fracture |
| GP | General Practitioner |
| HA | Hemiarthroplasty |
| IM | Intramedullary |
| SHS | Sliding Hip Screw |
| SSI | Surgical Site Infection |
| THR | Total Hip Replacement |

# 1 INTRODUCTION

Hip fractures are an important public health issue. They are associated with significant individual morbidity for the affected, as well as a burden on the healthcare system (Veronese and Maggi, 2018). The incidence of hip fractures is strongly correlated with age (Beerekamp et al., 2017). Thus, with the aging of the population, the number of hip fractures can be expected to increase, even though age-adjusted incidence seems to decline (Sögaard et al., 2016). Even though most fractures occur in women, the incidence in males is increasing (Pekonen et al., 2021). Patients with hip fractures are often elderly and have several co-morbidities, putting them at a higher risk of medical and surgical complications (Buecking et al., 2013; Carpintero et al., 2014).

Hip fractures consume a significant amount of healthcare resources due to their high occurrence and requirement for surgical treatment. One hip fracture is estimated to cost between 10,000 and 40,000 euros over a year (Haentjens et al., 2005; Häkkinen and Sund, 2021; Sund et al., 2011). Surgical complications increase the cost of treatment by more than doubling it and result in poorer patient outcomes (Edwards et al., 2008; Thakar et al., 2010; Tsang et al., 2014). As a result, to reduce the risk of complications, hip fracture treatment methods should be as safe as possible.

In the previous 30 years, we have seen several changes in the use of various surgical methods in hip fracture treatment. Osteosynthesis of intracapsular femoral neck fractures has largely been abandoned, even in the case of undisplaced fractures (Ma et al., 2019). In the case of subtrochanteric and unstable trochanteric fractures, intramedullary devices have been introduced and widely accepted as reliable implants (Xie et al., 2019). In some hip fracture types, evidence supports traditional treatment methods over newer ones. For example, total hip replacement (THR) seems to bring only a marginal functional advantage over hemiarthroplasty while being associated with more complications than THR (Hansson et al., 2020; Rogmark, 2020). In the treatment of pertrochanteric fractures, evidence supports the use of extramedullary implants rather than intramedullary implants introduced more recently (Aros et al., 2008; Egol et al., 2014; Swart et al., 2014).

It can thus be postulated that in hip fracture surgery, methods associated with low risk of complications and predictable outcomes should be chosen. It's also worth remembering that treating hip fractures entails more than just surgery, and a multidisciplinary approach involving geriatricians, general practitioners, physiotherapists, nurses, and others is probably the best way to improve patient outcomes (Häkkinen and Sund, 2021; Rogmark, 2020).

This thesis includes four studies considering the outcomes of hip fracture surgery. Questions such as how surgical methods for hip fractures perform in “real life” and whether complications can be reduced by selecting the appropriate treatment methods for patients received special attention. One goal was to see if it was possible to identify patients who were more prone to complications and, as a result, could be subjected to interventions to prevent those complications.

# 2 REVIEW OF THE LITERATURE

## 2.1 PROXIMAL FEMORAL FRACTURES

### 2.1.1 Hip anatomy and classification of proximal femoral fractures

The hip joint is a ball and socket synovial joint. It connects the proximal femur and lower extremity to the pelvic girdle. The hip joint capsule is attached to the acetabular edge proximally. Distally, the capsule is attached to the intertrochanteric line anteriorly and the femoral neck posteriorly. In the proximal femur, the capsule is attached to the intertrochanteric line anteriorly and the femoral neck posteriorly. The majority of the proximal femur's vascular supply comes from the medial circumflex artery, which penetrates the bone at the same level as the joint capsule. The small artery to the head of the femur that runs through the ligament of the head of the femur supplies only a small portion of the vascular supply. This is why dislocated intracapsular fractures can severely compromise the femoral head's vascular supply, resulting in avascular necrosis.

Proximal femoral fractures can be divided anatomically into intracapsular and extracapsular fractures. Intracapsular fractures are often referred to as fractures of the neck of the femur. The extracapsular fractures can subsequently be divided into trochanteric (or pertrochanteric) and subtrochanteric fractures (Figure 1).

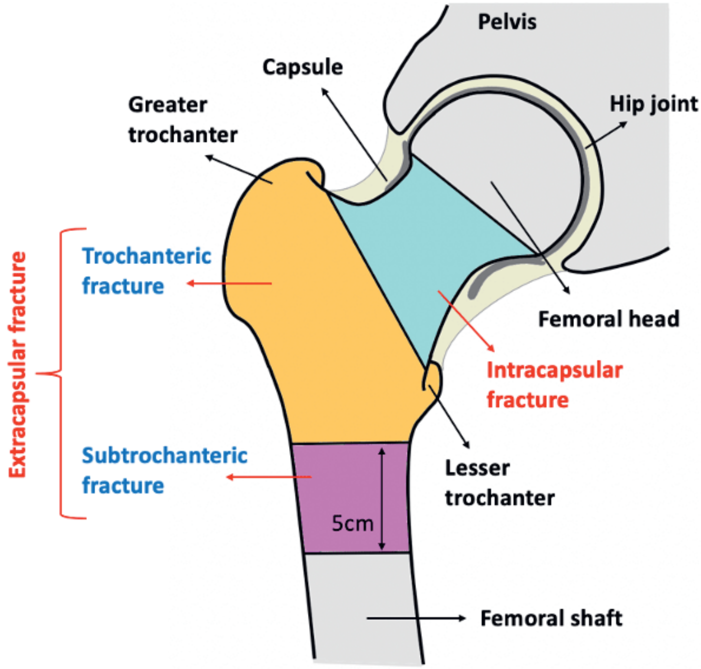


**Figure 1.** Anatomy of proximal femur and different subtypes of hip fractures. Adapted from Kyriacou and Khan 2020.

The AO OTA classification (Figure 2), which includes both intracapsular and extracapsular fractures and was revised in 2018, is primarily used for scientific purposes, as it is quite complicated for clinical practice (Newey et al., 1993). The Garden classification of femur neck fractures divides fractures according to their dislocation on an AP radiograph (Garden, 1961) (Figure 3).

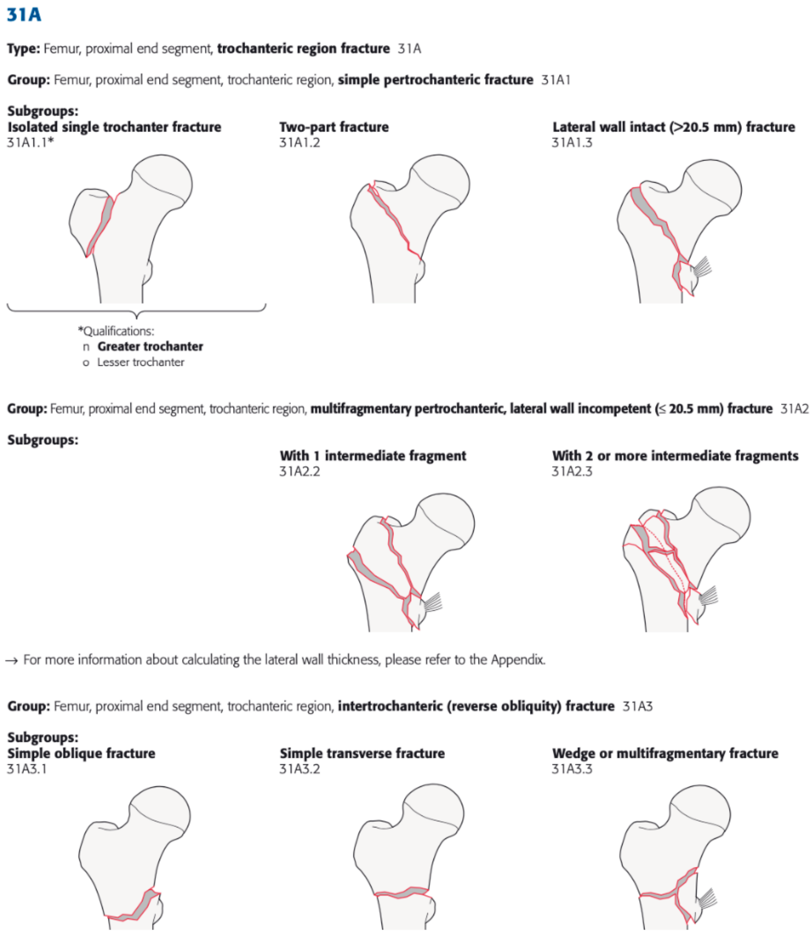


**Figure 2A.** The 2018 AO/OTA classification of trochanteric femur fractures. Downloaded from https://aotrauma.aofoundation.org/about/news/news-2018/news_classification_compendium_12072018

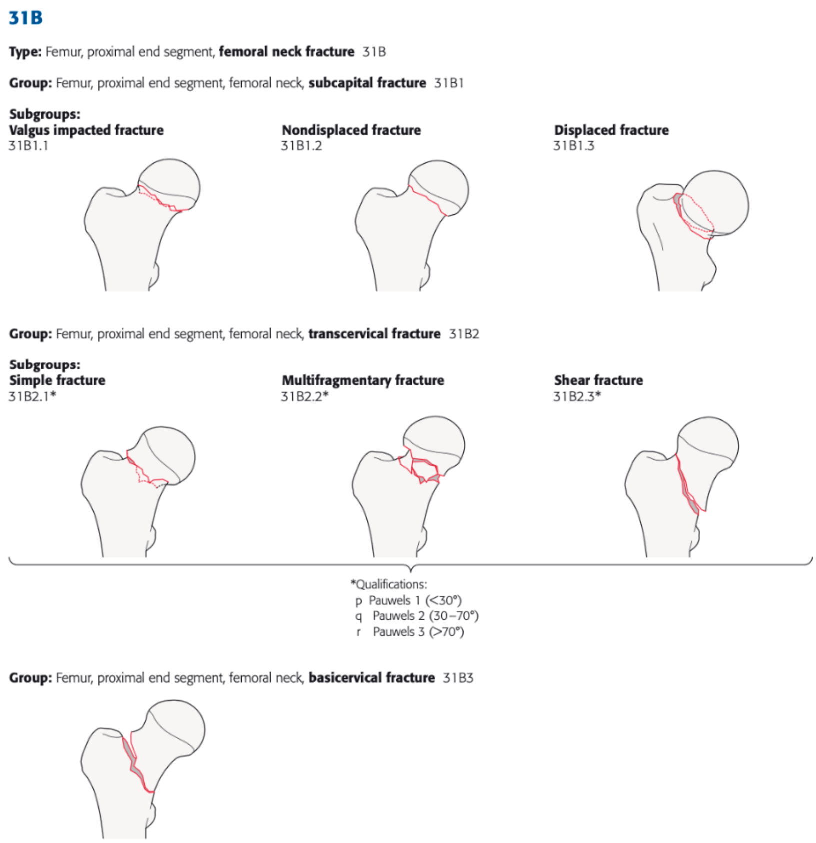


**Figure 2B.** The 2018 AO/OTA classification femoral neck fractures. Downloaded from https://aotrauma.aofoundation.org/about/news/news-2018/news_classification_compendium_12072018

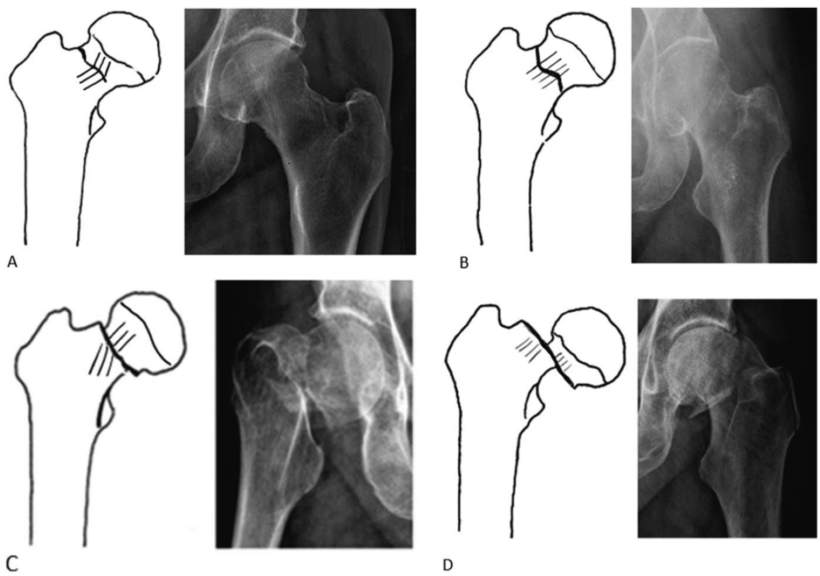


**Figure 3.** The Garden classification of femoral neck fractures. Shown are drawings and AP radiographs for types I (A), II (B), III (C), and IV (D). Adapted from Kazley et al. 2018.

Garden types 1 and 2 are often referred to as non-displaced and Garden types 3 and 4 as displaced fractures. This simplified classification has been employed for clinical use, as non-displaced fractures have been thought to be more suitable for osteosynthesis than displaced ones. Garden classification has been criticized for suboptimal interobserver agreement. The interobserver agreement becomes more acceptable when types 1-2 are grouped as non-displaced types and types 3-4 as displaced types (Thomsen et al., 1996; van Embden et al., 2012). It has also been detected that many Garden type I fractures should be classified as types II or III. (Kazley et al., 2018).

Pauwels (1935) introduced the first biomechanical classification of femur neck fractures, which included three fracture types. The classification is based on the angle between the fracture line in the distal fragment and the horizontal line. It can be described as follows:

- Type I: The angle is less than 30 degrees and compressive forces dominate
- Type II: The angle is 30-50 degrees, some shearing forces occurring making the fracture less stable
- Type III: With angles more than 50 degrees, significant shearing forces make fracture healing unpredictable.

More recently, the reliability and usefulness of the Pauwels classification in clinical practice have been questioned (van Embden et al., 2011).

The Evans classification, as modified by Jensen (1980), divides trochanteric fractures into five types based on displacement and number of fragments. Both AO/OTA and Jensen classifications, however, are unreliable (van Embden et al., 2010). Despite this, when it comes to trochanteric fractures, AO/OTA classification is still most widely used in the literature.

### 2.1.2 Incidence of proximal femoral fractures

Incidence of proximal femoral fractures is strongly linked to age, with rates beginning to rise sharply after 75 years in both men and women (Beerekamp et al., 2017; Hartholt et al., 2011). The risk of a hip fracture is two times higher in women than in men, according to age-adjusted hip fracture incidence (Hartholt et al., 2011; Kanis et al., 2012).

Worldwide, there are marked geographical and ethnic variations in age-adjusted hip fracture incidence (Cauley et al., 2014). Age-adjusted incidence is highest in Denmark, Norway, Sweden, and Austria for both women and men, and lowest in Nigeria, South Africa, Tunisia, and Ecuador (Kanis et al., 2012). Hip fracture incidence is considered high in Finnish men and moderate in Finnish women when compared to other countries (Kanis et al., 2012).

In recent years, the age-adjusted incidence of hip fractures has decreased in both genders, and the relative change has been more pronounced in women (Forsen et al., 2020; Kannus et al., 2018). Both the crude and age-adjusted incidence of hip fractures in Finland increased until the new millennium, after which they began to decline (Korhonen et al., 2013). Other European countries have seen a similar decline in age-adjusted incidence (Kanis et al., 2012; Rosengren et al., 2012; Stöen et al., 2012; Briot et al., 2015; Sögaard et al., 2016). However, incidence trends seem to differ between countries (Lucas et al., 2017). There appears to be no single factor that can account for the observed decline in age-adjusted incidence. Reduced smoking, lifestyle factors, higher BMI in the elderly population, better vitamin D status, and better health status have all been proposed as explanations for this shift.

The widespread use of antiosteoporotic medications, particularly bisphosphonates, has also been suggested as a factor in the decrease in the age-adjusted hip fracture rates. However, this has not been documented at the population level (Bourrion et al., 2021).

In western countries, the elderly population is steadily growing. Thus, the number of hip fracture patients is estimated to grow in the future despite the decline in the age-adjusted incidence of hip fracture patients. Another trend observed in epidemiological studies is that the average age of hip fracture patients is increasing (Korhonen, 2013).

### 2.1.3 Risk factors for proximal femoral fractures

Risk factors for hip fractures can be divided into those affecting the resistance of the proximal femur to trauma and those leading to an increased risk of falls (Veronese, 2018). Osteoporosis and low bone mineral density (BMD) are usually identified as major risk factors for hip fractures, but there are several other independent risk factors. These include increasing age, use of benzodiazepines, maternal history of hip fracture, and inability to get out of a chair (Cummings et al., 1995). Many of the risk factors independent of low BMD can be explained by their effect on increased susceptibility to falls.

Hip fracture risk factors can also be divided into non-modifiable and modifiable ones (LeBlanc et al., 2014). Non-modifiable risk factors include age over 65 years, family history of hip fracture, female sex, low socioeconomic status, and prior hip fracture. Modifiable risk factors include osteoporosis (low bone mineral density), falls, reduced levels of activity, vitamin D deficiency, and certain chronic medications (levothyroxine, loop diuretics, proton pump inhibitors, and selective serotonin reuptake inhibitors and sedatives).

Although most hip fractures occur in patients over 60 years of age, younger patients can also suffer from them. In particular, the younger hip fracture patients very often have comorbidities or abuse alcohol, and their biological age exceeds chronological age (Rogmark et al., 2018).

#### 2.1.4 Existing hip fracture registries and databases

In orthopedics, there is a growing interest in disease- or implant-specific registries yielding information about the performance of treatment modalities in clinical practice. Arthroplasty registries have led to this development, the Swedish knee arthroplasty register being the first national arthroplasty register (Malchau et al., 2018). There is quite a strong consensus that registries have produced a remarkable amount of information about arthroplasty surgery that otherwise might not have been produced.

Concerning hip fractures, there are several national hip fracture registries and at least one registry of a large service provider (Kaiser Permanente in the USA). Table 1 lists the current hip fracture registries in use.

**Table 1.** The existing and established hip fracture registries.

| NAME OF THE REGISTER | COUNTRY | NATIONAL / LOCAL | ESTABLISHED | REFERENCES |
|---|---|---|---|---|
| RIKSHÖFT | SWEDEN | NATIONAL | 1988 | Thorngren 2009 |
| DANISH MULTIDISCIPLINARY HIP FRACTURE REGISTRY | DENMARK | NATIONAL | 2003 | Mainz et al. 2004 |
| THE NORWEGIAN HIP FRACTURE REGISTER | NORWAY | NATIONAL | 2005 | Gjertsen et al. 2008 |
| SCOTTISH HIP FRACTURE AUDIT | SCOTLAND / UK | NATIONAL (SCOTLAND) | 1993 | |
| NATIONAL HIP FRACTURE DATABASE (NFHD) | ENGLAND AND WALES / UK | NATIONAL (ENGLAND AND WALES) | 2007 | NHFD Annual Report 2018 |
| IRISH HIP FRACTURE DATABASE (IFHD) | IRELAND | NATIONAL | 2013 | IHFD Annual Report 2018 |
| AUSTRALIAN & NEW ZEALAND HIP FRACTURE REGISTRY (ANZHFR) | AUSTRALIA AND NEW ZEALAND | NATIONAL | 2016 | ANZHFR Annual Report 2018 |
| SPANISH NATIONAL HIP FRACTURE REGISTRY (RNFC) | SPAIN | NATIONAL | 2017 | Ojeda-Thies 2019 |
| KAISER PERMANENTE HIP FRACTURE REGISTRY | USA | LOCAL (Service Provider) | 2015 | Inacio et al. 2015 |
| DUTCH HIP FRACTURE AUDIT | NETHERLANDS | NATIONAL | 2016 | Voeten et al. 2019 |
| PERFECT | FINLAND | NATIONAL | 2004 | Sund et al. 2011 |

The history of national hip fracture registries dates back to 1988 when RIKSHÖFT in Sweden was established. Largely based on experiences from this register, the SAHFE (Standardization Audit of Hip Fracture in Europe) was launched in 1995, and funded by European Union (Parker et al., 1998). This project has had a major influence on the structure of subsequently launched national registries.

Most of the registries tend to publish their results as annual reports on their web pages. In addition to annual reports, the registries have generated scientific publications about their results (Gjertsen et al., 2017;

Sund et al., 2011; Sjöstrand et al., 2013). When common variables are compared between registries, a relatively consistent picture of a typical hip fracture patient can be seen. However, there is a great variation in the types of fractures and treatment modalities, and length of stay in the hospital following the fracture (Johansen et al., 2017).

Most of the registries include data reported by hospitals, except for the Norwegian Hip Fracture Register, which also sends quality of life questionnaires to patients (Gjertsen et al., 2016). Other common features include register-based treatment guidelines and audits, which have been implemented at least in the United Kingdom and Ireland.

According to research, putting in place a national registry and monitoring system leads to improved care in the form of shorter waiting times and a lesser amount of certain complications, such as pressure ulcers (Saez-Lopez et al., 2017). It has even been shown that hip fracture audits may lower mortality among hip fracture patients (Neuburger et al., 2015). Regarding cost-effectiveness, some doubts have been cast over the national hip fracture registries (Parker, 2008).

## 2.2 SURGICAL TREATMENT FOR PER- AND SUBTROCHANTERIC P ROXIMAL FEMORAL FRACTURES

### 2.2.1 Osteosynthesis

Jewett implant was the first implant to gain popularity in the treatment of trochanteric proximal femoral fractures. It consisted of a rigid hip nail and side plate (Jewett, 1941). However, the lack of compression between fracture fragments often led to non-union. This led to the development of a sliding hip screw (SHS) that allowed compression in a controlled fashion (Schumpelick, 1955). Comparisons between rigid, Jewett kind of implants, and sliding hip screws have shown the superiority of the latter (Esser et al., 1986).

Osteosynthesis with SHS can be considered the gold standard of operative treatment for pertrochanteric femoral fractures (Stern, 2007). An acceptable alternative to SHS is the cephalomedullary hip nail. These methods have been shown to produce equivalent results in pertrochanteric fractures (Parker & Handoll, 2010). Cephallomedullary nails have been postulated to be biomechanically advantageous over SHS in some subtypes of pertrochanteric fractures (Boopalan et al., 2012). The choice of implant for pertrochanteric fracture fixation has also been studied from the cost-efficiency perspective. It seems that in the treatment of typical pertrochanteric fractures, the SHS produces comparable results with less cost (Aros et al., 2008; Egol et al., 2014; Swart et al., 2014).

After the year 2000, the use of intramedullary devices increased substantially at the expense of extramedullary implants. In 2005, the use of intramedullary devices exceeded extramedullary devices in the USA among young orthopedic surgeons (Anglen & Weinstein, 2008). An increase in the use of intramedullary devices has also been noted in a Swedish register study, even though the change was not similarly drastic (Rogmark et al., 2010).

An antegrade, trochanteric-entry intramedullary nail is the first-hand option for subtrochanteric femoral fractures in most centers when considering subtrochanteric fracture types (Borens et al., 2004; Sims, 2002). SHS is not recommended for subtrochanteric fractures, as the implant does not provide the stability required for uneventful healing (Haidukewych et al., 2001).

As an alternative to a 95-degree condylar screw or blade plate, a proximal femoral plate with locking screws has also been introduced. This implant has been associated with an unacceptably high risk of mechanic failure and can not, therefore, be recommended over an intramedullary nail for most subtrochanteric fractures (Glassner and Tejwani, 2011; Streubel et al., 2013).

### 2.2.2 Arthroplasty

Pertrochanteric and subtrochanteric fractures may also be treated with arthroplasty. Arthroplasty for extracapsular hip fractures is a demanding procedure and should therefore be used with caution. Most obvious indications for arthroplasty include patients who have osteoarthritis in the fractured hip, neglected fractures with delayed presentation, or particularly unstable fracture patterns with osteoporosis (Hoffman et al., 2014; Mäkinen et al., 2015). In selected cases, arthroplasty may produce similar or superior results to osteosynthesis (Fichman et al., 2016; Stappaerts et al., 1995). Concerns about higher mortality associated with arthroplasty must be taken into account, especially when treating elderly patients (Kim et al., 2005).

## 2.3 SURGICAL TREATMENT FOR FEMORAL NECK FRACTURES

### 2.3.1 Osteosynthesis

Osteosynthesis, usually with cannulated screws, has been used for both displaced and non-displaced femoral neck fractures (FNF). It has been thought that retaining patients' femoral heads yields the best possible functional outcomes. The risk of non-union and avascular necrosis of the femoral head is well known in displaced fractures after osteosynthesis (Florschutz et al., 2015). The reoperation rate after osteosynthesis for FNF is relatively high (17-35%) (Bhandari et al., 2003; Gjertsen et al., 2011; Rogmark & Johnell, 2006). It has also been shown that arthroplasty yields better functional outcomes than osteosynthesis when displaced femoral neck fractures are concerned (Frihagen et al., 2007). Consequently, clinical guidelines such as NICE (National Institute for Health and Care Excellence) generally recommend hip replacement over osteosynthesis for patients with a displaced FNF.

In the last 10-15 years, the use of osteosynthesis for undisplaced FNF has been questioned. Reoperations after undisplaced fractures seem to be less frequent (8-19%) than after displaced fractures (Clement et al., 2013; Gjertsen et al., 2011; Onativia et al., 2018; Rogmark et al., 2009). In a meta-analysis combining data from three comparative trials, it was found that compared to a hemiarthroplasty, osteosynthesis of undisplaced FNF was associated with similar functional results and more reoperations than arthroplasty (Ma et al., 2019). Reoperations after surgical treatment of undisplaced femoral neck fractures are more common after osteosynthesis than after arthroplasty, according to two retrospective studies (Griffin et al., 2016; Hui et al., 1994).

At least one large-scale randomized trial is currently underway to determine whether undisplaced femoral neck fractures should be treated with arthroplasty instead of osteosynthesis (Wolf et al., 2020).

As previously stated, the use of osteosynthesis for the treatment of femoral neck fractures seems to have diminished in recent years (Gjertsen et al., 2017; Rogmark et al., 2010).

### 2.3.2 Hemiarthroplasty

Replacement of the fractured femoral neck and head with a femoral component of a hip prosthesis is considered an appropriate treatment method for displaced femoral neck fractures in elderly patients.

There are different types of hemiarthroplasties. The implants can be divided into monopolar and bipolar ones, the latter having a possible advantage in the form of two gliding surfaces compared to monopolar implants (Figure 4). The former can be subdivided into modular and non-modular monopolar designs. Traditional non-modular monopolar stems have largely been abandoned in the treatment of proximal femoral fractures, at least in industrialized countries (Rogmark et al., 2011). It has to be noted, though, that evidence supporting the use of modular implants is relatively scarce (Parker, 2012b). Modular implants are regarded as easier and more controllable to insert into the femur at the right angle. For younger patients, bipolar arthroplasty has been recommended because it causes less acetabular erosion than monopolar implants. Bipolar arthroplasty has been linked to a slightly lower survival rate than unipolar hemiarthroplasty in previous studies (Leonardsson et al., 2012). However, more recent data from the Australian Joint Replacement Register suggests that the revision rate for bipolar implants would be lower than for monopolar implants (Farey et al., 2021).

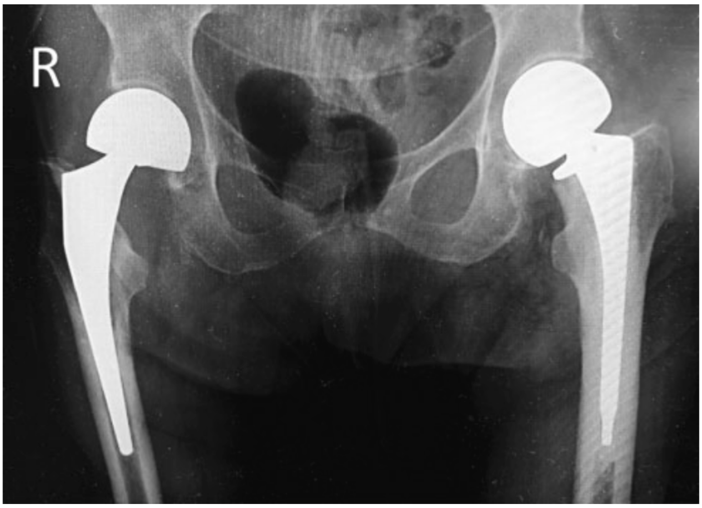


**Figure 4.** Monopolar hip hemiarthroplasty implant in the left and bipolar implant in the right hip. Adapted from Kibble et al. 2020.

The fixation of hemiarthroplasty with bone cement or without bone cement has also been studied. A systematic review published by Ahn et al. (2008) did not find any statistically significant differences between cemented and uncemented hemiarthroplasty in terms of mortality, pain, and complications. In their analysis, the revision rate was lower among patients treated with cemented hemiarthroplasty. According to the most recent update of the Cochrane Database Review on the use of arthroplasty for hip fractures, bone cement is associated with better mobility and less postoperative pain (Parker et al., 2010b). This review is based on studies comparing outdated non-modular femoral stems. Parker et al. (2010a) conducted a study comparing uncemented Austin-Moore hemiarthroplasty to cemented Thompson hemiarthroplasty. In a recent randomized study comparing contemporary prosthetic designs, cemented hemiarthroplasty was associated with better postoperative mobility than uncemented hemiarthroplasty (Parker & Cawley, 2020). They also observed a trend toward less mortality and periprosthetic fractures among patients receiving cemented implants. In an analysis of the Dutch Arthroplasty Register, no difference in mortality was noted between patients treated with cemented and uncemented hemiarthroplasty. However, there was a significantly higher nine-year revision rate (5.1% vs 3.1%) among patients treated with uncemented hemiarthroplasty (Duijnisveld et al., 2020).

Hemiarthroplasty is most often performed through anterolateral (modified Hardinge's approach) or posterior approach. The posterior approach is associated with a higher risk for dislocations (Pajarinen et al., 2003). It has also been suggested that a direct anterior approach could be used for the application of hemiarthroplasty (Kunkel et al., 2018; Langlois et al., 2015). This has not become a popular alternative. The anterolateral approach is advocated for its lower risk of dislocation, whereas the posterior approach has been promoted for its theoretically more atraumatic nature resulting in better functional outcome. In a recent meta-analysis about the optimal approach in hemiarthroplasty, it was concluded that the posterior approach does not have any advantage over the anterolateral approach, and the former is associated with a higher risk of dislocations (Sijp et al., 2018).

### 2.3.3 Total hip arthroplasty

Total hip replacement (THR) has been suggested to produce improved functional results, fewer reoperations, and less pain than hemiarthroplasty (HA) in lucid and more active patients (Burgers et al., 2012; Leonardsson et al., 2013). Functional improvements associated with THR are compromised by more dislocations and initial treatment costs (Burgers et al., 2012; Bhandari et al., 2019; Jameson et al., 2013).

Treatment algorithms have been published suggesting that total hip arthroplasty should be considered when treating more active patients benefiting from better function and being at lower risk for dislocations (National Institute for Health and Care Excellence [NICE], 2017). However, it also has been noticed that these guidelines are not always implemented as intended (Perry et al., 2016). Irrespective of guidelines, the use of total hip arthroplasty for hip fractures has increased substantially after the publishment of studies, suggesting better functional results after total hip arthroplasty (Stronach et al., 2020).

## 2.4 SURGICAL COMPLICATIONS RELATED TO HIP FRACTURE SURGERY

### 2.4.1 General surgical complications

General surgical complications, such as surgical site infections (SSI) and deep venous thrombosis, can make hip fracture surgery more difficult. The incidence of early (<30 days) deep SSI after hip fracture surgery was estimated to be 2.2% in a Norwegian Register Study (Pollman et al., 2020). In the same study, it was also found that deep SSI was associated with 1.8 times higher one-year mortality compared to patients without deep SSI. Identified risk factors for deep SSI after hip fracture surgery include cognitive impairment of patient, intraoperative complication, unusually long or short operative time, surgeon's lack of experience, reoperation, and development of postoperative hematoma (de Jong et al., 2017). Hip fracture surgery is also associated with a significant risk for DVT and subsequently, the use of antithrombotic agents is recommended (Balk et al., 2017).

### 2.4.2 Complications related to osteosynthesis

Malunion, non-union, and hardware failure are complications specific to osteosynthesis for hip fractures. In patients less than 60 years old, it has been estimated that malunion occurs in 7.1% of patients, nonunion in 9.3% of patients, and hardware failure in 9.7% of patients (Slobogean et al., 2015). In trochanteric fractures, non-union is less frequent than in FNF. In early reports of trochanteric fracture surgery with less stable implants, the non-union rate was reported to be over 10% (Hunter, 1975). However, with the use of more stable implants, such as SHS or CMN, non-union has been estimated to be much less frequent and is usually associated with an operative error, such as malreduction or unstable osteosynthesis (Iwakura et al., 2013). This suggests that stable osteosynthesis is a key factor leading to the union of trochanteric fractures. In general, the literature concentrating specifically on complications after osteosynthesis of hip fractures is relatively scarce.

### 2.4.3 Complications related to arthroplasty

Periprosthetic fractures, prosthesis dislocation, and "bone cement implantation syndrome" (BCIS), which occurs with cemented arthroplasty, are all complications specific to arthroplasty after a hip fracture.

Regarding all hip arthroplasty, uncemented hip arthroplasty is thought to carry a higher risk for periprosthetic fractures than cemented arthroplasty. Periprosthetic fractures have been found to occur in 15% of cases when uncemented components are used, compared to 0-3 percent when cemented arthroplasty is used (Moerman et al., 2017; Phillips et al., 2013). It is known that intraoperative calcar fractures increase the risk of subsequent revision arthroplasty (Miettinen et al., 2016).

Because of the higher risk for periprosthetic fractures, both AAOS and NICE guidelines recommend cemented over uncemented hemiarthroplasty for the treatment of femoral neck fractures. This is also supported by the available evidence (Parker et al., 2010).

The use of bone cement for fixation of hip arthroplasty may lead to bone cement implantation syndrome (BCIS) (Donaldson et al., 2009). The risk of BCIS can be lowered with some modifications to the surgical technique. The medullary lavage before cementing may decrease the risk of BCIS (Christie et al., 1995). The BCIS is thought to be caused by fat emboli escaping from the intramedullary canal as a result of bone cement pressurization. It has been suggested that BCIS could be avoided if no pressurization was used during surgery. In an elective setting, the risk for higher mortality resulting from BCIS can be reduced by using rigorous techniques (Sierra et al., 2009).

## 2.5 MORTALITY AFTER HIP FRACTURE SURGERY

Hip fractures most often occur in old, frail people and are associated with over 20% mortality in one year (Haleem et al., 2008; Mundi et al., 2014). The unadjusted mortality rate has remained at the same level, although the average age of hip fracture patients has increased over the past decades (Haleem et al., 2008; Mundi et al., 2014). When compared to the general population, hip fracture patients have a threefold higher mortality rate in the first four years after the fracture (Panula et al., 2011). When age and other major risk factors are taken into account, the risk of dying young after a hip fracture has decreased in recent years (Gjertsen et al., 2017). When fracture types are compared, intertrochanteric fractures appear to have a slightly higher early mortality rate than femoral neck fractures (Frisch et al., 2018a).

Several patient-related factors have been associated with mortality rates. It is known that co-morbidities and possibly male sex increase the mortality risk after hip fracture surgery (Bokshan et al., 2018; Guzon-Illescas et al., 2019). In a large, population-based sample, including eight different cohorts from Europe and USA, the same finding was detected (Katsoulis et al., 2017). Short-term, confounder-adjusted (1 year after the fracture) HR for mortality was 2.78 (95% CI 2.12-3.64), and mortality remained higher even after eight years (HR 1.79, 95% CI 1.57-2.05). It was also found that coexisting chronic disease and the hip fracture had a superadditive effect on mortality after the fracture.

Chronic kidney disease (CKD) has often been cited to increase the risk of death after hip fracture. Regarding this, it seems that only advanced CKD is associated with increased mortality after hip fracture (Frisch et al., 2018b; Robertson et al., 2018). Interestingly, in a Swedish prospective study, it was found that obese patients (Body Mass Index > 26) had better one-year survival than leaner patients (Flodin et al., 2016). Acute respiratory infections, such as COVID-19, increase the risk of death after hip fracture (Alcock et al., 2021).

Other patient-related factors, aside from co-morbidities, may have an impact on mortality after a hip fracture. Patient frailty and low handgrip strength were linked to a higher risk of death after a hip fracture in a recent systematic review (Xu et al., 2019).

The type of anesthesia or surgical technique used in the treatment of hip fractures can be assumed to have an impact on mortality. Spinal anesthesia and general anesthesia are the two most common types of anesthesia used in hip fracture treatment (Sciard et al., 2011). Traditionally, these methods have provided equal results when perioperative mortality is considered (Brox et al., 2016; Fields et al., 2015). Similarly, in most recent studies, the choice of anesthetic modality has not affected perioperative mortality (Xu, 2019).

THA has been widely used in the treatment of femoral neck fractures in more active patients. As a slightly longer operation than hemiarthroplasty, it can affect mortality. The available evidence shows, though, that mortality after THA is similar to mortality after hemiarthroplasty (Bhandari et al., 2019; Lewis et al., 2019).

Regarding different types of hemiarthroplasty, the cement fixation of the femoral stem has been associated with a risk of bone cement implantation syndrome (BCIS) which can cause severe hemodynamic disturbance (Donaldson et al., 2009). It has been suggested that cement fixation of the femoral stem would lead to increased peri- and postoperative mortality compared to the use of uncemented implants. However, in prospective studies comparing these two types of implants, similar mortality has been detected in several studies (Chammout et al., 2017; Inngul et al., 2015; Talsnes et al., 2013). In meta-analyses, the difference in mortality is either non-existent or rather small, while the functional outcome is better and complications less frequent when cemented arthroplasty is used (Kumar et al., 2019; Lin et al., 2019). There are even studies showing higher mortality when uncemented arthroplasty is used (Parker & Cawley, 2020; Richardson et al., 2020). In a recent register-based Danish study, it was shown that beyond the first postoperative day, cemented hemiarthroplasty was not associated with higher mortality than uncemented HA (Viberg et al., 2022).

The majority of trochanteric fractures are treated with osteosynthesis, but there are other options such as extramedullary or intramedullary implants. While there are differences in the occurrence of complications, the mortality seems to be the same after trochanteric fracture, irrespective of the surgical method used (Parker & Handoll, 2010).

Taken together, the choice of surgical method does not seem to affect mortality after femoral neck fracture (Rogmark & Johnell 2006; Rogmark, 2020).

# 3 AIMS OF THE STUDY

The aims of this study were:

I

To study the trends in the choice of the implant for hip fracture surgery in Finland.

II

To find out whether treatment results, the occurrence of complications, or costs of treatment would differ between intra- and extramedullary implants for the treatment of pertrochanteric proximal femoral fractures.

III

To study if there are differences between cemented and uncemented hemiarthroplasty in terms of perioperative complications, mortality, and outcomes.

IV

To find out the occurrence of surgical complications after hip fractures leading to a re-admission and study which co-morbidities or treatment decisions influence the risk for a re-admission.

# 6 CEMENTED OR UNCEMENTED HEMIARTHROPLASTY FOR THE TREATMENT OF FEMORAL NECK FRACTURES – RESULTS FROM A FINNISH DATABASE STUDY OF 25,174 PATIENTS

## 6.1 ABSTRACT

Background and purpose

Cemented hemiarthroplasty is preferred in treating displaced fractures of the femoral neck in the elderly. The cementing process may cause a fat embolism leading to serious complications or death. In this study we wanted to determine whether use of uncemented hemiarthroplasty (HA) would lead to reduced mortality and whether there are differences in the complications associated with these different types of arthroplasty.

Patients and methods

We identified 25,174 patients, treated with hemiarthroplasty for a femoral neck fracture in years 1999-2009 from the PERFECT database combining information from various treatment registries. The primary outcome was mortality. Secondary outcomes were reoperations, complications, readmissions and treatment times.

Results

Mortality was lower in the first postoperative days when uncemented HA was used. At 1 week there was no difference in mortality (3.9% for cemented HA and 3.4% for uncemented HA; p=0.09). Neither at one year was there a statistically significant difference in mortality (26% for cemented HA and 27% for uncemented HA; p=0.1). Among patients treated with uncemented HA there were more mechanical complications (3.7% vs.

2.8%; p<0.001), hip rearthroplasties (1.7% vs. 0.95; p<0.001) and femoral fracture operations (1.2% vs. 0.52%; p<0.001) during the first 90 days after hip fracture surgery.

Interpretation

In light of register data, mortality is similar between cemented and uncemented HA. However, uncemented HA is associated with more frequent mechanical complications and reoperations.

## 6.2 INTRODUCTION

Displaced fractures of the femoral neck are increasingly treated with arthroplasty instead of osteosynthesis (Rogmark 2010). Hemiarthroplasty (HA) is used in most patients (Bhandari et al. 2005). The operation can be performed using either cemented or uncemented femoral components. Cemented components have been preferred since they have been associated in meta-analyses with less postoperative pain and better mobility after surgery (Parker et al. 2010). However, these studies have mostly compared relatively outdated non-modular types of hemiarthroplasty.

After the introduction of modular hemiarthroplasty to hip fracture surgery in recent years, a number of prospective trials comparing cemented to uncemented hemiarthroplasty with equal results have been published (Figved et al. 2009, DeAngelis et al. 2012, Taylor et al. 2012). However, in a recent registry study comparing (mostly modular) cemented and uncemented hemiarthroplasty, more reoperations were detected among patients treated with uncemented hemiarthroplasty (Leonardsson et al. 2012). One explanation for this discrepancy may the relatively small sample size and incomplete follow-up associated with prospective studies (Talsnes 2013).

We studied mortality and results after hemiarthroplasty using Finnish register-based data.

## 6.3 PATIENTS AND METHODS

Patients with a first femoral neck fracture operated with hemiarthroplasty of the hip in Finland and admitted to surgical ward between 1.1.1999 - 31.12.2009 were identified from Finnish Hospital Discharge Register (FHDR) using the 10th revision of the International Classification of Diseases (ICD-10) diagnosis code S72.0 and the Finnish version of NOMESCO Classifications' Procedural Codes NFB10 (uncemented hemiarthroplasty) or NFB20 (cemented hemiarthroplasty).

Data on comorbidities, on the use of residential care and deaths for this population were extracted from the Finnish Health Care Register, reimbursement register (prescription database) of the Social Insurance Institution, using the unique personal identification number for each patient. Records in these registers include data such as: patient and provider ID-numbers, age, sex, area codes, and diagnosis and operation codes, as well as dates of admission, operation, and discharge (or death). The information from these registers has been gathered to the PERFECT (PERFormance, Efficiency, and Costs of Treatment Episodes) database. The Finnish register-data from PERFECT database concerning hip fracture patients has been compared to prospective audit data (Sund et al. 2007). The completeness of the register data was good; the positive agreement between audit and register data was 94.9%. Also the accuracy of easily measurable variables in the register data was at least 95%.

The validity of the individual registers mentioned above has been studied as well. The Finnish Hospital Discharge Register data has been compared to external audit data in 32 studies (Sund 2012). The coverage and positive predictive values for injury diagnoses has been over 90% in those studies. The prescription database data has been found to be in high concordance with self-reported medication (Haukka et al. 2007).

Reasons for death were extracted from the national Causes of Death Statistics. In Finland, injury-related deaths lead to a forensic autopsy in over 85% of cases, which is a higher rate than in most other countries (Lunetta et al. 2007). The validity of the of Finnish mortality statistics has also been studied and has been found reliable (Lahti and Penttilä 2003; Pajunen et al. 2005).

The primary outcome used in this study was total mortality. Secondary outcomes included new hip operations (procedure codes NFB*, NFC*, NFH*, NFJ*, NFS*, NFU*, NFW*, NFX*, and other NF*) and complications related to surgery or implant: diagnostic codes T84.0+T84.1 (mechanical complications), T81.4+T84.5 (infectious complications), T93.1 (late effects), S73.0 (hip luxations), S72.1-S72.4 (femoral fractures distal to femoral neck) as well as medical complications: I21 (acute myocardial infarction), I25 (ischemic heart disease), I26 (pulmonary embolism), I50 (heart failure), I63 (stroke) within ninety days since the index procedure. The procedural codes used in this study are shown in Table 7.

**Table 7.** Procedural codes (NOMESCO classification) used in study III.

| Code | Procedure |
|---|---|
| NF | Hip and thigh |
| NFB* | Primary prosthetic replacement of hip joint |
| NFB10 | Primary hemiarthroplasty of hip joint using cement |
| NFB20 | Primary hemiarthroplasty of hip joint not using cement |
| NFC* | Secondary prosthetic replacement of hip joint |
| NFH* | Miscellaneous operations on hip joint |
| NFJ* | Fracture surgery on femur |
| NFS* | Operations for infected tendons, joints and bones of hip and thigh |
| NFU* | Removal of implants and external fixation devices from hip and femur |
| NFW* | Reoperations on hip or thigh |

### 6.3.1 Study population

During the study period, 25,174 patients were treated with hemiarthroplasty for a femoral neck fracture in Finland. The use of cemented hemiarthroplasty remained constant in Finland during the study period. Use of uncemented hemiarthroplasty has increased in recent years, leading to a slightly increased total use of hemiarthroplasty in Finland (Figure 8). Background information about the study patients is given in Table 8.

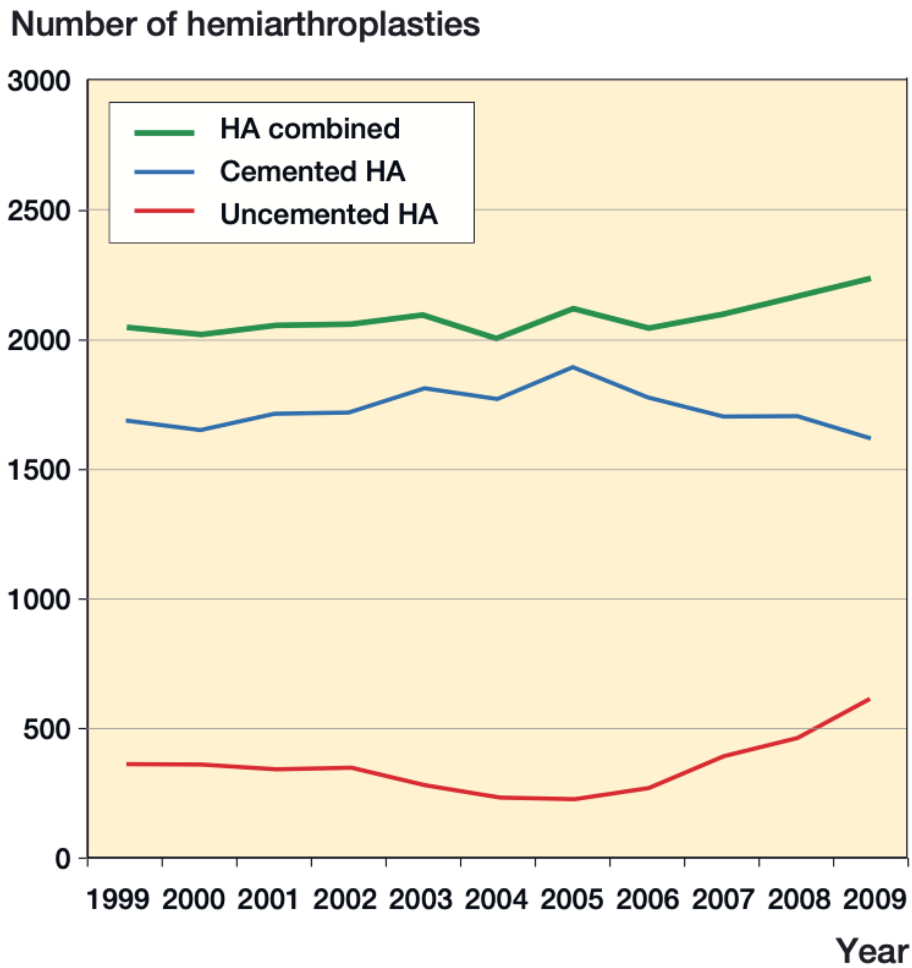


**Figure 8.** Annual numbers of cemented and uncemented hemiarthroplasties in Finland during the study period.

**Table 8.** Background information on the patients in study III, including duration of treatment, mortality and cost of treatment.

| | uncemented HA | cemented HA | P-value for difference (unadjusted) |
|---|---|---|---|
| Patients (n) | 4492 | 20682 | |
| Background characteristics | | | |
| Age (mean) | **81.1** | **80.7** | **0.002** |
| Men (%) | 26.2 | 26.2 | 0.50 |
| Admitted from long-term care (%) | **12.9** | **11.9** | **0.04** |
| Patients using calcium and vitamin D (%) | **20.5** | **18.3** | **<0.001** |
| Patients using antiosteoporotic agents (%) | 17.3 | 17.8 | 0.22 |
| Heart disease (%) | **46.5** | **39.2** | **<0.001** |
| Alcoholism (%) | 2.7 | 2.7 | 0.43 |
| Cancer (%) | 12.7 | 13.5 | 0.08 |
| COPD (%) | **14.3** | **13.2** | **0.02** |
| Dementia (%) | **23.8** | **20.4** | **<0.001** |
| Depression (%) | 25.6 | 24.9 | 0.17 |
| Parkinson's disease (%) | 6.2 | 6.2 | 0.44 |
| Mental disorders (%) | 14.1 | 13.4 | 0.11 |
| Rheumatoid arthritis (%) | 6.7 | 6.2 | 0.10 |
| Cerebrovascular disease (%) | **19.3** | **16.7** | **<0.001** |
| Treatment, outcomes and costs | | | |
| 30 day mortality (%) | **8.7** | **8.6** | **0.39** |
| Home at day 120 (%) | **53.5** | **56.9** | **<0.001** |
| 120 day mortality (%) | 18.0 | 17.1 | 0.07 |
| Home at day 365 (%) | **49.0** | **53.0** | **<0.001** |
| 365 day mortality (%) | **27.4** | **25.4** | **0.003** |
| The average duration of first treatment episode (days) in hospital | **6.6** | **7.4** | **<0.001** |
| Costs (€, mean) until discharge home | **10990** | **12050** | **<0.001** |

The exact type of hemiarthroplasty (implant manufacturer and model) is not registered in the PERFECT database. We therefore sent an e-mail survey (May - October 2012) to Finnish hospitals performing hemiarthroplasties. Of the 14 hospitals contacted, accounting for over 70% of hemiarthroplasties in Finland, none had used non-modular uncemented stems in the 2000's. Cemented non-modular hemiarthroplasty had been used up until 2005 in 4 of the hospitals contacted. On the basis of this survey we were able to determine that use of non-modular uncemented hemiarthroplasty has been infrequent in Finland during the study period.

### 6.3.2 Statistics

Mortality between the cemented and uncemented groups was examined using logistic regression analysis. The analysis was repeated for 365 outcomes that each described the status of patient (alive/dead) at certain day after the operation. In order to reduce the effects of confounding in this observational study, differences in distributions of observed covariates between the groups were adjusted using propensity score weighting (Austin 2011). Propensity scores, i.e. the probabilities of treatment assignment conditional on observed baseline characteristics, were calculated using generalized boosted regression model (McCaffrey et al. 2013). In the model, treatment assignment (cemented/uncemented) was dependent variable and all observed background variables listed in Table 8 as independent variables as the aim was to balance all observed covariates between the groups. Secondary outcomes were analysed using Cox's regression model, also adjusted via propensity score weighting. We assumed non-informative censoring and follow-up was until outcome event or censoring due to death or last day of the observation period, whichever occurred first. Proportional hazards assumption was tested using weighted Schoenfeld residuals. We also performed sensitivity analyses using proportional hazards model for competing risks proposed by Fine and Gray for secondary outcomes as death can be considered as a competing risk for those events. As results were almost identical we report only results from Cox regressions. Data preprocessing and analyses were performed with R 2.15.3 and extension packages muste 0.5.39, twang 1.3-11 and cmprsk 2.2-6.

### 6.3.3 Ethics

The ethical committee of the National Institute for Health and Welfare (THL) approved the study (THL TuET §138/2010).

## 6.4 RESULTS

The initial mortality after surgery with cemented HA was higher compared to uncemented HA (Figure 9). At day 1 postoperatively, the mortality for cemented HA was 1.49% and for uncemented HA 0.73% (OR=2.12; p<0.001). The difference in mortality at day 4 was still statistically significant (2.90% for cemented and 2.36% for uncemented HA; OR=1.27; p=0.03). At 5 days, the difference was no longer statistically significant and at 1 week the mortality for cemented HA was 3.94% and for uncemented HA 3.41 % (OR=1.16; p=0.1). During the follow-up, there was a trend towards lower mortality among patients receiving cemented HA, but it did not reach statistical significance at one year (25.6% vs. 26.7 %; p=0.2).

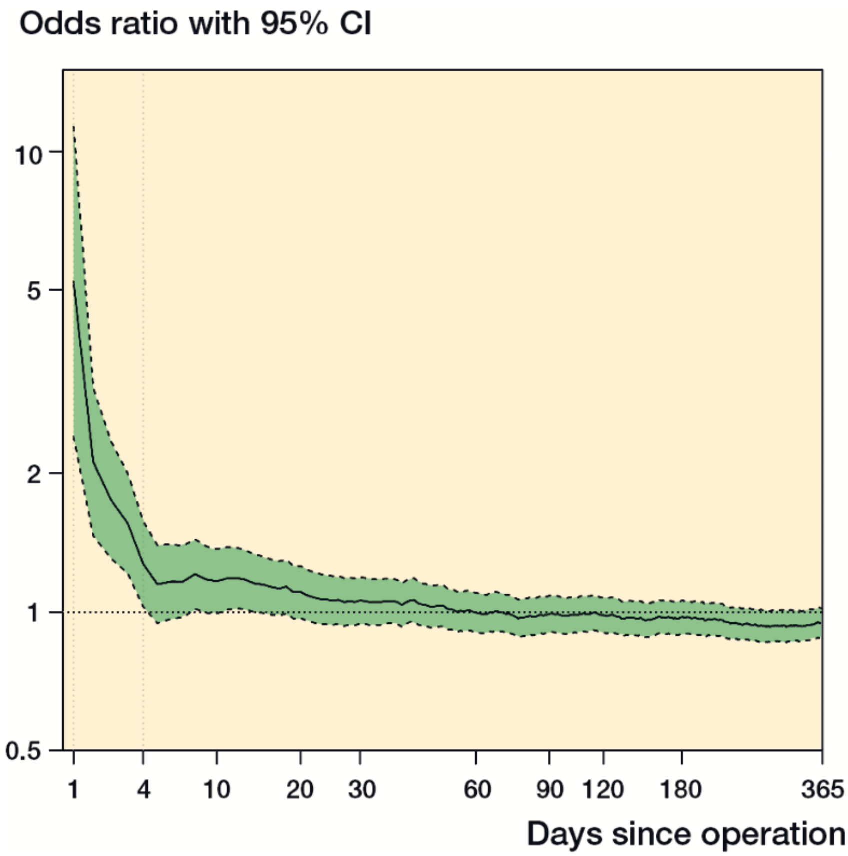


**Figure 9.** The relative and cumulative risk of death in patients receiving a cemented hemiarthroplasty compared to patients receiving an uncemented hemiarthroplasty. Mortality was higher in the cemented group until day 4. From day 5 onward, no statistically significant difference in mortality was found.

We were also interested whether the fat embolism would be cited more often as one of the causes of death in patients receiving cemented HA. In the cemented group, a fat embolism was cited as one of the causes (primary or contributory) of death in 14% of cases and in the uncemented group it was present in 9.0% of cases.

We also studied mortality in hospitals that had performed more than 100 cemented and 100 uncemented HA during the study period. The mortalities at 1 week were 4.4% for cemented HA and 3.5% for uncemented HA (p=0.06). In all, their mortality rates did not differ statistically significantly from the mortality of the study group as whole.

Patients treated with cemented HA tended to have less morbidity, and were eventually discharged home more often than patients treated with uncemented HA. The cost of treatment was higher among patients treated with cemented HA (Table 8).

Complications of hip fracture treatment with HA were studied by comparing the occurrence of certain diagnostic codes and procedural codes on operated patients during the first 90 days after hip fracture surgery (Table 9). There were more mechanical complications and new surgical procedures among patients treated with uncemented HA.

The number of new treatment periods for various medical complications (ischemic heart attacks, cerebrovascular disturbances) during the first 90 days was similar between the groups (Table 9).

**Table 9.** The occurrence of certain diagnostic codes and new operations on the hip joint among the patients in study III within 90 days of the index procedure.

| | uncemented HA | cemented HA | RR (upper and lower) | P-value for difference (unadjusted) |
|---|---|---|---|---|
| Ischemic heart disease (acute) | 2.41% | 2.16% | 0.90 (0.73-1.11) | 0.31 |
| Ischemic heart disease (chronic) | 8.40% | 7.86% | 0.93 (0.83-1.04) | 0.19 |
| Pulmonary embolism | 0.94% | 0.86% | 0.92 (0.66-1.28) | 0.61 |
| Heart insufficiency | 4.21% | 4.71% | 1.12 (0.96-1.30) | 0.14 |
| Cerebrovascular disturbances | 2.58% | 2.79% | 1.08 (0.89-1.32) | 0.44 |
| **New femoral fractures** | **2.85%** | **1.63%** | **0.57 (0.46-0.70)** | **<0.001** |
| Infectious complications | 2.30% | 1.89% | 0.82 (0.66-1.02) | 0.08 |
| **Mechanical complications** | **3.72%** | **2.77%** | **0.74 (0.62-0.88)** | **<0.001** |
| **Rearthroplasties of hip (NFC*)** | **1.66%** | **0.95%** | **0.57 (0.43-0.74)** | **<0.001** |
| **Fracture surgeries on femur (NFJ*)** | **1.19%** | **0.52%** | **0.44 (0.32-0.61)** | **<0.001** |
| Operations for infection (NFS*) | 0.42% | 0.27% | 0.65 (0.38-1.10) | 0.11 |
| **Implant removals (NFU*)** | **1.29%** | **0.78%** | **0.60 (0.44-0.82)** | **0.001** |
| **Reoperations on hip or thigh (NFW*)** | **0.76%** | **0.50%** | **0.66 (0.44-0.97)** | **0.03** |

## 6.5 DISCUSSION

The use of hemiarthroplasty for treatment of femoral neck fractures has remained stable in Finland during the years 1999–2009. Uncemented hemiarthroplasty has gained more popularity during the most recent years, possibly related to the introduction of newer prosthetic implant models to hip fracture surgery. The use of osteosynthesis with screws for femoral neck fractures has been relatively infrequent in Finland. This was reflected in our study, as we did not observe the increase in hemiarthroplasties noted in Sweden (Rogmark et al. 2011), where osteosynthesis has traditionally been a more popular choice for femoral neck fractures.

Cemented hemiarthroplasty has been preferred over uncemented hemiarthroplasty because of less postoperative pain and better mobility (Parker et al. 2010). Most studies comparing cemented and uncemented hemiarthroplasty have compared relatively outdated non-modular stems. It seems that use of monoblock prostheses is diminishing, making these studies potentially outdated (Rogmark et al. 2012). There have been a few prospective, randomized studies comparing modular, contemporary hemiarthroplasty with and without bone cement. In those studies, uncemented, modular hemiarthroplasty has produced equivalent results to cemented hemiarthroplasty in terms of functional outcomes, complications and mortality (Figved et al. 2009, DeAngelis et al. 2012, Taylor et al. 2012, Talsnes et al. 2013).

In a Swedish registry study uncemented hemiarthroplasty was associated with more reoperations when compared to cemented hemiarthroplasty (Leonardsson et al. 2012). We detected the same in our study. We found more hip rearthroplasties, fracture surgeries on the femur, implant removals, mechanical complications and reoperations on the hip among patients treated with an uncemented hemiarthroplasty. Our and Leonardsson's findings are of interest since they are in contrast to the results of prospective trials (Figved et al. 2009, DeAngelis et al. 2012, Taylor et al. 2012). We think that this may reflect the difficulties faced when the results of prospective trials are applied to clinical practice. Prospective, randomized trials usually have high internal validity, but consequently a portion of the population of interest is excluded from the study. This may lead to a situation where clinical results are different from the results of randomized trials.

Early postoperative mortality after cemented hemiarthroplasty was higher in our study. This could be a consequence of 'bone cement implantation syndrome' (Donaldson 2009), where fat and bone marrow cause emboli in pulmonary arteries, as fat embolism was more often detected in deceased patients who had received cemented hemiarthroplasty. However, the difference in mortality was reversed in follow-up and a trend towards lower mortality was seen in patients treated with cemented hemiarthroplasty. In this respect, our results reflect the trends seen in Australian registry data (Costain et al. 2011). In contrast to their results though, we did not see a statistically significant increase in 1-year mortality associated with uncemented hemiarthroplasty. It has to be noted also, that in a recent British database study, no increase in peri-operative mortality was detected with the use of cement (Costa et al. 2011). In light of these slightly contrasting results, it seems that the fixation method itself has little effect on mortality, at least beyond first postoperative week.

Treatment times and treatment costs were higher among patients treated with cemented hemiarthroplasty. It has to be noted, however, that these results were obtained without adjustment with propensity score weighting. Consequently, these results may be caused by other differences between the study groups.

The limitations of our study include the general drawbacks of register studies, i.e. their retrospective nature and reliance on diagnostic codes used during normal clinical practice. The validity of the Finnish PERFECT database, though, has been shown to be good (Sund 2011). Another limitation is the lack of information about the type of implant used for surgery. We conducted an e-mail survey and contacted hospitals accounting for over 70% hemiarthroplasties in Finland. It seems that use of uncemented, non-modular hemiarthroplasty has been scarce in Finland during our study period, similar to the situation in Sweden (Rogmark et al.

2012). Despite these limitations, we believe that registry-based studies have their role in hip fracture research and should be encouraged. We think that an optimal hip fracture registry would include operative details including implant type and information about possible reoperations. However, the data gathered should also include information about postoperative treatment, rehabilitation and medical complications. In this regard we think that a modern arthroplasty registry combined with information similar to the PERFECT data would be close to an ideal hip fracture registry.

In conclusion, we found no differences in postoperative mortality after 1 week between hip fracture patients treated with cemented or uncemented hemiarthroplasty. Uncemented hemiarthroplasty was associated with more hip reoperations and mechanical complications during the first 90 days after hip fracture surgery.

# 7 RISK FACTORS FOR EARLY READMISSION DUE TO SURGICAL COMPLICATIONS AFTER TREATMENT OF PROXIMAL FEMORAL FRACTURES – A FINNISH NATIONAL DATABASE STUDY OF 68,800 PATIENTS

## 7.1 ABSTRACT

Introduction

Hip fracture surgery is associated with a considerable amount medical and surgical complications, which adversely impacts the patient's outcome and/or increases costs. We evaluated what risk factors were associated with the occurrence of early readmission due to surgical complications after hip fracture surgery.

Material and methods

A nationwide database with 68,800 hip fracture patients treated between 1999 and 2011 was studied to uncover the association of readmissions with co-morbidities, fracture types, different hospital types and treatment methods using the Cox proportional hazards model.

Results

Early readmission within three months due to hip fracture surgery complications occurred at a rate of 4.6%. Increased occurrence of readmission was found among patients with: heavy alcoholism (HR 1.38; 95% CI: 1.23–1.53); Parkinson's disease (PD; HR 1.22; 95% CI: 1.05–1.42); pre-existing osteoarthritis (HR 2.02; 95% CI: 1.83–2.23); rheumatic disease (HR 1.44; 95% CI: 1.27–1.65); as well as those with a fracture of the femur

neck, depression, presence of a psychotic disorder, an operative delay of at least three days, or previous treatment with total hip arthroplasty.

Conclusion

Our results indicate that there are several factors associated with an increased risk of early readmission. We suggest that in the presence of these factors, the surgical treatment method and postoperative protocol should be carefully planned and performed.

## 7.2 INTRODUCTION

Hip fractures constitute a large portion of services rendered at a typical hospital (Parker and Johanson 2006). According to the Finnish Hospital Discharge Register (FHDR), the annual occurrence of new hip fractures is approximately 7,000 per year in a population of 5.4 million (Hongisto et al. 2014). Worldwide, the annual average hip fracture incidence varies between 150–250 fractures per 100,000 population (Kanis et al. 2012). Although age-standardized incidence of hip fractures seems to decline in industrialized countries, an aging population will ensure increasing numbers of these fractures in the coming years (Kannus et al. 2006; Briot et al. 2015).

Hip fracture patients often suffer from medical and surgical complications (Buecking et al. 2013; Carpintero et al. 2014; Matsuo et al. 2018). Although medical complications are more frequent, surgical complications like deep wound infections, fixation failures or dislocations of hip arthroplasty often lead to further surgical interventions which more than doubles the cost of treatment. Along with increased costs, the occurrence of a surgical complication adversely affects the outcome for a hip fracture patient (Edwards et al. 2008; Thakar et al. 2010; Tsang et al. 2014). It is therefore important to find ways to avoid these complications in order to lessen the burden on the healthcare system and our patients. There is some data from single-center prospective studies reporting the incidence of complications after hip fracture surgery (Parker and Handoll

2010; Parker et al. 2010b; Gjertsen et al. 2012; Hansson et al. 2015; Härstedt et al. 2015). In addition, reoperations after hip hemiarthroplasties have been reported from the Norwegian and Swedish arthroplasty registries (Leonardsson et al. 2012; Rogmark et al. 2014). There are also reports concerning the overall re-admission rate not focusing on the surgical complications (Lee et al. 2017).

The primary aim in this study was to quantify, from a national database, the occurrence of early surgical complications leading to readmission and to report the co-morbidities they would be associated with. The secondary aim was to find whether differences in the occurrence of complications between different treatment methods or fracture types existed.

## 7.3 PATIENTS AND METHODS

The data were extracted from the PERFormance, Effectiveness and Cost of Treatment episodes (PERFECT) hip fracture database (Häkkinen 2011; Peltola et al. 2011; Sund et al. 2011; Häkkinen 2017). For the purposes of this study, 68,800 over 50-year-old patients admitted in Finland for their first proximal femoral fracture from 1.1.1999 to 31.12.2011 were identified using the 10th revision of the WHO International Classification of Diseases (ICD-10) diagnostic codes S72.0, S72.1, S72.2 and the Finnish version of the Nordic Medico-Statistical Committee Classifications' Procedural Codes, NFB10-50, NFJ50, NFJ52 or NFJ54.

Data on co-morbidities, use of residential care and deaths for this population were extracted from the Finnish Health and Social Welfare Care Register, reimbursement registries of the Social Insurance Institution and from the National Causes of Death Statistics, using the unique personal identification number for each patient[21]. Records in these registries include data such as: patient and provider ID-numbers, age, sex, area codes, diagnosis and operation codes, as well as dates of admission, operation, and discharge (or death). The validity of the Finnish registry-data for hip fractures has been found to be very good (Sund et al. 2007).

For the purposes of this study, we defined an early readmission for surgical complication as one occurring within three months from index hip fracture operation, that was associated with a ICD-10 diagnostic code of: M96.6 (Fracture of bone following insertion of orthopedic implant, joint prosthesis, or bone plate); T81.0 (Hemorrhage and hematoma complicating a procedure); T81.4 (Infection following a procedure); or T84 (Complications of internal orthopedic prosthetic devices, implants and grafts).

In order to target the secondary aim of this study, fractures of neck of femur (S72.0), pertrochanteric fractures (S72.1) and subtrochanteric fractures (S72.2) were studied separately. Various treatment methods were divided into partial prosthetic replacement of hip joint (NFB10-20), total prosthetic replacement of hip joint (NFB30-50), screw fixation of neck of femur (NFJ50), fixation of proximal femur with plate and screws (NFJ52) and intramedullary nailing (NFJ54). To control for differences in the occurrence of complications between hospital types, hospitals were divided into four categories: university hospitals; central hospitals treating more than 200 hip fractures per year; central hospitals treating less than 200 hip fractures per year; and other hospitals (usually small regional hospitals).

### 7.3.1 Statistical analysis

The occurrence of complications was modelled using the Cox proportional hazards model. Follow-up time was three months from the operation day, until complication, or death, whichever occurred first. Observations terminating in death or the end of follow-up time were considered censored. Factors adjusted in the analyses included age, sex, co-morbidities, residential status at baseline and an operation wait time of more than two days in-hospital. Clustering of hospitals was also taken into account. In addition, the year of operation and hospital type was adjusted for using stratification, allowing the use of a different baseline hazard within the model. Data pre-processing and analyses were performed with R-3.2.2 and extension packages Survo R 0.6.20 and survival 2.38-3. A p-value of less than 0.05 was considered statistically significant.

### 7.3.2 Ethics

Ethics approval was obtained from the National Institute for Health and Welfare for this study (THL TuET §138/2010).

## 7.4 RESULTS

Using the inclusion criteria, we identified 42,541 femoral neck fractures, 24,983 pertrochanteric fractures and 5,276 subtrochanteric fractures treated surgically in Finland. The total annual occurrence of first hip fractures increased from 5,131 to 5462 from 1999–2011; however, there was no change in relative amounts of fracture types during that time (Figure 10). The characteristics of the study population are presented in Table 10.

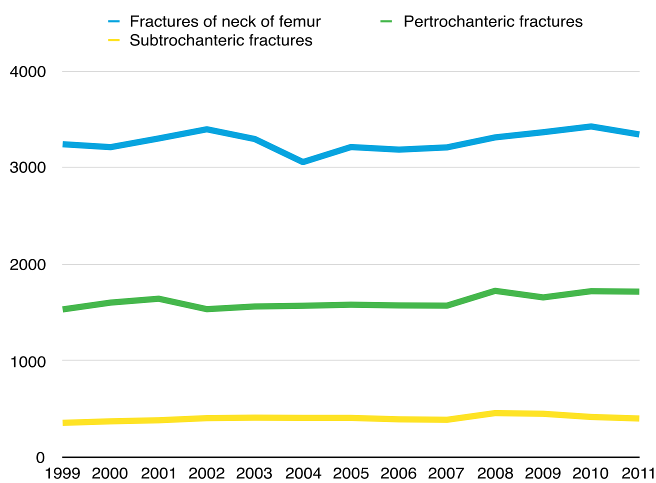


**Figure 10.** The annual occurrence of hip fracture types in Finland during study period in over 50-years old patients (first hip fractures).

**Table 10.** Background information on the patients in study IV, including occurrence of comorbidities and fracture types.

| | | n |
|---|---|---|
| Background characteristics | | |
| Age (mean, years) | 78 | |
| Men, % | 30,4 | 20 941 |
| Admitted from long-term care, % | 15,8 | 10 865 |
| Patients using calcium and vitamin D, % | 18,6 | 12 820 |
| Patients using antiosteoporotic agents, % | 18,6 | 12 815 |
| Heart disease, % | 37,4 | 25 762 |
| Alcoholism, % | 4,2 | 2 886 |
| Cancer, % | 12,5 | 8 615 |
| Chronic obstructive pulmonary disease, % | 13,1 | 9 004 |
| Dementia, % | 17,5 | 12 095 |
| Depression, % | 22,7 | 15 584 |
| Parkinson's disease, % | 4,9 | 3 384 |
| Psychotic mental disorders, % | 11,9 | 8 157 |
| Rheumatoid disease, % | 6,7 | 4 585 |
| Cerebrovascular disease, % | 15,8 | 10 889 |
| | | |
| Fracture types | | |
| Fracture of neck of femur | 61,8 | 42 541 |
| Pertrochanteric fracture | 30,5 | 20 983 |
| Subtrochanteric fracture | 7,7 | 5 276 |

Various surgical methods were utilized in the treatment of proximal femoral fractures (Figure 11). The use of an intramedullary nail increased during the study period while use of plate and screws decreased. The use of arthroplasty (both hemi- and total arthroplasty) also became more popular at the expense of screw fixation.

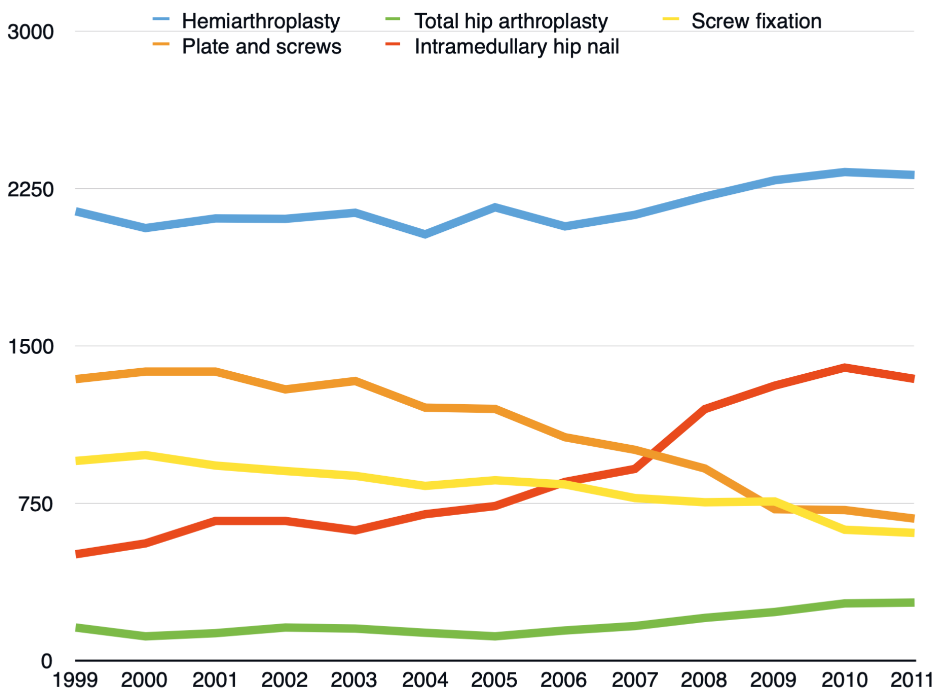


**Figure 11.** The annual use of different surgical methods in the treatment of hip fractures in Finland 1999-2011 (first hip fractures in over 50-year-old patients).

The relative risks for early readmission due to surgical complication were studied in different hospital types. Risk was found to be 0.80 (0.73–0.88, p<0.0001) in central hospitals treating more than 200 hip fracture patients a year and 0.96 (0.87–1.06, p=0.445) in central hospitals treating 200 or less hip fracture patients a year when compared to university hospitals. Therefore, we adjusted for hospital type for the following comparisons.

Specific occurrence of readmissions for surgical complications over the study period according to fracture type is illustrated in Figure 12. Occurrence of surgical complications remained less frequent among pertrochanteric fractures (3.1%) than subtrochanteric fractures (4.9%) or fractures of the neck of the femur (5.4%). The occurrence for infections was 1.4%, 2.1%, and 1.7%, respectively.

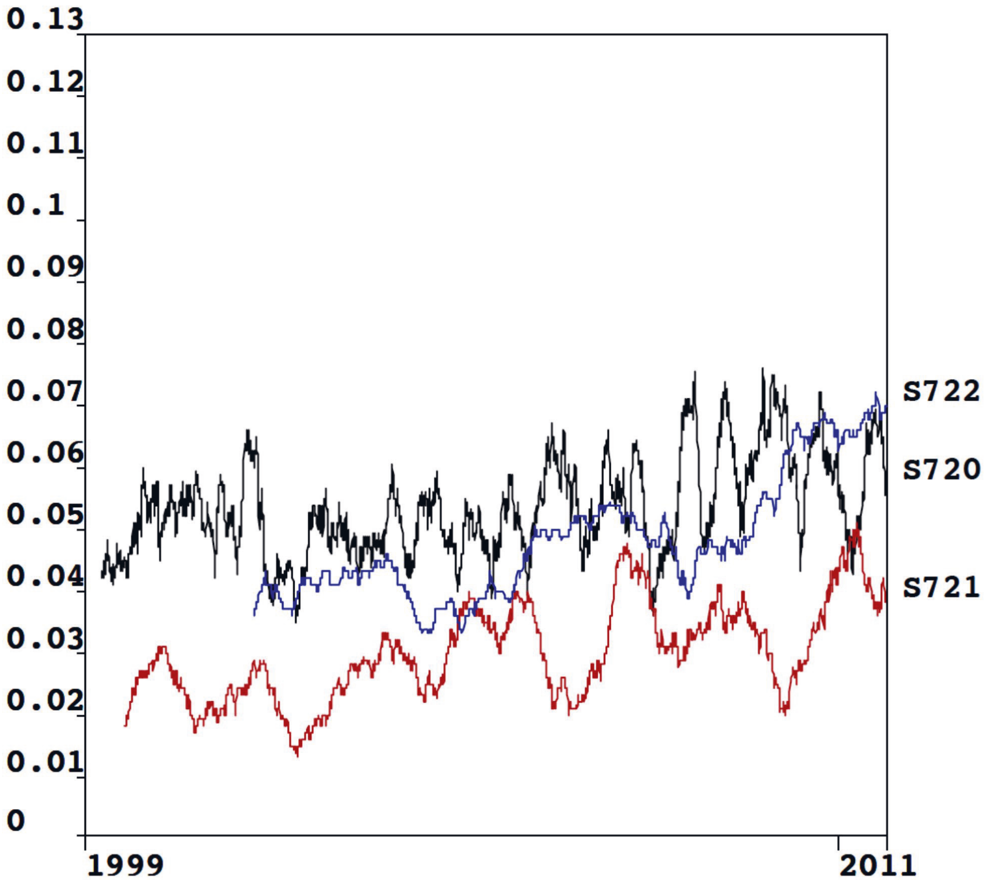


**Figure 12.** Occurrence of early re-admissions due to surgical complications according to fracture-types over study period. — = S72.0 (Fracture of neck of femur); — = S72.1 (Pertrochanteric fracture) ; — = S72.2 (Subtrochanteric fracture).

Differences in the occurrence of early surgical complications according to surgical method in the initial hip fracture operation were noted as well (Figure 13). The arthroplasties – in particular total hip replacement (THR) – were associated with more surgical complications in the early postoperative period after hip fracture surgery.

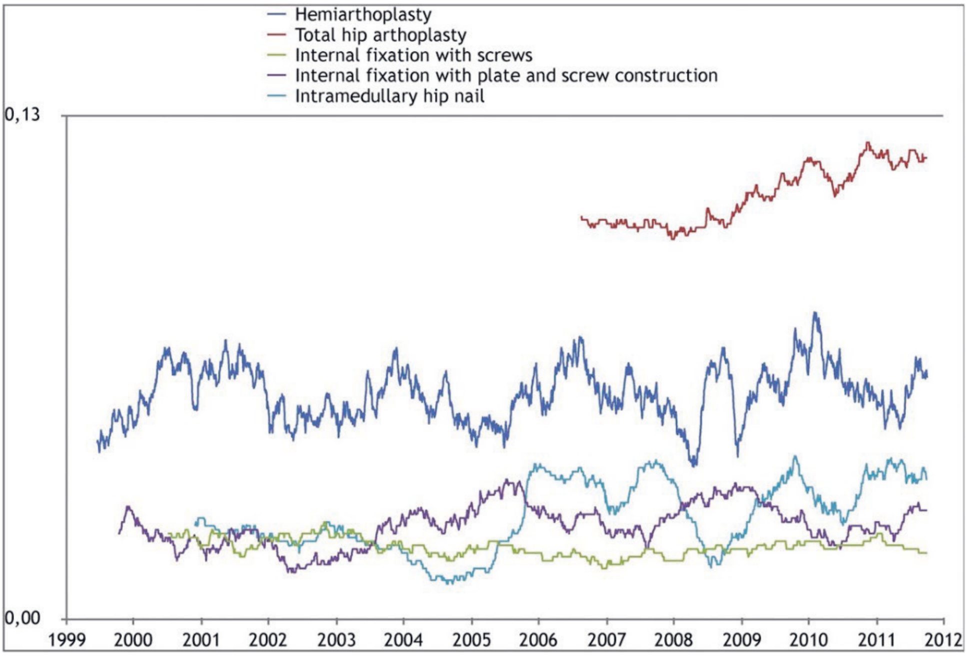


**Figure 13.** The occurrence of early re-admissions due to surgical complications according to surgical method used in fracture surgery.

In the patients treated with cannulated screws, re-fracture around the implant was relatively more common complication than in the patients treated with other methods (Table 11). Also, postoperative hemorrhage comprised a larger proportion of complications in patients treated with osteosynthetic methods than patients treated with arthroplasty.

**Table 11.** The distribution of complication types according to type of operative procedure used.

| | Fixation with cannulated screws (N=511) | Sliding hip screw and side plate (N=346) | Intramedullary nail (N=328) | Hemiarthroplasty (N=1641) | Total hip arthroplasty (N=236) | Other or unspecified procedure (N=136) | Combined (N=3198) |
|---|---|---|---|---|---|---|---|
| Re-fracture around the implant (%) | 10 | 2,0 | 2,1 | 2,3 | 2,5 | 6,6 | 3,7 |
| Postoperative hemorrhage (%) | 7,2 | 16 | 16 | 6,1 | 3,4 | 5,1 | 8,1 |
| Postoperative infection (%) | 28 | 47 | 58 | 36 | 20 | 35 | 37 |
| Other (%) | 55 | 35 | 25 | 56 | 74 | 53 | 51 |

Association of early surgical complications with various co-morbidities in hip fracture patients was noted as well. Alcoholism and Parkinson's disease (PD) were associated with increased risk of complications (Figure 14). Similarly, depression, psychotic disorders, rheumatoid diseases, pre-existing osteoarthritis and an operative delay of at least three days were linked to increased complication risk. The operative delay was also associated with an increased risk for surgical complications (Table 12).

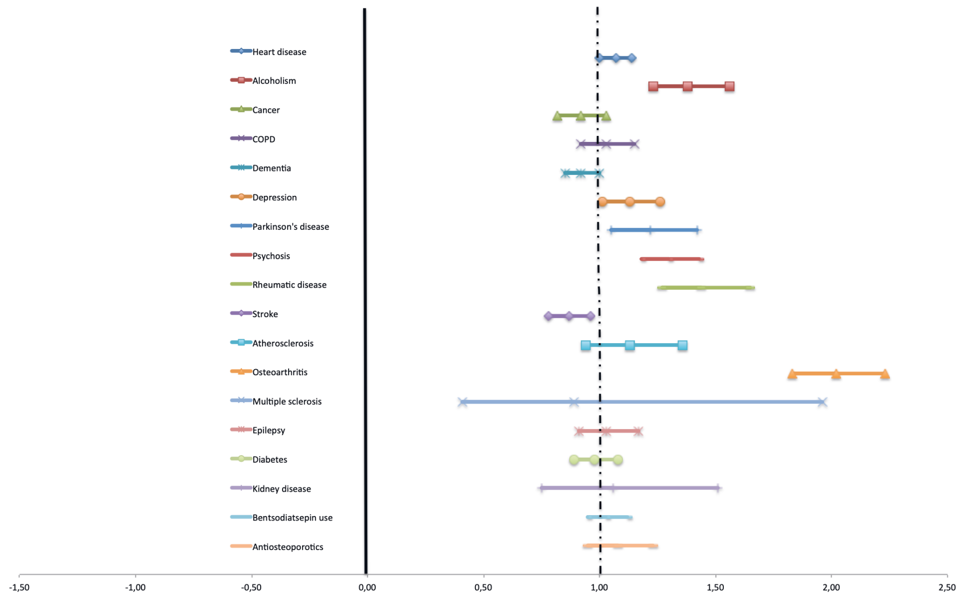


**Figure 14.** Relative risks for an early readmission due to a surgical complication in patients with above-mentioned, pre-existing comorbidities.

**Table 12.** The occurrence of readmission due to surgical complication within first three months after a hip fracture operation. *HR, hazard ratio; HRLCI, hazard ratio lower confidence interval; HRUCI, hazard ratio upper confidence interval.

| | Relative risk for readmission due to surgical complication within three months | | |
|---|---|---|---|
| | HR | HRLCI - HRUCI | p-value |
| **Men** | 1,00 | | |
| **Women** | 0,91 | 0,85 to 0,97 | 0,004 |
| | | | |
| **Fracture of neck of femur** | 1,00 | | |
| **Pertrochanteric fracture** | 0,56 | 0,52 to 0,61 | < 0,0001 |
| **Subtrochanteric fracture** | 0,85 | 0,72 to 0,99 | 0,039 |
| | | | |
| **Operative delay <3days** | 1,00 | | |
| **Operative delay >=3 days** | 1,20 | 1,04 to 1,38 | 0,013 |

## 7.5 DISCUSSION

To our knowledge, this study is the first nationwide register-based hip fracture survey with a focus on early surgical complications after a hip fracture and its' treatment. Our estimate of the occurrence of early readmissions for surgical complications is in line with published results from single-center studies (Carpintero et al. 2014; Edwards et al. 2008; Thakar et al. 2010; Tsang et al. 2014).

Early readmission within 90 days for surgical complications after hip fracture was chosen as the primary outcome, as surgical complications have a major impact on the results of hip fracture care due to associated increases in cost and mortality (Thakar et al. 2010). The outcome was deemed reliable, since readmission is a well-defined event. In addition, the timeframe limits the chance of the event being due to a contralateral fracture. We are aware that our outcome measure does not include less serious complications (i.e. superficial wound problems) not leading to a readmission.

Co-morbidities are linked to higher mortality after a hip fracture (Franzo et al. 2005; Smith et al. 2014; Bokshan et al. 2018). Less is known whether co-morbidities could increase the risk for surgical complications after a hip fracture. We were able to detect a higher risk for an early readmission for surgical complication among patients with alcohol abuse, Parkinson's disease (PD), rheumatoid disorders and existing osteoarthritis, but not all co-morbidities carried such a risk. One such co-morbidity is diabetes, which was not associated in our study with a higher occurrence of readmission for surgical complications. This finding has been made also earlier in one study (Golinvaux et al. 2014).

We were able to show an association between alcohol abuse and readmission for surgical complications after hip fracture. This result is supported by the study of Faroug et al., where heavy alcohol abuse was linked to hip fracture complications (Faroug et al. 2014). The relationship of excessive preoperative alcohol consumption with surgical complications in general is known (Eliasen et al. 2013). Concerning hip fracture patients, it has been detected earlier that mortality is elevated in alcoholic patients (Yuan et al. 2001). It also seems that use of THR for hip fracture in alcoholic patients carries a high risk for revision surgery (Kosola et al. 2017).

We found that patients with PD have more complications after hip fracture treatment. This is a novel finding. It has been found that patients with PD recover more slowly from a hip fracture, but in previous studies heightened risk for surgical complications has not been noted (Idjadi et al. 2005; Walker et al. 2013; Yuasa et al. 2013; Bliemel et al. 2015). However, these single-center studies included relatively low numbers of PD patients. It is thus possible that they were underpowered and unable to detect the differences in surgical complications among these patients. In the setting of an elective THR, it is known that PD patients are at risk for dislocation (Jämsen et al. 2014).

We observed an increased risk for early readmission for surgical complications when THR was used for treatment of hip fractures. THR has been studied and found to be a reliable treatment method for femoral neck fractures in randomised prospective trials (Blomfeldt et al. 2007). It has also been suggested that THR would be more cost-effective method when compared to hemiarthroplasty for the treatment of femoral neck fractures (Carroll et al. 2011). Neither of these studies report any significant increase in early complications after THR. The difference between these findings and our results may be due to study design. Prospective trials usually have a certain amount of exclusion criteria in order to obtain a high internal validity. However, when their results are extrapolated to clinical practice, the treated population tends to be more heterogenous. Similarly, in clinical trials surgeons performing the operations are often dedicated to a specific field and procedure. It may be that THR, as a more challenging procedure than hemiarthroplasty, is more prone to complications when it is applied by less experienced surgeons on a more heterogeneous patient population.

We found that readmissions were less frequent among patients treated in non-university central hospitals when compared to university hospitals which treat the highest volume of hip fractures. When we studied non-university hospitals with more precision, we found that hospitals treating more than 200 hip fracture patients performed better than the units with lower volume. Laarhoven et al. have detected that level II trauma centers with high volume of hip fractures may be superior in performing hip fracture surgery (Laarhoven et al. 2015). This is in concordance with our results since most non-university hospitals treating hip fracture patients in Finland can be classified as level II trauma centers. Our data does not support the centralization of hip fracture patients to level I trauma centers.

The strength of our study is the inclusion of all over 50-year old patients treated for their first proximal femoral fracture in Finland during 1999–2011. Consequently, our results give a picture of how the health-care system performs in everyday practice. The PERFECT database used in this study is based on routinely collected data from Finnish healthcare registers (Häkkinen 2011; Peltola et al. 2011; Sund et al. 2011). The validity of the data from these registers such as FHDR, Health Care Register and the Causes of Death Register have been compared to prospectively collected hip fracture audit data (Sund et al. 2007). The validity of the FHDR alone has been assessed in over 30 additional studies where positive predictive values and completeness have been found to be over 90% (Sund 2012). The prescription database data, which forms a part of our assessment on co-morbidities, has been found to be in high concordance with self-reported medication (Haukka et al. 2007). Based on the above, it seems that the Finnish register data is valid enough for a performance assessment of hip fracture treatment, yielding data that supplements the prospective trials. Another strength in our register-data is that all patients are followed through the patient pathway, and are not limited to the primary treating hospital.

The limitations of this study are inherent to register studies, such as reliance on the accurate use of diagnostic and procedural codes used during normal clinical practice. We do not consider the retrospective design as a major limitation because all patients who had surgery for hip fracture were followed, and selection as a source of bias is not probable. The primary outcome, an early readmission for a surgical complication, is not equivalent for all surgical complications. The PERFECT data does not identify early reoperations occurring during the primary treatment period in the hospital. This period, however, is usually relatively short in Finland and patients are often transferred to a rehabilitation unit or health center ward on the second or third postoperative day. Thus, we believe that most often surgical complications are treated during a second readmission in our healthcare system. Additionally, we find early readmissions to be an important outcome since they represent an unexpected occurrence in the patient pathway and should be a target for appropriate measures. While our estimate of early complications may not be an absolute number of all surgical complications, it is a suitable outcome for comparisons and identification of risk factors for complications.

## 7.6 CONCLUSIONS

In conclusion, we detected an overall rate of 4.6% for early readmissions for surgical complications after hip fracture surgery. Based on our results, extra precaution and awareness should be used when treating patients with alcohol abuse, PD, rheumatoid disorders or pre-existing osteoarthritis, as these patients may be more prone in acquiring surgical complications after hip fracture surgery. The use of THR for hip fractures warrants further surveillance in registries as it may be associated with increased early complications compared to what has been suggested in prospective trials. Finally, we find our results support a creation of a hip fracture database at the national level in most countries.

# 8 GENERAL DISCUSSION

Hip fractures are the most common fractures treated operatively. Hip fractures and their surgical treatment are associated with complications and consume a considerable amount of healthcare resources. The optimization of hip fracture care would consequently lead to better treatment results and better use of healthcare resources. In this thesis, the performance of different surgical methods for hip fractures was studied in a real-life setting and a register study was chosen as the primary method. It was found that certain surgical methods (extramedullary osteosynthesis for trochanteric fractures and cemented hemiarthroplasty) seem to produce reliable outcomes with fewer complications than others. It was also found that comorbidities affected the occurrence of surgical complications after hip fracture surgery.

## 8.1 OUTCOMES AFTER TROCHANTERIC HIP FRACTURE SURGERY

Trochanteric hip fractures are generally treated with osteosynthesis. The extramedullary implants have been recommended as the primary choice for most common types of trochanteric fractures (Barton et al., 2010; Jones et al., 2006; Parker & Handoll, 2010; Queally et al., 2014). According to evidence from randomized trials, even the most unstable A3 trochanteric fractures could be treated with extramedullary implants yielding comparable results to intramedullary implants (Parker et al., 2018).

The intramedullary implants were introduced in the 1990s. The first implants were associated with a considerable amount of mechanical complications (Mavrogenis et al., 2016, Hesse & Gächter, 2004). So-called new generation (or third-generation) trochanteric nails were introduced in Finland in 2005 and 2006. In this thesis, an increase in the use of intramedullary implants occurred after this, and the same trend has also been noted in other countries (Forte et al., 2008; Rajaratnam, 2009). A possible explanation for the increase could be the marketing efforts associated with the introduction of new implants. Although final decisions about treatment methods should be based on scientific data, active marketing efforts also have effects on this (Gelberman et al., 2010; Hasan et al., 2000).

This thesis shows an increase in the number of intramedullary implant-related mechanical complications in 2006. An explanation for this could be a learning curve effect, occurring at a time when nails were introduced to surgeons formerly accustomed to extramedullary implants. The amount of surgical procedures needed to adopt a new technology varies depending on how drastic the change is compared to the prevailing technique (Sarpong et al., 2020). In the field of orthopedics, it has been estimated that at least 20-25 operations are needed for the adoption of new techniques (Jain et al., 2007). More specifically, a learning curve effect has also been demonstrated in the use of intramedullary implants for trochanteric fractures (Audige et al., 2003). In this thesis, it was found that postoperative infections after trochanteric fracture surgery was increased at the same time as the use of intramedullary implants was on the rise. It cannot be ruled out that at least some of those infections might be related to more unfamiliar operative techniques and longer operative time associated with the use of new implants.

In a longer perspective, the use of intramedullary implants for trochanteric fractures has been associated with more prevalent iatrogenic femoral shaft fractures than the use of extramedullary implants (Handoll & Parker, 2010, Utrilla et al., 2005; Mavrogenis et al., 2016; Queally et al., 2014). It has been suggested that new-generation nails would have fewer complications than older-generation nails (Bhandari et al., 2009; Bonnaire et al., 2020; Norris et al., 2011; Parker et al., 2012; Zou et al., 2009). In this thesis, it was noticed that peak incidence of mechanical complications attenuated after the initiation phase of new generation nail use. However, under previous studies (Aros et al., 2008; Rogmark et al., 2010), all complications requiring re-admission or reoperation in this thesis study remained on a higher level in patients receiving an intramedullary implant for trochanteric fracture.

It is known that trochanteric fractures are associated with worse functional outcomes than cervical fractures (Turesson et al., 2018).

Regarding the surgical method or implant chosen, no difference in functional outcomes has been noted between methods (Parker & Handoll, 2010; Queally et al., 2014). An exception to this might be the most unstable A3 type of trochanteric fracture. Treatment of this fracture type with traditional extramedullary may lead to medialization of the femoral shaft. Some data is suggesting that medialization of femoral diaphysis may subsequently lead to suboptimal functional outcomes (Bretherton & Parker, 2016). It has also been speculated that functional outcomes would be better with newer generations of intramedullary implants (Rocca et al., 2007). However, no superiority of new generation intramedullary nails has been demonstrated over extramedullary implants in comparative trials (Queally et al., 2014). This includes even the A3 type of fractures mentioned above (Parker et al., 2018).

The risk of death after a trochanteric hip fracture is thought to be independent of the choice of implant used for osteosynthesis (Mattisson et al., 2018, Radcliff et al., 2012). In this thesis, higher mortality was detected among patients receiving an intramedullary implant compared to patients treated with an extramedullary implant. This difference persisted even after regression analysis and adjustment for known risk factors for death. The conclusive reason for this finding remains open. Possible explanations could be more prevalent postoperative complications after the use of intramedullary implants and the possibility that patients receiving an intramedullary had different (possibly more unstable) fractures. It is of interest, however, that in two other registered studies, a similar heightened risk of death has been noted among patients treated with intramedullary implants (Whitehouse et al., 2019; Wolf et al., 2021).

Intramedullary implants are more expensive than traditional extramedullary implants. This price difference was reflected in this thesis. A similar difference in the cost of treatment was noted by Rogmark et al. (2010) in their report on Swedish register data concerning the treatment of proximal femoral fractures.

## 8.2 OUTCOMES AFTER FEMORAL NECK FRACTURE SURGERY

Optimal treatment for FNF has been a subject of debate for years. The popularity of arthroplasty has grown over osteosynthesis (Florschutz et al., 2015; Rogmark et al., 2010). Similarly, in this thesis, the use of osteosynthesis was a less frequent treatment for FNF than arthroplasty in Finland between 1999 and 2009. It is known that osteosynthesis of FNF is associated with a high rate of non-union and reoperations (Florschutz et al., 2015; Ma et al., 2019). Focusing on the early complications, it was found that re-fractures around the cannulated screws did occur in 10% of cases, considerably more often than with arthroplasty. As the thesis was not designed to study the later complications, non-union or malunion could not be estimated reliably.

The optimal type of arthroplasty for FNF has been the subject of debate. Options include total arthroplasty, hemiarthroplasty, and hemiarthroplasty with the bipolar femoral head. All of these can be implanted with or without bone cement. Various kinds of implants have differences in terms of complications and functional outcomes (Jameson et al., 2013; Leonardsson et al., 2013; Parker et al., 2010b). In general, it is thought that total hip arthroplasty yields better functional outcomes but possibly more complications, such as dislocations, than HA (Guyen, 2019; Lewis et al., 2020). It has also been suggested that the differences between various arthroplasties are so small that we should pay attention to other factors than the choice of the prosthetic implant (Rogmark, 2020).

Cemented hemiarthroplasty is preferred over uncemented hemiarthroplasty because of less postoperative pain and better postoperative mobility (Parker et al., 2010). Most studies comparing cemented and uncemented hemiarthroplasty have compared older non-modular stems (Parker et al., 2010a, 2010b). It seems that the use of non-modular stems is diminishing, making these studies potentially outdated (Rogmark et al., 2012).

There have been a few prospective, randomized studies comparing modular, contemporary hemiarthroplasty with and without bone cement. The published results considering modern HA are somewhat conflicting. In some studies, the uncemented modular HA has produced equivalent results to the cemented HA (DeAngelis et al., 2012; Figved et al., 2009; Taylor et al., 2012; Talsnes et al., 2013). In a Swedish registry study, uncemented hemiarthroplasty was then again associated with more reoperations when compared to cemented hemiarthroplasty (Leonardsson et al., 2012). However, when taken together, it seems that uncemented HA with current femoral stems is associated with more complications without any advantages over cemented stems (Veldman et al., 2017).

This thesis showed that patients treated with uncemented hemiarthroplasty experienced more hip arthroplasties, fracture surgeries on the femur, implant removals, mechanical complications, and reoperations on the hip than patients treated with cemented hemiarthroplasty. This is in line with combined results from prospective trials (Veldman et al., 2017) and registry study results from Sweden (Leonardsson et al., 2012). It seems prudent to state that to avoid complications, cemented HA should be preferred over uncemented HA.

Early postoperative mortality after cemented hemiarthroplasty was higher in this thesis. This could be a consequence of "bone cement implantation syndrome" (Donaldson, 2009; Hines, 2018), where fat and bone marrow cause emboli in pulmonary arteries. The mortality was reversed in follow-up, and a trend toward lower mortality was seen in patients treated with cemented hemiarthroplasty. The results of this thesis study reflect the trends seen in Australian registry data (Costain et al., 2011) where one-year mortality was higher among patients treated with uncemented hemiarthroplasty. In contrast to the Australian results, a statistically significant increase in one-year mortality associated with uncemented hemiarthroplasty was not seen. Also, in a British database study, no increase in peri-operative mortality was detected with the use of cement (Costa et al., 2011). Similarly, the combined results from prospective trials do not support the hypothesis that the use of bone cement for HA would increase mortality after FNF (Veldman et al., 2017). Interestingly, the results of this thesis are very similar to the ones in a recent Danish register study, where cemented HA was associated with higher mortality on the first postoperative day but not beyond (Viberg et al., 2022). Based on the above, it seems that the cementing of the hip hemiarthroplasty has little effect on overall mortality. As uncemented hemiarthroplasty carries a higher risk of complications, it seems that cemented hemiarthroplasty should be the primary choice for FNF.

THA has been suggested to be superior to hemiarthroplasty when treating FNF. This suggestion is based on prospective trials (Blomfeldt et al., 2007; Carroll et al., 2011). These trials did not detect more complications than hemiarthroplasty. In this thesis, a contrary observation was found. The registry analysis consistently showed that total hip arthroplasty was associated with more early postoperative complications than other surgical methods for FNF. The different results from this thesis and the above-mentioned prospective studies could be explained by the difference between prospective trials and registry studies. Patients are generally operated on by a research group, which includes dedicated professionals in former, whereas register analysis provides a perspective on what happens in "real life." In the question of total hip arthroplasty for FNF, it can mean that when less experienced, even junior surgeons do the operation, more complications can occur. Also, in prospective studies, the study population is usually more homogeneous than in clinical practice. It could be that in practice, total hip arthroplasty has also been used for patients more prone to complications (Bhandari et al., 2019).

Taken together, this thesis suggests that cemented hemiarthroplasty is still the treatment of choice for most patients with FNF. The uncemented hemiarthroplasty does not seem to offer any significant benefit over cemented hemiarthroplasty. Total hip arthroplasty should be offered with caution and probably carried out by experienced arthroplasty surgeons.

## 8.3 COMPLICATIONS AND MORTALITY RELATED TO HIP FRACTURE SURGERY

In this thesis, early readmissions within 90 days for surgical complications occurred in 4.6% of hip fracture patients in Finland. This is comparable to results published in single-center studies (Carpintero et al., 2014; Edwards et al., 2008; Thakar et al., 2010; Tsang et al., 2014).

It was found that the readmission risk was higher for patients with alcohol abuse (HR 1.38; 95% CI: 1.23-1.53), Parkinson's disease (PD) (HR 1.22; 95% CI: 1.05-1.42), rheumatoid disorders (HR 1.44; 95% CI: 1.27-1.65) and pre-existing osteoarthritis (HR 2.02; 95% CI: 1.83-2.23). The association between alcohol use and the risk of hip fracture complications has previously been reported (Faroug et al., 2014). Concerning PD, a similar finding between complications after the hip fracture has not been reported. It is known that recovery after hip fracture is slower in PD patients (Bliemel et al., 2015; Idjadi et al., 2005; Walker et al., 2013; Yuasa et al., 2013), and that the risk for dislocation after an elective hip THA is higher (Jämsen et al., 2014). Interestingly, diabetes was not associated with an increased risk for surgical complications after a hip fracture. This is consistent with another earlier study (Golinvaux et al., 2014).

The concentration of certain surgical procedures in bigger units is a theme being discussed. Concerning hip fractures, there is one earlier study (Laarhoven et al., 2015) showing that high-volume level II trauma centers performed better than level I trauma centers in hip fracture care. In agreement with this, we found that hospitals with more than 200 hip fracture operations performed better than ones with lower volumes (RR for readmission for complications was 0.80, 95% CI 0.73-0.88). However, patients treated at university hospitals had similar amounts of readmissions for complications in non-university hospitals. As the non-university hospitals in Finland are in practice level II trauma centers, the results of this thesis do not support the centralization of hip fracture patients to level I trauma centers. In an earlier study, no relationship between hip fracture care effectiveness and hospital volume was found (Sund, 2010). Instead of concentrating on acute care of hip fractures, patient pathway micro-level interventions and focus on rehabilitation seem to improve the efficiency of hip fracture care (Häkkinen & Sund, 2021).

## 8.4 PERSPECTIVES FOR FUTURE RESEARCH

A considerable achievement has been achieved during the past 30 years regarding the surgical treatment of hip fractures. A consensus has been reached that most FNF should be treated with arthroplasty rather than with osteosynthesis. We also know that when treating FNF, a cemented arthroplasty is more reliable than uncemented. Concerning trochanteric fractures, we know that osteosynthesis with extramedullary implants is a safe and cost-effective method, although comparable results can be obtained with intramedullary implants. However, when more detailed comparisons between different surgical methods are made, the advantages of one method over another are starting to be subtle. For example, different trochanteric nail implants seem to produce equal results (Shin et al., 2017). Newer and more expensive implants do not always lead to better results and may even be associated with more complications than more simple methods. Also, this thesis showed that total hip arthroplasty may lead to more complications than hemiarthroplasty and that trochanteric nails do not offer any advantage over extramedullary implants when treating trochanteric fractures. The above-mentioned means that it is often difficult to achieve good results towards perfectness. In this light, reliable implants, such as cemented hemiarthroplasty and extramedullary hip nails, represent good methods, and total hip arthroplasty or trochanteric nails methods are trying to reach perfection.

It has been suggested that other factors than the choice of the surgical method are more important to obtain optimal outcomes for hip fracture patients (Rogmark, 2020). These factors include the identification of patients at high risk for medical and surgical complications, optimal medical treatment of patients, and effective rehabilitation. At the moment, a considerable amount of resources is used to make various comparisons between different surgical methods or implants. It is possible, though, that these resources could be re-allocated more efficiently to find out what are optimal rehabilitation and treatment processes for hip fracture patients.

Prospective, randomized clinical trials (RCTs) are invaluable when the effects of well-defined surgical methods need to be found. In orthopedics, ground-breaking results have been obtained in elective surgery with the help of RCTs (Sihvonen et al., 2013; Beard et al., 2018). These, and other famous RCTs, share the common theme that elective surgery is studied and patient groups are rather homogeneous. When it comes to hip fracture treatment, the situation is different. Hip fracture surgery is urgent care. As mentioned above, we do not precisely know what are the major factors affecting treatment results. It, therefore, seems plausible that register studies could have a major role in perfecting hip fracture care. There are some successful hip fracture registries. This is where we should be more proactive, as orthopedic surgeons and other professionals are responsible for hip fracture care. Another feature that might lead to better results would be the publicity of treatment results of hospitals and other institutions taking care of hip fracture patients. A healthy competition for better outcomes would be beneficial for hip fracture patients.

# 9 CONCLUSIONS

I During the study period use of intramedullary implants for pertrochanteric fractures exceeded the use extramedullary implants in 2008 and thereafter. Femoral neck fractures were mostly treated with arthroplasty. The use of total hip arthroplasty increased after 2005 but hemiarthroplasty remained more popular type of arthroplasty.

II Concerning pertrochanteric fractures, the use of intramedullary implants was associated with higher mortality, more postoperative subtrochanteric and diaphyseal femoral fractures and more new operations on hip and thigh. The initial treatment costs were higher among patients treated with intramedullary implants compared to treatment with extramedullary implants. These results support the use of extramedullary implants in the treatment of most pertrochanteric fractures.

III The mortality at one week and one year was similar among patients receiving cemented and uncemented hemiarthroplasty for femoral neck fracture. Mechanical complications leading to readmission were less prevalent among patients receiving cemented HA. Patients treated with cemented hemiarthroplasty had less comorbidities and were more often discharged home than patients treated with uncemented hemiarthroplasty. These results support the use of cemented HA over uncemented HA for femoral neck fractures.

IV Among all patients treated for hip fracture, the rate for early (three months postoperatively) readmission for surgical complication was 4.6%. Comorbidities increasing risk for complications were heavy alcoholism, Parkinson's disease, pre-existing osteoarthritis and rheumatic disease. The other variables increasing risk for complications were fracture located in the neck of femur, an operative delay over three days and choice of total hip arthroplasty as the surgical method. These results should be acknowledged when trying to optimize the treatment of hip fracture patients.

# REFERENCES

Adams CI, Robinson CM, Court-Brown CM, McQueen MM 2001. Prospective randomized controlled trial of an intramedullary nail versus dynamic screw and plate for pertrochanteric fractures of the femur. J Orthop Trauma 15:394-400.

Ahn J, Man LX, Park S, Sodl JF, Esterhai JL 2008. Systematic review of cemented and uncemented hemiarthroplasty outcomes for femoral neck fractures. Clin Orthop Relat Res 466:2513-2518.

Alcock H, Moppett E, Moppett I 2021. Early mortality outcomes of patients with fragility hip fracture and concurrent SARS-CoV-2 infection: a systematic review and meta-analysis. Bone Jt Open 2:314-322.

Anglen JO, Weinstein JN 2008. Nail or plate fixation of intertrochanteric hip fractures: Changing pattern of practice. A review of the American Board of Orthopaedic Surgery Database. J Bone Joint Surg (Am) 90-A:700-707.

Aros B, Tosteson A, Gottlieb D, Koval K 2008. Is a sliding hip screw or IM nail the preferred implant for intertrochanteric fracture fixation? Clin Orthop Rel Res 466:2827-2832.

Audige L, HAnson B, Swiontkowski MF 2003. Implant-related complications in the treatment of unstable pertrochanteric fractures: meta-analysis of dynamic screw-plate versus dynamic screw-intramedullary nail implants. Int Orthop 27:197-203.

Auston P 2011. An introduction to propensity score methods for reducing the effects of confounding in observational studies. Multivar Behav Res 46:399-424.

Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR). Hip, Knee & Shoulder Arthroplasty: 2020 Annual Report, Adelaide; AOA, 2020: 1-474. [Accessed from: https://aoanjrr.sahmri.com/annual-reports-2020]

Azegami S, Gurusamy K, Parker M 2011. Cemented versus uncemented hemiarthroplasty for hip fractures: a systematic review of randomised controlled trials. Hip Int 21:509-517.

Balk EM, Ellis AG, Di M, Adam GP, Trikalinos TA 2017. Venous thromboembolism prophylaxis in major orthopedic surgery: Systematic review update. Comparative Effectiveness Review No. 191. (Prepared by the Brown Evidence-based Practice Center under Contract No. 290-2015-00002-I.) AHRQ Publication No. 17-EHC021-EF. Rockville, MD: Agency for Healthcare Research and Quality. www.effectivehealthcare.ahrq.gov/reports/final.cfm. DOI: https://doi.org/10.23970/AHRQEPCCER191.

Barton TM, Gleeson R, Topliss C, Greenwood R, Harries WJ, Chesser TJ 2010. A comparison of the long gamma nail with the sliding hip screw for the treatment of AO/OTA 31-A2 fractures of the proximal part of the femur. J Bone Joint Surg (Am) 92-A:792-798.

Beard DJ, Rees JL, Cook JA, Rombach I, Cooper C, Merritt N, Shirkey BA, Donovan JL, Gwilym S, Savulescu J, Moser J, Gray A, Jepson M, Tracey I, Judge A, Wartolowska K, Carr AJ, on behalf of the CSAW Study Group 2018. Lancet 391:329-338.

Beerekamp M, de Muinck Keizer R, Schep N, Ubbink D, Panneman M, Goslings J 2017. Epidemiology of extremity fractures in the Netherlands. Injury 48:1355-1362.

Bhandari M, Devereaux PJ, Swiontkowski MF, Tornetta III O, Obremskey W, Koval KJ, Nora S, Sprague S, Schemitsch EH, Guyana GH 2003. Internal fixation compared with arthroplasty for displaced fractures of the femoral neck. J Bone Joint Surg (Am) 85-A:1673-1681.

Bhandari M, Devereaux PJ, Tornetta P, Swiontkowski MF, Berry DJ, Haidukewych GJ, Schemtisch EH, Hanson BP, Koval K, Dirschl D, Leece P, Keel M, Petrisor B, Heetveld M, Guyatt GH 2005. Operative management of displaced femoral neck fractures in elderly patients – an interbnational survey. J Bone Joint Surg (Am) 87:2122-2130.

Bhandari M, Schemitsch E, Jönsson A, Zlowodzki M, Haidukewych GJ 2009. Gamma nails revisited: Gamma nails versus compression hip screws in the management of intertrochanteric fractures of the hip: A meta-analysis. J Orthop Trauma 23:460-464.

Bhandari M, Einhorn TA, Guyatt G, Schemitsch EH, Zura RD, Sprague S, Frihagen F, Guerra-Farfan E, Kleinlugtenbelg YV, Poolman RW, Rangan A,

Bzovsky S, Heels-Ansdell D, Thabane L, Walter SD, Devereaux PJ, HEALTH Investigators 2019. Total hip arthroplasty or hemiarthroplasty for hip fracture. New Engl J Med 381:2199-2208.
Bliemel C, Oberkircher L, Eschbach D-A, Lechler P, Balzer-Geldsetzer M, Ruchholtz S, Buecking B 2015. Impact of Parkinson's disease on the acute care treatment and medium-term functional outcome in geriatric hip fracture patients. Arch Orthop Trauma Surg 135:1519-1526.
Blomfeldt R, Törnkvist H, Eriksson K, Söderkvist A, Ponzer S, Tidermark J 2007. A randomised controlled trial comparing bipolar hemiarthroplasty with total hip replacement for displaced intracapsular fractures of the femoral neck in elderly patients. Bone Joint J 89-B:160-165.
Bokshan SL, Marcaccio SE, Blood TD, Hayda RA 2018. Factors influencing survival following hip fracture among octogenarians and nonagerians in the United States. Injury 49:685-690.
Bonnaire F, Lein T, Fülling T, Bule P 2020. Reduced complication rates for unstable trochanteric fractures managed with third-generation nails: Gamma 3 nail versus PFNA. Eur J Trauma Emerg Surg 46:955-962.
Boopalan PR, Oh JK, Kim TY, Oh CW, Cho JW, Shon WY 2012. Incidence and radiologic outcome of intraoperative lateral wall fractures in OTA 31A1 and A2 fractures treated with cephalomedullary nailing. J Orthop Trauma 26:638-642.
Borens O, Wettstein M, Kombot C, Chevalley F, Mouhsine E, Garofalo R 2004. Long gamma nail in the treatment of subtrochanteric fractures. Arch Orthop Trauma Surg 124:443-447.
Bourrion B, Souty C, Fournier L, Vilcu A-M, Blanchon T, Boelle P-Y, Hanslik T, Francois M 2021. Bisphosphonate use and hospitalization for hip fractures in women: An observational population-based study in France. Int J Environ Res Public Health 18:8780.
Bretherton CP, Parker MJ 2016. Femoral medialization, fixation failures, and functional outcome in trochanteric hip fractures treated with either a sliding hip screw or an intramedullary nail from within a randomized trial. J Orthop Trauma 30:642-646.
Bridle SH, Patel AD, Bircher M, Calvert PT 1991. Fixation of pertrochanteric fractures of the femur: A randomised prospective comparison of the

gamma nail and the dynamic hip screw. J Bone Joint Surg (Br) 73-B:330-334.
Briot K, Maravic M, Roux C 2015. Changes in number and incidence of hip fractures over 12 years in France. Bone 81:131-137.
Brox WT, Chan PH, Cafri G, Inacio MCS 2016. Similar mortality with general or regional anesthesia in elderly hip fracture patients. Acta Orthop 87:152-157.
Buecking B, Eschbach D, Koutras C, Kratz T, Balzer-Geldsetzer M, Dodel R, Ruchholtz S 2013. Re-admission to Level 2 unit after hip-fracture surgery – Risk factors, reasons and outcome. Injury 44:1919-1925.
Burgers PT, Van Geene AR, Van den Bekerom MP, Van Lieshout EM, Blom B, Aleem IS, Bhandari M, Poolman RW 2012. Total hip arthroplasty versus hemiarthroplasty for displaced femoral neck fractures in the healthy elderly: a meta-analysis and systematic review of randomized trials. Int Orthop 36:1549-1560.
Burgers PT, Van Geene AR, van den Bekerom MP, van Lieshout EM, Blom B, Aleem IS, Bhandari M, Poolman RW 2021. Total hip arthroplasty versus hemiarthroplasty for displaced femoral neck fractures in the healthy elderly: a meta-analysis and systematic review of randomized trials. Int Orthop 36:1549-1560.
Butt MS, Krikler SJ, Nafie S, Ali MS 1995. Comparison of dynamic hip screw and gamma nail: a prospective, randomized, controlled trial. Injury 26:615-618.
Carpintero P, Caeiro J, Carpintero R, Morales A, Silva S, Mesa M 2014. Complications of hip fractures: A review. World J Orthop 5:402-411.
Carroll C, Stevenson M, Scope A, Evans P, Buckley S 2011. Hemiarthroplasty and total hip arthroplasty for treating primary intracapsular fracture of the hip: a systematic review and cost-effectiveness analysis. Health Technol Assess 15:1-74.
Cauley J, Chalhoub D, Kassem A, Fuleihan G 2014. Geographic and ethnic disparities in osteoporotic fractures. Nat Rev Endocrinol 10:338-351.
Chammout G, Muren O, Laurencikas E, Boden H, Kelly-Pettersson P, Sjöö H, Stark A, Sköldenberg O 2017. More complications with uncemented than

cemented femoral stems in total hip replacement for displaced femoral neck fractures in the elderly. Acta Orthop 88:145-151.
Christie J, Robinson CM, Singer B, Ray DC 1995. Medullary lavage reduces embolic phenomena and cardiopulmonary changes during cemented hemiarthroplasty. J Bone Joint Surg (Br) 77-B:456-459.
Clark D, Ahmed A, Baxendale B, Moran CG 2001. Cardiac output during hemiarthroplasty of the hip: a prospective, controlled trial of cemented and uncemented prostheses. J Bone Joint Surg (Br) 83-B: 414-418.
Cleary K 2009. National Patient Safety Report: mitigating surgical risk in patients undergoing hip arthroplasty for fractures of the proximal femur (NPSA/2009/RRR001). http://www.nrls.npsa.nhs.uk/resources/?EntryId45=59867 (Date last accessed October 7th, 2021)
Clement ND, Green K, Murray N, Duckworth AD, McQueen MM, Court-Brown CM 2013. Undisplaced intracapsular hip fractures in the elderly: predicting fixation failure and mortality. A prospective study of 162 patients. J Orthop Sci 18:578-585.
Costa M, Griffin X, Pendleton N, Pearson M, Parsons N 2011. Does cementing the femoral component increase the risk of peri-operative mortality for patients having replacement surgery for a fracture of the neck of femur? Data from the National Hip Fracture Database. J Bone Joint Surg (Br) 93-B: 1405-1412.
Costain D, Whitehouse S, Pratt N, Graves SE, Ryan P, Crawford RW 2011. Perioperative mortality after hemiarthroplasty related to fixation method. A study based on the Australian Orthopaedic Association National Joint Replacement Registry. Acta Orthop 82:275-281.
Crawford CH, Malkani AL, Cordray S, Roberts CS, Sligar W 2006. The trochanteric nail versus sliding hip screw for pertrochanteric hip fractures: a review of 93 cases. J Trauma 60:325-328.
Davidson D, Pike J, Garbuz D, Duncan CP, Masri PA 2008. Intraoperative periprosthetic fractures during total hip arthroplasty. Evaluation and management. J Bone Joint Surg (Am) 90-A:2000-2012.
DeAngelis JP, Ademi A, Staff I, Lewis CG 2012. Cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures: A

prospective randomized trial with early follow-up. J Orthop Trauma 26:135-140.
Donaldson AJ, Thomson HE, Harper NJ, Kenny NW 2009. Bone cement implantation syndrome. Br J Anaesth 102:12-22.
Duijnisveld BJ, Koenraadt KLM, Steenbergen LN, Bolder SBT 2020. Mortality and revision rate of cemented and uncemented hemiarthroplasty after hip fracture: an analysis of the Dutch Arthroplasty Register (LROI). Acta Orthop 91:408-413.
Edwards C, Counsell A, Boulton C, Moran CG 2008. Early infection after hip fracture surgery: risk factors, costs and outcome.Bone Joint J 90-B:770-777.
Egol K, Marcano A, Lewis L, Tejwani N, McLaurin T, Davidovitch R 2014. Can the use of an evidence-based algorithm for the treatment of intertrochanteric fractures of the hip maintain quality at a reduced cost? Bone Joint J 96-B:1192-1197.
Eliasen M, Groenkjaer M, Skov-Ettrup LS, Mikkelsen SS, Becker U, Tolstrup JS, Flensborg-Madsen T 2013. Preoperative alcohol consumption and postoperative complications. Ann Surg 258:930-942.
van Embden D, Rhemrev SJ, Meylaerts SA, Roukema GR 2010.
The comparison of two classifications for trochanteric femur fractures: the AO/ASIF classification and the Jensen classification. Injury 41:377-381.
van Embden D, Roukema GR, Rhemrev SJ, Genelin F, Meylaerts SA 2011.
The Pauwels classification for intracapsular hip fractures: is it reliable? Injury 42:1238-1240.
van Embden D, Rhemrev SJ, Genelin F, Meylaerts SA, Roukema GR 2012.
The reliability of a simplified Garden classification for intracapsular hip fractures. Orthop Traumatol Surg Res 98:405-408.
Emery R, Broughton N, Desai K, Bulstrode CJ, Thomas TL 1991. Bipolar hemiarthroplasty for subcapital fracture of the femoral neck. A prospective randomized trial of cemented Thompson and uncemented Moore stems. J Bone Joint Surg (Br) 73-B:322-324.
Esser MP, Kassab JY, Jones DH. Trochanteric fractures of the femur. A randomised prospective trial comparing the Jewett nail-plate with the dynamic hip screw. J Bone Joint Surg (Br) 68-B:557-560.

Farey JE, Cuthbert AR, Adie S, Harris IA 2021. Revision risk after unipolar or bipolar hemiarthroplasty for femoral neck fractures: An instrumental variable analysis of 62,875 procedures from the Australian Orthopaedic Association National Joint Replacement Registry. J Bone Joint Surg (Am) 103:195-204.

Faroug R, Amanat S, Ockendon M, Shah SV, Gregory JJ 2014. The outcome of patients sustaining a proximal femur fracture who suffer from alcohol dependency. Injury 45:1076-1079.

Fichman SG, Mäkinen TJ, Safir O, Vincent A, Lozano B, Kashigar A, Kuzyk PR 2016. Arthroplasty for unstable pertrochanteric hip fractures may offer a lower re-operation rate as compared to cephalomedullary nailing. Int Orthop 40:15-20.

Fields AC, Dieterich JD, Buterbaugh K, Moucha CS 2015. Short-term complications in hip fracture surgery using spinal versus general anaesthesia. Injury 46:719-723.

Figved W, Opland V, Frihagen F, Jervidalo T, Madsen JE, Nordsletten L 2009. Cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures. Clin Orthop Relat Res 467:2426-2435.

Flodin L, Laurin A, Lökk J, Cederholm T, Hedström M 2016. Increased 1-year survival and discharge to independent living in overweight hip fracture patients. Acta Orthop 87:146-151.

Florschutz AV, Langford JR, Haidukewych GJ, Koval KJ 2015. Femoral neck fractures: current management. J Orthop Trauma 29:121-129.

Forsen L, Sögaard A, Holvik K, Meyer H, Omsland T, Stigum H, Dahl C 2020. Geographic variations in hip fracture incidence in a high-risk country stretching into the Arctic: a NOREPOS study. Osteoporos Int 31:1323-1331.

Forte ML, Virnig BA, Kane RL, Durham S, Bhandari M, Feldman R, Swiontkowski MF 2008. Geographic variation in implant use for pertrochanteric hip fractures. J Bone Joint Surg (Am) 90-A:691-699.

Foster A, Thompson N, Wong J, Charlwood AP 2005. Periprosthetic femoral fractures – a comparison between cemented and uncemented hemiarthroplasties. Injury 36:424-429.

Franzo A, Francescutti C, Simon G 2005. Risk factors correlated with post-operative mortality for hip fracture surgery in the elderly: A population-based approach. Eur J Epidemiol 20:985-991.

Frihagen F, Nordsletten L, Madsen JE 2007. Hemiarthroplasty or internal fixation for intracapsular displaced femoral neck fractures: randomized controlled trial. BMJ 335:1251-1254.

Frisch NB, Wessell N, Charters M, Greenstein A, Shaw J, Peterson E, Guthrie ST 2018. Hip fracture mortality: Differences between intertrochanteric and femoral neck fractures. J Surg Ortho Adv 27:64-71.

Frisch NB, Wessell N, Jildeh TR, Greenstein A, Guthrie ST 2018. Early-stage chronic kidney disease and hip fracture mortality. J Surg Ortho Adv 27:226-230.

Garden R 1961. Low-angle fixation in fractures of the femoral neck. J Bone Joint Surg (Br) 43-B:647-663.

Gelberman RH, Samson D, Mirza SK, Callaghan JJ, Pellegrini VD 2010. Orthopaedic surgeons and the medical implant industry: The threat to scientific integrity and the public trust. J Bone Joint Surg (Am) 92-A:765-777.

Gjertsen JE, Fevang JM, Matre K, Vinje T, Engesaeter LB 2011. Clinical outcome after undisplaced femoral neck fractures. Acta Orthop 82:268-274.

Gjertsen JE, Baste V, Fevang J, Furnes O, Engesaeter LB 2016. Quality of life following hip fractures: results from the Norwegian hip fracture register. BMC Musculoskelet Disord 17:265.

Gjertsen JE, Dybvik E, Furnes O, Fevang JM, Havelin LI, Matre K, Engesaeter LB 2017. Improved outcome after hip fracture surgery in Norway. Acta Orthop 88:505-511.

Glassner PJ, Tejwani NC 2011. Failure of proximal femoral locking compression plate: A case series. J Orthop Trauma 25:76-83.

Golinvaux NS, Bohl DD, Basques BA, Baumgaertner MR, Grauer JN 2014. Diabetes confers little to no increased risk of postoperative complications after hip fracture surgery in geriatric patients. Clin Orthop Relat Res 473:1043-1051.

Griffin J, Anthony TL, Murphy DK, Brennan KL, Brennan ML 2016. What is the impact of age on reoperation rates for femoral neck fractures treated with internal fixation and hemiarthroplasty? A comparison of hip fracture outcomes in the very elderly population. J Orthop 13:33-39.

Guyen O 2019. Hemiarthroplasty or total hip arthroplasty in recent femoral neck years? Orthop Traumatol Surg Res 105:S95-S101.

Guzon-Illescas O, Fernandez EP, Villarias NC, Donate FJ, Pena M, Alonso-Blas C, Garcia-Vadillo A, Mazzucchelli R 2019. Mortality after osteoporotic hip fracture: incidence, trends, and associated factors. J Orthop Surg Res 14:203.

Haentjens P, Lamraski G, Boonen S 2005. Costs and consequences of hip fracture occurrence in old age: An economic perspective. Disabil Rehab 27:1129-1141.

Haidukewych GJ, Israel TA, Berry DJ 2001. Reverse obliquity fractures of the intertrochanteric region of the femur. J Bone Joint Surg (Am) 83-A:643-650.

Haleem S, Lutchman L, Mayahi R, Grice JE, Parker MJ 2008. Mortality following hip fracture: Trends and geographical variations over the last 40 years. Injury 39:1157-1163.

Hansson S, Rolfson O, Åkesson K, Nemes S, Leonardsson O, Rogmark C 2015. Complications and patient-reported outcome after hip fracture. A consecutive annual cohort study of 664 patients. Injury 46:2206-2211.

Hansson S, Bülow E, Garland A, Kärrholm J, Rogmark C 2020. More hip complications after total hip arthroplasty than after hemi-arthroplasty as hip fracture treatment: analysis of 5,815 matched pairs in the Swedish Hip Arthroplasty Register. Acta Orthop 91:133-138.

Hartholt KA, Oudshoorn C, Zielinski SM, Burgers PT, Panneman MJ, van Beeck EF, Patka P, van der Cammen TJ 2011. The epidemic of hip fractures: Are we on the right track? PLoS One 6:e22227.

Hasan A, Pozzi M, Hamilton JR 2000. New surgical procedures: can we minimise the learning curve? BMJ 320:171-173.

Haukka J, Suvisaari J, Tuulio-Henriksson A, Lönnqvist J 2007. High concordance between self-reported medication and official prescription database information. Eur J Clin Pharmacol 63:1069-1074.

Herndon J, Bechtol C, Crickenberger D 1974. Fat embolism during total hip replacement: A prospective study. J Bone Joint Surg (Am) 56-A:1350-1362.
Hesse B, Gächter A 2004. Complications following the treatment of trochanteric fractures with the gamma nail. Arch Orthop Trauma Surg 124:692-698.
Hines CB 2018. Understanding bone cement implantation syndrome. AANA J 86: 433-441.
Hoffmann M, Hartel M, Rueger JM, Lehmann W 2014. Primary prosthetic replacement in per- and intertrochanteric fractures. Eur J Trauma Emerg Surg 40:273-277.
Hongisto M, PIhlajamäki H, Niemi S, Nuotio M, Kannus P, Mattila V 2014. Surgical procedures in femoral neck fractures in Finland: a nationwide study between 1998-2011. Int Orthop 38:1685-1690.
Hui AW, Anderson GH, Choudhry R, Boyle J, Gregg PJ 1994. Internal fixation or hemiarthroplasty for undisplaced fractures of the femoral neck in octogenarians. J Bone Joint Surg (Br) 76-B:891-894.
Hunter GA 1975. The results of operative treatment of trochanteric fractures of the femur. Injury 6:202-205.
Häkkinen U 2011. The PERFECT project: measuring performance of health care episodes. Ann Med 43:S1-S3.
Häkkinen U 2017. Description of PERFECT datab ase, http://www.thl.fi/en/web/thlfi-en/research-and-expertwork/projects-and-programmes/projects/21963 (Last accessed 10 April 2017, updated 2 January 2017).
Häkkinen U, Sund R 2021. What works? The association of organisational structure, reforms and interventions on efficiency in treating hip fractures. Soc Sci Med 274:113611.
Härstedt M, Rogmark C, Sutton R, Melander O, Fedorowski A 2015. Impact of comorbidity on 6-month hospital readmission and mortality after hip fracture surgery. Injury 46:713-718.
Idjadi J, Aharonoff GB, Su H, Richmond H, Egol KA, Zuckermann JD, Koval KJ 2005. Hip fracture outcomes in patients with Parkinson’ disease. Am J Orthop 34:341-346.

Inngul C, Blomfeldt R, Ponzer S, Enocson A 2015. Cemented versus uncemented arthroplasty in patients with a displaced fracture of the femoral neck: a randomised controlled trial. Bone Joint J 97-B:1475-1480.

Iwakura T, Niikura T, Lee SY, Sakai Y, Nishida K, Kuroda R, Kurosaka M 2013. Breakage of a third generation gamma nail: A case report and review of the literature. Case Rep Orthop vol 2013, Article ID 172352.

Jain NP, Jowett AJ, Clarke NM 2007. Learning curves in orthopaedic surgery: a case for super-specialisation. Ann R Coll Surg Engl 89:143-146.

Jameson SS, Lees D, James P, Johnson A, Nachtsheim C, McVie JL, Rangan A, Muller SD, Reed MR 2013. Cemented hemiarthroplasty or hip replacement for intracapsular neck of femur fracture? A comparison of 7732 matched patients using national data. Injury 44:1940-1944.

Jensen JS 1980. Classification of trochanteric fractures. Acta Orthop Scand 51:803-810.

Jewett EL 1941. One-piece angle nail plate for trochanteric fractures. J Bone Joint Surg (Am) 23-A:803-810.

Johansen A, Golding D, Brent L, Close J, Gjertsen J-E, Holt G, Hommel A, Pedersen AB, Röck ND, Thorngren K-G 2017. Using national hip fracture registries and audit databases to develop an international perspective. Injury 48:2174-2179.

Jones HW, Johnston P, Parker M 2006. Are short femoral nails superior to the sliding hip screw? A meta-analysis of 24 studies involving 3,279 fractures. Int Orthop 30:69-78.

De Jong L, Klem TM, Kuijper TM, Roukema GR 2017. Factors affecting the rate of surgical site infection in patients after hemiarthroplasty of the hip following a fracture of the neck of the femur. J Bone Joint Surg (Br) 99-B:1088-1094.

Jämsen E, Puolakka R, Peltola M, Eskelinen A, Lehto MUK 2014. Surgical outcomes of primary hip and knee replacements in patients with Parkinson’s disease: a nationwide registry-based case-controlled study. Bone Joint J 96-B:486-491.

Kanis JA, Odén A, McCloskey EV, Johansson H, Wahl DA, Cooper C 2012. A systematic review of hip fracture incidence and probability of fracture worldwide. Osteoporos Int 23:2239-2256.

Kannus P, Niemi S, Parkkari J, Palvanen M, Vuori I, Järvinen M 2006. Nationwide decline in incidence of hip fracture. J Bone Min Res 21:1836-1838.

Kannus P, Niemi S, Parkkari J, Sievänen H 2018. Continuously declining incidence of hip fracture in Finland. Arch Gerontol Ger 77:64-67.

Katsoulis M, Benetou V, Karapetyan T, Feskanich D, Grodstein F, Petterson-Kymmer U, Eriksson S, Wilsgaard T, Jörgensen L, Ahmed LA, Schöttker B, Brenner H, Bellavia A, Wolk A, Kubinova R, Stegeman B, Bobak M, Boffetta B, Trichopoulou A 2017. Excess mortality after hip fracture in elderly persons from Europe and USA: the CHANCES project. J Intern Med 281:300-310.

Kazley JM, BAnerjee S, Abousayed MM, Rosenbaum AJ 2018. Classifications in Brief: Garden classification of femoral neck fractures. Clin Orthop Rel Res 476:441-445.

Kibble K, Peck SC, Parikh HR, Flagstad I, Gorman T, Okelana AB, Cunningham BP 2020. Geriatric femoral neck fractures: Hemiarthroplasty implant trends across a health system from 2006 to 2018. Ger Orthop Surg Rehab 11:1-7.

Kim SY, Kim YG, Hwang JK 2005. Cementless calcar-replacement hemiarthroplasty compared with intramedullary fixation of unstable intertrochanteric fractures. A prospective, randomized study. J Bone Joint Surg (Am). 87-A:2186-2192.

Korhonen N, Niemi S, Parkkari J, Sievänen H, Palvanen M, Kannus P 2013. Continuous decline in incidence of hip fracture: nationwide statistics from Finland between 1970 and 2010. Osteoporos Int 24:1599-1603.

Kosola J, Kaipia A, Laitinen MK, Nieminen J 2017. Complications after surgical treatment of femoral neck fractures in men wigh alcohol dependence syndrome: retrospective register analysis of 154 cases. Arch Orthop Trauma Surg 137:967-973.

Kukla C, Heinz T, Gaebler C, Heinze G, Vecsei V 2001. The standard Gamma nail: a critical analysis of 1,000 cases. J Trauma 51:77-83.

Kumar P, Rainish RK, Neradi D, Kumar V, Agarwal S, Aggarwal S 2019. Hemiarthroplasty for neck of femur fractures: to cement or not? A systematic review of literature and meta-analysis. European J Orthop Surg Traumatology 29:731-746.

Kunkel ST, Sabatino MJ, Kang R, Jevsevar DS, Moschetti WE 2018. A systematic review and meta-analysis iof the direct anterior approach for hemiarthroplasty for femoral neck fracture. Eur J Orthop Surg Traumatol 28:217-232.

Kyriacou H, Khan WS 2020. Important perioperative factors, guidelines and outcomes in the management of hip fractures. J Perioper Pract 31:140-146.

Laarhoven J, Lammeren G, Houwert R, Laarhoven C, Hietbrink F, Leenen L, Verleisdonk EJ 2015. Isolated hip fracture care in an inclusive trauma system: A trauma system wide evaluation. Injury 46:1042-1046.

Lafont N, Kalonji M, Barre J, Guillaume C, Boogaerts JG 1997. Clinical features and echocardiography of embolism during cemented hip arthroplasty. Can J Anesth 44:112-117.

Lahti R, Penttilä A 2003. Cause-of-death query in validation of death certification by expert panel: effects on mortality statistics in Finland, 1995. Forensic Sci Int 131:113-124.

Langlois J, Delambre J, Klouche S, Faivre B, Hardy P 2015. Direct anterior Hueter approach is a safe and effective approach to perform a bipolar hemiarthroplasty for femoral neck fracture. Acta Orthop 86: 358-362.

LeBlanc K, Muncie H, LeBlanc L 2014. Hip fracture: Diagnosis, treatment, and secondary prevention. Am Fam Phys 89:945-951.

Lee T-C, Ho P-S, Lin H-T, Ho M-L, Huang H-T, Chang J-K 2017. One-year readmission risk and mortality after hip fracture surgery: A national population-based study in Taiwan. Aging Dis 8:402-409.

Leonardsson O, Kärrholm J, Åkesson K, Garellick G, Rogmark C 2012. Higher risk of reoperation for bipolar and uncemented hemiarthroplasty. Acta Orthop 83:459-466.

Leonardsson O, Garellick G, Kärrholm J 2012. Changes in implant choice and surgical technique for hemiarthroplasty. 21,346 procedures from the Swedish Hip Arthroplasty Register 2005-2009. Acta Orthop 83:7-13.

Leonardsson O, Rolfson O, Hommel A, Garellick G, Åkesson K, Rogmark C 2013. Patient-reported outcome after displaced femoral neck fracture: a national survey of 4467 patients. J Bone Joint Surg (Am) 95:1693-1699.
Lewis DP, Waever D, Thorninger R, Donnelly WJ 2019. Hemiarthroplasty vs total hip arthroplasty for the management of displaced neck of femur fractures: A systematic review and meta-analysis. J Arthroplasty 34:1837-1843.
Lin FF, Chen YF, Chen B, Lin CH, Zheng K 2019. Cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures: A meta-analysis of randomized controlled trials. Medicine 98:e14634.
Lucas R, Martins A, Severo M, Silva P, Monjardino T, Rita Gaio A, Cooper C, Barros H 2017. Quantitative modelling of hip fracture trends in 14 European countries: testing variations of a shared reversal over time. Sci Rep 7:3754.
Lunetta P, Lounamaa A, Sihvonen S 2007. Surveillance of injury-related deaths: medicolegal autopsy rates and trends in Finland. Inj Prev 13:282-284.
Luo X, He S, Li Z, Huong D 2012- Systematic review of cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures in older patients. Arch Orthop Trauma Surg 132: 455-463.
Ma H-H, Chou T-F, Tsai S-W, Chen C-F, Wu P-K, Chen W-M 2019. Outcomes of internal fixation versus hemiarthroplasty for elderly patients with an undisplaced femoral neck fracture: a systematic review and meta-analysis. J Orthop Surg Res 14:320.
Malchau H, Garellick G, Berry D, Harris WH, Robertson O, Kärrholm J, Lewallen D, Bragdon CR, Lidgren L, Herberts P 2018. Arthroplasty implant registries over the past five decades: Development, current, and future impact. J Orthop Res 36:2319-2330.
Matsuo M, Yamagami T, Higuchi A 2018. Impact of age on postoperative complication rates among elderly patients with hip fracture: a retrospective matched study. J Anesth 32:452-456.
Mattisson L, Bojan A, Enocson A 2018. Epidemiology, treatment and mortality of trochanteric and subtrochanteric hip fractures: data from the Swedish fracture register. BMC Musculoskelt Disord 19:369.

Mavrogenis AF, Panagopoulos GN, Megaloikonomos PD, Igoumenou VG, Galanopoulos I, Vottis CT, Karabinas P, Koulouvaris P, Kontogeorgakos VA, Vlamis J, Papagelopoulos PJ 2016. Complications after hip nailing for fractures. Orthopaedics 39:e108-116.

McCaffrey DF,. Griffin BA, Almirall D, Slaughter ME, Ramchand R, Burgette LF 2013. A tutorial on propensity score estimation for multiple treatments using generalized boosted models. Stat Med 32:3388-3414.

Miettinen SA, Mäkinen T, Kostensalo I, Mäkelä K, Huhtala H, Kettunen JS, Remes V 2016. Risk factors for intraoperative calcar fracture in cementless hip arthroplasty. Acta Orthop 87:113-119.

Moerman S, Mathijssen NM, Niesten DD, Riedijk R, Rijnberg WJ, Koëter S, van de Hei, KK, Tuinebreijer WE, Molenaar TL, Nelissen RG, Vochteloo AJ 2017. More complications in uncemented compared to cemented hemiarthroplasty for displaced femoral neck fractures: a randomized controlled trial 201 patients, with one year follow-up. BMC Musculoskel Disord 18:169.

Mundi S, Pindiprolu B, Simunovich N, Bhandari M 2014. Similar mortality rates in hip fracture patients over the past 31 years. Acta Orthop 85:1-6.

Mäkinen TJ, Gunton M, Fichman SG, Kashigar A, Safir O, Kuzyk PR 2015. Arthroplasty for pertrochanteric hip fractures. Orthop Clin North Am 46:433-444.

National Institute for Health and Care Excellence. Hip fracture: the management of hip fracture in adults. NICE clinical guideline 124. NICE, 2011, updated in 2017.

Neuburger J, Currie C, Wakeman R, Tsang C, Plant F, De Stavola B, Cromwell DA, van der Meulen J 2015. The impact of a national clinician-led audit initiative on care and mortality after hip fracture in England: an external evaluation using time trends in non-audit data. Med Care 53:686-691.

Newey M, Ricketts D, Roberts L 1993. The AO classification of long bone fractures: an early study of its use in clinical practice. Injury 24:309-315.

Norris R, Bhattacharjee D, Parker MJ 2012. Occurrence of secondary fracture around intramedullary nails used for trochanteric hip fractures: A systematic review of 13,568 patients. Injury 43:706-711.

Onativia IJ, Slulittel PA, Diaz Dilernia F, Gionzales Viezcas JM, Vietto V, Ramkumar PN, Buttaro MA, Piuzzi NS 2018. Outcomes of nondisplaced intracapsular femoral neck fractures with internal screw fixation in elderly patients: a systematic review. Hip Int 28:18-28.

Pajarinen J, Savolainen V, Tulikoura I, Lindahl J, Hirvensalo E 2003. Factors predisposing to dislocation of the Thompson hemiarthroplasty: 22 dislocations in 338 patients. Acta Orthop Scand 74:45-48.

Pajunen P, Koukkunen H, Ketonen M, Jerkkola T, Immonen-Räihä P, Kärjä-Koskenkari P, Mähönen M, Niemelä M, Kuulasmaa K, Palomäki P, Mustonen J, Lehtonen A, Arstila M, Vuorenmaa T, Lehto S, Miettinen H, Torppa J, Tuomilehto J, Kesäniemi YA, Pyörälä K, Salomaa V 2005. The validity of the Finnish Hospital Discharge Register and Causes of Death Registry data on coronary heart disease. Eur J Cardiovasc Prev 12:132-137.

Panula J, Pihlajamäki H, Mattila VM, Jaatinen P, Vahlberg T, Aarnio P, Kivelä S-L 2011. Mortality and cause of death in hip fracture patients aged 65 or older – a population-based study. BMC Musculoskel Dis 12:105.

Parker MJ, Currie CT, Mountain JA, Thorngren KG 1998. Standardised audit of hip fracture in Europe (SAHFE). Hip Int 8:10-15.

Parker MJ, Gurusamy K 2006. Internal fixation versus arthroplasty for intracapsular proximal femoral fractures in adults. Cochrane Database Syst Rev. CD001708. Doi: 10.1002/14651858.CD001708.pub2.

Parker MJ, Johanson A 2006. Clinical review: hip fracture. BMJ 333:27-30.

Parker MJ 2008. Databases for hip fracture audit. Acta Orthop 79:577-579.

Parker MJ, Handoll H 2010. Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults. Cochrane Database Syst Rev 9:CD000093.

Parker MJ, Pryor G, Gurusamy KS 2010. Cemented versus uncemented hemiarthroplasty for intracapsular hip fractures: A randomizedn controlled trial in 400 patients. J Bone Joint Surg (Br) 92-B: 116-122.

Parker MJ, Gurusamy KS, Azegamy S 2010. Arthroplasties (with and without bone cement) for proximal femoral fractures in adults. Cochr Database Syst Rev CD001706. DOI:10.1002/14651858.CD001706.pub4

Parker MJ, Bowers TR, Pryor GA 2012. Sliding hip screw versus the Targon PF nail in the treatment of trochanteric fractures of the hip: A randomised study of 600 fractures. J Bone Joint Surg (Br) 94-B:391-397.
Parker MJ 2012. Cemented Thompson hemiarthroplasty versus cemented Exeter Trauma Stem (ETS) hemiarthroplasty for intracapsular hip fractures: A randomized trial of 200 patients. Injury 43:807-810.
Parker MJ, Raval P, Gjertsen J-E 2018. Nail or plate fixation for A3 trochanteric hip fractures: A systematic review of randomised controlled trials. Injury 49:1319-1323.
Parker MJ, Cawley S 2020. Cemented or uncemented hemiarthroplasty for displaced intracapsular fractures of the hip: a randomized trial of 400 patients. Bone Joint J 102-B:11-16.
Parvizi J, Johnson B, Rowland C, Ereth MH, Lewallen DG 2001. Thirty-day mortality after elective total hip arthroplasty. J Bone Joint Surg (Am) 83-A:1524-1528.
Pauwels F 1935. Der Schenkelhalsbruch, ein mechanisches problem. Stuttgart: F. Enke.
Pekonen SR, Kopra J, Kröger H, Rikkonen T, Sund R 2021. Regional and gender-specific analyses give new perspectives for secular trend in hip fracture incidence. Osteoporos Int 32:1725-1733.
Peltola M, Juntunen M, Häkkinen U, Rosenqvist G, Seppälä TT, Sund R 2011. A methodological approach for register-based evaluation of cost and outcomes in health care. Ann Med 43:S4-S13.
Perry DC, Metcalfe D, Griffin XL, Costa ML 2016. Inequalities in use of total hip arthroplasty for hip fracture: population based study. BMJ 353:i2021.
Phillips JR, Moran CG, Manktelow AR 2013. Periprosthetic fractures around hip hemiarthroplasty performed hip fracture. Injury 44:757-762.
Pitto R, Blunk J, Kössler M 2000. Transesophageal echocardiography and clinical features of fat embolism during cemented total hip arthroplasty. A randomized study in patients with a femoral neck fracture. Acta Orthop Trauma Surg 120:53-58.
Pollmann CT, Dahl FA, Rötterud JH, Gjersten J-E, Åröen A 2020. Surgical site infection after hip fracture – mortality and risk factors: an observational cohort study of 1,709 patients. Acta Orthop 91:347-352.

Queally JM, Harris E, Handoll HH, Parker MJ 2014. Intramedullary nails for extracapsular hip fractures in adults. Cochrane Database Syst Rev 12:CD004961.
Radcliff TA, Regan E, Cowper Ripley DC, Hutt E 2012. Increased use of intramedullary nails for intertrochanteric proximal femoral fractures in Veterans Affairs hospitals. J Bone Joint Surg (Am) 94:833-840.
Rajaratnam A 2009. Current trends in the relationship between orthopaedic surgeons and industry (editorial). J Bone Joint Surg (Br) 91-B:1265-1266.
Richardson G, Lethbridge L, Dunbar M 2020. Increased mortality with the use of cementless fixation for femoral neck fractures: Analysis of 5883 hip arthroplasty cases. J Arthroplasty 35:3627-3630.
Robertson L, Black C, Fluck N, Gordon S, Hollick R, Nguyen H, Prescott G, Marks A 2018. Hip fracture incidence and mortality in chronic kidney disease: the GLOMMS-II record linkage cohort study. BMJ Open 8:e020312.
Rocca G, Inguaggiato M, Migliorini A 2007. Gamma nail surgical revision after 15 years of experience: results. Osteo Trauma Care 15:117-122.
Rogmark C, Johnell O 2006. Primary arthroplasty is better than internal fixation of displaced femoral neck fractures: A meta-analysis of 14 randomized studies with 2,289 patients. Acta Orthop 77:359-367.
Rogmark C, Flensburg L, Fredin H 2009. Undisplaced femoral neck fractures – no problems? A consecutive study of 224 patients treated with internal fixation. Injury 40:274-276.
Rogmark C, Spetz C-L, Garellick G 2010. More intramedullary nails and arthroplasties for treatment of hip fractures in Sweden – Registry analysis of 144,607 patients, 1998-2007. Acta Orthop 81:588-592.
Rogmark C, Leonardsson O, Garellick G, Kärrholm J 2012. Monoblock hemiarthroplasties for femoral neck fractures – A part of orthopaedic history? Analysis of national registration of hemiarthroplasties 2005-2009. Injury 43:946-949.
Rogmark C, Fenstad AM, Leonardsson O, Engesaeter LB, Kärrholm J, Furnes O, Garellick G, Gjertsen J-E 2014. Posterior approach and uncemented stems increases the risk of reoperation after hemiarthroplasties in

elderly hip fracture patients. An analysis of 33,205 procedures in the Norwegian and Swedish national registries. Acta Orthop 85:18-25.

Rogmark C, Kristensen MT, Viberg B, Rönnquist SS, Overgaard S, Palm H 2018. Hip fractures in the non-elderly – Who, why and whither? Injury 49:1445-1450.

Rogmark C 2020. Further refinement of surgery will not necessarily improve outcome after hip fracture. Acta Orthop 91:123-124.

Rosengren VE, Ahlborg HG, Mellström D, Nilsson J-Å, Björk J, Karlsson MK 2012. Secular trends in Swedish hip fractures 1987-2002. Birth cohort and period effects. Epidemiology 23:623-630.

Saez-Lopez P, Branas F, Sanchez-Hernandez N, Alonso-Garcia N, Gonzalez-Montalvo JI 2017. Hip fracture registries: utility, description, and comparison. Osteoporos Int 28:1157-1166.

Santini S, Rebeccato A, Bolgan I, Turi G 2005. Hip fractures in elderly patients treated with bipolar hemiarthroplasty: comparison between cemented and cementless implants. J Orthopaed Traumatol 6:80-87.

Sarpong NO, Herndon CL, Held MB, Neuwirth AL, Hickernell TR, Geller JA, Cooper HJ, Shah RP 2020. What is the learning curve for new technologies in total joint arthroplasty? A Review. Curr Reb Musculoskel Med 13:675-679.

Saudan M, Lubbeke A, Sadowski C, Riand N, Stern R, Hoffmeyer P 2002. Pertrochanteric fractures: is there and advantage to an intramedullary nail? A randomized, prospective study of 206 patients comparing the dynamic hip screw and proximal femoral nail. J Orthop Trauma 16:386-393.

Schumpelick W, Jantzen PM 1955. A new principle in the operative treatment of trochanteric fractures of the femur. J Bone Joint Surg (Am) 37-A:693-698.

Sciard D, Cattano D, Hussain M, Rosenstein A 2011. Perioperative management of proximal hip fractures in the elderly: the surgeon and the anesthesiologist. Minerva Anest 77:1-8.

Shin YS, Chae JE, Kang TW, Han SB 2017. Prospective randomized study comparing two cephalomedullary nails for elderly intertrochanteric

fractures: Zimmer natural nail versus proximal femoral nail antirotation II. Injury 48:1550-1557.
Sierra RJ, Timperley JA, Gie GA 2009. Contemporary cementing technique and mortality during and after Exeter total hip arthroplasty. J Arthropl 24:325-332.
Sihvonen R, Paavola M, Malmivaara A, Itälä A, Joukainen A, Nurmi H, Kalske J, Järvinen TL for the Finnish Degenerative Meniscal Lesion Study (FIDELITY) Group 2013. New Engl J Med 369:2515-2524.
van de Sijp MPL, van Delft D, Krijnen P, Niggebrugge AHP, Schipper IB 2018. Surgical approaches and hemiarthroplasty outcomes for femoral neck fractures: A meta-analysis. J Arthroplasty 33:1617-1627.
Singh GK, Deshmukh RG 2006. Uncemented Austin-Moore and cemented Thompson unipolar hemiarthroplasty for displaced fracture neck of femur – Comparison of complications and patient satisfaction. Injury 37:169-174.
Sims SH 2002. Subtrochanteric femoral fractures. Orthop Clin North Am 33:113-126.
Sjöstrand D, Hommel A, Johansson A 2013. Causes of surgical delay and demographic characteristics in patients with hip fracture. A one year Register Study of 484 patients. Open J Orthop 3:193-198.
Skinner JA, Kay PR, Hart AJ 2012. Introducing new joint replacements to clinical practice (Editorial). BMJ 344:d8188.
Sköldenberg O, Ekman A, Salemyr M, Boden H 2010. Reduced dislocation rate after hip arthroplasty for femoral neck fractures when changing from posterolateral to anterolateral approach. A prospective study of 372 hips. Acta Orthop 81:583-587.
Slobogean GP, Sprague SA, Scott T, Bhandari M 2015. Complications following young femoral neck fractures. Injury 46:484-491.
Smith T, Pelpola K, Ball M, Ong A, Myint PK 2014. Pre-operative indicators for mortality following hip fracture surgery: a systematic review and meta-analysis. Age Ageing 43:464-471.
Stappaerts KH, Deldycke J, Broos PL, Staes FF, Rommens PM, Claes P 1995. Treatment of unstable pertrochanteric fractures in elderly patients with

a compression hip screw or with the Vandeputte (VDP) endoprosthesis: A prospective randomized study. J Orthop Trauma 9:292-297.
Stern R 2007. Are there advances in the treatment of extracapsular hip fractures in the elderly? Injury 38:S77-S87.
Streubel PN, Moustoukas MJ, Obremskey WT 2013. Mechanical failure after locking plate fixation of unstable intertrochanteric femur fractures. J Orthop Trauma 27:22-28.
Stronach BM, Bergin PF, Perez JL, Watson S, Jones LC, McGwin G, Ponce BA 2020. The rising use of total hip arthroplasty for femoral neck fractures in the United States. Hip Int 30:107-113.
Stöen RÖ, Nordsletten L, Meyer HE, Frihagen JF, Falch JA, Lofthus CM 2012. Hip fracture incidence is decreasing in the high incidence area of Oslo, Norway. Osteoporos Int 23:2527-2534.
Sund R, Nurmi-Lüthje I, Lüthje P, Tanninen S, Narinen A, Keskimäki I 2007. Comparing properties of audit data and routinely collected register data in case of performance assessment of hip fracture treatment in Finland. Meth Inf Med 46:558-566.
Sund R 2010. Modeling the volume-effectiveness relationship in the case of hip fracture treatment in Finland. BMC Health Serv Res 10:238.
Sund R, Juntunen M, Lüthje P, Huusko T, Häkkinen U 2011. Monitoring the performance of hip fracture treatment in Finland. Ann Med 43:S39-S46.
Sund R 2012. Quality of the Finnish Hospital Discharge Register: a systematic review. Scand J Public Health 40:505-515.
Swart E, Makhni E, Macaulay W, Rosenwasser M, Bozic K 2014. Cost-effectiveness analysis of fixation options for intertrochanteric hip fractures. J Bone Joint Surg (Am) 96:1612-1620.
Sögaard A, Holvi K, Meyer H, Tell G, Gjesdal C, Emaus N, Grimnes G, Schei B, Forsmo S, Omsland T 2016. Continued decline in hip fracture incidence in Norway: a NOREPOS study. Osteoporos Int 27:2217-2222.
Talsnes O, Vinje T, Gjertsen JE, Dahl OE, Engesaeter LB, Baste V, Pripp AH, Reikerås O 2013. Perioperative mortality in hip fracture patients treated with cemented and uncemented hemiprosthesis: a register study of 11,210 patients. Int Orthop 37:1135-1140.

Talsnes O, Hjelmstedt F, Pripp A, Reikerås O, Dahl O 2013. No difference in mortality between cemented and uncemented hemiprosthesis for elderly patients with cervical hip fracture. A prospective randomized study on 334 patients over 75 years. Arch Orthop Trauma Surg 133:805-809.

Taylor F, Wright M, Zhu M 2012. Hemiarthroplasty of the hip with and without cement: A randomized clinical trial. J Bone Joint Surg (Am) 94:577-583.

Thakar C, Alsousou J, Hamilton T, Willett K 2010. The cost and consequences of proximal femoral fractures which require further surgery following initial fixation. Bone Joint J 92-B:1669-1677.

Thomsen N, Jensen C, Skovgaard N, Pedersen M, Pallesen P, Soe-Nielsen N, Rosenklint A 1996. Observer variation in the radiographic classification of fractures of the neck of the femur using Garden's system. Int Orthop 20:326-329.

Tsang S, Aitken S, Golay S, Silverwood R, Biant L 2014. When does hip fracture surgery fail? Injury 45:1059-1065.

Turesson E, Ivarsson K, Thorngren K-G, Hommel A 2018. Hip fractures – treatment and functional outcome. The development over 25 years. Injury 49:2209-2215.

Utrilla AL, Reig JS, Munoz FM, Tufanisco CB 2005. Trochanteric gamma nail and compression hip screw for trochanteric fractures – a randomized, prospective, comparative study in 210 elderly patients with a new design of the gamma nail. J Orthop Trauma 19:229-233.

Varley J, Parker M 2004. Stability of hip hemiarthroplasties. Int Orthop 28:274-277.

Veldman HD, Heyligers IC, Grimm B, Boymans TA 2017. Cemented versus cementless hemiarthroplasty for a displaced fracture of the femoral neck. A systematic review and meta-analysis of current generation hip stems. Bone Joint J 99-B:421-431.

Veronese N & Maggi S. 2018. Epidemiology and social costs of hip fracture. Injury 49:1458-1460.

Viberg B, Pedersen AB, Kjaersgaard A, Lauritsen J, Overgaard 2022. Risk of mortality and reoperation in hip fracture patients undergoing cemented versus uncemented hemiarthroplasty. Bone Joint J 104-B:127-133.
Walker RW, Chaplin A, Hancock RL, Rutherford R, Gray WK 2013. Hip fractures in people with idiopathic Parkinson's disease: Incidence and outcomes. Mov Disord 28:334-340.
Whitehouse MR, Berstock JR, Kelly MB, Gregson CL, Judge A, Sayers A, Chesser TJ 2019. Higher 30-day mortality associated with the use of intramedullary nails compared with sliding hip screws for the treatment of trochanteric hip fractures. Bone Joint J 101-B:83-91.
Wolf O, Sjöholm P, Hailer NP, Möller M, Mukka S 2020. Study protocol: HipSTHeR – a register-based randomised controlled trial – hip screws or (total) hip replacement for undisplaced femoral neck fractures in older patients. BMC Geriatr 20:19.
Wolf O, Mukka S, Ekelund J, Rogmark C, Möller M, Hailer NP 2021. Increased mortality after intramedullary nailing of trochanteric fractures: a comparison of sliding hip screws with nails in 19,935 patients. Acta Orthop (Epub ahead of print) https://doi.org/10.2340/17453674.2021.862
Xie H, Xie L, Wang J, Chen C, Zhang C, Zheng W. 2019. Intramedullary versus extramedullary fixation for the treatment of subtrochanteric fracture: A systematic review and meta-analysis. Int J Surg 63:43-57.
Xu BY, Yan S, Low LL, Vasanwala FF, Low SG 2019. Predictors of poor functional outcomes and mortality in patients with hip fracture: a systematic review. BMC Musculoskelet Disord 20:568.
Zou J, Xu Y, Yang H 2009. A comparison of proximal femoral nail antirotation and dynamic hip screw implants in trochanteric fractures. J Int Med Res 37:1057-1064.
Yuan Z, Dawson N, Cooper GS, Einstadter D, Cebul R, Rimm AA 2001. Effects of alcohol-related disease on hip fracture and mortality: A retrospective cohort study of hospitalized Medicare beneficiaries. Am J Public Health 91:1089-1093.

Yuasa T, Maezawa K, Nozawa M, Kaneko K 2013. Surgical outcome for hip fractures in patients with and without Parkinson's disease. J Orthop Surg (Hong Kong) 21:151-153.

# TERO YLI-KYYNY

This thesis provides information about the effect of surgical methods and patient-related risk factors on the outcome after hip fracture surgery. Cemented hemiarthroplasty (HA) was associated with less complications than other surgical options when femoral neck fractures were treated. In the treatment of pertrochanteric hip fractures, more expensive intramedullary implants did not result in better outcomes than extramedullary implants. Several patient-related risk factors for complications after hip fracture surgery were identified.

UNIVERSITY OF
EASTERN FINLAND

**uef.fi**

**PUBLICATIONS OF**
**THE UNIVERSITY OF EASTERN FINLAND**
Dissertations in Health Sciences

ISBN 978-952-61-4532-7
ISSN 1798-5706