UiT The Arctic University of Norway

Faculty of Health Sciences
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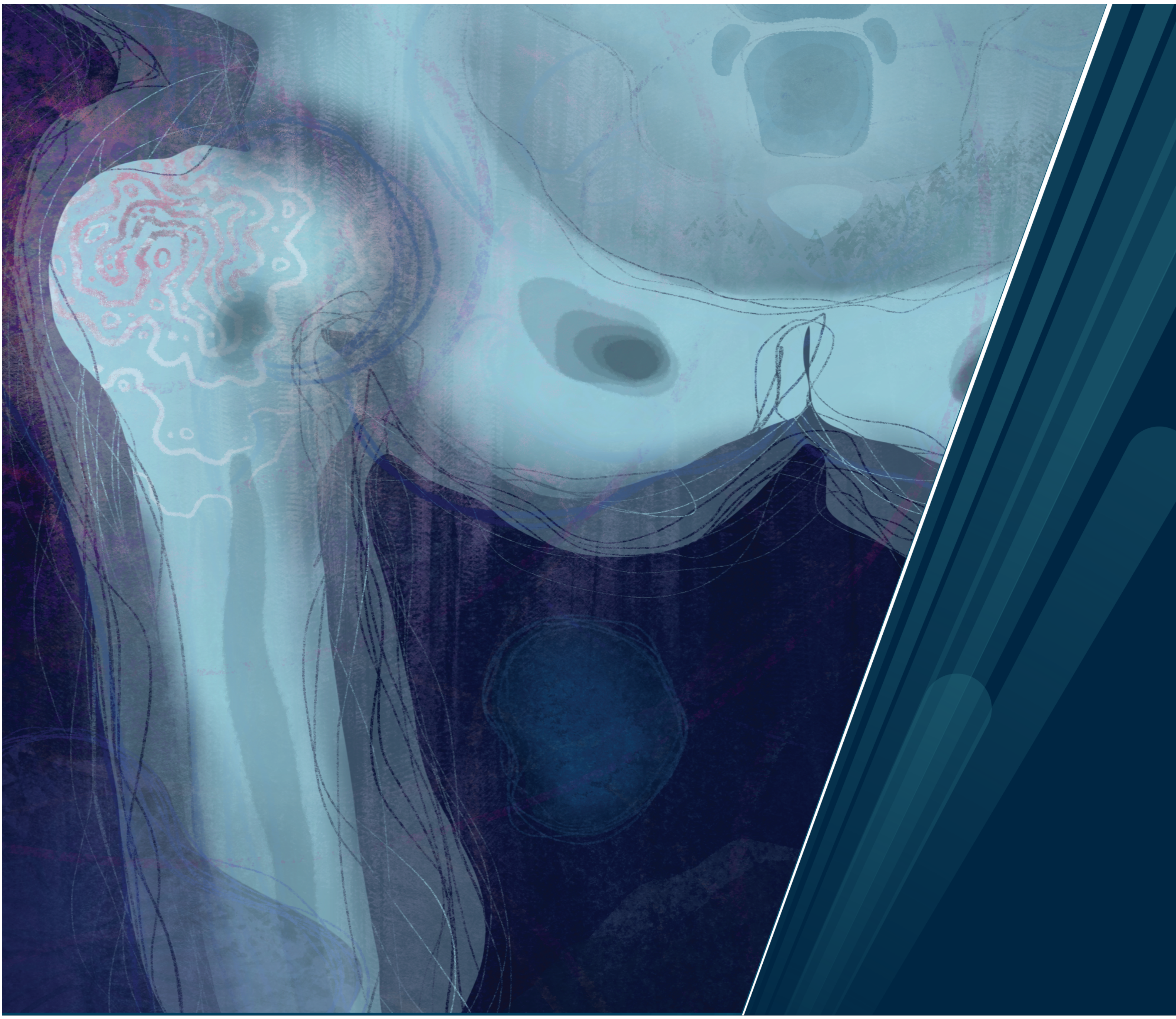
Hip fractures in Norway

Inequity in treatment and outcomes

Cato Kjærvik

A dissertation for the degree of Philosophiae Doctor May 2022



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Department of Community Medicine

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Department of Surgery

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"If all variation were bad, solutions would be easy. The difficulty is in reducing the bad variation, which reflects the limits of professional knowledge and failures in its application, while preserving the good variation that makes care patient centred."

A G Mulley (2010)[1]

Artwork on cover page by Maja Hassel - 2022

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1 Acknowledgements

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After I sent an e-mail to Barthold Vonen at CCDE in 2018 inquiring as to where I could find information on how many patients choose not to have surgery at their local hospital, and why, he responded with an invitation to join a project they were about to start and to answer this question myself. The opportunity to be a part of the KlinReg project from the beginning and to design my project with a team of experienced scientists and with my fellow PhD-students has been truly inspiring. Thank you Barthold, I am grateful that you let me be a part of this project and that you took on the role as my pragmatic main supervisor to meet the university policy.

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2 List of abbreviations

AAOS – American Academy of Orthopedic Surgeons

AO – Arbeitsgemeinschaft für Osteosynthesefragen

ASA – American Society of Anesthesiologists

CCI – Charlson Comorbidity Index

CI – Confidence Interval

EBG – Evidence Based Guidelines

EBM – Evidence Based Medicine

FNF – Femoral Neck Fracture

HA - Hemiarthroplasty

IMN – Intramedullary nail

KM – Kaplan-Meier

NHFR – Norwegian Hip Fracture Register

NICE – National Institute of Health and Care Excellence

NOA – Norwegian Orthopaedic Association

NOREPOS – Norwegian Epidemiologic Osteoporosis Studies

OTA – Orthopedic Trauma Association

RCT – Randomized Controlled Study

RHA – Regional Health Authority

SHS – Sliding Hip Screw

SMR – Standardized Mortality Ratio

THA – Total Hip Arthroplasty

3 List of publications

This thesis is based upon three papers, referred to in the text by their Roman numerals (I-III).

I. Kjaervik C, Stensland E, Byhring HS, Gjertsen J-E, Dybvik E, Soereide O.
Hip fracture treatment in Norway deviation from evidence-based treatment guidelines: data from the Norwegian Hip Fracture Register, 2014 to 2018[2].
Bone Jt Open 2020 Oct 14 (10):644-653. DOI: 10.1302/2633-1462.110.BJO-2020-0124.R1

II. Kjaervik C, Gjertsen J-E, Engeseter L, Stensland E, Dybvik E, Soereide O.
Waiting time for hip fracture surgery: hospital variation, causes, and effects on postoperative mortality: data on 37,708 reported operations to the Norwegian Hip Fracture Register from 2014 to 2018[3].
Bone Jt Open 2021 Sep; 2(9):710-720. DOI: 10.1302/2633-1462.29.BJO-2021-0079.R1

III. Kjaervik C, Gjertsen J-E, Stensland E, Saltyte-Benth J, Soereide O.
Hip fracture mortality in Norway 2014 to 2018 - modifiable and non-modifiable risk factors. A linked multi-registry study. Bone Joint J 2022;104-B (7): in press

4 Summary

Hip fractures commonly affect frail elderly people and have significant consequences for the patient and society. The aim of this research project was to examine variation in treatment and outcomes after hip fracture in Norway, explore explanations for and consequences of variation of in-hospital waiting time, and assess risk factors for death after hip fracture and their relative importance. The survival pattern and duration of excess mortality after hip fractures were also assessed.

The project was a retrospective study based on 41,699 recorded hip fractures in the National Hip Fracture Register (NHFR) from 2014 to 2018. Data from the NHFR were linked with data from the Norwegian Patient Registry and Statistics Norway. A survey of the services provided in all Norwegian hospitals treating hip fractures was also carried out.

The study showed a clear variation between Norwegian hospitals regarding adherence to evidence-based guidelines for treatment of hip fractures. Only 54.9% of patients received treatment as recommended in the guidelines. A main proportion of non-adherence was related to preoperative waiting time before treatment and the use of uncemented prosthetic stems. The average waiting time from admission to surgery was 23 hours. The longest waiting time was observed for patients with high comorbidity, and in hospitals with high patient volumes. Deviations from guidelines had consequences for patients in the form of increased mortality and increased reoperation rates. An increasing proportion of patients received recommended treatment towards the end of the study period. Patient factors (comorbidity, socioeconomic and residential status), and system factors (hospital volume and availability of orthogeriatric services) affected mortality and hence survival after hip fractures. Non-modifiable risk factors were more strongly associated to death than modifiable ones. Excess mortality measured by standardized mortality ratios (SMR) after hip fractures was initially high, with a SMR of 3.53 at one year. SMR remained high but falling during the first 24 months, then levelling off but was higher than the reference population (SMR 2.48) at six years.

Adherence to evidence-based guidelines for treatment of hip fractures varied considerably, with increasing adherence over the study period of five years. The waiting time from hospitalization to surgery was affected by both patient and system factors. Increased waiting time led to increased mortality for patients. Patient, socioeconomic and healthcare factors contributed to increased mortality after hip fractures. Hip fracture patients have significant excess mortality compared to the general population, especially the first year after the injury.

5 Sammendrag

Hoftebrudd rammer hovedsakelig eldre og skrøpelige mennesker og har betydelige konsekvenser for pasienten og samfunnet. Målet med forskningsprosjektet var å belyse variasjon i behandling og utfall etter hoftebrudd i Norge, kartlegge forklaringer på og konsekvensene av variasjon i ventetid i sykehus, vurdere risikofaktorer for død etter hoftebrudd og deres relative betydning. I tillegg ønsket man å vurdere overlevelsesmønsteret og estimere varigheten av overdødelighet etter hoftebrudd.

Prosjektet var en retrospektiv observasjonsstudie av innsamlede registerdata basert på 41699 hoftebrudd registrert i Nasjonalt hoftebruddregister fra 2014 til 2018. Data om disse pasientene ble koplet med personentydige data fra Norsk Pasientregister og Statistisk sentralbyrå. Det ble også gjennomført en kartlegging av tjenestetilbudet ved alle norske sykehus som rutinemessig behandler hoftebrudd.

Studien viste en tydelig variasjon mellom norske sykehus med hensyn til etterlevelse av kunnskapsbaserte retningslinjer for behandling av hoftebrudd og 54,9% av pasientene fikk behandling som anbefalt i retningslinjene. Manglende etterlevelse var spesielt relatert til preoperativ ventetid, og bruk av usementert protesestamme. Avvik fra retningslinjer hadde konsekvenser for pasientene, i form av økt dødelighet og økt reoperasjonsrate. En økende andel av pasientene fikk anbefalt behandling mot slutten av studieperioden. Gjennomsnittlig ventetid fra innleggelse til operasjon var 23 timer. Ventetiden var lengst for pasienter med høy komorbiditet, og i sykehus med stort volum. Forlenget ventetid økte dødeligheten etter operasjon. Pasientfaktorer (komorbiditet, sosioøkonomi og bostatus), og systemfaktorer (sykehusvolum og tilgjengelighet av ortogeriatriske tjenester) påvirket dødeligheten etter hoftebrudd. Ikke-modifiserbare risikofaktorer var sterkere assosiert til død enn modifiserbare. Overdødeligheten målt med Standardiserte Mortalitets Ratio (SMR) etter hoftebrudd var høy i begynnelsen, med en SMR på 3,53 etter ett år. SMR var vedvarende høy, men falt de første 24 månedene for så å flate ut på signifikant høyere nivå enn referansepopulasjonen etter 6 år (SMR 2.48).

Etterlevelse av kunnskapsbaserte retningslinjer for behandling av hoftebrudd varierte betydelig, med økende etterlevelse utover i studieperioden på 5 år. Ventetiden fra innleggelse til operasjon ble påvirket av både pasient- og systemfaktorer. Økt ventetid medfører økt dødelighet for pasientene. Pasient-, sosioøkonomiske og helsesystemfaktorer bidrar til økt dødelighet etter hoftebrudd. Hoftebruddpasienter opplever en betydelig overdødelighet sammenliknet med den generelle befolkningen, spesielt første året etter skaden.

6 Introduction

Equality in healthcare provision is a fundamental guiding principle in the Norwegian healthcare system. Equity for all inhabitants in treatment provided, whoever they are and wherever they live, is expected by patients, the public and politicians irrespective of political affiliation[4]. In the Assignment Document from the Ministry of Health and Care Services to the Regional Health Authorities (RHAs) in Norway in 2021, reduction of unwarranted variation is one (of many) directives to the RHAs[5]. The document encourages research addressing variation, particularly whether observed variation is unwarranted and whether it is an expression of over- or under-consumption of health services.

This thesis addresses inequity in treatment and offer a more comprehensive understanding of treatment outcomes after proximal femoral fractures in Norway.

6.1 Patient and societal burden of hip fractures

Proximal femoral fractures, commonly called hip fractures, are a potentially devastating injury in a fracture population consisting of mostly elderly people. On average, the Norwegian society see one hip fracture every hour of the year[6]. Table 1 presents a summary of statistics related to the hip fracture population in Norway 2014-2018.

	All patients	Women	Men
Median age (years)	83	84	80
Range (years)	4-105	4-105	6-104
Interquartile range (years)	76.0-90.0	77.5-90.5	71.5-88.5
% > 70 years of age	83.0	86.4	76.0

Table 1: Summary of statistics on hip fracture patients in Norway 2014-2018. Data from ***Paper III***

As pointed out by the Global Burden of Disease Collaborative Network[7], fractures in older people (the fourth most prevalent type being hip fractures) have a potential for disability, impaired quality of life, health loss and high healthcare costs, and are a major burden to individuals, families and society. Thus, it is of great importance to ensure the best possible and most equally distributed treatment for this group of patients.

Common treatment outcome denominators for these patients are a postoperative high mortality rate, reduced quality of life and a deterioration in post-treatment disability compared to pre-fracture status[8, 9]. Projections suggest that the health loss measured in disability adjusted life years is likely to double by 2040, with an associated increase of up to 65% including costs of surgery and total health and social care costs[10]. The Global Burden of Disease project estimates that years lived with disability were 2.94 million in 2019, an increase of 62% from 1999[7].

Treatment of hip fractures involves significant expenses for the healthcare system, in terms of both surgery and subsequent rehabilitation and care[10]. In a meta-analysis of 113 studies published in 2017, Williamson and coworkers[11] estimated the pooled cost for treatment in hospital for a hip fracture to be USD 10,075, and the total health and social care costs in the 12 months following a hip fracture to be a global mean of USD 43,669, which is greater than the costs following acute coronary syndrome (USD 32,345) and ischaemic stroke (USD 34,772).

Consequently, the burdens after a hip fracture are carried both by the patient and by society. The pre- and post-treatment pathway of care is intended to minimize the disease burden for the patient, and to reduce the strain on the healthcare system.

6.2 Pathogenesis and epidemiology

The pathogenesis of a hip fracture is multifactorial, but risk factors for fracture can be divided in two main groups[12]. The first group comprises factors that reduce bone mineral density and might lead to osteoporosis. Osteoporosis and reduced bone mineral density make bones weaker and more susceptible to fractures. The second group comprises factors that increase the risk and rate of falls, subjecting the patient to a mechanical trauma. Both osteoporosis and falls are common in elderly people.

In Norway, close to 9,000 patients experience a hip fracture every year[13]. North America and Europe have had the highest fracture rates and all the Scandinavian countries except Finland are among those with the highest incidence[14]. Epidemiology varies between countries, but globally it is estimated that hip fractures will affect around 18% of women and 6% of men during their lifetime[15]. The age-adjusted fracture rate in Norway for people over 50 years was 82/10,000 for women and 39/10,000 for men in 2007[16]. Sixty-nine percent of patients in Norway were women (2014-2018; ***Paper I***).

The age-specific incidence rate of hip fractures may be declining, especially in Western countries[17-19]. Data from the Norwegian Epidemiologic Osteoporosis Studies (NOREPOS) document similar trends in Norway, with women having the most marked decline in incidence[20, 21]. Figure 1 illustrates the changes in the number of hip fractures by age group in Norway in 2010, 2015 and 2020 based on data from the Norwegian Hip Fracture Register (NFHR). It is of note that the reduction is more marked in women than in men.

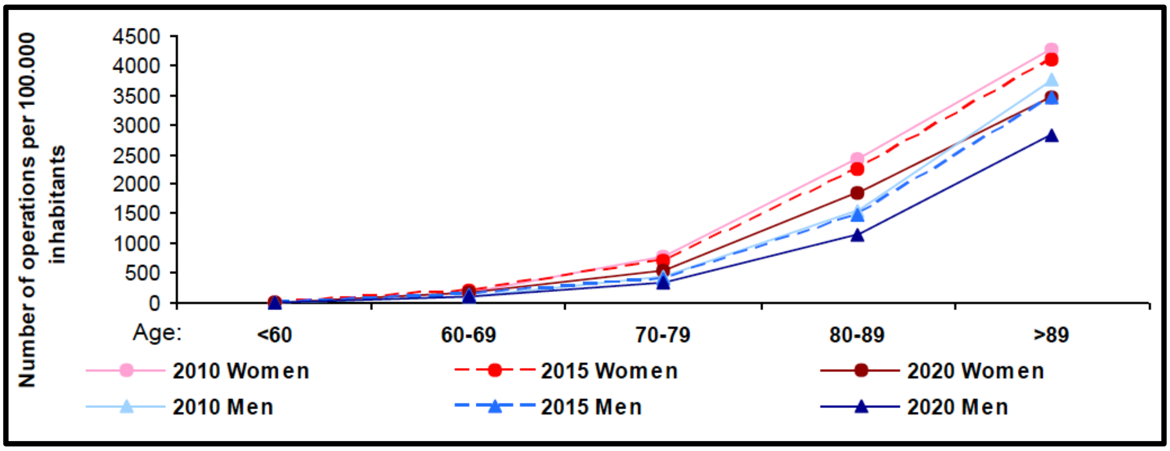

Figure 1: Incidence of primary operations for hip fractures (in 2010, 2015 and 2020) (Annual Report, Norwegian Hip Fracture Register, 2021. Reprinted with permission[6])

The reduction in incidence has not been fully explained, but several individual, environmental and societal causes have been proposed: better general health, improved vitamin D status, daily smoking reduction, fewer physically inactive people and better medication treatment of osteoporosis[21]. Interestingly, however, the rates of second hip fractures were unchanged.

It is estimated that an annual decline in hip fracture rates of 1.2-2.2% is required to counteract the effect of a growing population and an increase in life expectancy[22]. The number of hip fractures is, on balance, expected to increase owing to the growing population and increased longevity, which outweigh the decline in incidence[10].

For society, a strong focus on primary and secondary prevention to reduce the number of fractures will be increasingly important. Secondly, optimal treatment of the injured patients is needed to reduce the disease burden of the patients and consequences for health services.

6.3 Classification

Proximal femoral fractures comprise all fractures in the anatomical proximal part of the femoral bone (Figure 2).

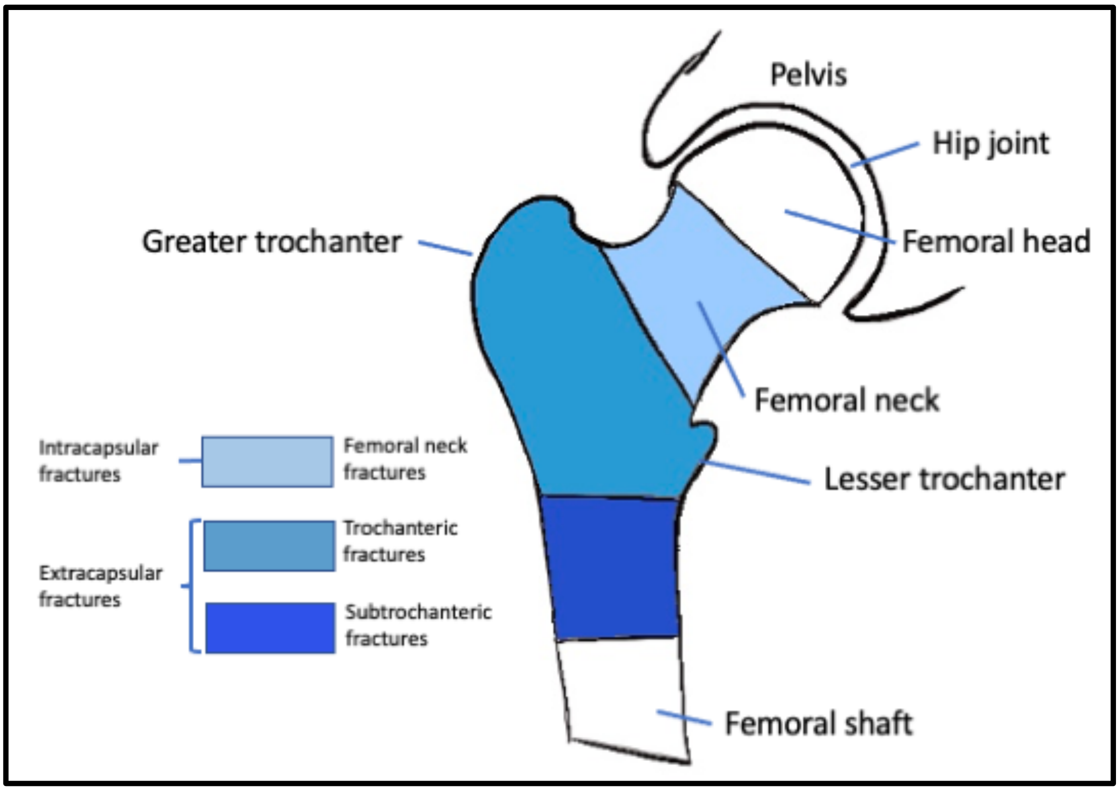

Figure 2: Anatomy of the proximal femur

Femoral neck fractures can be divided into intracapsular and extracapsular, referring to their relation to the hip joint capsule. Extracapsular femoral neck fractures are commonly called lateral or basocervical fractures[23]. In the term trochanteric fractures all inter- and pertrochanteric fractures are included. Subtrochanteric fractures are located from the distal limit of the lesser trochanter to 5 cm distally. Femoral head fractures, isolated fractures of the major or minor trochanter and other comminute and/or otherwise unclassifiable fractures also occur in this anatomic region and will not be described further in this thesis.

Distribution of proximal femoral fractures in a population of 5.4 million inhabitants (2021) is exemplified by 2018 data from the National Hip Fracture Register (NHFR) (Table 2). Subgroup classification is primarily based on examination and evaluation of fracture patterns on plain radiographs, supplemented with CT or MRI imaging studies if necessary[24]. Classification is useful for research purposes and as a guide for optimal treatment.

Femoral Neck Fractures		n	%
	Garden 1+2	961	11.5
	Garden 3+4	3,413	41.0
	Basocervical	197	2.4
Trochanteric fractures			
	AO/OTA A1	1,101	13.2
	AO/OTA A2	1,276	15.3
	AO/OTA A3	225	2.7
Subtrochanteric		492	5.9
Other fracture types or combinations of several fractures		572	6.9
Pathological		92	1.1
Missing		5	0.1
Total		8,334	100

Table 2: Distribution of hip fractures registered in the Norwegian Hip Fracture Register (2018); % denotes proportion of all hip fractures reported in 2018 (Patients treated with THA are not included). Fracture classification is given in text

6.3.1 Garden classification

In 1961, Robert Symon Garden presented a classification system[25] for intracapsular femoral neck fractures that divides such fractures into four subgroups (Figure 3):

Garden I: Incomplete fracture, including valgus impacted fractures

Garden II: Complete fracture, without displacement

Garden III: Complete fracture, with partial displacement

Garden IV: Complete fracture, with full displacement

The validity of this classification system has been shown to be poor, even with a simplified version categorizing fractures as undisplaced (Garden I+II) and displaced (Garden III + IV)[26]. The Garden classification system can be refined further; if there is a posterior tilt of the femoral neck of more than 20^0 in Garden I or II fractures, the fracture is also defined as displaced. The scientific basis are studies showing a high rate of failure following internal fixation in such fractures[27]. Despite fairly poor validity, the dichotomy of undisplaced versus displaced fracture remains as the most consistent predictor of failure. The alternative Pauwels classification gives useful biomechanical insight but has no practical use in contemporary fracture treatment[28].

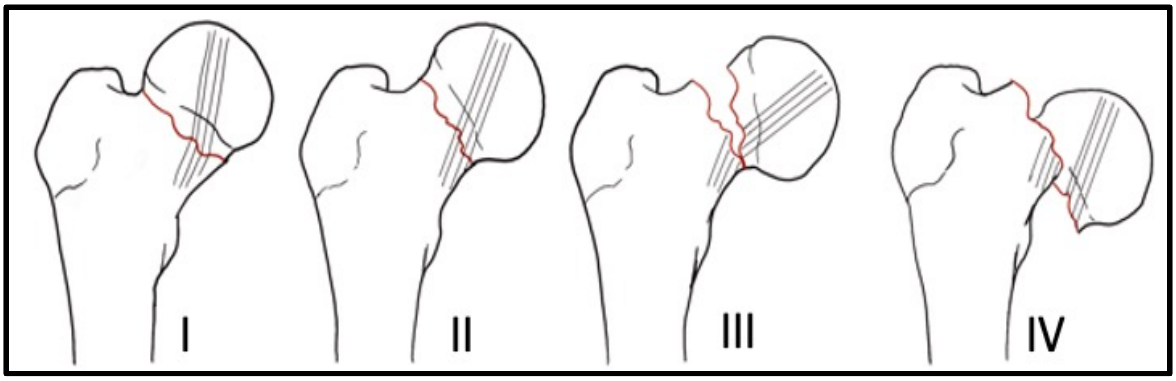

Figure 3: Garden classification of hip fractures

6.3.2 Basocervical fractures

Basocervical or lateral femoral neck fractures are not part of the classification systems discussed above. Basocervical fractures follow the plane of the hip joint capsule at the border of the femoral neck and the trochanter region. The AO/OTA classification (see later) describes them as intracapsular. However, biomechanically they have similar properties to those of extracapsular fractures[23]. We also know that lateral (basocervical) fractures have a distinct prognostic impact (see for instance **Paper I**).

6.3.3 Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association (AO/OTA)

The Arbeitsgemeinschaft für Osteosynthesefragen (AO) fracture classification system was developed by the Swiss-led AO group, and Müller et al. presented their AO classification system of femoral fractures in 1980[29]. In 1990 a comprehensive classification of fractures in long bones was presented[30]. The AO classification systems were later adopted by the American Orthopedic Trauma Association (OTA), and since 1996 AO and OTA have presented a unified classification with regular updates[31, 32].

The classification is based on location of the fracture in anatomical areas and degree of comminution. The classification divides the trochanteric fractures based on severity, with three main groups A1, A2 and A3 and three subtypes within each main group (Figure 4) giving a total of nine fracture types[29] with their inherent prognostic implications. The validity of the AO/OTA classification has been shown to be acceptable particularly so when only dividing the fractures into the main groups (A1-A3)[33].

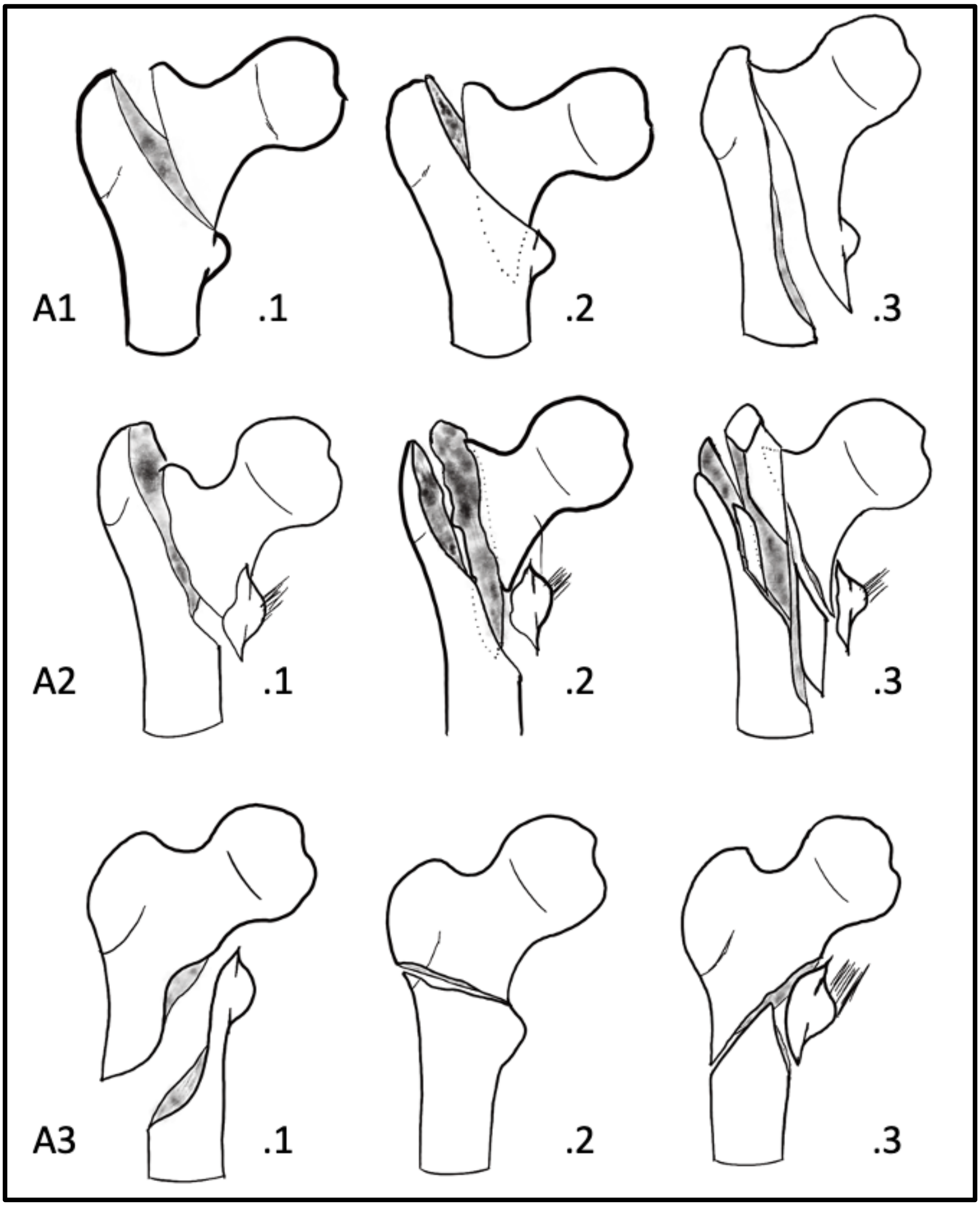

Figure 4: AO/OTA classification of trochanteric fractures

6.3.4 Subtrochanteric fractures

Subtrochanteric fractures have been classified by several systems but the most accepted is Seinsheimer's definition; i.e., fractures <5 cm below the lesser trochanter[34]. AO/OTA has a subdivision of femoral shaft fractures located in the area <3 cm below the lesser trochanter[35]. In this thesis we have chosen, in line with the NHFR, to adopt Seinsheimer's definition.

6.3.5 Classification used in this thesis

In the NHFR, which is the hip fracture data supplier for this thesis, fractures are classified according to Garden for femoral neck fractures,[25] and according to AO/OTA for trochanteric fractures.[29] The NHFR has categorized fractures in the area <5cm below the lesser trochanter as subtrochanteric, and basocervical fractures are categorized in a separate group[13, 36]. Complex and compound fractures are classified separately.

6.4 Treatment of hip fractures

Historically, treatment of hip fractures was non-operative (i.e., conservative), with bed rest and subsequent gradual mobilization guided and limited by pain. This resulted in high post-fracture mortality and considerable suffering for the patients. The first operations for hip fractures were performed in the mid-19th century[37]. In the 20th century the development of surgical techniques and approaches, implants, infection prophylaxis and modern anaesthetic methods soon led to operative treatment of hip fractures as the preferred treatment option.

6.4.1 Current treatment principles

The basic principle in the treatment of hip fractures is rapid stabilization of the fracture, enabling early mobilization with weight bearing with acceptable pain[38] to enable a quick return to home and to pre-fracture physical function.

There are two main strategies for surgical treatment. The first treatment option is osteosynthesis, where the aim is to reduce the fracture to an acceptable position by manipulation and then to fix and retain the bony parts in this position by internal fixation until the fracture heals. There is a plethora of internal fixation material: screws or pins, sliding hip screws (SHS) or intramedullary nails (IMN) depending on the type of fracture.

Screws/pins (Figure 5a) are used as two or three parallel implants introduced into the femoral neck through small skin incisions on the lateral aspect of the thigh. This classical fixation method represents a minor surgical trauma for the patient and preserves hip articulation and is used both for displaced and undisplaced fractures. Today internal fixation is used for femoral neck fractures in young patients, and in undisplaced fractures in the elderly. There is no clear consensus on choice of implant[39]. Increased reoperation rates in the displaced fracture group mean that screws/pins are no longer recommended for such fractures[27].

SHS (Figure 5b) is a concept involving a lag screw being inserted in the femoral neck, which is subsequently inserted into a barrel fixed to a metal plate attached to the lateral aspect of the trochanteric region. This construction gives axial and rotational support for unstable fractures and can be enforced with an extra lateral support plate, particularly in unstable fractures. SHS are most commonly used for stable trochanteric fractures (AO/OTA A1) in Norway[13], but also for subtrochanteric fractures. Recent years have seen more use of SHS in basocervical fractures[39].

IMNs (Figure 5c) are implants inserted into the intramedullary canal through a small skin incision proximal to the major trochanter. Additionally, they may have one or two lag screws in the femoral neck and most nails have the option of a distal locking screw for rotational stability. IMNs are commonly used for unstable trochanteric (AO/OTA A3) and subtrochanteric fractures, and now appear to outnumber SHS[40].

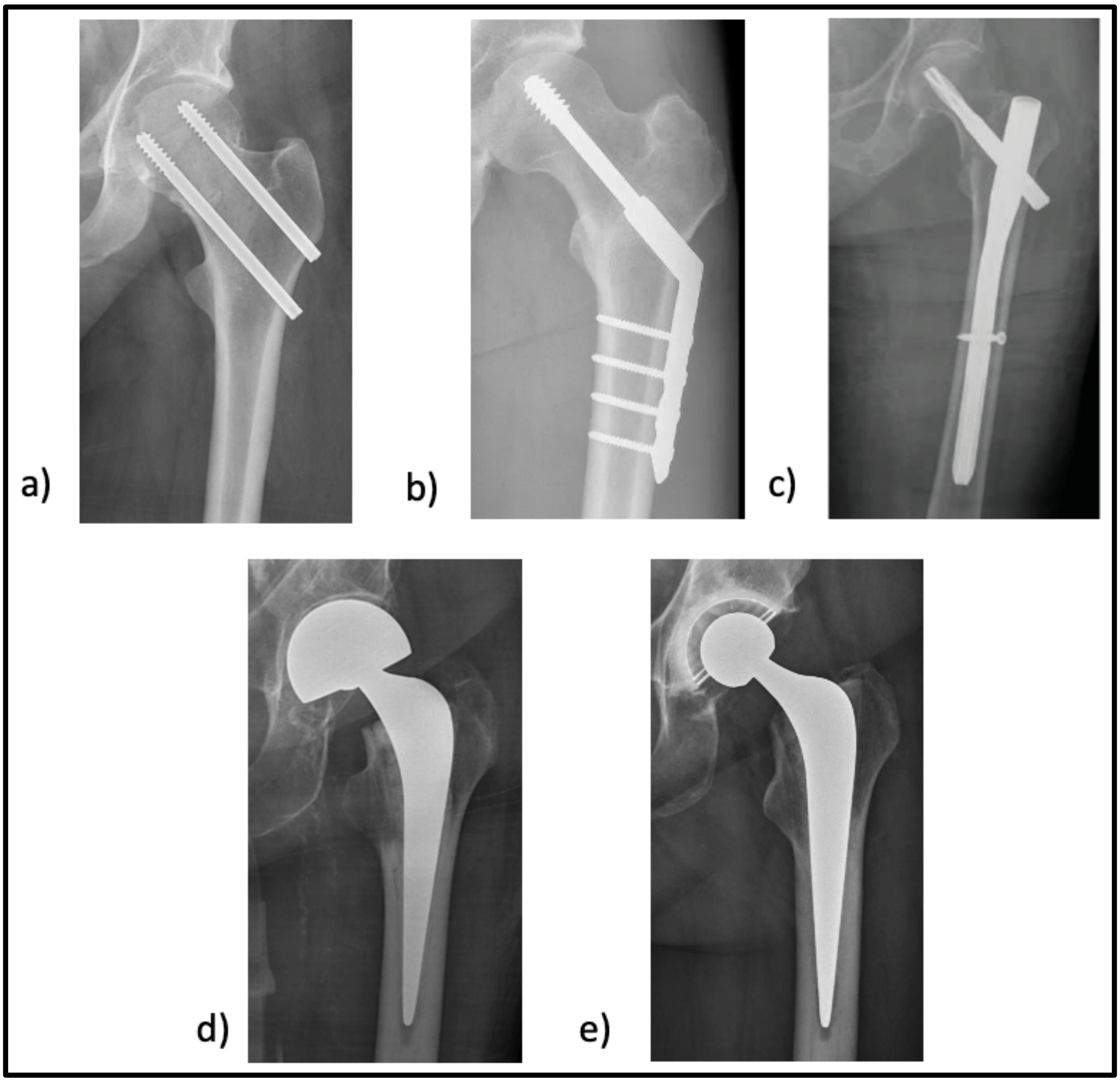

Figure 5: Surgical alternatives in hip fracture care: a) parallel screws, b) sliding hip screw, c) intramedullary nail, d) hemiarthroplasty, e) total hip arthroplasty

The second treatment option is to replace the fractured area and the femoral head with either hemiarthroplasty (HA) or total arthroplasty (THA). In HA (Figure 5d) there is a femoral stem and a head, either mono-block or bipolar. The femoral stem is fixed to the femur with or without the use of bone cement. In THA (Figure 5e) an acetabular cup is added and can be fixed with or without cement.

Arthroplasty is most commonly used for displaced femoral neck fractures (Garden types III + IV and posterior tilt >20^0) but may also be used for other hip fracture types[13]. The clear advantage of arthroplasty is that fracture/bone healing is not a prerequisite, and that the risk of malunion, non-union and avascular necrosis is eliminated[41]. It is of note that patients report better functional outcome following arthroplasty than following osteosynthesis[42, 43].
An (over)abundance of hip implants has been marketed over the years in different designs[6]. Generally prostheses are marketed as equivalent products, but we know that there are well documented differences, particularly in long-term results[6, 44].

6.4.2 Current surgical treatment controversies

Despite a voluminous scientific literature addressing hip fracture treatment, there are still ongoing controversies regarding some treatment options.

It is still debated whether patients should be offered THA or HA. HA has been the standard treatment for decades but increasing evidence may indicate a better functional outcome for THA in physically fit patients[45]. The evidence is, however, not unambiguous nor undisputed and the superiority of THA is still debated[46, 47]. THA also has a higher rate of hip-related complications than HA[48]. In Britain, THA is recommended for selected fit patients who are cognitively intact and are able to walk independently pre-fracture[49]. The updated guideline from AAOS also advocates THA for carefully selected patients with displaced FNFs[50]. Admittedly, the term *"selected patients*" introduces an element of individual surgeon bias.

There is also controversy regarding the optimal fixation method of the prosthetic stem to the femur. Uncemented arthroplasty is in routine use for total hip replacement (all indications), and the transfer of this fixation method to hip fracture care may be logical. However, recent data show a higher risk of complications, mainly periprosthetic fractures, after uncemented arthroplasty[51, 52]. Both NICE and the AAOS guidelines recommend use of cemented stems[49, 50]. Some studies may indicate a possible cement-related increase in perioperative mortality[53], which is an argument for using an uncemented arthroplasty. Ongoing studies or updated evidence-based guidelines will hopefully clarify this dilemma.

Basocervical fractures represent only 2.4-3.5% of hip fractures in Norway (2014-2018; Table 2). These fractures have been treated with parallel screws/pins, SHS or HA/THA. No definitive recommendation for treatment has been established. It appears likely that parallel implants are insufficient due to poor mechanical strength[38].

The choice of implant in trochanteric fractures classified as AO/OTA A1 and AO/OTA A2 is between SHS and IMN. Despite numerous studies, no firm conclusions as to comparative effectiveness can be drawn. The NICE guideline[49] concludes that SHS should be preferred based on lower costs of implant in a situation where comparative clinical results are inconclusive. The Norwegian guideline[54] also concludes that SHS should be favoured for AO/OTA A1 fractures, and states that the evidence is inconclusive for AO/OTA A2 fractures.

6.4.3 Perioperative pathways of care

The perioperative pathway of care has an impact on patient experience and outcome. Waiting time from admission to surgery has been shown to affect mortality after hip fractures[55]. Current recommendations are to perform surgery within 24-48 hours of admission, and surgery within 48 hours is also used as a quality indicator (or key performance indicator) in the governance of Norwegian hospitals.

Comprehensive geriatric assessment (CGA) in regular wards and comprehensive geriatric care (CGC) in geriatric wards (orthogeriatric units) have been shown to improve outcomes after hip fractures. Eamer et al., in a Cochrane review, showed that CGA reduced mortality and discharge to a higher level of care[56]. In addition, CGA probably reduced total costs related to care[57].

The Trondheim Hip Fracture Trial concluded that CGC improved mobility and activities of daily living compared to traditional orthopaedic care[58, 59]. CGC also improved medical care by improving prescription of medications during the care process, including secondary prevention of fractures by initiating treatment of osteoporosis and reducing use of sedative medications that increase risk of falls[60]. Merged data from the Oslo Orthogeriatric Trial[61] and the Trondheim Hip Fracture Trial have demonstrated a positive effect on activities of daily life up to 12 months after surgery in patients admitted to a CGC-unit[62]. Both the NICE and the AAOS guidelines recommend interdisciplinary care and geriatric assessment as a part of the pathway of care[49, 50].

6.5 Variation in care of hip fracture patients

If the main goal for a society is to provide equal healthcare to the population, any observed variation that is unrelated to population case-mix or random events can be considered unwarranted. Figure 6 is a graphical presentation of an analysis of the concept of *variation*. To quantify the random and case-mix components in a patient- or disease-specific group is difficult and will vary in magnitude between diagnoses and patient groups. In the hip fracture population, it is likely that these components are modest, particularly so as moderate differences in geographical incidence rates for hip fractures have been noted by the NOREPOS research group[63]. In addition, register studies with high coverage reduces the element of randomness.

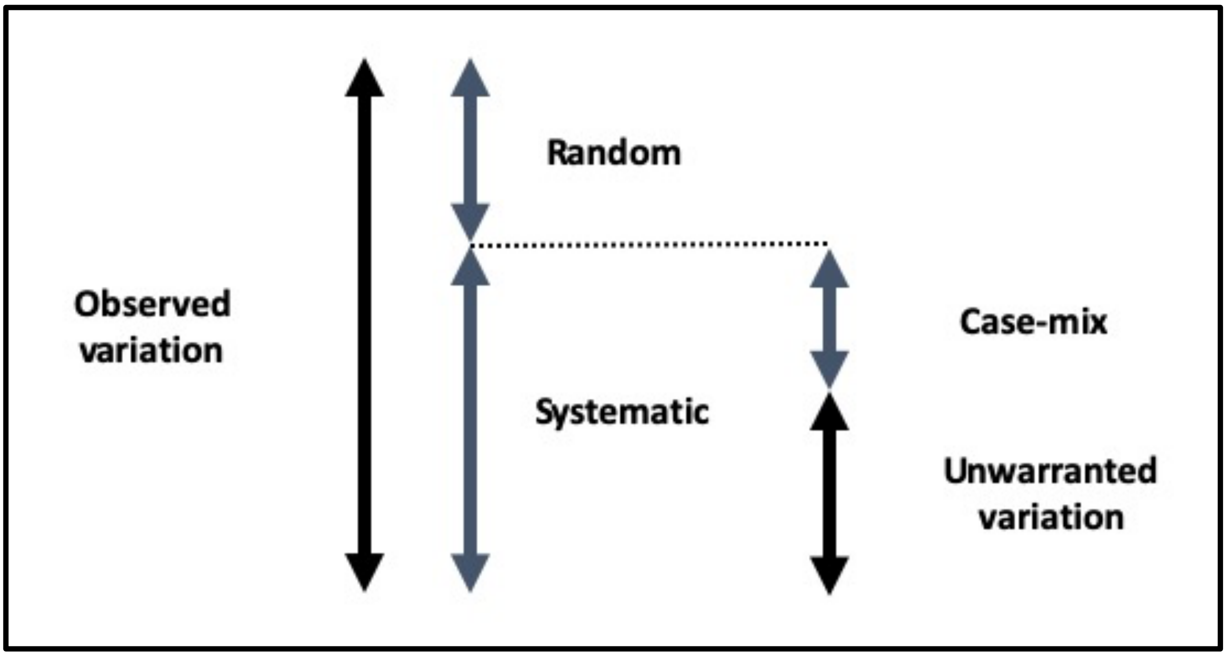

Figure 6: Components of variation (Reprinted with permission from Centre of Clinical Documentation and Evaluation[64])

In 1938, J. Alison Glover first drew attention to unexplained differences in medical practice (i.e. variation), both geographical and socioeconomic, using the tonsillectomy rates between geographical areas in UK as an example[65]. Since then, there has been a growing awareness of differences in healthcare provision and outcomes.

Research on variation in healthcare has been pioneered and developed by Professor John E. Wennberg at Dartmouth College in New Hampshire, USA. He has summarized and systematized decades of research in the book *Tracking Medicine. A Researcher's Quest to Understand Health Care* (2010)[66]. His research led the Dartmouth research community to publish *"The Dartmouth Atlas of Health Care"* in the 1990s [67]. The atlas describes the variation in the use of health services in the United States across 3,436 hospital service areas. Internationally, such data has become the prototype for a growing number of initiatives that demonstrate similar variation in the use of health services, regardless of their organization and financing.

In Norway, health atlases have been published for several patient groups: neonatal, child healthcare, elderly healthcare, chronic obstructive pulmonary disease healthcare, mental healthcare, obstetrics, gynaecology and day surgery (see www.helseatlas.no[68]). EuroHope is a European health atlas initiative that describes differences in treatment in Europe (including Nordic hospitals[69]) for several diagnoses and diseases (heart attack, stroke, hip fracture, breast cancer and newborns with low weight). In the UK the "Atlas of Variation" covers a wide aspect of disease groups in documenting variation in provision of healthcare to the population[70]. Almost without exception, there is an observed variation in the supply and consumption of health services in and between regions and countries.

The key element in Wennberg's research is the description of categories of healthcare[66]. These are 1) *"Necessary care"* – care based on high-level medical evidence, and for which the benefits of care far exceed the potential risks and consequences, 2) *"Preference-sensitive care"* – care where there is more than one option of treatment or care, and the choice is based on the opinion of the individual professionals (medical expertise), and patient preference, and 3) *"Supply-sensitive care"* – services for which available resources influence treatment options (utilization).

A hip fracture is a medical emergency and care is indisputably "necessary care". Nearly all patients receive treatment unless they are moribund, and surgery is contraindicated. On the other hand, in care pathways and specific fracture treatment there are more options and diversity and preference-sensitive and supply-sensitive mechanisms are involved[66]. Figure 7 is a simplified schematic representation of factors influencing practice style. The health care provider(s) have a strong and decisive influence on treatment preferences.

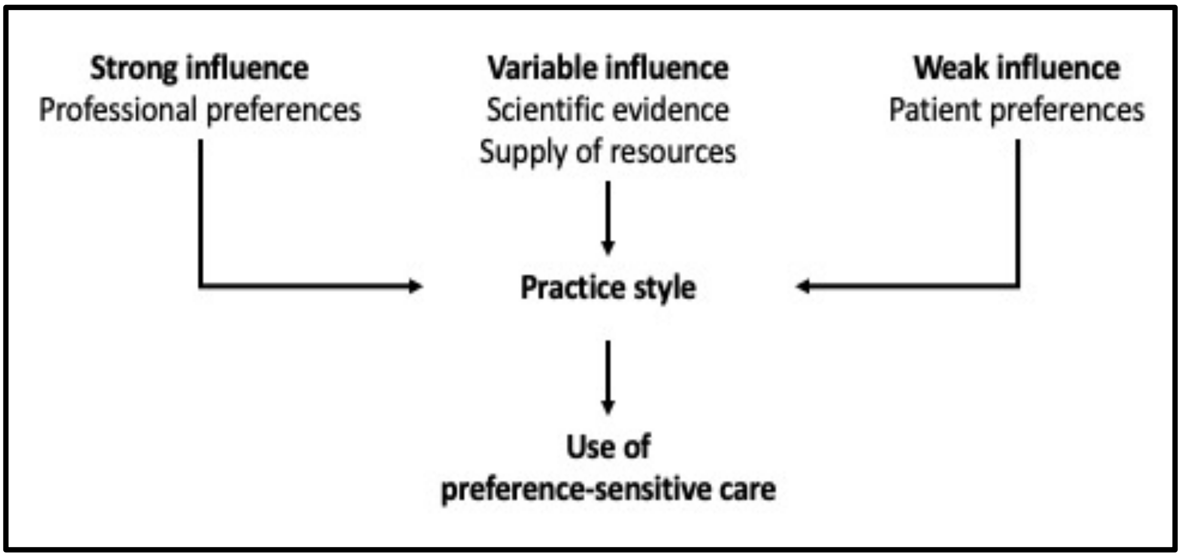

Figure 7: Delegated decisions in preference-sensitive care (Modified after Wennberg et al[66])

Patient preferences have a weaker influence on preferred treatment than both medical evidence and professional preferences and opinion. The hip fracture population is old, and many patients have cognitive impairment, and one would expect patient involvement to be weak. The health service bears a great responsibility for equity in services provided in a situation where patients have minimal influence over their care pathway.

In 2016, the Centre for Clinical Documentation and Evaluation, governed and financed by the Northern Norway Health Authority, published a report on indicators for measuring unjustified variation[64]. This report suggests that treatment for hip fractures is not equal for residents in Norway, and that there appear to be geographical differences.

As alluded to above, observed variation may be caused by multiple factors, which have been summarized and simplified in Figure 8. Variation will be affected both by demands from the patient and decisions in the service supply chain. Data inaccuracy and random variation add to the complexity. Demonstrating variation is important, as a first step to later identifying and rectifying causes of variation. For health and hospital services, however, it is important to shed light on factors, including differences in care pathways that may explain variation. In a research context, the explanatory mechanisms must be studied; whether the reason for the variation is deviation(s) from evidence-based guidelines, in structural conditions in the hospitals (beds, degree of specialization, staffing and internal logistics (waiting time)) or if the variation can be explained by patient factors (comorbidity, frailty).

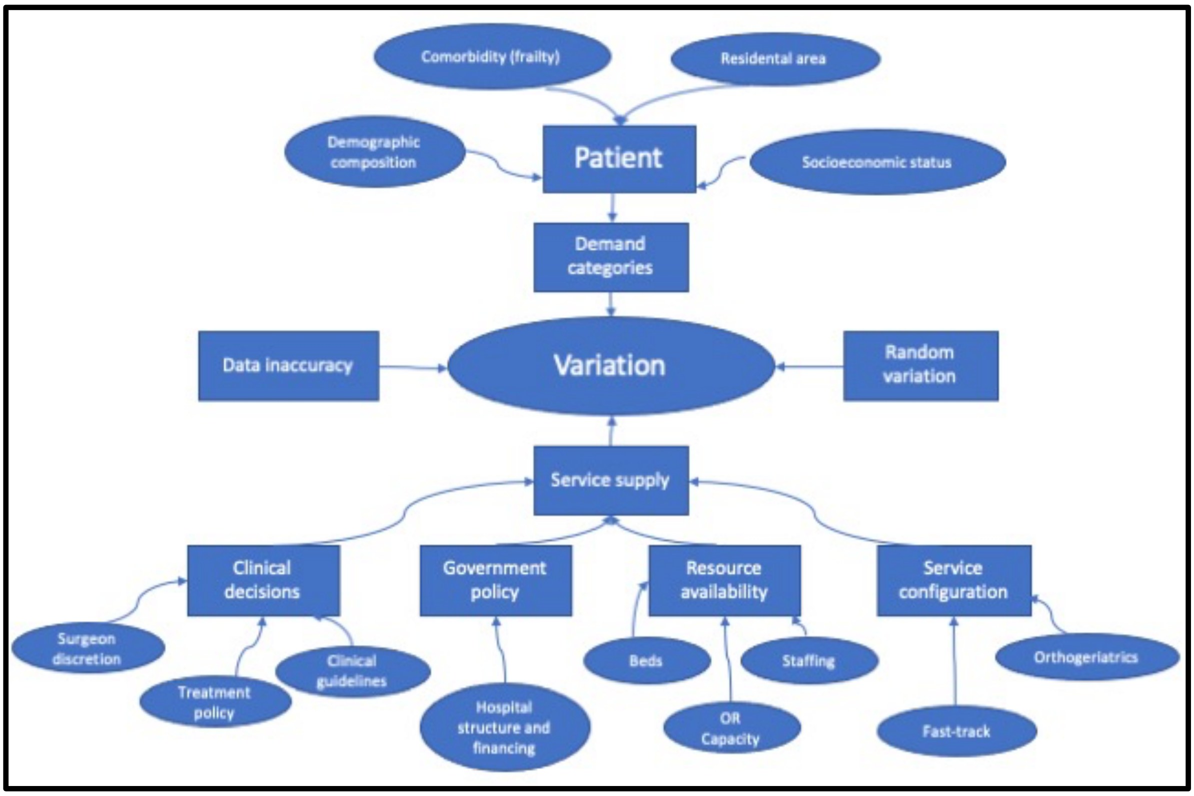

Figure 8: Factors affecting observed variation in hip fracture care (modified from Appleby et al.[71])

Documenting unjustified variation is an opportunity to improve treatment, leading to improved quality of care, provide a better basis for better prioritization, and may improve treatment processes. Knowledge of unwarranted variation is mainly based on research on elective treatment, and less is known regarding patients with medical emergencies like hip fractures. A challenge is to reduce unwarranted variation, while preserving variation that reflects patient-centred choices[1].

6.6 Mortality after hip fractures

Mortality as an outcome measure is seen as an important "quality indicator" by the public, politicians, patients and health care providers. Mortality related to treatment is a measurable and hard endpoint in evaluation of treatment and is commonly used in hip fracture research. Sheehan et al. identified 39 patient- and healthcare system-related factors which might be associated with post-hip fracture mortality[72]. Other researchers have emphasized the importance of socio-cultural risk factors (financial and educational status of patients, and residence factors such as living alone/cohabiting and urban/rural), and structure and processes of healthcare (pre- and in-hospital delay, hospital status, and in-hospital services)[8, 73-78].

The relative value of different risk factors is not clearly understood and seems under-researched. Of all risk factors identified some are possible to modify, while others will only give information to identify patients at risk. It is crucial to identify the most important focus areas where it is possible to improve care. A separate issue is the relative importance of risk factors in determining post-treatment mortality.

When factors affecting patient outcomes are identified, a division into modifiable and non-modifiable factors might be useful as a guiding principle and to raise awareness of risk factors that can be modified. The non-modifiable risk factors provide information to stratify patient risk, while identification of modifiable factors can also enable improvement of care pathways.

Many of the clinical studies involving mortality after hip fracture surgery are limited in scope and often have few risk factors incorporated into the mortality and/or survival analyses; further they often use mortality as an outcome when comparing different types of surgery or alternative pathways of care. Variety in patient characteristics has not been examined and understood to the same extent.

7 Aim of the thesis

The overall aim of the thesis is to expand knowledge of factors affecting inequity in treatment and outcomes after hip fractures. Specific research questions formulated were:

- Describe variation in the treatment of hip fractures in Norway expressed as adherence to guidelines, analyse which factors affect variation in treatment provided and analyse the consequences of variation (***Paper I***).
- Describe in-hospital preoperative waiting time for surgery in hip fracture patients in Norway, assess whether patient- and system-related factors affect waiting time and analyse whether prolonged waiting time had potential negative consequences (***Paper II***).
- Identify risk factors for mortality after hip fractures and estimate their relative importance and elucidate mortality and survival patterns following fractures and duration of excess mortality (***Paper III***).

8 Materials and methods

8.1 Study design

The thesis is based on retrospective analyses of national prospectively collected register data.

8.2 Data acquisition

Data from the NHFR on all patients, identified by a unique personal 11-digit national identification number, and registered from January 2014 to December 2018 was extracted and comprise the study population for this thesis. Data from the National Patient Registry (NPR) (a national administrative database for specialist health care) and Statistics Norway (SN) were linked to the NHFR fracture population for the period January 2013 to December 2019 using the national identification number.

In addition, a national survey of hospitals treating hip fractures was conducted to obtain information on hospital characteristics and organization of hip fracture care. Data from the NHFR and the hospital survey were used in the analyses described in ***Paper I***. In ***Paper II*** a dataset with linked data from the NHFR and the NPR and the hospital survey was used in the analyses. In ***Paper III*** a dataset with linked data from the NHFR, the NPR, SN and the hospital survey was used in the analyses.

8.2.1 Register data

The Norwegian Hip Fracture Register

The NHFR, organized as a quality registry, was founded in 2005 by the Norwegian Orthopaedic Association (NOA) and operates within the constraints of Norwegian regulations and laws (see Chapter 8.4). All hospitals performing hip fracture surgery in Norway supply information on hip fracture patients to the register[79]. Orthopaedic surgeons report predefined information on paper (Appendix I) and the registration form is completed by the surgeon after both primary and any later (secondary) surgery. Information on hip fracture patients treated with a THA is primarily recorded in the Norwegian Arthroplasty Register and subsequently imported to the NHFR[79]. Date of death is imported to the NHFR from the Norwegian National Population Register on a regular basis.

A quality register will rely on completeness of reporting and completeness indices have been calculated by the NHFR according to the formulae described in Figure 9. Completeness in NHFR for primary operations in the period 2015-2016, using NPR data as reference, was 88% for osteosynthesis, 94% for HA and 87.8% for THA[13]. In the period 2017-2018 completeness rates were virtually unchanged: 88% for osteosynthesis, 94% for HA and 91% for THA[6].

For reoperations the completeness of reporting was substantially lower: 80% for osteosynthesis, 73% for HA and 84% for THA[6].

$$\text{Completeness rate NHFR} = \frac{\text{only NHFR} + \text{inclusion both registers}}{\text{only NPR} + \text{only NHFR} + \text{inclusion both registers}}$$

$$\text{Completeness rate NPR} = \frac{\text{only NPR} + \text{inclusion both registers}}{\text{only NPR} + \text{only NHFR} + \text{inclusion both registers}}$$

Figure 9: Formulae for completeness in the NHFR and the NPR (Annual Report, Norwegian Hip Fracture Register, 2021. Reprinted with permission[6])

In this thesis, information on all patients registered in the NHFR from 1 January 2014 to 31 December 2018 was included. Patient national identification number, residential area (municipality), time of injury, time of surgery, waiting time, type of fracture and treatment/surgical method, ASA score[80], experience level of surgeon, and date of death were recorded.

Norwegian Patient Registry

The Norwegian Patient Registry (NPR) collects administrative data on all patients treated in the publicly financed specialist health service. All providers are obliged to report predefined data on all patient contacts with the health service, including diagnoses, dates and exact times for admission and discharge, and procedures (surgical, medical and radiological). All diagnoses are reported according to the ICD-10 classification system (2016 version)[81], while all surgical procedures are reported based on the NOMESCO classification (2009 version)[82].

All hip fractures recorded in the NHFR from 1 January 2014 to 31 December 2018 were identified in the NPR by their personal identification number. All inpatient and outpatient episodes from 1 January 2013 to 31 December 2019 were identified (i.e., at least one year before and after the index event), along with information on concomitant diagnosis/diagnoses, medical and operative procedures, and emigration. NPR also provided dates and times of admission and procedure(s).

ICD-10 codes in the NPR were used to categorize patients according to the Charlson Comorbidity Index (CCI) with the Quan modification[83], i.e. No comorbidity 0, Mild comorbidity 1-2, Moderate comorbidity 3-4 and Severe comorbidity ≥5[84]. CCI is validated for use on NPR data[85], and was used in the analyses in ***Papers II-III***.

The NPR also provided times of admission and procedures, which facilitated calculation of in-hospital waiting time for surgery. Waiting time in hours from admission to start of surgery was calculated. Waiting time was used in the analyses in ***Papers II-III***.

Statistics Norway

SN is a professionally independent national institution responsible for collecting, producing and publishing official statistics related to the economy, population and society at national, regional and local level. SN collects, analyses and presents data/statistics from over 100 administrative registries. SN also conducts a wide array of research, and its data and statistics provide a general picture of the nation.

On the individual level, demographic information (marital status and household type) and socioeconomic data (household income, highest completed education level, and residential status) were collected. In this thesis, patients' residential status was defined as living alone, cohabiting, or living in a healthcare facility. SN defines residential status as either single-family or multi-family households, in addition to one group not part of a household (i.e., living in a healthcare facility, residing in a secret location, long-term imprisonment). The single-family household has a subgroup for people living alone. For all practical purposes, in our population the persons who are not part of a standard household (single- or multi-family) are living in healthcare facilities.

Total household income (net salary, capital income, social security and pension) in the year prior to surgery in Norwegian kroner (NOK) (NOK 100 = EUR 9.88 in February 2022) was categorized in quartiles. Educational status was grouped in three levels according to the International Standard of Classification of Education: low (lower secondary education), medium (upper secondary to short-cycle tertiary education), and high (bachelor´s level and above)[86].

The number of inhabitants in municipalities where the patients resided at the time of injury was retrieved from SN and the municipalities were categorized as small (<5,000 inhabitants), medium (5,000-19,999) or large (≥20,000 inhabitants). The number of inhabitants and number of deaths for the entire national population were supplied by SN in sex-specific five-year age groups. This information was used to estimate age- and sex-standardized mortality ratios.

The above information was used in the analysis in ***Paper III***.

8.2.2 Hospital characteristics and hip fracture service configuration

An online survey of the characteristics of all 43 hospitals (organized in 23 hospital trusts) in Norway that routinely treat hip fracture patients was conducted in 2019, and all hospitals responded. The hospitals varied from small community hospitals with a catchment area of fewer than 30,000 inhabitants to large regional and university hospitals[87].

Information was collected on the organisation of hip fracture care, presence of written hospital treatment policies/guidelines, dedicated unit for hip fracture patients, interdisciplinary care including available professional groups (physiotherapist, specialist in internal medicine, orthogeriatric services, geriatrician, occupational therapist and others), number of beds in the orthopaedic ward(s), number of orthopaedic consultants and specialist registrars/residents, population in the catchment area, and whether the hospital had 24/7 service for hip fracture patients. The survey form (in Norwegian) is shown in Appendix II. In Norway, hip fractures are primarily managed by orthopaedic surgeons/trainees.

The survey was based on self-reported data which may introduce some uncertainty as there is no uniform professional consensus on definition of administrative hospital/departmental elements, such as the definition of an orthogeriatric unit. Similarly, many of the data elements are interrelated and therefore introduce some potential analytical challenges for the analyses of risk. Information from the characterization of hospitals was used in analyses in ***Papers I-III***.

8.2.3 Evidence-based clinical practice and treatment recommendations/guidelines

Background information

In 1972 the Scottish epidemiologist Archie Cochrane (1909-1988) suggested that summaries of randomized controlled trials (RCTs) should form the basis of clinical practice and be an organized activity[88, 89]. He was a staunch supporter of randomized control trials and spent much of his career promoting their use in research. It may be argued that he had an ideological basis for his initiatives formulated in the phrase *"all effective treatment should be free"*[90]. Such a phrase leads of course to the question of what constitutes *effective treatment*. A biography of Cochrane tells of a lifelong journey of trying to distinguish between scientifically valid medical treatments and invalid ones[91].

Cochrane introduced the terms *effectiveness*, *efficiency,* and *equality* as his yardstick for evaluating healthcare in the UK (National Health Services; NHS). According to Shah and Chung[91] the term *effectiveness* was used as a measure of how much a medical activity changes the natural course of a disease in an RCT. They further stated: "*Efficiency* was used to refer to how well the health care system utilized resources such as doctors, nurses, medical equipment, lodging, etc. to implement an effective medical intervention. Whereas effectiveness and efficiency were used to assess the cure aspect of medical interventions, *equality* was used to assess care and the variation of care amongst different hospitals".

Cochranes's ideas were adopted by many others and led to the foundation of the Cochrane Collaboration in 1993 by Ian Chalmers and a group of 70 international colleagues.
This was followed by the establishment of many Cochrane centres around the world, review groups, methodological discussion groups, etc. and led to a rapidly expanding theoretical base for activities within the Cochrane collaboration framework, and to a taxonomy of processes (search strategies, level of evidence, hierarchy of evidence, grading of evidence, systematization of findings, etc.) Cochrane is known as one of the fathers of modern clinical epidemiology and is considered the originator of the concept of evidence-based medicine.

It is of note that the term "*evidence-based medicine"* was not used initially, neither in professional discussions nor in medical scientific databases until 1992, when Guyatt et al. coined the term[92]. The goal of EBM was to solidify the scientific foundation of medicine and to reduce uncertainties in medical decision-making.

There are many definitions of EBM. A central theme in all is variants of the formulation *"(EBM is) the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients"*[93]. Muir Gray, a pioneer in how best scientific evidence can be applied to management decisions, stated in 1997: *"Evidence-based clinical practice is an approach to decision making in which the clinician uses best evidence available, in consultation with the patients, to decide upon the option which suits the patient best"*[94].

It is beyond the scope of this thesis to discuss EBM in detail. In short, the term EBM reflects a systematic approach to evaluate the best current knowledge and transfer this to the best decisions for the individual patient. The process has some key elements (simplified in Figure 10):

- Transferral of clinical uncertainty to answerable questions that results in the framing of key research questions to be examined.
- Systematic identification and retrieval of the best scientific evidence available
- Critical appraisal of the available evidence to evaluate their internal and external validity
- Evidence reviews, either through systematic literature reviews [Note 1] or formal metanalyses [Note 2] of the available data.

High level[Note3] clinical effectiveness studies are the backbone of practice guideline development and provide a solid foundation for a final appraisal of the scientific evidence which may include legal, economic (cost and cost effectiveness studies) and ethical consequences of the health technology in question. Such broader knowledge base is used for clinical guideline development (or to inform policy decisions in a Health Technology

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[Note 1] A systematic review is a research article that identifies relevant studies, appraises their quality, and summarizes their results using a scientific methodology.
[Note 2] Meta-analysis is a statistical technique for combining the results of several individual studies to produce summary results. (Note that some publications called meta-analyses are not systematic reviews).
[Note3] The terms "high level" and "low level" evidence refer to the notion of a "hierarchy of evidence"

Assessment (HTA) process[95/Note 4]). A critical appraisal is particularly important if the scientific literature is equivocal or have a low level of evidence. As an example, NICE guidelines (Table 3) introduced cost elements in the recommendation for SHS in AO/OTA A1 fractures.

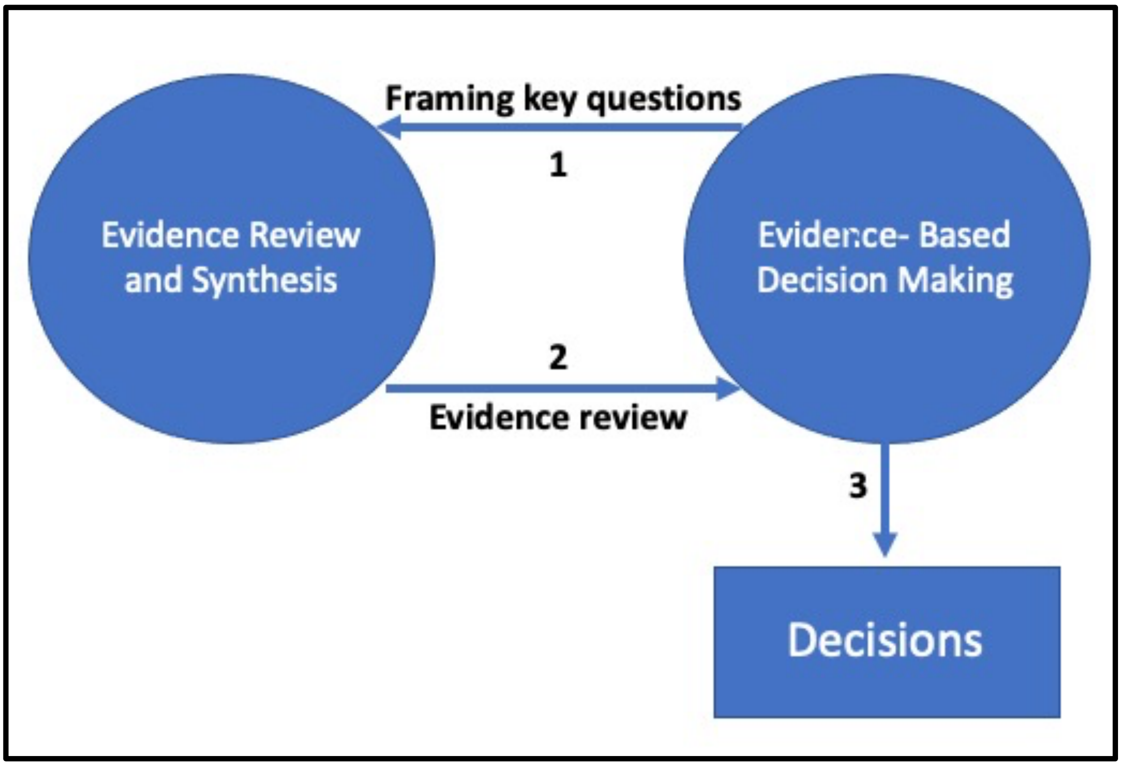

Figure 10: Relationship between evidence reviews and evidence-based medicine decisions (Modified from Teutsch and Berger[96])

Guidelines used in this thesis:

In the abundance of guidelines and recommendations published, mostly consensus-based, high-quality evidence-based guidelines developed according to the principles above were selected in this thesis. Online searches in the Guidelines International Network database[97], McMasters Plus[98], the Cochrane database[99] and PubMed[100] were performed. Searches with the terms: "hip fracture", "hip fracture treatment" "hip fracture guideline", "proximal femoral fracture treatment" and "proximal femoral fracture guideline" published up to 2020 identified six relevant high-quality evidence-based guidelines fulfilling the GRADE principles[101].

[Note 4] Health Technology Assessment (HTA) is defined as "*a multidisciplinary process that uses explicit methods to determine the value of a health technology at different points in its lifecycle. The purpose is to inform decision-making in order to promote an equitable, efficient, and high-quality health system*".

- Scottish Intercollegiate Guidelines Network (SIGN): *Management of hip fractures in older people (2009)*[102]
- National Institute for Health and Care Excellence: *Hip fracture: management (2011/2017)*[49]
- American Academy of Orthopedic Surgeons (AAOS): *Management of hip fractures in the elderly (2014)*[103]
- Australian and New Zealand Hip Fracture Registry (ANZHFR): *Australian and New Zealand Guideline for Hip Fracture Care (2014)*[104]
- German Society for Trauma Surgery (GSTS): *Schenkelhalsfraktur des Erwachsenen (2015)*[105]
- Finnish Medical Association and Finnish Orthopaedic Association: *Lonkkamurtuma (2017)*[106]

The Finnish and German guidelines[105, 106] were published in their respective native languages and were not included in the further evaluation. The main argument against their use here was that the language restrictions presumably led to little impact on Norwegian practice.

NICE updated the evidence assessment of their existing guideline in 2017[49]. AAOS published a new and updated guideline "Management of Hip Fractures in Older Adults" in 2021[50]. In 2021 the guidelines from SIGN and GSTS were withdrawn based on outdated evidence base and new guidelines are expected in due course.

In 2018 a Norwegian consensus-based interdisciplinary guideline (in Norwegian) was published[54] in collaboration between the Norwegian Orthopaedic Association, the Norwegian Geriatric Society and the Norwegian Society of Anaesthesiology. The guideline gives recommendations for pre-, peri- and post-operative care and a summary was included in Paper I. The Norwegian guideline, although consensus-based, was in principle based on and concurred with the evidence-based guideline published by NICE in the UK[49], and was therefore highly relevant for Norwegian current practice.

The five guidelines cover most hip fracture types but three of the five guidelines (AAOS, SIGN, NOA) address hip fracture treatment in the elderly only. Table 3 shows a summary of the recommendations in the guidelines mentioned above.

Guidelines represent a framework for treatment and cannot cover all varieties of fracture types. Based on the summary in Table 3, it appears that the published guidelines will cover more than 90% of all hip fractures (supporting data in Table 2). Secondly, a guideline is based on the evidence at the time of publication. Expected updates of the SIGN and GSTS recommendations could provide new guidance. This is, however, not likely as we have not witnessed any paradigm shifts in hip fracture treatment over the last ten years. Nevertheless, some treatment choices have not yet been fully clarified and some minor changes must be anticipated.

		Evidence based guidelines				**Consensus based guidelines**
		SIGN 2009	NICE 2011/2017	AAOS 2014/2021	ANZHFR 2014	NOA 2018
Fracture type independent						
	Experienced surgeon	+	+		+	+
	Timing of surgery	Same or next day	<24h		Same or next day	<24h
			<48h	<48h		Daytime
Fracture type dependent						
Femoral neck						
Garden 1-2 (undisplaced)						
	Screw fixation	+		+		+
Garden 3-4 (displaced)						
	Arthroplasty	+	+	+	+	+
	Cemented stem	+	+	+	+	+
Trochanteric						
AO/OTA A1						
	Sliding hip screw	+	+	=	=	+
AO/OTA A2						
	Sliding hip screw	+	+	=/	=	=
	Intramedullary nail	=	=	=/+	=	=
Intertrochanteric						
AO/OTA A3 incl. reverse oblique						
	Intramedullary nail	+		+	+	+
Subtrochanteric						
	Intramedullary nail	+	+	+	+	+

The symbol + indicates an expected positive effect, the symbol = indicates equipoise.

Abbreviations: SIGN - Scottish Intercollegiate Guidelines Network; NICE - National Institute of Care Excellence; AAOS - American Academy of Ortopedic Surgeons; ANZHFR- Australian and New Zealand Hip Fracture Registry; NOA - Norwegian Orthopaedic Association; AO - Arbeitsgemeinschaft für Osteosynthesefragen; OTA - Orthopedic Trauma Association.

Table 3: Summary of guideline recommendations for treatment of hip fractures (reproduced from ***Paper I****)*

8.3 Statistical analysis

All statistical analyses were performed using SAS/STAT for Windows (SAS Institute, Cary, North Carolina, USA). Version 7.1 was used for Paper I, while for Papers II and III version 8.2 was used.

In the descriptive statistics in ***Papers I-III***, continuous variables are presented as means, medians and interquartile ranges. Categorical variables are presented as frequencies and percentages.

In ***Paper I*** adherence to guideline recommendations was calculated as a mean of annual proportions of patients treated according to the recommendations described in guidelines in Chapter 8.2.3, i.e., treatment within 48 hours of admission, by a surgeon with more than three years of experience, and with fracture type specific surgical treatment according to the guidelines. This was performed for each hospital in Norway over the study period. Logistic regression models were used to study the effect of potential predictors of adherence and results are presented as odds ratios (ORs) with 95% confidence interval (CI). All analyses were adjusted for age, sex and ASA class.

In ***Paper II*** differences between categorical variables were analysed using multiple logistic regression, with possible adjustment for sex, age and ASA class. Age-dependent risk of death at 30 and 365 days after surgery was estimated by logistic regression analysis. Comparison between groups and differences in means of waiting time before surgery were evaluated by analysis of variance (ANOVA) with Bonferroni corrections. The corrections were justified due to the obvious non-normal distribution of the observations.

In ***Paper III*** continuous variables are presented as means and standard deviations (SD). A Cox regression model was used to assess the association between available covariates and mortality. Covariates were specified a priori, based on the hypotheses for the study and available covariates in the registries.

The assumption of proportional hazards in a Cox model was assessed by inspection of Kaplan-Meier (KM) survival curves for categorical variables. Further, time-dependent continuous and categorical covariates were generated by interaction between covariates and a function of time. These were included in the model, followed by a test of proportionality using the PROC PHREG procedure in SAS[107]. Time-dependent covariates were entered into the Cox model whenever the proportional hazards assumption was violated. Potential non-linear association between survival and the continuous variable age was assessed by including age as a second-order polynomial into the model[107]. The model with all possible interactions was reduced by use of Bayes Information Criterion. The results are presented as hazard ratios (HRs) with corresponding 95% CIs and p-values. For time-dependent variables, regression coefficients and standard errors are presented.

The Wald χ^2 statistic[108, 109], which assesses the strength of association between each covariate and mortality in the Cox regression model, was used in combination with degrees of freedom (df) to quantify the strength of association of covariates in the model (Wald χ^2 – df).

We visualized the survival pattern for relevant covariates using KM survival curves. Median survival times in days with 95% CI were estimated based on the KM analysis.

In addition, we compared patient mortality with the expected rate of death in an age- and sex-standardized reference population. Based on information from SN on deaths in sex-specific five-year age groups in the Norwegian population, we calculated expected mortality rates using indirect standardization. Standardized mortality ratios (SMRs) were estimated monthly after fracture during the first year, and annually for the remaining observation period. We also calculated SMRs stratified by gender.

To examine potential geographical variation, particularly whether the hospital organization or the municipality where the patients lived affected outcome measures, exploratory multilevel analyses were performed. Multilevel analysis as a statistical method is applied if there is reason to believe that patients in one subpopulation are more likely to function in the same way than patients in a different subpopulation. An intraclass correlation coefficient was estimated on three levels: RHA, municipality and hospital. No significant differences were found, and multilevel statistical analyses were therefore abandoned.

In all papers statistical analyses were two-sided, a 95% CI was calculated and p-values below 0.05 were considered statistically significant.

8.4 Ethical and legal considerations

The project was approved by the Northern Norway Regional Committee for Medical and Health Research Ethics and was exempted from the duty of confidentiality (REK 2018/1955). A data protection integrity assessment was compiled according to the European Union General Data Protection Regulation, valid in Norway since 20 July 2018. The project was funded by the Northern Norway RHA (HNF1482-19), covering a 50% PhD scholarship for six years from 1 January 2019. No competing interests were declared.

The NHFR is authorized by the Norwegian Data Protection Authority to collect and store data on hip fracture patients (authorization issued 3 January 2005; reference number 2004/1658 to 2 SVE /-). The NHFR required patients to sign a written, informed consent declaration, and when unable to understand or sign, a family member could sign the consent form on their behalf [Note5]. The NHFR is financed by the Western Norway RHA.

The author of this thesis was president of the NOA when the Norwegian interdisciplinary guidelines were published in 2018, and representatives from NOA were involved in the collaboration. The president and the board of NOA had no influence on the evaluation of evidence or preparation of the guidelines which were performed independently by the appointed professionals.

[Note 5] From 2021, an update in national legislation changed the requirement for informed consent to a right to refuse data collection in the NHFR.

8.5 Patient involvement

All research projects funded by the Northern Norway RHA are obliged to have a patient representative in the project group. Hip fracture patients have no patient organization or specific patient group. From the Nordland Hospital Trust Patient Council, a representative from the Nordland County Senior Council, Mai-Helen Walsnes, was appointed and joined the project group. She was a member of the group during the planning of the research and progress of the project, attended the group's meetings and was included in communication related to the meetings. As a patient representative, she has provided useful insights and perspectives on research questions.

9 Summary of results

9.1 Paper I

Kjaervik C, Stensland E, Byhring HS, Gjertsen J-E, Dybvik E, Soereide O. **Hip fracture treatment in Norway deviation from evidence-based treatment guidelines: data from the Norwegian Hip Fracture Register, 2014 to 2018.** Bone Jt Open. 2020 Oct 14;1(10):644-653. DOI: 10.1302/2633-1462.110.BJO-2020-0124.R1

International and national guidelines were identified, and treatment recommendations extracted. All 43 hospitals routinely treating hip fractures in Norway were characterised. From the Norwegian Hip Fracture Register (NHFR), hip fracture patients aged >65 years and operated in the period 2014-2018 for fractures with conclusive treatment guidelines were included (n=29,613: femoral neck fractures (n=21,325), stable trochanteric fractures (n=5,546), inter- and subtrochanteric fractures (n=2,742)). Adherence to treatment recommendations and a composite indicator of best practice were analysed. Patient survival and reoperations were evaluated for each recommendation.

Median age of the patients was 84 years and 69% were women. Seventy-nine percent were treated within 48 hours, and 80% by a surgeon with more than three years' experience. Adherence to guidelines varied substantially but was significantly better in 2018 than in 2014. Having a dedicated hip fracture unit (OR 1.06) and a hospital hip fracture programme (OR 1.16) increased the probability of treatment according to best practice. Surgery after 48 hours increased one-year mortality significantly (OR 1.13). Alternative treatment to arthroplasty for displaced femoral neck fractures (FNFs) increased mortality after 30 days (OR 1.29) and one year (OR 1.45) and increased the number of reoperations (OR 4.61). An uncemented stem increased the risk of reoperation significantly (OR 1.23).

9.2 Paper II

Kjaervik C, Gjertsen J-E, Engeseter L, Stensland E, Dybvik E, Soereide O. **Waiting time for hip fracture surgery: hospital variation, causes, and effects on postoperative mortality: data on 37,708 reported operations to the Norwegian Hip Fracture Register from 2014 to 2018.** Bone Jt Open 2021 Sep; 2(9):710-720. DOI: 10.1302/2633-1462.29.BJO-2021-0079.R1

The study included 37,708 hip fractures in the Norwegian Hip Fracture Register from January 2014 to December 2018 and coupled these with data in the Norwegian Patient Registry. Information about date and time of admission, operation, and death from January 2013 to December 2019 was recorded. Hospitals treating hip fractures were characterized according to their hip fracture care. Waiting times defined in hours and by the term 'expedited surgery' (surgery on the day of, or after admission) were estimated.

Mean waiting time was 23 hours; 2.8% waited three days or more, and 27% of these patients were operated outside regular daytime working hours. Expedited surgery was given to 84% of patients, and 52.5% were treated during daytime. ASA 4/5 patients were more likely to have daytime surgery (OR 1.59; 95% CI 1.38-1.83; p<0.001) and less likely to receive expedited surgery than ASA 1 patients (OR 0.29; 95% CI 0.24-0.36; p<0.001). Low volume hospitals treated a larger proportion of patients during daytime than high volume hospitals (OR 1.26; 95% CI 1.16-1.37; p<0.001). Expedited surgery occurred less frequently in high-volume hospitals. Waiting time increased significantly with higher ASA classes and Charlson Comorbidity Index scores. High volume hospitals had significantly longer waiting times than low and intermediate-low volume hospitals. Patients not receiving expedited surgery had statistically significantly higher 30-day and one-year mortality rates (OR 1.19; 95% CI 1.08-1.31; p<0.001 and OR 1.13; 95% CI 1.06-1.20; p<0.001), respectively.

9.3 Paper III

Kjaervik C, Gjertsen J-E, Stensland E, Saltyte-Benth J, Soereide O. **Hip fracture mortality in Norway 2014 to 2018 - modifiable and non-modifiable risk factors. A linked multi-registry study** (Accepted - Bone Joint J 28.03.22)

Data on 37,394 hip fractures in the Norwegian Hip Fracture Register from January 2014 to December 2018 was linked to data from the Norwegian Patient Registry, Statistics Norway, and characteristics of acute care hospitals. Cox-regression analysis was performed to estimate risk factors associated with mortality. Wald statistic was used to estimate and illustrate relative importance of risk factors. We calculated standardized mortality ratios (SMRs) comparing deaths among hip fracture patients to expected deaths in a standardized reference population.

Mean age was 80.2 (SD 11.4) years, 67.5% were females. Patient factors (male gender, increasing comorbidity (ASA class and Charlson Comorbidity Index)), socioeconomic factors (low income, low education level, living in a healthcare facility), and healthcare factors (hip fracture volume, availability of orthogeriatric services) were associated with increased mortality. Non-modifiable risk factors appeared more important than modifiable factors. The SMR analyses suggested that cumulative excess mortality among hip fracture patients was 15.5% in the first year and 41.2% at six years. SMR was most pronounced the first year and falling from 10.92 in the first month to 3.53 after 12 months, and 2.48 after 6 years observation. Substantial differences in median survival time were found, particularly for patient-related factors.

10 Discussion

10.1 Methodological considerations

In clinical research the main objective is to reveal new information that expands the knowledge base for medical decision making, followed by changes in clinical practice. Clinical research can generally be categorized in two groups: experimental or observational studies. The categorization depends on whether the investigator assigns the exposure or not.

Observational studies can be grouped into the two main categories of analytical or descriptive studies. Analytical studies feature a comparison (control group), unlike descriptive studies[110]. Experimental studies are subdivided into randomized or non-randomized studies. RCTs represent the gold standard in experimental research (effectiveness studies) and will in principle have a high level of evidence[111]. RCTs may prove causality and treatment effects, whilst observational studies can only reveal an association between an exposure and an outcome[111].

Not all research questions in medicine can be answered with an experimental design. Observational studies, particularly register-based ones, may supplement RCTs in situations when an RCT may be unethical or unfeasible[112], particularly in studies based on large (national) populations. Although EBM represented a paradigm shift in the understanding of clinical research findings it is not a panacea. Both health economists (Sønbø Kristiansen & Mooney[113]) and clinicians (Lassen et al[112]) have pointed out that other scientific studies than RCTs and high level EBM papers are necessary, for instance register based studies as used in this thesis.

Effect estimates correspond well between RCTs and observational studies[114], and results from both must be included in evaluations of the scientific literature or in systematic reviews.
In recent years register based RCTs, utilizing the registries as platforms for data collection and follow-up with randomization at inclusion, have received increased attention[115].

10.1.1 Register-based studies

Register studies, such as the present thesis, have several strengths and advantages in the process of gaining new scientific knowledge[116, 117], but also have limitations to be acknowledged.

The main strengths of register studies are[118]:

- The national registries supplying the data used in this thesis (NFHR, NPR and SN), all provide broad data sets and large samples of nationally collected data. The high completeness of reporting to the NHFR[13] (see Chapter 8.2.1) minimizes the risk of selection bias despite the consensus-driven voluntary registration. The data and consequently the findings reported here reflect a "real life" situation. Non-selection is particularly important in hip fracture patients who, due to advanced age and physical and/or cognitive impairment, may be excluded from experimental clinical studies (RCTs).
- Representativeness (completeness of databases) gives a high degree of generalizability, which ensures external validity. Both the NPR and SN record information/data elements electronically, giving a high degree of completeness. Data from such mandatory registers may be of higher quality than self-reported data[116].
- The data are already collected and available for use, with the specific purpose of supplying information for national statistics, research and quality improvement. This reduces costs of procurement of data and facilitates access to data. In addition, it reduces the load of the patients which does not have to report this information.
- Independent prospective collection of data reduces recall bias and possible influences of the study on diagnostic or therapeutic processes.
- National register data bases provide a reliable source for long-term follow-up observations, both hard endpoints (as mortality and reoperations) and also a variety of patient related outcomes. This enables studies of time-dependent occurrences and the observation of outcomes which might present after a long latency period.
- Registers provide demographic information, allowing for adjustment of potential confounders[116]. Combining data sets from several registers on an individual level provides a broad information base that reduces residual confounding even further.

The main limitations of register studies are[118]:

- The researchers cannot influence the selection of variables in the data set and cannot specify criteria for data quality. Potentially useful variables might be uncollected, missing, inaccurate or misclassified. From a researcher perspective, distance from the data collection means that research topics must suit the collected data. On a similar note, it might be difficult to know exactly how the data were collected and generated[116]. It is important to be aware of the exposure(s) and outcome(s) in the available registries. In the NHFR, the primary exposure and inclusion criteria is a hip fracture. In addition, a large set of variables are available to obtain alternative exposures and outcomes. It is necessary in the planning of the study to ascertain that the available cohort(s) coincide with the target population of the studies planned.

- The registers contain information selected for the purpose of the register and might lack important confounder information. Linking data from several registers allows for the inclusion of variables that might contribute to a reduction of residual confounding.
- Missing data in registries can give analytical challenges. Although the actual number of such observations is low, it might in some circumstances affect the analyses. In addition, missing data introduces the concept of underreporting, where systematic lack of registration leads to missing data. For instance, education taken abroad might not be recorded in SN if this information is not captured by other systems, as we see in the national student financing system.
- Data quality may vary. The data should be validated against a gold standard, which might be difficult to define. Often validation is done against other registries to check for completeness. This is only possible where variables are available from two or more registries. The data in the NPR are recorded for administrative purposes and not for medical or health research. Precision and compliance in coding and data delivery makes the data quality variable. In a Norwegian study, Lofthus et al. showed a significant overestimation of fractures in general in administrative data[119]. Assessment of data quality is necessary when data is extracted from host registries in preparation for analysis. Combining data from the NFHR and the NPR reduces the risk of overestimation of the number of included patients.
- With large available data sets "data mining" or "data dredging" might lead to misleading post hoc analyses. It is important to proceed in an orderly fashion in the research process. The scientific questions (i.e., the hypotheses) should lead to analyses of the data, not the opposite.

It is of interest to note the narrow CIs observed in all statistical analyses (**Papers I-III**). This phenomenon reflects the high number of patients studied. On this note it may be argued that CIs in large population-based analytical studies may not be required, since "all" potential persons are included.

Similarly, the results documented have identified nominally small, but still statistically significant differences in outcomes. Such data are found in the analyses and presentation of the effects of modifiable and non-modifiable risk factors (***Paper II***) and in the presentation of survival patterns following hip fracture treatment (see Figure 3 in ***Paper III***).

The minor differences may lead to a discussion of the terms *statistically significant* versus *clinically relevant*. An alternative way of discussing "small" but significant differences is to note that a small difference on a population level may represent large nominal differences on an individual level. As an example, in the hip fracture population in this thesis of around 40,000 patients, a 1% change in risk will transform into a relatively large number of individuals (400 people) who are potentially affected. Similarly, the small but significant survival differences between categories of variables (***Paper III***, Table 3) translate into differences in median survival which is not insignificant in elderly patients.

Small differences should not lead to therapeutic nihilism. Seemingly unimportant clinical differences can be statistically significant in register-based population studies with large sample sizes. Measures of association with CIs show the strength, direction and range of an effect. These measures, combined with knowledge of the exposures and outcomes measured, prepare the ground for an evaluation of the relevance of the finding[110]. It is not sufficient to only evaluate the p-value, which merely addresses the possibility of chance. "Statistical significance" does not necessarily equal clinical relevance.

10.1.2 Evaluation of guidelines

In ***Paper I***, international evidence-based guidelines fulfilling the GIN standards[49, 102-104] were assessed to establish a reference treatment norm for hip fractures. The basis of the guidelines was experimental and observational studies of high quality with a level of certainty (or strength of evidence) according to the GRADE principles[101].

In hip fracture treatment, the shift from osteosynthesis of displaced FNFs to arthroplasty was observed and incorporated in the evidence base in the included guidelines. Yet some controversies (Chapter 6.4.3) do remain, and new knowledge acquired during the study period may have changed clinical practice. Despite this, the evidence-based guidelines employed in ***Paper I*** form a solid basis for defining best current practice, as significant paradigm shifts in treatment policy for hip fractures have not been observed.

10.1.3 Characterization of hospitals

To describe service provision, a characterization of hospitals treating hip fractures in Norway was performed. The survey was based on an online form filled out by the NHFR liaison orthopaedic surgeon in hospitals in Norway. The survey (Google Forms; Appendix II) consisted of both multiple-choice questions and free text fields. The response rate was 100%.

There is no common taxonomy in Norway nor internationally used to characterize hospitals, service delivery and care pathways. Therefore, it is legitimate to question whether the selected variables in the survey were adequate to characterize service provision. Secondly, the absence of uniform definitions made it difficult to characterize specific services. Due to a rising number of publications related to orthogeriatric services and interdisciplinary care, we included questions on available professional resources (geriatrician, internal medicine consultant, orthogeriatric team, physiotherapist, occupational therapist and others) and whether the hospitals had defined programmes or care pathways for hip fracture patients.

The survey was answered by specialist orthopaedic surgeons and might introduce an element of recall bias. Inter-observer variation can also occur given that the liaison orthopaedic specialist interpreted and answered the questions independently without consultation with other staff members. The actual responses on fracture volume and catchment area population were cross-checked against data from NFHR. Interrelated variables were evaluated to control for obvious logical errors. Hospitals with seemingly conflicting information were contacted for confirmation or correction.

From an analytical perspective we note that many of the recorded information elements were interrelated. Consequently, a note of caution was warranted when the influence(s) of hospital characteristics were analysed and presented.

10.1.4 Comorbidity and patient risk factors

We know from an abundance of studies that patient comorbidity, both as individual risk factors expressing disease entities or as comorbidity indices, have a strong impact on postoperative mortality and can act as possible confounder(s) in analyses of hip fracture patients.

In register-based studies such risk indices must either be based on administrative data or on a simplified clinical assessment of risk. NHFR records a global risk assessment score expressed as ASA class (see below), while ICD-10 diagnoses for specified accompanying diseases routinely reported to the NPR were used to create a summary comorbidity index (CCI; see below). The Charlson Comorbidity Index (CCI)[120] and the equivalent Elixhauser Comorbidity Index[121] are examples of established summary comorbidity indices estimated on the basis of recorded ICD10-diagnostic codes in administrative data bases, here the NPR. The Charlson Comorbidity Index was first developed in 1987 by Mary Charlson[84] and colleagues as a weighted index to predict risk of death within 1 year of hospitalization for patients with specific comorbid conditions. Nineteen medical conditions were originally included in the index. The use of the CCI has been validated using Norwegian data (NPR)[85].

While some authors document their validity in predicting mortality[122, 123], others report a low predictive power of such indices in a hip fracture population[124]. The main challenge is the data quality in administrative databases, more specifically, if relevant accompanying comorbidities have been coded and reported. Missing codes might lead to an underestimation of comorbidity and the method of calculation might differ between countries and studies. The result indices should be judiciously interpreted across national systems. In three Nordic countries the distribution of CCI-scores in hip fracture patients do vary (Table 4), and notably, the index calculations are based on different validations and weighting of diagnosis. The external validity of a calculated CCI-score might therefore be variable, but the internal validity seems adequate considering the validations performed in each country using the score. The consequence is probably not misleading results, but rather a potential for a “stage migration phenomenon” effect. In medical science, stage migration, originally a term coined by Feinstein et al[125] in 1985, represents the altered detection or classification of illness that leads to the movement of people from the one classification stage to another. High detection of comorbidity/illnesses in one area makes the population seem more ill than another population where lower detection makes them seem less comorbid and healthier. Data presented in *Papers II and III* document a discriminatory power of CCI in influencing preoperative waiting ting and in predicting mortality. The categorization of the CCI index in populations in Scandinavia (Table 4) differs somewhat, but the survival patterns in *Paper III* (Supplementary Figures A and B*)* of the association between ASA score, the CCI and mortality are comparable to data published by Ek et al.[123]

CCI Score	Kjærvik et al[3]	Ek et al[123]	Öztürk et al[126]
0	69.0	49.9	39.5
1-2	22.0	43.4	40.3
3+	8.9	6.7	20.3
Method of calculation based on	Nilssen et al[85]	Brusselaers et al[127]	Charlson et al[84]

Table 4: Distribution of Charlson Comorbidity Index (CCI) in different data sets

The ASA classification is an expression of operative risk based on clinical observation and assessment of the patients. The ASA classification was introduced in 1941[80] and has undergone few modifications, despite vast advances and changes in surgical and anaesthetic practice. Inter-observer consistency is fair and stable over time[128]. ASA has repeatedly been found useful and reproducible in prediction of mortality for the patient, despite the rather crude clinical assessment of the patient[129]. ASA class is reported routinely to the NHFR.

In Norway, ASA classification is performed by the attending anaesthesiologist close to the time of operation and probably represent the best ASA class achievable for that individual patient. A moderate correlation between the CCI and ASA has been demonstrated, and both indices demonstrate a similar correlation with one-year mortality[123]. Both scores show equal predictive value of 30-day mortality but CCI demands calculative power[130].

Some scoring systems for risk assessment and prediction of mortality in orthopaedic surgery are based on clinical assessment and physiological parameters such as the POSSUM[131] (Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity) system and the Nottingham Hip Fracture Score[132]. They are somewhat time-consuming in routine use and have some limitations in accuracy but are validated to predict mortality. Frailty indices like Sernbo Score[133] and Clinical Frailty Scale[134] are all indices based on clinical assessment of the patient and both have proven associations to mortality. Frailty indices are not recorded routinely in clinical practice in Norway and therefore not available in any available registers. Recently, Gilbert et al[135] developed and published a frailty index based on routine administrative data (as in NPR). The use of such index should be explored and validated based on NPR data. We hypothesize that the ASA score, CCI and a frailty index will be intercorrelated, but further studies are required to elucidate their relative value as a prognostic risk score both for postoperative mortality and for postoperative physical function and need for community healthcare.

10.1.5 Statistics

Choices of statistical methods depend on the available data and the purpose of the study. In this thesis, standard methods for descriptive statistics were used, and assessments of association and survival analyses were performed with commonly used methods available in most statistical computer packages.

Logistic regression analysis is a standard method to model probability of a discrete outcomes and was utilized in ***Papers I and II***. The main limitation is the assumption that the relationship between the dependent and the independent variables is uniform[136], and this had to be incorporated into the interpretation of analyses.

Analysis of variance (ANOVA) was performed in ***Paper II*** to assess differences in waiting time between separate groups. One assumption for ANOVA is normality. Due to an observed obvious right skew in the waiting time variable, a Bonferroni correction was applied to reduce risk of a Type 1 error.

Kaplan-Meier and Cox regression analyses, which are standard for survival analysis, were used in ***Paper III***. Cox regression models enable adjustment for relevant covariates. The Cox models assume proportionality with a constant (not time-dependent) hazard with time. This is not always present and can lead to analytical challenges. A recent literature review has demonstrated that many research papers do not mention whether the proportionality assumption was actually checked and reported, and sometimes also the method used[137]. In ***Paper III***, sex and ASA were time-dependent covariates violating the proportional hazard assumption and had to be analysed separately in a linear regression model for coefficients, and with generated time dependent covariates in the Cox model.

In ***Paper III*****,** the Wald statistic was estimated with the purpose of ranking the relative importance of covariates**.** The Wald statistic (also called the Wald chi-square test) is a parametric statistical measure to confirm whether a set of independent variables is 'significant' in a model or not[108]. The Wald statistic may be more inaccurate in small sample sizes, which is considered less important in a register study[109]. In our study the test was performed with a modification: subtracting the degrees of freedom to introduce a penalty for the numbers of parameters. This is an adjustment first introduced in the R statistical programme[138].

When interpreting the results, the rank represents the strength of the statistical association and not necessarily the clinical importance nor the relative importance of each covariate. The Wald statistic is therefore a surrogate marker of relative importance. Recently, Cao and associates[139] explored the predictive ability (and therefore the relative value) of preoperative characteristics in hip fracture patients using advanced modelling techniques and could present the relative variable importance in predicting 30-day mortality.

10.1.6 Summary

In this thesis the aim and design of the studies were planned and decided before data collection and were described in the application for funding. The aim of the data collection was to provide adequate data for exposure (hip fractures) and outcomes (i.e., mortality and survival, reoperations and waiting time). In addition, several covariates were added to reduce residual confounding and were obtained through a wide selection of variables obtained from three registries and an online survey of hospitals.

For this project, in which evaluation of treatment and outcomes for an entire national hip fracture population was planned, experimental design was not an option. This thesis therefore contains observational prospective cohort studies based on national register data, which implies that we are unable to prove causality, only associations between exposures and outcomes.

The "Strengthening the Reporting of Observational Studies in Epidemiology"[140] (STROBE) statement and the "Reporting of Studies Conducted using Observational Routinely-Collected Health Data"[141] (RECORD) statement are both guidelines providing minimum reporting requirements for observational studies. The STROBE statement is designed for observational cohort, cross-sectional and case-control studies. The RECORD statement is designed as an extension to observational studies using routinely collected data, i.e., administrative data, disease registers and health surveillance data. All papers in this thesis have been written according to both the STROBE and RECORD statements, given the nature of this project and an observational prospective cohort design based on routinely collected data.

10.2 General discussion

In the following, the results from the **Papers I-III** will be set in a broader context and the overall findings will be discussed.

10.2.1 Adherence to guidelines and practice variation

Clinicians strive to provide and the society expects evidence-based and high quality health care in an environment of rapidly changing treatment alternatives, rising expectations from patients, families and society, in a health services system with allegedly constrained resources, and with a complexity of delivery systems and processes of care[142].

In **Paper I,** a marked deviation in adherence to guideline recommendations was demonstrated. The mean composite best practice indicator (surgery within 48 hours with an experienced surgeon on the team and fracture type specific recommended treatment) was 50% in 2014, increasing to 59% in 2018, indicating that a substantial proportion of the patients did not receive "best practice", i.e., high quality care.

Adherence to the item specific guideline recommendations also differed substantially between hospitals and the mean proportion fulfilling the recommendations varied from 68%-96% (Table 5).

Adherence to guideline recommendations in treatment of hip fractures in Norway 2014-2018.			
	Lowest	Mean	Highest
Surgery within 48 h	71 %	83 %	91 %
Experienced surgeon	65 %	83 %	96 %
Parallel screws for undisplaced FNFs	51 %	86 %	99 %
Arthroplasty for displaced FNFs	79 %	96 %	99 %
Arthroplasty with cemented stem	0.3%	80 %	99.7%
Sliding hip screw for AO/OTA A1	0 %	68 %	99 %
Intramedullary nail for AO/OTA A2+A3	9 %	76 %	100 %

*Table 5: Proportion of patients treated according to guideline recommendations in Norway – data from **Paper I***

Guidelines do not cover all clinical facets and patient's needs, implying that 100% compliance to guideline recommendations is not a realistic aim nor desirable. The NHFR has established a set of quality indicators where a *satisfactory level* is set at 90%, reflecting that individual adaptations in treatment for patients who do not fit the item specific guideline algorithm is warranted. Similarly, some surgeon discretion must be accepted to provide patient-centred care.

The substantial differences between hospitals observed in ***Paper I*** (Table 5) were unexpected. Forsén et al.[63] and the Darthmouth Atlas of Health Care[67] have shown some geographical differences in incidence of hip fractures in Norway and the USA respectively, but there is no reason to believe that geographical differences in incidence of fractures and case-mix of patients could explain the variation in practice among Norwegian hospitals of the magnitude described in ***Paper I***. Thus, we hypothesize that most of the observed variation is unwarranted.

Hip fractures are a disease entity in which there is negligible variation in the decision whether to treat or not. Consequently, the observed variation must be attributed to treatment preferences or to a disorderly treatment process. In hip fractures where clear national guideline recommendations and professional consensus do exist, one would expect smaller treatment variation. This might contrast diseases with ongoing controversies as to what reflects best practice[66]. Some of the largest variations identified in ***Paper I*** (Table 5), were observed in areas with some known current treatment controversies (see Chapter 6.4.3).

Variation in treatment of hip fractures is not a Norwegian phenomenon only. In the annual reports of the Danish[143], Swedish[144] and British[145] hip fracture registers similar variation is observed. In the 2021 annual report of the British National Hip Fracture Database, 71% of the patients received an operation recommended by NICE[145]. This was a reduction of 3 percentage points from 2020 and was mainly caused by unsubstantiated use of intramedullary nails. In the same report 69% of patients received treatment within the day after admission, i.e., prompt surgery (the term "expedited surgery" was used in ***Paper II*** and is synonymously to "prompt surgery" used by the UK register). Comparably, in ***Paper II***, we found that 74% of the patients were operated within the day after admission.

In 2013 Zielinski and coworkers[146] found 74% adherence to guidelines, most of the deviations were related to use of internal fixation for displaced FNFs (Garden III-IV) in patients >65 years of age. This contrasts the findings here that the use of arthroplasty for displaced FNF was the recommendation with highest average compliance (96%; ***Paper I***, Table 4) and with minute variation between hospitals. In the Netherlands other surgical specialists than orthopaedic surgeons may also treat hip fractures and compliance to guidelines there varied significantly between trauma and non-trauma certified orthopaedic surgeons and general surgeons[147]. In Norway hip fractures are almost exclusively operated on by orthopaedic surgeons and residents, and one of the quality indicators recommended by NHFR is that one of the attending surgeons should have at least three years of experience of fracture surgery.

The stark contrast between unequivocal guideline recommendations (Table 3, page 36) and clinical practice in some hospitals as to the use of uncemented hip prostheses could be explained by new scientific evidence after the guidelines (Table 3) were published supporting use of uncemented hips. Here it is of note that AAOS published updated guidelines in 2021 and uphold the recommendation of cemented stems based on evidence rated as strong[50].

Can variation be explained? In **Paper I** we found that non-adherence to guidelines (best practice) was associated to hospital and system factors adjusted for age, sex and ASA class (comorbidity). This suggests that knowledge from EBGs do not necessarily guarantee dissemination of best practice. Grove et al[148], in an extensive systematic review, described that socialization and interactions of medical professionals and "word-by-mouth", that cultural and normative elements of surgical practice and the existence of competing sources of knowledge are significant drivers of variation. Wensing et al[149] described that professional networks with practice comparison and role modelling can enhance good practice, and that professional networks with many interactions may spread innovations more quickly than networks with less interaction. Consequently, little professional interaction may lead to slower adaption of change than in professional environments with many interactions. In **Paper I**, we did not find that increasing hospital size, expressed by fracture volume, in general was correlated to better compliance. "Low" volume and "Intermediate high" volume hospitals were significant more compliant than high volume hospitals. It is an unexplained paradox that some high-volume hospitals which include all regional and university hospitals where professional interactions should be marked, were among those with marked deviation(s) from guidelines.

Birkmeyer et al[150] argued that hospitals have a “surgical signature” and suggested that variation primarily reflected physicians’ opinion and how patient preferences are incorporated in the decision processes. Data in **Paper I** clearly demonstrate that some hospitals have made an explicit choice of not complying with recommended guidelines (example: 0% SHS in AO/OTA A1 fractures, 100% IMN in AO/OTA A1 and 0.3% cemented stems in arthroplasties in one hospital). Such deviations indicate a systematic and substandard evidence practice in some hospitals. Guidelines specify how health care and treatment are supposed to be carried out. Guideline recommended practice reduces the clinicians’ choices and surgeons` discretion and professional freedom. Timmermans[151] stated that this transition, from surgeons discretion to less freedom, might be a threat to professional autonomy, which in turn can increase resistance to implementation and treatment changes. But if the notion of “EBM practice leads to high quality care” is valid we must sacrifice less professional freedom for a “common good”. Compliance to guidelines is not exclusively determined by the surgeons. Structural factors and processes of care are the responsibility of a higher organizational level in the hospitals and managerial decisions may affect translation of guidelines into clinical practice.

Deviations from guideline recommendations are not unique in hip fracture surgery. It is beyond the scope of this thesis to discuss this topic in full, but deviations are observed in conservative treatment of osteoarthritis in the knee, with reduced adherence with increasing severity of disease[152], and in the administration of pre- and intraoperative antibiotics in a variety of surgical specialities including orthopaedics[153] (more than a third of surgical episodes resulted in administration discordant with established guidelines). Emergency surgery had lower degree of adherence to guidelines compared to non-emergency surgery (58% vs 64%).

A challenging aspect of medical care is the impressive and rapid rate at which new practice information but not necessarily best knowledge, is produced and published. Evidence-based guidelines will rapidly loose legitimacy as time passes if the knowledge base is not revised regularly and is updated. Bastian et al[154] in 2010 described an information overload (information drowning) for clinicians with 75 trials and 11 literature reviews published every day. They point out the importance of and need for streamlined and innovative methods to review and disseminate new knowledge and best evidence.

The term *translational research (*for definition, see National Institute of Health[155]) is a scientific concept focusing on the how to translate research findings, from basic research into clinical practice for a population[156]. The transition process is challenging, particularly if the aim is to enhance the adoption of best practices in the community/population. Better understanding of these processes to secure the translation of important research findings to clinical practice is required[157]. Knowledge translates into practice, but not to all clinicians or patients. Kreuter and Wang[158] argued that science alone is not sufficient to support successful dissemination and implementation of research findings, and that scientists may be poorly suited to facilitate this process. They argue for a more professional dissemination system to ensure transition to practice.

Matharu et al[159] noted an improvement in compliance to guidelines among surgeons after NICE issued an updated guideline on venous thromboembolism. They observed that one-third of the surgeons surveyed changed their practice after publication of the guideline. However, Ament et al[160] in a review have shown a decline in adherence to guidelines over time; they observed a dwindling adherence after more than one year after publication of a guideline.

A successful implementation of evidence-based practice depends on system factors, organizational factors, and individual factors[161] as outlined and summarized in Figure 13.

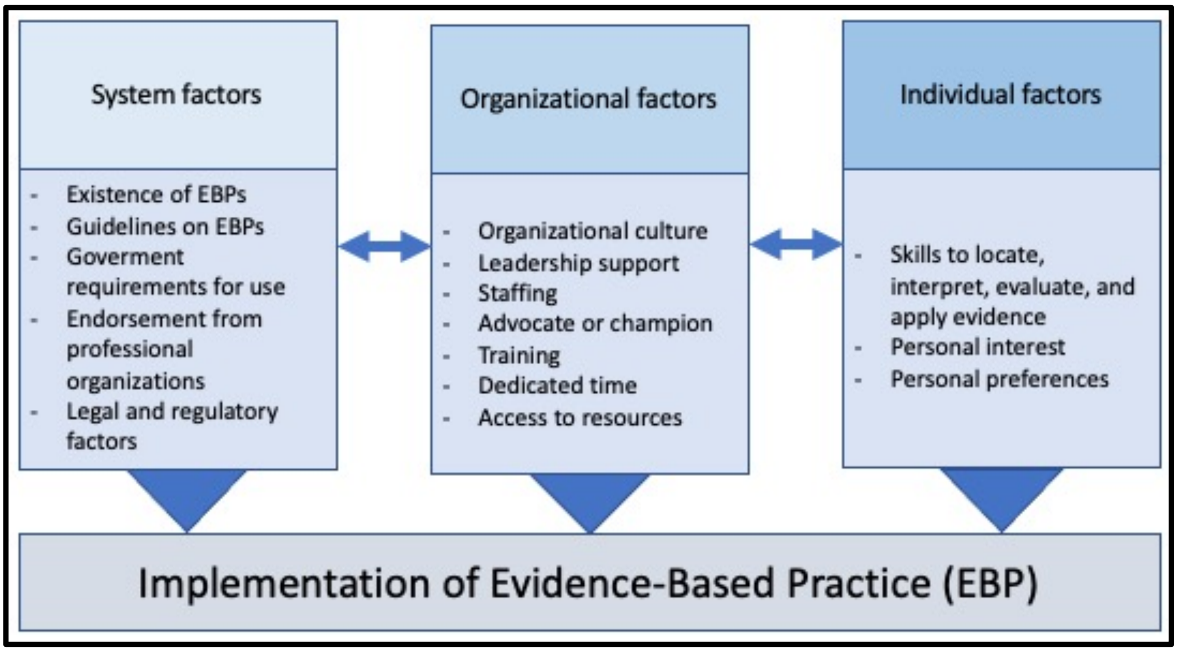

Figure 13: Implementation of evidence based practice (Based on Kennedy et al[161])

Wensing et al[149] described governmental control as a method of implementing improved care in the form of legislation, financial sanctions, and disciplinary measures, i.e., use of traditional political instruments. In the UK the NHS has introduced "best practice tariff" as a measure to improve care by reducing reimbursements if Key Performance Indicators are not fulfilled. Such economic disincentives have not led to a significant improvement of outcomes[162]. In Israel, a reimbursement system based on economic incentives if waiting time to surgery is reduced has led to reduction of waiting time[163]. In Canada however, no effect on waiting time was observed after implementing a targeted funding reform[164]. In Norway and other Nordic countries such financial systems have not been proposed nor tested.

The NFHR publishes results online regularly[165], supplying information to all interested parties and to encourage practice improvement. Open and updated information may act as stimulus to change practice through a motivational and professional reinforcement approach contrary to the top-down policy approach earlier described by Wensing et al[164]. Motivation by giving continuous feedback on current practice, and reinforcement by offering reminders of areas to improve appear to be a preferred policy and is the basic incitement for medical quality registers.

Non-compliance to guidelines resulted in negative outcomes for patients with increased mortality and reoperations as consequences (***Paper I***). Such results support the literature reviews on treatment effectiveness which served as the knowledge base for the evidence-based guidelines summarized in Table 3 and ***Paper I*** (*Table 1)*[49, 54, 102-104]. Farrow et al also showed increased survival after hip fractures and reduced likelihood of discharge to a higher level of care when adhering to national practice standards in Scotland[166]. Taken together the results support the clinical utility of the guidelines and their use as benchmarking tools to improve care of hip fractures.

Dissemination of knowledge and translation to routine clinical practice is challenging. The substantial deviation from EBGs found in ***Paper I*** and by other authors may indicate that EBGs are only one approach to implement high quality care. Efforts must be made to identify different avenues for optimizing the translational processes.

A proportion of the observed deviation from guidelines could theoretically arise from patient preferences and raises the question of patient information. Patients have a legal right to information that empowers them, i.e., give them insight in and a fundament to consent to the proposed treatment with its consequences and alternatives. Obtaining an informed consent in an elderly population with high prevalence of cognitive impairment[167] might be challenging. Studies have shown a variable acquisition of consent in elderly patients[168, 169], and it is likely that many hip fracture patients do not fully understand the consequences of treatment offered by the surgeon and the hospital staff. Dahlberg et al[168] studying elderly patients admitted to surgical departments did not find in any of 102 patients´ clinical charts evaluated legally valid recorded assessment of competence to consent. An alternative strategy might be based on the term *presumed* consent. But presumed consent should be applied in three situations only: patient incapacity, clinical urgency and clarity on the correct course of action[167]. In hip fracture patients with an average waiting time of 23 hours (***Paper II***) prior to surgery, incapacity might be present, but a clinical urgency inherent in hip fracture treatment cannot be used as an excuse for substandard information and collection of a proper consent. For patients, the best mode of treatment action is not straightforward. In the hip fracture population with elderly and frail patients presenting as a surgical emergency it is likely that patient preferences are of minor importance to the clinicians. This leads to an even greater responsibility for the care providers to supply adequate information, obtain consent and deliver high quality patient-centred care.

10.2.2 Waiting time from admission to surgery

In all three papers the effect of waiting time from admission to surgery on outcome (mortality) was explored and **Paper II** addressed both patient- and healthcare-related factors affecting waiting.

In **Paper I** a statistically significant association between surgery within 48 hours of admission and reduced one-year mortality was found. In **Paper II** expedited surgery (surgery within the day after admission) was shown to be associated with reduced 30-day and one- year mortality in analyses adjusted for age, sex, and comorbidity (CCI), but the effect was not observed when adjusting for ASA risk class. In **Paper III**, in a multivariate model using data from multiple linked registers, there was no significant association between expedited surgery and mortality.

An abundance of papers has explored the effect of waiting time on mortality, mainly hypothesizing that longer waiting time is associated with adverse outcomes and a higher postoperative mortality rate. According to a PubMed search, approximately 200 scientific papers have been published on this topic since 2000. Evidence-based guidelines for hip fracture treatment[49, 54, 102-104] generally advise expedited surgery, with somewhat varying time limits, but all guidelines recommend surgery at least within 48 hours.

In 2016, Lewis and Waddel[170] published an extensive narrative review on the evidence of timing of hip fracture surgery. Assessment of institutional observational studies, two RCTs, register-based studies, metanalyses and systematic reviews lead the authors to conclude that "early" operation is probably best for fit patients, and that delaying surgery to optimize correctable comorbidities is advisable, but no consensus exists regarding timeframe or time threshold.

In 2017, Morrisey et al[171] and Pincus and coworkers[172] demonstrated an association between waiting time and mortality, and advocated a threshold of higher risk at 24 hours. Pincus et al[172] also showed a corresponding increase in medical complications with prolonged waiting. In a meta-analysis from 2021 including 521,857 hip fractures, Welford et al.[173], found lower mortality in patients operated within 24 hours and advocate that when there is no reversible contraindication that fractures should be treated within 24 hours.

In a Danish registry study[126] from 2019 including 36,552 patients, a detrimental effect of surgical delay, defined as >24 hours delay, on 30-day mortality, with "no or medium level" comorbidity was found. Surgical delay also increased one-year mortality in "healthy" patients without comorbidity. A large Swedish registry study from 2020[174] including 56,675 patients from a national cohort showed no significant negative effect (i.e. no association) of waiting time to surgery on mortality for "healthier patients". Thus, the Danish and Swedish studies present contradictory findings regarding the effect of waiting time for "healthier" patients. Comorbidity in these two studies was expressed by the CCI (i.e., accompanying diseases) and ASA risk class categorization respectively. In ***Paper II***, and in line with Greve et al.[174], we found that the correlation between waiting time and mortality disappeared when adjusting for ASA class. Our findings also mirror those of Öztürk and coworkers[126], in that the detrimental effect on mortality persisted when adjusting for comorbidity (CCI). Those authors did not, however, adjust for ASA class. Adjustment alters the results substantially indicating residual confounding.

In **Paper III** the association of expedited surgery with mortality was non-significant in a multivariate model, and when the relative importance of different factors was explored, waiting time in general had the lowest association of all the significant factors.

The scientific literature on this topic is characterized by a significant heterogeneity of studies with[170]:

- Varying patient populations/databases
- Subgroup analyses
- No uniform definition of early surgery
- Variable case-mix
- Variable adjustment for potential confounders
- Variable endpoints (death (mortality), morbidity, length of stay, quality of life or PROMs, return to independent living, costs).

The associations between waiting time and mortality found in our papers are well in line with the contemporary literature discussed above. The effect of waiting time is probably not equal for all patients, as pointed out by Greve et al[174]. A strictly enforced waiting time limit will probably not be applicable or beneficial for all patients. Some patients have correctable comorbidities and will benefit from a delay, for instance anticoagulated, septic and cardiac failure patients[54].

Hip fracture patients are immobilized, bedridden and dependent on care during their waiting time for surgery. In such a situation they are at risk of developing complications, such as urinary tract infections, venous thromboembolism, pneumonia and pressure ulcers[175]. Kelly-Petterson et al[175] advised that patients with higher age and ASA class, males and those with subtrochanteric fractures should be prioritized for surgery as such patients are most prone to complications. Shen et al[176] also documented an increase in adverse medical effects other than mortality with prolonged waiting. One other study[177] has shown an improved ability to return to independent living, a shorter hospital stay and a reduced risk of pressure ulcers in patients receiving early rather than late surgery. These findings suggest that other outcome measures than mortality might be more informative.

It may be argued (***Paper II***) that the waiting time quandary and the conflicting research findings cannot be isolated to a research question only and that a strong patient perspective and voice are required in an "ideal waiting time" decision-making process. We do not need more research to conclude that an acute unoperated hip fracture leads to immobility in a prone position, care dependency, pain, venous stasis and potential thrombosis, risk of catabolism and that significant and reversible comorbidities should be corrected. With that in mind, and with respect for the many conundrums in health care structure and processes, it appears warranted to conclude that most hip fracture patients should be treated by expedited (prompt) surgery. Applying a patient perspective, the waiting time quality indicator of 48 hours is not justified as the 48-hour limit frequently will add an extra night waiting with additional suffering for the patient as a result (*Figure 3* in ***Paper II***). The patient perspective is particularly important in a clinical situation in which the negative effect of waiting on patients using "hard" endpoints is marginal.

There is a striking contrast between the abundance of published research papers addressing the potential detrimental effects of waiting time and the relatively few scientific articles elucidating factors influencing or explaining "long" waiting time. In **Paper II** both patient (comorbidity and fracture type) and system factors (treatment type, ward organization and hip fracture volume) affected the in-hospital waiting time. Of note is the significant linear regression between hip fracture volume (as a surrogate marker of hospital size) and the proportion of patients having expedited surgery. Large (high volume) hospitals had a lower proportion of expedited (prompt) surgery than smaller hospitals.

In a scoping review Sheehan et al included 26 studies regarding patient and system factors affecting waiting time for hip fracture surgery[178]. They concluded that age, anticoagulant therapy, clinical stability, comorbidity and socioeconomic status were the main patient factors influencing delay, while out-of-hours admission, operating room availability and surgery type were the most important system factors. Others[179, 180] have pointed to comorbidity and hospital size as prominent factors associated to waiting, comparable to the findings in **Paper II**. High volumes of recent surgical hospital admissions and competition for surgical resources (i.e. infrastructure) within hospitals were shown by Nilsen et al.[181] to increase delay. This paper indirectly supports the findings in ***Paper II*** by suggesting that high hospital hip fracture volume increases delay.

Fast-track surgery is an organisational strategy to streamline patient pathways of care from admission to surgery, and from surgery to discharge. Such concepts have been implemented worldwide with slightly differing organization but with the same overall goal: expedited and optimal flow through the care pathway[182]. Larsson et al showed that "fast track" reduced time to X-ray and admission to ward but had no effect on time to surgery or on any other measured outcomes[183]. In a 2021 review, Maher et al[184], included seven studies and a total of 5,723 patients to evaluate the effects of fast-track pathways of care and showed that time from admission to diagnosis and admission to ward was reduced, delirium rate was reduced, while time to surgery and postoperative mortality remained unchanged. Evaluating the effects of fast-track surgery on mortality introduces analytical complexity compared to studies of waiting time directly, since the effect of fast-track surgery may be indirect through reduced time to surgery. As an additional observation, Maher el al[184] found that a fast-track pathway was not followed by reduced waiting time to surgery.

In summary, we may conclude that there is genuine uncertainty regarding the "ideal" preoperative waiting time interval. A potential statistically significant negative effect of waiting (**Paper I and II**) may disappear when a broader and multivariate analysis is performed (**Paper III**). At best waiting time has a marginal and negative effect on postoperative mortality (see 10.2.3).

The discussion on the ideal waiting time for hip fracture surgery is complex because there are a large number of factors directly or indirectly affecting both waiting time and mortality[55]. The complexity makes it challenging to specify generalizable recommendations for the entire hip fracture population. Waiting time is clearly important to the patient, regardless of the findings in studies and all patients should receive final treatment with as short a delay as possible. Prolonged waiting has consequences for the patients and "softer endpoints" such as medical complications and patient pain and suffering might be more important than mortality. A waiting time limit of 48 hours, involving two nights bedridden, used as a quality indicator in Norway is unlikely to be in the best interest of hip fracture patients.

10.2.3 Mortality and mortality patterns

Paper III analyses a broad range of patient factors, characteristics of hospital systems and socioeconomic/educational data and their association to mortality assessed in a single multivariate analytical model. The wide range of covariates and perspectives introduced here not only give information on the relative value of relevant cofactors, but also give more realistic results related to the effect (odds ratios) of covariates on mortality. Introducing patient, socioeconomic and health system variables simultaneously in analyses also reduce the challenges related to residual confounding.

The overall mortality data presented here **(Paper I** (n=29,613) **and Paper III** (n=37,394)) are in line with those of national hip fracture register studies from Denmark, Sweden and the UK (Table 6). Thirty-day mortality rates of 8-9% and a one-year death rates of 22-27% are what can probably be expected in contemporary orthopaedic practice at the national level.

Country of origin	**Norway 2014-2018**	**Norway 2014-2018**	**Denmark 2000-2014**	**Sweden 2014-2017**	**UK 2000-2010**
	Kjærvik et al. (n=29,613) **Paper I**	Kjærvik et al. (n=37,394) **Paper III**	Gundel et al.[185] (n=113,721)	Meyer et al.[19] (n=54,743)	Klop et al.[186] (n=148,144)
30-day mortality	8.6%	7.8%	9.6%	7.8%	
One-year mortality	25.7%	22.6%	27%	25.3%	22.0%

Table 6: Hip fracture mortality in national hip fracture populations

This thesis does not address temporal changes in mortality specifically but a study from Denmark[201] concluded that mortality rates there were stable in the period 2000-2014. This is similar to Swedish register data [19] which also demonstrated unchanged mortality rates following hip fractures between 1998 and 2017, but with a slight improvement when adjusting for comorbidity. This contrasts population-based UK data[186] demonstrating a decrease in one-year mortality (2000-2008 vs 2009-2010) corresponding to a 1.8% percentage point mortality reduction in one-year mortality. Similarly, a register-based study from Sweden [187] revealed a decline in the four-month mortality rate from 14.9% in 1999 to 10.0% in 2017. A note of caution is warranted here as the UK study[186] also found that the all-cause mortality in the reference population declined at the same rate as that of hip fracture patients. Thus, the difference between mortality in the hip fracture population and the reference population remained constant indicating that the excess mortality caused by hip fractures was unchanged over the study period.

Paper III (Figure 3) demonstrated an excess cumulative mortality difference compared to a reference population of 16 percentage points after one year (22.6% mortality in patients versus 6.4% in controls) and 41 percentage points after six years (69.1% mortality in patients versus 27.9% in controls). Excess mortality with time, estimated using SMRs, is illustrated in Figure 14 (CIs added to Figure 3B, **Paper III**).

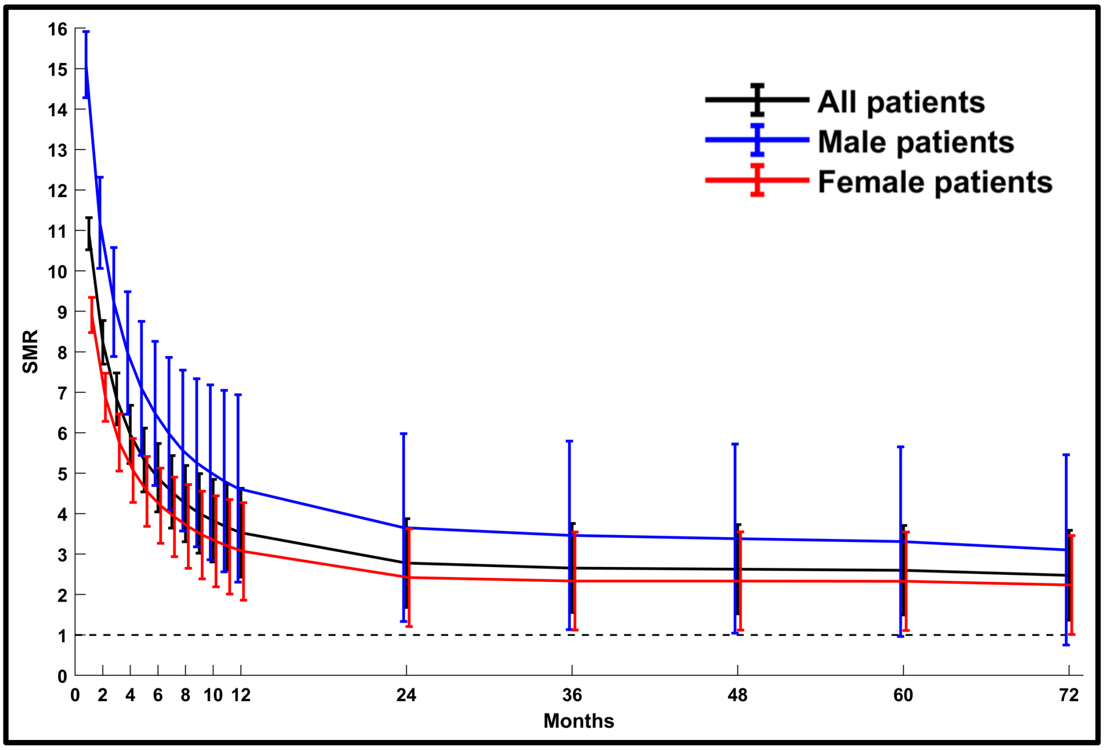

*Figure 14: Excess mortality expressed as SMR following hip fractures (vertical bars represent 95% CI), modified from Figure 3B, **Paper III***

Excess mortality (SMR) dropped quite markedly during the initial 12 months after surgery with an SMR at one year of 3.5. Over the follow-up period a further reduction was found with an SMR of 2.5 after six years. Excess deaths compared to a reference population occurred mainly during the first 24 months after treatment, but with a persistently higher SMR up to six years as shown by the CI in Figure 14. The initial quite marked sex difference is apparent in Figure 14, corroborating the time dependency described in ***Paper III*** (Figure 2). Men had a consistently higher SMR than women up to six years (3.1 versus 2.2 respectively at 6 years).

The substantial excess mortality rates observed in the first year are further illustrated in the Kaplan-Meier survival curves shown in Supplementary Figures A and B in **Paper III.** After an initial quite marked drop the survival curves for variable categories levelled off to a more linear decline. Notably, patients in ASA class 1 had no initial drop in survival compared to the reference population. Comparable findings are presented by Ek et al.[123], in patients aged from 60 to 79 years. They also found no initial drop for the CCI 0 category in either male or female patients. Further, similar initial drops in survival, between the CCI and the ASA classes and mortality is graphically similar in ***Paper III*** and the study by Ek et al.[123]

The findings and pattern of excess mortality rates in this thesis correspond well with the study by Finnes et al[188] from Norway. They analysed data from hospital records (n=6,054; not population-based) in Oslo, Norway and found that hip fracture patients had a considerable higher mortality than a reference population the first year post-treatment with the SMR ranging from 3.6 to 4.5 in men and 2.8 to 3.6 in women. Solbakken and coworkeres[189] in a study based on data from the NOREPOS hip fracture database found that hip fracture patients had an overall two-fold increased mortality risk (hazard rate ratio 2.26) compared to matched subjects over a two-to-seventeen-year follow-up period.

Similarly, a systematic epidemiological literature review[8] based on data from 1956 to 2005 concluded that excess mortality was highest the first months after surgery, after which it rapidly declined, but it remained elevated for years. Kanis and coworkers[190] studied a Swedish hip fracture population (n=158,589) and found that mortality was higher than in the general population at all ages immediately after the fracture and decreased markedly over a period of six months but still remained higher than that of the general population. The meta-analysis published by Haantjens et al.[75] further corroborated the findings of Abrahamsen et al.[8] and Kanis et al.[190] and in ***Paper III***. Vestergaard and coworkers[191] in a Danish cohort study (data from 1977 to 2001) concluded that the excess mortality might persist up to 20 years after the fracture and stated that the major cause of excess mortality was the fracture event and post-fracture complications, not pre-existing comorbidity.

Multiple studies have concluded that men had higher post treatment mortality than women after a hip fracture[8, 75, 188, 192]. Kannegaard et al[192] could not explain the gender difference after controlling for comorbidities and medication and concluded that male gender in itself is a risk factor. This is in line with results presented in ***Paper III***; men had higher mortality than women even when adjusting for many covariates including comorbidity (CCI) and surgical risk (ASA class). A new and significant finding (***Paper III***) was the time-dependent high mortality risk identified in men the first few weeks after surgery. Of note is that this gender difference (i.e., the hazard rate) is not constant over time for men (***Paper III,*** *Figure 2*).

It is apparent from all the studies referred to above and from ***Paper III*** that the highest excess mortality is found the first few months after surgery, with a further quite marked reduction over the next 24 months, followed by a levelling off. How long the excess death rate persists is still unknown.

A pragmatic division between modifiable and non-modifiable risk factors was introduced in ***Paper III.*** The term *modifiable* is used for cofactors which can be modified by professional interventions (for instance waiting time for surgery) whereas *non-modifiable* factors relate to patient and socioeconomic elements (for instance ASA class, household income and residential status) and hospital characteristics. It may be argued that the medical fitness of the patients, expressed by ASA risk classes, can be improved by preoperative medical interventions, but this argument is unlikely to be valid, as ASA risk stratification was recorded by the anaesthesiologists' just prior to surgery as mentioned in Chapter 10.1.4.

The analysis attempted to estimate the relative value of each risk factor (Table 4, ***Paper III***) and the non-modifiable factors had a statistically stronger association with mortality than modifiable variables. Such findings could lead to therapeutic nihilism, but it is still imperative to improve modifiable factors despite their weaker association with mortality. Small differences in mortality risk on a fracture population level may constitute large differences in remaining life for the individual patient in this age group. In a large number of papers studying mortality after hip fracture patients on a population level, small but still significant differences are often found. In a geriatric population, reduced survival, even less than a year, may represent a substantial reduction of the remaining lifespan.

The effects of patient and system factors on mortality (***Paper III***) were comparable to findings published in a study based on cohort data from the Swedish Perioperative Register[73] and a study based on data from the Swedish National Quality Registry for Hip Fracture Patients by Cao et al.[74] which aimed to explore the predictive ability of different risk factors. In their modelling study they concluded that age, sex and ASA class had the greatest impact on mortality.

Risk scoring and stratification in analyses of mortality/survival are mandatory. In register-based studies the more composite and complex scoring systems, such as POSSUM[131] and the Nottingham Hip Fracture Score[132], are not feasible and are unavailable. Currently only ASA class and indices based on registered diagnoses like the CCI, or the Elixhauser Index can be used in such studies. Both ASA and CCI scoring have prognostic impact and their categories predict mortality/survival as outlined in ***Paper III*** and by Ek et al.[123]. ASA class is recorded routinely in the NHFR and is easy to use in clinical practice and is estimated routinely as part of the preoperative anaesthesiology assessment of the patients. CCI requires coupling of disease-specific registries, here the NHFR, and administrative databases such as the NPR. Ek et al.[123] conclude that ASA may be preferable compared to CCI due to its convenience and accessibility for health care staff. Neither Ek et al.[123] nor the data in this thesis provide information as to the preference, if any, of the two. Both ASA and CCI are feasible, have prognostic value, but may reflect somewhat different aspects of physical fitness of the patients.

The effect of socioeconomic data/status on mortality was analysed in ***Paper III***. Increased household income and a higher level of education were associated with reduced mortality. These results are in accordance with data from the Danish Multidisciplinary Hip Fracture Registry[76] where lower 30-day mortality and lower rate of readmissions were associated with higher family income and level of education. By contrast, Quah et al.[77] found no significant association between 30-day mortality and the most deprived populations, while Thorne et al.[193] reached a different conclusions in another population from the UK. Their findings were not based on data on an individual level contrasting the study of Kristensen et al.[76] and ***Paper III***. Auais and colleagues[194] in a scoping review published in 2019 found that socioeconomic status affected physical recovery and mortality after hip fractures, similarly to ***Paper III*** and Kristensen et al.[76].

Residential status had a strong association with mortality (***Paper III*)**. The mortality rates of patients living alone or being cohabiting were similar, while patients living in a health care facility had a mortality rate (HR 1.94) double the patients residing alone. Few comparable studies have been published. Living arrangements had varying and conflicting results in the scoping review by Auais et al.[194]. Dahl et al.[195] from Norway found increased mortality in both male and female patients living alone, most notably in younger men (<60 years). However, Dahl et al.[195] analyzed a selected population (50 to 79 years) while ***Paper III*** included all patients. Cohabiting status was not associated with 30- day mortality in adjusted analyses in a Danish nationwide cohort study by Kristensen et al.[76]. Neither Dahl et al.[195] nor Kristensen et al.[76] placed patients living in a healthcare facility in a specific category as in ***Paper III***.

Age and comorbidity differed substantially between the three residential groups analyzed in ***Paper III***. Table 7 gives supplementary information on key patient characteristics of the present study population (***Paper III***). If patients living in a healthcare facility are included in the group living alone or excluded the analyses might be misleading.

	Living alone	**Cohabiting**	**Living in a healthcare facility**
Age; Mean (SD)	82.4 (10.5)	76.4 (11.7)	86.1 (8.5)
ASA ≥3%	65.0%	55.9%	81.7%
CCI ≥3%	8.8%	10.6%	3.8%

Table 7: Distribution of age and comorbidity by residential status

The effect of residential status on mortality seems unclear at the present time, partly because of the very limited number of good studies and the lack of uniform description of residential status. Data presented here document that patients living in a health care facility should be categorized separately.

Of particular note is the finding in ***Paper III*** that hospitals with high fracture volume had higher mortality than those with fewer hip fractures. This finding was unexpected as there is no tradition in Norway of transferring hip fracture patients with increased risk to a higher level of care, except that severe trauma patients with a concomitant hip fracture will be transferred to a higher level of care (a trauma centre) as outlined in the national trauma plan. This could theoretically explain the higher observed mortality in high volume hospitals. However, an exploratory analysis does not support such a notion, e.g., the age distribution was similar in all hospital volume groups. In ***Paper II***, waiting time from admission to surgery was longer in high volume hospitals. Prolonged waiting time is a separate risk factor for increased mortality (discussed in Chapter 10.2.2) and might introduce a bias that explains the increased observed mortality in high volume hospitals. In line with this, Nilsen and co-workers found that a high volume of surgical admissions was associated with delayed surgery and increased 60-days mortality. In a study based on 66,578 patients from the National Hip Fracture Database in the UK, Farrow et al[196] found no effect of volume on 30-day mortality.

In contrast, a large Korean study[197] reported lower mortality in hospitals with a higher volume of hip fracture surgery. Thus, there are contradictory findings as to effect of the volume, but if any, the negative effect of volume seems to be small.

In ***Paper III***, a weak association between reduced mortality and the presence of orthogeriatric services was found. A Cochrane review from 2018 concluded that orthogeriatric services probably resulted in reduced mortality and reduced discharge frequency to a higher level of care, but there were few high-quality studies to determine if and when such services are more effective[56]. Prestmo et al.[58] found that immediate admission to comprehensive geriatric care in a dedicated ward improved mobility after four months, and in a later study Prestmo et al.[59] concluded that the effect was most pronounced in younger, female participants with higher scores on pre-fracture activities of daily living. Neither Prestmo et al. nor the Cochrane review found any association with mortality contrary to the findings in ***Paper III***. The NICE and the AAOS guidelines recommend that interdisciplinary care and geriatric assessment should be part of the pathway of care for hip fracture patients[49, 50].

The concept of comprehensive geriatric assessment was defined by Rubinstein in 1991[198] as a coordinated, multidisciplinary collaboration, in contrast to traditional care. In ***Papers I-III*** the presence of orthogeriatric services is based on the hospitals self-reporting and does not represent a quality-assured assessment of the services, making comparison to other service provision difficult.

Farrow and coworkers[196] assessed the effect of different structural factors on outcomes after hip fractures in a study of 66,578 patients from the UK. They found that dedicated hip fracture units and participation in hip fracture research trials led to higher best practice tariff attainment and reduced length of stay, but these factors had no significant effect on mortality. In ***Paper I*** we found that a dedicated hip fracture unit favoured the presence of best practice, measured as recommended surgery by an experienced surgeon within 48 hours of admission. The broader analysis in ***Paper III*** did not demonstrate any effect of such units on mortality.

The conclusion is that healthcare tailored to the need of geriatric patients is one of several cofactors which might add small increments of care quality and better fracture outcome. A wider system-orientated and patient-focused perspective leads to the conclusion that hard endpoints such as changes in mortality are insufficient and that softer endpoints such as quality of life, ability to walk and independence might be equally important.

11 Conclusions and implications

Paper I:

- There was substantial variation between hospitals in adherence to evidence-based guidelines for hip fracture treatment in Norway
- Non-adherence to hip fracture guidelines can be ascribed to in-hospital factors
- Poor adherence had significant negative consequences for patients with increased mortality rates at 30 and 365 days and higher reoperation rates.

A variation in adherence to guidelines with consequences for patients which cannot be attributed to case-mix or random events must be considered unwarranted and efforts must be made to reduce this variation. Hospitals must evaluate their practice and increase compliance to established guidelines if deviation is marked. A 100% adherence is neither expected nor intended, but it should be expected that adherence rates are the fairly equal and there should be small variations between hospitals. The focus must be made on the transition from research (i.e., EBM guidelines) to practice. Alternative pathways to dissemination of "best" knowledge must be explored.

Paper II:

- Variations in waiting time from admission to hip fracture surgery depended on both patient and hospital factors.
- Not receiving expedited treatment increased 30-day and one-year mortality rates.

More than small differences between hospitals must be considered unwarranted. The case-mix or random effects cannot explain the observed variation between hospitals. The individual patient must receive patient-centred care which implies that some patients need optimization before surgery, but patients should not wait when fit for surgery. Hospitals must evaluate their pathways of care for these frail patients. The quality indicator of a "48 hours waiting time" limit is not in the best interest of the average hip fracture patient.

Paper III:

- Hip fractures lead to substantial excess mortality compared to a reference population
- Patient-, socioeconomic- and healthcare system-related factors all contributed to excess mortality, and non-modifiable cofactors were more important than modifiable ones
- Apparently small survival differences translated into substantial disparity in median survival time in this elderly population.

Hip fracture is an event with potential detrimental consequences for any patient. Efforts to reduce these consequences must be made. Non-modifiable factors give useful information for risk stratification of patients. Modifiable factors should be corrected or amended to improve care pathways for the hip fracture patients. Small improvements can provide substantial extended survival benefits for patients.

12 Further research

1. Mechanisms of implementation of guidelines and recommendations should be studied. Qualitative studies to determine the dominating mechanisms at different levels of the healthcare system are called for.

   The results in ***Paper I*** showed a marked difference in adherence to guidelines between hospitals in Norway and pointed out some factors that might affect deviation from guidelines. The mechanisms for enhancing translation of research to practice are not known. Qualitative studies to explore how professionals at different levels of care obtain and utilize knowledge could bring us one step further.

2. The ideal waiting time for hip fracture surgery is complex because there are many factors directly or indirectly affecting both waiting time and mortality as shown in ***Paper II***. It would be of interest to examine further if softer endpoints, as patient related outcomes and use of healthcare services postoperatively, are associated to waiting time. Similarly, more detailed studies addressing patient's comorbidity and the potential improvement during the waiting time period are needed. The main aim is to identify patients who could benefit from waiting and optimization as opposed to those who should receive surgery without delay.

3. The effect of socioeconomic status on hip fracture patients' use of healthcare services postoperatively and the potential effect on patient-related outcomes should be the subject of further research.

   The analyses performed in ***Paper III*** revealed survival differences related to socioeconomic factors. It would be of interest to explore whether socioeconomic categories lead to different healthcare services utilization postoperatively, and the potential consequences for patients.

~~4.~~ Duration of excess mortality compared to a reference population should be studied as a follow up to ***Paper III***. Levelling off with time of the mortality curve after hip fractures, possibly to a lower level than the reference population (**Paper III**, figure 3), could be studied with an extended observation period.

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14 Appendices

14.1 Appendix I – Hospital registration form - NHFR

NASJONALT HOFTEBRUDDREGISTER
Nasjonalt Register for Leddproteser
Helse Bergen HF, Ortopedisk klinikk
Haukeland universitetssjukehus
Møllendalsbakken 7
5021 BERGEN
Tlf: 55976452

F.nr. (11 sifre)..
Navn:..

(Skriv tydelig ev. pasientklistrelapp – **spesifiser sykehus**.)
Sykehus:..

HOFTEBRUDD

PRIMÆRE OPERASJONER PÅ BRUDD I PROKSIMALE FEMURENDE og ALLE REOPERASJONER, inkludert lukket reponering av hemiproteser. Ved primæroperasjon med totalprotese og ved reoperasjon til totalprotese brukes kun hofteproteseskjema. Alle produktklistrelapper settes i merket felt på baksiden av skjemaet.

AKTUELLE OPERASJON
☐1 Primæroperasjon ☐2 Reoperasjon

SIDE (ett kryss) (Bilateral opr.= 2 skjema)
☐1 Høyre ☐2 Venstre

OPR TIDSPUNKT (dd.mm.åå) |__|__| |__|__| |__|__| kl |__|__|

BRUDD TIDSPUNKT (dd.mm.åå) |__|__| |__|__| |__|__| kl |__|__|
Dersom det er usikkerhet om bruddtidspunkt, fyll ut neste punkt.

TID FRA BRUDD TIL OPERASJON I TIMER
☐1 0-6 ☐2 >6-12 ☐3 >12-24 ☐4 >24-48 ☐5 >48

KOGNITIV SVIKT
☐0 Nei ☐1 Ja (Se test på baksiden) ☐2 Usikker

ASA-KLASSE (se bakside av skjema for definisjon)
☐1 Frisk
☐2 Asymptomatisk tilstand som gir økt risiko
☐3 Symptomatisk sykdom
☐4 Livstruende sykdom
☐5 Moribund

TYPE PRIMÆRBRUDD (ÅRSAK TIL PRIMÆROPERASJON) (Kun ett kryss)
Se baksiden for klassifikasjon
☐1 Lårhalsbrudd udislokert (Garden 1 og 2)
☐2 Lårhalsbrudd dislokert (Garden 3 og 4)
☐3 Lateralt lårhalsbrudd
☐4 Pertrokantært tofragment (AO klassifikasjon A1)
☐5 Pertrokantært flerfragment (AO klassifikasjon A2)
☐9 Intertrokantært (AO klassifikasjon A3)
☐6 Subtrokantært
☐7 Annet, spesifiser..

TYPE PRIMÆROPERASJON (Kun ett kryss)
(Fylles ut bare ved primæroperasjon - eget skjema for totalproteser)
(Fest produktklistrelapp på baksiden eller spesifiser nøyaktig produkt)
☐1 To skruer eller pinner
☐2 Tre skruer eller pinner
☐3 Bipolar hemiprotese
☐4 Unipolar hemiprotese
☐5 Glideskrue og plate
☐6 Glideskrue og plate med trokantær støtteplate
☐7 Vinkelplate
☐8 Kort margnagle uten distal sperre
☐9 Kort margnagle med distal sperre
☐10 Lang margnagle uten distal sperre
☐11 Lang margnagle med distal sperre
☐12 Annet, spesifiser...

Navn / størrelse og katalognummer...

ÅRSAK TIL REOPERASJON (Flere enn ett kryss kan brukes)
☐1 Osteosyntesesvikt/havari
☐2 Ikke tilhelet brudd (non-union/pseudartrose)
☐3 Caputnekrose (segmentalt kollaps)
☐4 Lokal smerte pga prominerende osteosyntesemateriale
☐5 Brudd tilhelet med feilstilling
☐6 Sårinfeksjon – overfladisk
☐7 Sårinfeksjon – dyp
☐8 Hematom
☐9 Luksasjon av hemiprotese
☐10 Osteosyntesematerialet skåret gjennom caput
☐11 Nytt brudd rundt implantat
☐12 Løsning av hemiprotese
☐13 Annet, spesifiser...

TYPE REOPERASJON (Flere enn ett kryss kan brukes)
(Fest produktklistrelapp på baksiden eller spesifiser nøyaktig produkt)
☐1 Fjerning av implantat (Brukes når dette er eneste prosedyre)
☐2 Girdlestone (= fjerning av implantat og caput)
☐3 Bipolar hemiprotese
☐4 Unipolar hemiprotese
☐5 Re-osteosyntese
☐6 Debridement for infeksjon
☐7 Lukket reposisjon av luksert hemiprotese
☐8 Åpen reposisjon av luksert hemiprotese
☐9 Annet, spesifiser...

Navn / størrelse og katalognummer...

FIKSASJON AV HEMIPROTESE
(For totalprotese sendes eget skjema til hofteproteseregisteret)
☐1 Usementert ☐1 med HA ☐2 uten HA
☐2 Sement med antibiotika Navn...
☐3 Sement uten antibiotika Navn..

PATOLOGISK BRUDD (Annen patologi enn osteoporose)
☐0 Nei ☐1 Ja, type...

TILGANG TIL HOFTELEDDET VED HEMIPROTESE (Kun ett kryss)
☐1 Fremre (mellom sartorius og tensor)
☐2 Anterolateral (mellom gluteus medius og tensor)
☐3 Direkte lateral (transgluteal)
☐4 Bakre (bak gluteus medius)
☐5 Annet, spesifiser...

ANESTESITYPE
☐1 Narkose ☐2 Spinal ☐3 Annet, spesifiser..

PEROPERATIVE KOMPLIKASJONER
☐0 Nei ☐1 Ja, hvilke(n)..

OPERASJONSTID (hud til hud)......................minutter.

ANTIBIOTIKAPROFYLAKSE ☐0 Nei ☐1 Ja

	Navn	Dosering	Varighet i timer
Medikament 1	....		...............timer
Medikament 2	....		...............timer
Medikament 3	....		...............timer

TROMBOSEPROFYLAKSE
☐0 Nei ☐1 Ja: Første dose ☐1 Preoperativt ☐2 Postoperativt

Medikament 1 .... Dosering opr.dag.......................................
Dosering videre .... Varighet ...... døgn
Medikament 2 .... Dosering .... Varighet ...... døgn

FAST TROMBOSEPROFYLAKSE
☐0 Nei ☐1 Ja, type: ....

FIBRINOLYSEHEMMER
☐0 Nei ☐1 Ja, medikament : .... Dosering ....

OPERATØRERFARING
Har en av operatørene mer enn 3 års erfaring i hoftebruddkirurgi? ☐0 Nei ☐1 Ja

Lege...
Legen som har fylt ut skjemaet (navnet registreres ikke i databasen).

202 038 Bergen Grafisk as - 01.2016

RETTLEDNING

Registreringen gjelder alle operasjoner for hoftebrudd (lårhals, pertrokantære og subtrokantære) og alle reoperasjoner, også reposisjoner, på pasienter som er primæroperert og reoperert for hoftebrudd. **Ved primæroperasjon med totalprotese og ved reoperasjon til totalprotese sendes bare skjema til hofteproteseregisteret.**
Ett skjema fylles ut for hver operasjon. Originalen sendes Haukeland universitetssjukehus og kopien lagres i pasientens journal. Pasientens fødselsnummer (11 sifre) og sykehuset må være påført. Aktuelle ruter markeres med kryss. Pasienten skal på eget skjema gi samtykke til registrering i Nasjonalt hoftebruddregister.

Kommentarer til enkelte punkt:
OPERASJONS- OG BRUDDTIDSPUNKT
Operasjonstidspunkt (dato og klokkeslett) må føres opp på alle primæroperasjoner. Det er også sterkt ønskelig at dato og klokkeslett for *bruddtidspunkt* føres opp. Dette bl.a. for å se om tid til operasjon har effekt på prognose. (Hvis en ikke kjenner klokkeslettet for bruddtidspunkt lar en feltet stå åpent. En må da prøve å angi omtrentlig tidsrom fra brudd til operasjon på neste punkt).
Ved reoperasjon er ikke klokkeslett nødvendig.

KOGNITIV SVIKT
Kognitiv svikt kan eventuelt testes ved å be pasienten tegne klokken når den er 10 over 11. En pasient med kognitiv svikt vil ha problemer med denne oppgaven.

ASA-KLASSE (ASA=American Society of Anesthesiologists)
ASA-klasse 1: Friske pasienter som røyker mindre enn 5 sigaretter daglig.
ASA-klasse 2: Pasienter med en asymptomatisk tilstand som behandles medikamentelt (f.eks hypertensjon) eller med kost (f.eks diabetes mellitus type 2) og ellers friske pasienter som røyker 5 sigaretter eller mer daglig.
ASA-klasse 3: Pasienter med en tilstand som kan gi symptomer, men som holdes under kontroll medikamentelt (f.eks moderat angina pectoris og mild astma).
ASA-klasse 4: Pasienter med en tilstand som ikke er under kontroll (f.eks hjertesvikt og astma).
ASA-klasse 5: Moribund/døende pasient

GARDENS KLASSIFISERING AV LÅRHALSBRUDD
Garden 1: Ikke komplett brudd av lårhalsen (såkalt innkilt)
Garden 2: Komplett lårhalsbrudd uten dislokasjon
Garden 3: Komplett lårhalsbrudd med delvis dislokasjon. Fragmentene er fortsatt i kontakt, men det er feilstilling av lårhalsens trabekler. Caputfragmentet ligger uanatomisk i acetabulum.
Garden 4: Komplett lårhalsbrudd med full dislokasjon. Caputfragmentet er fritt og ligger korrekt i acetabulum slik at trabeklene er normalt orientert.

AO KLASSIFIKASJON AV TROKANTÆRE BRUDD

A1: Pertrokantært tofragment brudd A2: Pertrokantært flerfragment brudd A3: Intertrokantært brudd Subtrokantært brudd*

*Subtrokantært brudd: Bruddsentrum er mellom nedre kant av trokanter minor og 5 cm distalt for denne.

REOPERASJONSÅRSAK
Dyp infeksjon defineres som infeksjon som involverer fascie, protese, ledd eller periprotetisk vev.

IMPLANTAT
Implantattype må angis entydig. Produktklistrelapp er ønskelig for å angi katalognummer for osteosyntesematerialet eller protesen som er brukt.

PEROPERATIVE KOMPLIKASJONER
Vi ønsker også å få meldt dødsfall på operasjonsbordet og peroperativ transfusjonstrengende blødning.

ANTIBIOTIKAPROFYLAKSE
Her føres det på hvilket antibiotikum som er blitt benyttet i forbindelse med operasjonen. Det anføres dose, antall doser og profylaksens varighet. F.eks. Medkament 1: Keflin 2g x 4, med varighet 4,5 timer.

TROMBOSEPROFYLAKSE
Medikament, dose og antatt varighet av profylaksen skal angis separat for oprerasjonsdagen og senere. Det skal også oppgis om pasienten står fast på tromboseprofylakse (AlbylE, Marevan, Plavix ol).

FIBRINOLYSEHEMMER
Her føres det på om en benytter blødningsreduserende legemidler i forbindelse med operasjonen (f.eks. Cyklokapron).

Kontaktpersoner vedrørende registreringsskjema er:
Overlege Jan-Erik Gjertsen, Ortopedisk klinikk, Haukeland universitetssjukehus. Tlf. 55 97 56 86 (email: jan-erik.gjertsen@helse-bergen.no)
Konsulent Nasjonalt Hoftebruddregister: Randi Furnes. Tlf. 55 97 37 42 (email: nrl@helse-bergen.no)
Internett: http://nrlweb.ihelse.net/

PRODUKTKLISTRELAPPER:

14.2 Appendix II – Hospital characterization survey form

Kartlegging av sykehus som behandler hoftebrudd

Håper dere har anledning til å fylle ut skjemaet som vil gi oss informasjon om de sykehus som behandler hoftebrudd i Norge

Del uten navn

1. For hvilket sykehus gjelder svarene?

____

2. Hvordan er pasientene plassert i sykehuset. Har dere egen ortopedisk sengepost?

Markér bare én oval.

- ( ) Ja *Hopp til spørsmål 3*
- ( ) Nei *Hopp til spørsmål 4*

Antall senger

Ved egen ortopedisk sengepost. Hvor mange senger har sengepost/avdeling?

3. Antall senger i ortopedisk avdeling

____

Hopp til spørsmål 5

Antall senger øremerket for ortopedi

Ved felles sengepost. Hvor mange senger er øremerket ortopediske pasienter?

4. Antall senger øremerket for ortopedi?

____

Hopp til spørsmål 5

Dedikert enhet

5. Har dere en dedikert enhet for hoftebruddpasienter?

Markér bare én oval.

- Ja
- Nei

Program / retningslinjer

6. Har dere foretaks- eller sykehusspesifikke program/retningslinjer for brudd i proksimale femurende

Markér bare én oval.

- Ja *Hopp til spørsmål 7*
- Nei *Hopp til spørsmål 9*

Hopp til spørsmål 9

Sykehusspesifikt program /retningslinjer

Involverer dette andre faggrupper? Evt hvilke? Flere svar er mulige.

7. Hvilke faggrupper er rutinemessig involvert i behandlingen av hoftebruddpasienter

Merk av for alt som passer

- [ ] Geriater
- [ ] Indremedisiner
- [ ] Ortogeriatrisk team
- [ ] Fysioterapeut
- [ ] Ergoterapeut
- [ ] Andre

8. Kan du gi en kort beskrivelse av program?

Hopp til spørsmål 9

Bemanning overleger

Her ønsker vi å vite om hvordan sykehuset er bemannet med hensyn til ortopeder og LIS.

9. Antall ortopediske overlegestillinger har sykehuset ?

10. Antall besatte overlegestillinger per dags dato?

11. Er noen overleger i Nordsjøturnus / vikarordninger?

Markér bare én oval.

- Ja *Hopp til spørsmål 14*
- Nei *Hopp til spørsmål 12*

Hopp til spørsmål 12

Bemanning LIS-leger

12. Antall ortopediske LIS-stillinger?

13. Antall besatte LIS-stillinger per dags dato

Hopp til spørsmål 16

Nordsjøturnus/vikarordninger

14. Antall overleger i Nordsjøturnus?

15. Antall overleger som dekkes av vikarer?

Hopp til spørsmål 12

Vaktordning

Hvordan er vaktberedskap med hensyn til ortopediske pasienter og hoftebrudd organisert

16. Eget ortopedisk vaktlag?

Markér bare én oval.

- Ja
- Nei

17. Generell kirurgisk vakt (ikke egen ortopedisk vakt)

Markér bare én oval.

- Ja
- Nei

18. Dekning av døgn

Markér bare én oval.

- 24 timer, 7 dager i uken hele året *Hopp til spørsmål 22*
- Andre *Hopp til spørsmål 19*

Hopp til spørsmål 21

Tidsfordeling vakt

Hvordan er ortopedisk vakt/beredskap organisert ved ditt sykehus?

19. Hvordan vaktordning har ditt sykehus med hensyn til ortopediske pasienter og hoftebrudd

Merk av for alt som passer

- [ ] Døgnvakt 5 av 7 dager
- [ ] Vakt deler av døgnet hele uken
- [ ] Vakt deler av døgnet i ukedager
- [ ] Andre løsninger

20. Ved dekning deler av uke/døgn - Er det da organisert overføring til andre sykehus for behandling?

Markér bare én oval.

- Ja
- Nei

Endringer siste 5 år

21. Har det vært noen endringer i bemanning, tjenester eller vakt i de siste 5 år?

Takk for dine svar og ditt samarbeid!

22. Hva er din E-post?

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14.3 Appendix III – Regional Ethics Committee Approval

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK nord			06.11.2018	2018/1955/REK nord
			Deres dato:	**Deres referanse:**
			25.09.2018	

Vår referanse må oppgis ved alle henvendelser

Barthold Vonen
SKDE

2018/1955 Likeverdige helsetjenester – uansett hvor du bor?

Forskningsansvarlig institusjon: Senter for klinisk dokumentasjon og evaluering, Senter for klinisk dokumentasjon og evaluering
Prosjektleder: Barthold Vonen

Vi viser til søknad om forhåndsgodkjenning av ovennevnte forskningsprosjekt. Søknaden ble behandlet av Regional komité for medisinsk og helsefaglig forskningsetikk (REK nord) i møtet 25.10.2018. Vurderingen er gjort med hjemmel i helseforskningsloven § 10.

Prosjektleders prosjektomtale
Hensikten med dette regionale samarbeidsprosjektet innen pasientnær helsetjenesteforskning er å gi grunnlag for å forstå, forklare og utjevne geografisk og annen uberettiget variasjon i kvalitet, helsetjenestebruk og behandlingsvalg blant store pasientgrupper, med et endelig mål om et bedre og likere helsetjenestetilbud til befolkningen i nord og i landet forøvrig. Mulige forklaringsfaktorer på pasient- familie-, kommune- og helseforetaksnivå skal studeres. Fire pasientgrupper inngår i prosjektet knyttet til leddproteser, hoftebrudd, hjerteinfarkt og hjerneslag. Persondata fra Norsk pasientregister, Kommunalt pasient- og brukerregister, kliniske kvalitetsregistre, Dødsårsaksregistret og SSB kobles og danner basis for prosjektet. Helseatlasmetodikk og flernivåmodeller vil bli brukt i analysene. Prosjektet ledes fra SKDE, i tett samarbeid med nasjonale og internasjonale forskningsinstusjoner og brukerorganisasjoner. Fire arbeidspakker, hvorav tre PhD-prosjekt inngår.

Vurdering

Komiteen vurderte at Åse-Irene Wrålsen og Hanne Husom Haukland var inhabile og de fratrådte møtet da saken ble behandlet, jf. fvl. § 6.

Om prosjektet
Prosjektet innebærer en geografisk studie av helsetjenester hvor resultatene skal *«gi grunnlag for å forstå, forklare og utjevne variasjon i kvalitet og helsetjenestebruk blant store pasientgrupper, med et endelig mål om et bedre og likere helsetjenestetilbud til befolkningen»*, jf. prosjektbeskrivelsen.

Prosjektet har 22 prosjektmedarbeidere og det søkes om godkjenning fra REK til å koble opplysninger fra følgende register; Norsk pasientregister, Kommunalt pasient- og brukerregister, kliniske kvalitetsregistre (Leddproteseregisteret, Hoftebruddregisteret, Hjerteinfarktregisteret, Hjerneslagregisteret), Dødsårsaksregistret og SSB.

Besøksadresse:
MH-bygget UiT Norges arktiske universitet 9037 Tromsø

Telefon: 77646140
E-post: rek-nord@asp.uit.no
Web: http://helseforskning.etikkom.no/

Framleggingsplikt
De prosjektene som skal framlegges for REK er prosjekt som dreier seg om "medisinsk og helsefaglig forskning på mennesker, humant biologisk materiale eller helseopplysninger", jf. helseforskningsloven § 2. "Medisinsk og helsefaglig forskning" er i § 4 a), definert som "virksomhet som utføres med vitenskapelig metodikk for å skaffe til veie ny kunnskap om helse og sykdom". Det er altså formålet med studien som avgjør om et prosjekt skal anses som framleggelsespliktig for REK eller ikke.

I dette prosjektet er formålet å bidra til økt kunnskap om geografiske forskjeller i helsetjenester som videre vil kunne få betydning for utforming av helsetjenestene. Dette skal gjøres gjennom kobling av helseopplysninger fra ulike registre.

Prosjektet skal således ikke vurderes etter helseforskningsloven.

Dispensasjon fra taushetsplikt/samtykke
Prosjektleder søker om fritak fra taushetsplikt/samtykke for kobling av data fra alle inkluderte pasienter. Prosjektet faller ikke inn under helseforskningsloven, men prosjektet skal bruke personopplysninger fra helsesektoren i forbindelse med forskningen. REK er delegert myndighet til å gi dispensasjon fra taushetsplikten etter helsepersonelloven § 29 og forvaltningslovens § 13 d, i forbindelse med slik forskning.

I vurderingen av om det kan gis unntak for samtykke må REK vurdere alle sider av prosjektet, herunder om det er av vesentlig interesse for samfunnet og om hensynet til deltagernes velferd og integritet er ivaretatt.

Ettersom dette prosjektet har som mål å *«forstå, forklare og utjevne geografisk og annen uberettiget variasjon»* i helsetjenester, har studien en vesentlig interesse for samfunnet.

I vurderingen av om deltagerens velferd og integritet er ivaretatt er det vektlagt at det ikke kreves samtykke fra deltakerne for utlevering av data fra de omsøkte registrene listet i helseregisterloven § 11 eller fra SSB. For de nasjonale kvalitetsregistrene som ikke er forskriftsbaserte (Leddproteseregisteret og Hoftebruddregisteret) er data innsamlet med grunnlag i informert samtykke. REK finner at det således vil være forsvarlig å innvilge dispensasjon fra samtykke slik som omsøkt.

Det presiseres at REK kun har anledning til å innvilge dispensasjon fra taushetsplikt/samtykke for Norsk pasientregister, Kommunalt pasient- og brukerregister, Dødsårsaksregisteret og Hjerte- og karregisteret. For SSB, herunder FD-trygd og utdanningsregister og KOSTRA, har REK ikke hjemmel til å innvilge dispensasjon. For Leddproteseregisteret og Hoftebruddregisteret foreligger det samtykke.

Vedtak
Etter søknaden fremstår prosjektet ikke som et medisinsk og helsefaglig forskningsprosjekt som faller innenfor helseforskningsloven. Prosjektet er ikke framleggingspliktig, jf. helseforskningsloven § 2.

Med hjemmel i forskrift av 02.07.09 nr. 989, er REK delegert myndighet til å gi dispensasjon fra taushetsplikt etter helsepersonelloven § 29 første ledd og forvaltningsloven § 13 d. Det gis dispensasjon fra taushetsplikt for innhenting og kobling av data som omsøkt.

Det presiseres at databehandling ikke kan påbegynnes før alle nødvendige godkjenninger foreligger.

Sluttmelding og søknad om prosjektendring
Prosjektleder skal sende sluttmelding til REK nord på eget skjema senest 30.06.2025, jf. hfl. § 12. Prosjektleder skal sende søknad om prosjektendring til REK nord dersom det skal gjøres vesentlige endringer i forhold til de opplysninger som er gitt i søknaden, jf. helseforskningsloven. § 11.

Klageadgang
Du kan klage på REKs vedtak, jf. forvaltningsloven § 28 flg. Klagen sendes til REK nord. Klagefristen er tre uker fra du mottar dette brevet. Dersom vedtaket opprettholdes av REK nord, sendes klagen videre til Den nasjonale forskningsetiske komité for medisin og helsefag for endelig vurdering.

14.4 Appendix IV – Papers I – III

Papers reproduced with kind permission of the Bone & Joint Publishing.

Papers I and II are published in the Bone & Joint Open.

Paper III including Supplementary Material is in press in the Bone & Joint Journal, expected printed July 2022. Pre-publication version of the paper reproduced in the thesis.

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TRAUMA

Hip fracture treatment in Norway

DEVIATION FROM EVIDENCE-BASED TREATMENT GUIDELINES: DATA FROM THE NORWEGIAN HIP FRACTURE REGISTER, 2014 TO 2018

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Aims
The aim of this study was to describe variation in hip fracture treatment in Norway expressed as adherence to international and national evidence-based treatment guidelines, to study factors influencing deviation from guidelines, and to analyze consequences of non-adherence.

Methods
International and national guidelines were identified and treatment recommendations extracted. All 43 hospitals routinely treating hip fractures in Norway were characterized. From the Norwegian Hip Fracture Register (NHFR), hip fracture patients aged > 65 years and operated in the period January 2014 to December 2018 for fractures with conclusive treatment guidelines were included (n = 29,613: femoral neck fractures (n = 21,325), stable trochanteric fractures (n = 5,546), inter- and subtrochanteric fractures (n = 2,742)). Adherence to treatment recommendations and a composite indicator of best practice were analyzed. Patient survival and reoperations were evaluated for each recommendation.

Results
Median age of the patients was 84 (IQR 77 to 89) years and 69% (20,427/29,613) were women. Overall, 79% (23,390/29,613) were treated within 48 hours, and 80% (23,635/29,613) by a surgeon with more than three years' experience. Adherence to guidelines varied substantially but was markedly better in 2018 than in 2014. Having a dedicated hip fracture unit (OR 1.06, 95%CI 1.01 to 1.11) and a hospital hip fracture programme (OR 1.16, 95% CI 1.06 to 1.27) increased the probability of treatment according to best practice. Surgery after 48 hours increased one-year mortality significantly (OR 1.13, 95% CI 1.05 to 1.22; p = 0.001). Alternative treatment to arthroplasty for displaced femoral neck fractures (FNFs) increased mortality after 30 days (OR 1.29, 95% CI 1.03 to 1.62)) and one year (OR 1.45, 95% CI 1.22 to 1.72), and also increased the number of reoperations (OR 4.61, 95% CI 3.73 to 5.71). An uncemented stem increased the risk of reoperation significantly (OR 1.23, 95% CI 1.02 to 1.48; p = 0.030).

Conclusion
Our study demonstrates a substantial variation between hospitals in adherence to evidence-based guidelines for treatment of hip fractures in Norway. Non-adherence can be ascribed to in-hospital factors. Poor adherence has significant negative consequences for patients in the form of increased mortality rates at 30 and 365 days post-treatment and in reoperation rates.

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Keywords: Hip fracture, Orthopaedic surgery, Health care, Small area variation, Guidelines

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Bone Joint Open 2020;1-10:644–653.

Introduction
Hip fractures in older people represent a devastating injury for the individual, and treatment is followed by elevated mortality, reduced quality of life and disability.[1] Surgery is the only effective treatment, and with the increasing longevity of the population hip fractures represent a steadily growing and substantial burden for hospitals and social services in our societies.[2]

The concept of variation in health care treatment was pioneered by John

Wennberg.[3] Annual reports from the Norwegian Hip Fracture Register (NHFR) have shown significant variations in the treatment of hip fractures in Norway.[4] We know that patient preferences can affect variation.[3] However, for a surgical emergency such as a hip fracture, patients have little or no influence on the choice of treatment. Unwarranted variation in hip fracture treatment, therefore, depends mostly on the preference of the provider (surgeon and hospital). Treatment guidelines have been introduced to give patients the best evidence-based treatment, thereby reducing unwarranted variation.[5-9] Guidelines are also tools to reduce inequity by providing care of equal quality.

The main aim of this paper was, in a national setting, to describe compliance with international and national treatment guidelines and variation in hip fracture treatment based on data from the NHFR. Further aims are to analyze relevant factors explaining deviation from the guidelines and to determine consequences of non-adherence.

Methods

The Norwegian Hip Fracture Register. This is a population-based (5.3 million inhabitants in 2018) national prospective study based on data from the NHFR. The term "hip fracture" denotes patients with femoral neck fractures (FNFs: ICD10 code S72.0), trochanteric (ICD10 code S72.1) and subtrochanteric (ICD10 code S72.2) fractures. The NHFR has collected data on all hip fracture patients admitted to hospitals in Norway since 2005. The NHFR receives a form with information on patients, primary operations, and subsequent reoperations. Information on patients receiving total hip arthroplasty (THA) is primarily registered in the Norwegian Arthroplasty Register (NAR) and subsequently imported to the NHFR.[10]

Completeness of reporting to the NHFR is evaluated regularly by comparing registry data with the national administrative database (Norwegian Patient Registry) operated by the Norwegian Directorate of Health. Completeness in 2015 to 2016 was 88.2% for osteosynthesis, 94.5% for hemiarthroplasties, and 87.8% for total hip arthroplasties.[4]

Data from all patients registered with a hip fracture in the NHFR in the five-year period (January 2014 to December 2018) admitted to all 43 hospitals in Norway routinely treating hip fractures were included. Data on patient characteristics (age, sex, American Society of Anesthesiologists grade[11]), fracture type, and treatment information (time from injury to surgery, type of treatment, experience level of the surgeon, and reoperations) were extracted. Information on time from injury to operation, fracture type, and experience level of the surgeon were unavailable for hip fracture patients treated with THA, since this is not recorded in the NAR.

Follow-up. The patients were followed in the NHFR until time of reoperation. Patients without reoperations were censored at time of death or on 31 December 2019. Data on death was provided to NHFR by the Norwegian National Population Register.

Characteristics of Norwegian acute care hospitals/hospital trusts. We performed an online survey of the characteristics of all 43 hospitals (23 hospital trusts) in Norway that routinely treat hip fracture patients. The hospitals varied from small community hospitals with a catchment area of fewer than 30,000 inhabitants to large regional and university hospitals.[12] Information was collected on the organization of hip fracture care, presence of hospital treatment policies/guidelines, dedicated unit for hip fracture patients, interdisciplinary care including an orthogeriatric unit, number of beds in the orthopaedic ward(s), number of orthopaedic consultants and specialist registrars/residents, and whether the hospital had 24/7 service for hip fracture patients. We ranked the hospitals by treatment volume (low to high) and then divided them into four volume groups with an equal number of hospitals in each group.

Evidence-based hip fracture guidelines. Guidelines were identified from the Guidelines International Network (GIN),[13] using the search terms “hip fracture” and “hip fracture treatment”. We also searched for evidence-based guidelines in BMJ Best Practice and PubMed. We identified six relevant guidelines of high quality. We excluded a Finnish and a German guideline published in their respective native languages. We also added a consensus-based Norwegian guideline.[5,14]

From international guidelines[6-9] we extracted treatment recommendations. They largely coincide with the Norwegian interdisciplinary guideline, which is based on the critical literature review and evidence base published by National Institute for Health and Care Excellence (NICE) in the UK.[9] Three of the five guidelines (American Academy of Orthopaedic Surgeons (AAOS), Scottish Intercollegiate Guidelines Network (SIGN), Norwegian Orthopaedic Association (NOF)) address hip fracture treatment in the elderly. The guideline recommendations are summarized in Table I, which also outlines treatment-related and outcome variables where the NHFR could provide information. Guideline summaries were extracted by two experienced orthopaedic surgeons (CK, J-EG).

Recommendations independent of type of fracture included data on the time of treatment within 48 hours after injury and on surgeon competence, in the NHFR defined as more than three years of experience with fracture surgery. Fracture type-dependent treatment recommendations included treatment of undisplaced (Garden types 1 and 2[15]) femoral neck fractures (FNFs) with screw fixation (two or three screws or pins), treatment of displaced FNFs (Garden types 3 and 4) with

Table I. Summary of guideline reccomendations for treatment of hip fractures. The arrow in the final column indicates the direction of effect if the guideline is followed.

	Evidence based guidelines				Concensus based guidelines		
Variable	**SIGN 2009**[9]	**NICE 2011**[7]	**AAOS 2014**[8]	**ANZ 2014**[6]	**NOF 2018**[5,14]	**Recommendations and outcomes**	
Fracture type independent							
Experienced surgeon	+	+	N/A	+	+	+	↓REOP*
Timing of surgery	Same or next day	< 24 h < 48 h	< 48 h	Same or next day	< 24 h Daytime	< 48 h	↓MORT,* ↑PROM*
Fracture type dependent							
Femoral neck							
Garden[15] 1 to 2 (undisplaced)							
Screw fixation	+	N/A	+	N/A	+	+	↓LOS, ↓MORT,* ↑PROM*
Garden 3 to 4 (displaced)							
Arthroplasty	+	+	+	+	+	+	↓MORT
Cemented stem	+	+	+	+	+	+	↓REOP,* ↑PROM*
Trochanteric							
AO/OTA[16] A1							
Sliding hip screw	+	+	=	=	+	+	↓MORT,* ↓REOP,* ↓LOS, ↓OT
AO/OTA A2							
Sliding hip screw	+	+	=	=	=	=	
Intramedullary nail	=	=	=	=	=	=	
Intertrochanteric							
AO/OTA A3 incl reverse oblique							
Intramedullary nail	+	N/A	+	+	+	+	↓REOP*
Subtrochanteric							
Intramedullary nail	+	+	+	+	+	+	↓REOP*

*Data available in the NHFR.
+, positive effect; =, equipoise; AAOS, American Academy of Ortopaedic Surgeons; ANZ, Australian and New Zealand Hip Fracture Registry; LOS, length of stay; MORT, mortality; N/A, not applicable; NICE, National Institute of Care of Excellence; NOF, Norwegian Orthopaedic Association; OT, operating time; OTA, Orthopaedic Trauma Association; PROM, Patient Related Outcome Measure; REOP, reoperations; SIGN, Scottish Intercollegiate Guidelines Network.

arthroplasty (hemi- or total hip arthroplasty) and use of a cemented stem.

For trochanteric fractures type AO/Orthopaedic Trauma Association (AO/OTA) A1,[16] the guidelines recommend a sliding hip screw (SHS) rather than an intramedullary nail (IMN). For intertrochanteric fractures, type AO/OTA A3, and subtrochanteric fractures, the guidelines recommend IMN. For trochanteric fractures, type AO/OTA A2, there is equipoise between SHS and IMN. These fractures were therefore not included in the analysis.

We estimated the proportion of patients receiving treatment fulfilling the guideline recommendations described in Table I, i.e. treatment within 48 hours; y a surgeon with more than three years' of experience; and using fracture-specific recommended treatment. This composite best practice indicator, reflecting and summarizing adherence to guideline recommendations, was calculated for each fracture-specific group. We also estimated best practice for all hip fractures as a group, i.e. practice that fulfilled the guideline criteria for all fracture types.

The NHFR contained data on 41,699 patients treated for a hip fracture in the five-year period between January 2014 and December 2018 (Figure 1). We excluded in sequential order patients with pathological fractures (treatment based on surgeon discretion), patients younger than 65 years (the focus was on elderly patients), patients with ASA grade 5 (moribund patients at operation), or with missing information on ASA grade. Similarly, patients with fracture types with equal recommendations in the guidelines (basocervical fractures and multifragmented trochanteric fractures, type AO/OTA A2), combined fracture types and those in whom fracture type was missing were excluded. Subsequently, 29,613 patients were included in the study: 21,325 FNF, 5,546 trochanteric and 2,742 sub- or intertrochanteric fractures (Figure 1). We included 20,427 women and 9,186 men, with median age 84 years (interquartile range (IQR) 78 to 89) and 83 years (IQR 75 to 88) respectively. Patient characteristics and fracture types are outlined in Table II.

Statistical analysis. The analysis was performed using SAS/STAT for Windows v. 7.1 (SAS Institute, Cary, North Carolina, USA). Continuous variables are presented as medians and ranges for patients and hospital characteristics. Treatment distribution is presented in numbers

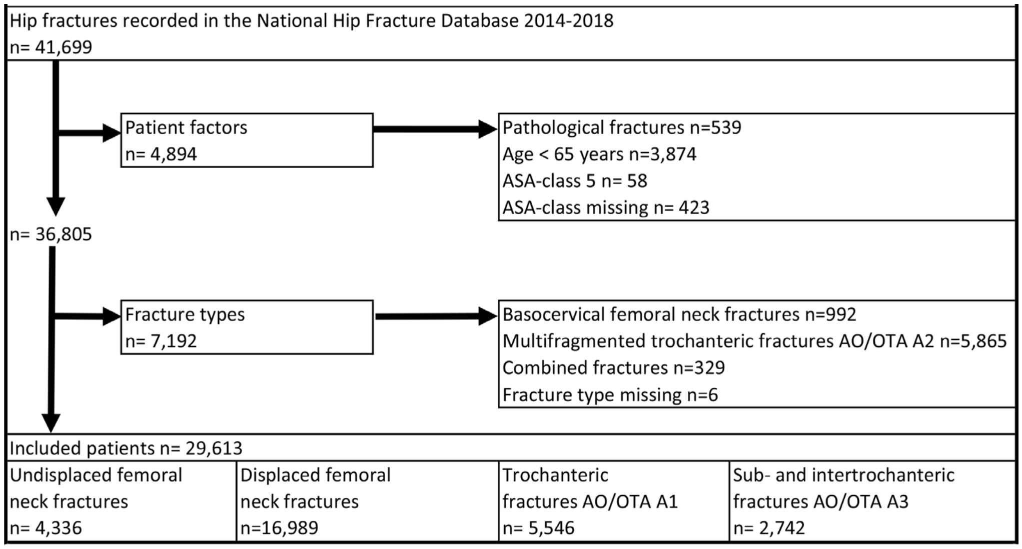

Fig. 1

Patient selection-study population. OTA, Orthopaedic Trauma Association; ASA, American Society of Anesthesiologists.

Table II. Population characteristics.

Variable	n (%)
Study population	29,613
Women	20,427 (69.0)
Men	9,186 (31.0)
Median age, yrs (IQR)	84 (77 to 89)
ASA grade	
1	538 (1.8)
2	9,393 (31.7)
3	17,251 (58.3)
4	2,431 (8.2)
Surgeon experience in fracture surgery	
< 3 years	4,686 (15.8)
> 3 years	23,635 (79.8)
Missing	1,292 (4.4)
Time of surgery after injury	
< 48 hours	23,390 (79.0)
> 48 hours	4,931 (16.6)
Missing	1,292 (4.4)
Fracture type	
Undisplaced femoral neck (Garden 1 to 2)	4,336 (14.6)
Displaced femoral neck (Garden 3 to 4)	16,989 (57.4)
Trochanteric AO/OTA A1	5,546 (18.7)
Intertrochanteric AO/OTA A3	879 (3.0)
Subtrochanteric	1,863 (6.3)

ASA, American Society of Anaesthesiologists; IQR, interquartile range; OTA, Orthopaedic Trauma Association.

and percentages. Adherence to guideline recommendations was calculated as a mean of annual proportions of patients treated according to the recommendations described. This was performed for each hospital over the study period and adjusted for age and sex. We used logistic regression (LR) models to measure the effect of the predictors of adherence and results are presented as odds ratios (ORs). All analyses were adjusted for age, sex, and ASA class. For all LR analyses, a 95% confidence interval (CI) was calculated and p-values below 0.05 were considered statistically significant.

Ethics, funding and conflict of interest. The project was approved by the Northern Norway Regional Committee for Medical and Health Research Ethics and was exempted from the duty of confidentiality (REK 2018/1955). A data protection integrity assessment was compiled according to the EU General Data Protection Regulation (GDPR). The project was funded by the Northern Norway Regional Health Authority (HNF1482-19). No competing interests were declared.

The NHFR is authorized by the Norwegian Data Protection Authority to collect and store data on hip fracture patients (authorisation issued 3 January 2005; reference number 2004/1658 to 2 SVE/-). The NHFR required patients to sign a written, informed consent declaration, and when unable to understand or sign, a family member could sign the consent form on their behalf. The NHFR is financed by the Western Norway Regional Health Authority.

Results

Patient and treatment characteristics. Overall, two-thirds of the patients had severe comorbidity (ASA class 3 to 4; n = 19,682). A majority of the patients were treated within 48 hours of injury and by an experienced surgeon (79%; n = 23,390). FNFs were most prevalent (72%; n = 21,325). Fracture treatment is outlined in Table III. Most (86%; n = 3,747) undisplaced FNFs were treated with screw fixation, whereas almost all (96%; n = 16,219) displaced FNFs were treated with arthroplasty. In all, 68% of trochanteric fractures received SHS (n = 3783) while IMN was used in 76% (n = 2,084) of inter- and subtrochanteric fractures.

Table III. Treatment distribution in 29,613 patients with a hip fracture.

Category, n (%)	Total	Screw fixation	Arthroplasty	SHS	IMN	Other
Undisplaced FNF (Garden 1 to 2)	4,336	3,747 (86.4)	463 (10.7)	90 (2.1)	11 (0.3)	25 (0.6)
Displaced FNF (Garden 3 to 4)	16,989	605 (3.6)	16,219 (95.5)	76 (0.4)	20 (0.1)	69 (0.4)
Trochanteric fracture AO/OTA A1	5,546	4 (< 0.1)	10 (0.2)	3,783 (68.2)	1,651 (29.8)	98 (1.8)
Intertrochanteric fracture AO/OTA A3	1,863	3 (0.2)	1 (< 0.1)	335 (18.0)	1,518 (81.5)	6 (0.3)
Subtrochanteric	879	0	8 (0.9)	308 (35.0)	554 (63.0)	9 (1.0)

FNF, femoral neck fracture; IMN, intramedullary nail; OTA, Orthopaedic Trauma Association; SHS, sliding hip screw.

Table IV. Hospital characteristics (2018 data).

Variable	Total	Median (IQR)
Population base in catchment area	5,300,000	82,000 (42,000 to 140,000)
Orthopaedic consultants	481	7 (5 to 17)
Orthopeadic specialist registrar/resident	284	7 (3 to 9)
Orthopaedic beds in hospital	1,053	21 (12 to 30)
Hip fracture volume, 2014 to 2018 (total)	41,699	777 (444 to 1,238)
Hip fracture volume, 2014 to 2018 (included in study)	29,613	553 (309 to 892)
Low (11 hospitals)	2,213	238 (83 to 276)
Intermediate low (11 hospitals)	5,331	480 (450 to 533)
Intermediate high (11 hospitals)	8,030	696 (615 to 862)
High (10 hospitals)	14,039	1,327 (1,018 to 1,809)
Hospitals routinely treating hip fractures, n (%)	43 (100)	
Separate orthopaedic ward, n (%)	32 (74)	
Dedicated hip fracture unit, n (%)	11 (26)	
Orthogeriatric service, n (%)	14 (33)	
Hospital hip fracture programme, n (%)	37 (86)	
24/7 service for hip fracture patients, n (%)	37 (86)	

Hospital characteristics. Treatment volume and organization of orthopaedic services are given in Table IV. The majority of hospitals (74%; n = 32)) reported having a separate orthopaedic ward, a hospital hip fracture programme (86%; n = 37)) and 24/7 service for hip fracture patients (86%; n = 37)). A dedicated hip fracture unit was present in 26% of the hospitals (n = 11), while an orthogeriatric service was present in 33% (n = 14). The hospitals had a median of seven orthopaedic consultants (IQR 5 to 17) and seven specialist registrars/residents (IQR 3 to 9) in orthopaedic surgery. In the study period, the median hospital patient volume was 553 (IQR 309 to 892).

Hospital adherence to guidelines. Variation in adherence to guideline recommendations (described in Table I) related to hospital category (volume groups) has also been estimated and is illustrated in Figure 2.

A mean 83% of patients (71% to 91%) was treated within 48 hours (Figure 2a) and 83% of patients (65% to 96%) were treated by an experienced surgeon (Figure 2b). For undisplaced FNFs screw fixation was used in 86% of patients (51% to 99%; Figure 2c).

The majority of patients (mean 96% (79% to 99%)) with a displaced FNF received an arthroplasty (Figure 2d), and a mean 80% of these patients (0.3% to 100%) had a cemented stem. Seven of the 43 hospitals used a cemented prosthetic stem in fewer than 40% of the arthroplasties in contrast to five hospitals that used bone cement in all patients (100%; Figure 2e).

In trochanteric fractures the mean proportion receiving guideline-recommended treatment with a SHS was 68% (0% to 99%; Figure 2f). In inter- and subtrochanteric fractures, the mean proportion of patients treated with the recommended IMN was 76% (9% to 100%). In 14 hospitals (33%) the mean proportion receiving IMN for such fractures was below 30%, while 16 hospitals used IMN in more than 90% of patients (Figure 2g).

The mean composite best practice indicator for the group of hip fractures in January 2014 to December 2018 was 55% (Figure 2h).

During the five-year study period, adherence improved for all fracture types, except for trochanteric fractures (Figure 3); the mean composite "best practice indicator" increased from 50% (2014) to 59% (2018).

Predictors for adherence to guidelines. Adherence to guidelines, expressed by the composite measure of best practice calculated for all hip fractures, is shown in Table V. Hospitals with a dedicated hip fracture unit adhered more often to guidelines than those without such a unit (OR 1.06 (95% CI 1.01 to 1.11); p = 0.025). Furthermore, hospitals with a hip fracture programme were more compliant in following guidelines compared

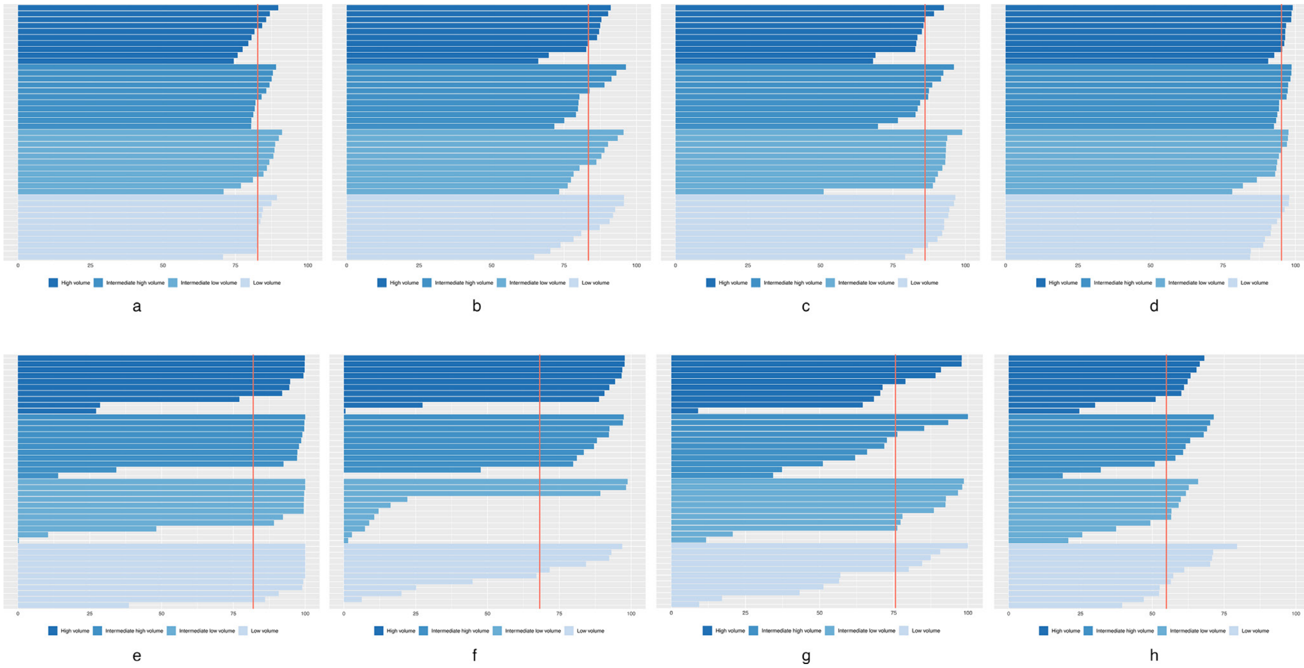

Fig. 2

a) Surgery within 48 hours. b) Surgeon with more than three years of fracture surgery experience. c) Undisplaced femoral neck fractures (FNFs) treated with screw fixation. d) Displaced FNFs treated with arthroplasty. e) Arthroplasties with cemented stem. f) Trochanteric AO/OTA A1 fractures treated with sliding hip screw (SHS). g) Intertrochanteric AO/OTA A3 and subtrochanteric fractures treated with intramedullary nail (IMN). h) Best practice 2014 to 2018 mean values.

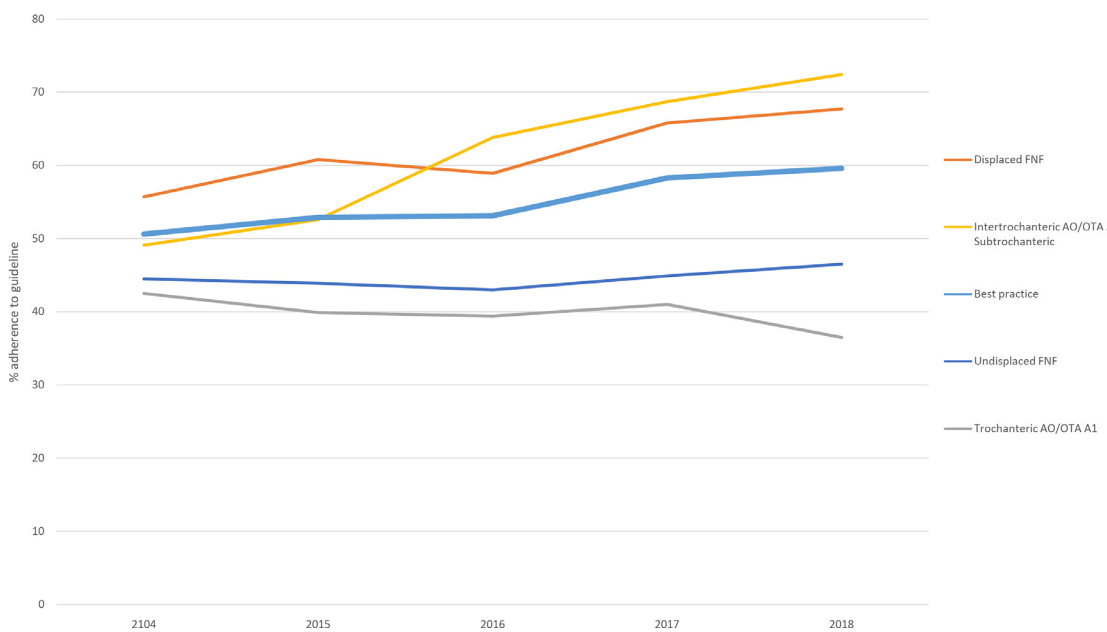

Fig. 3

Fracture specific adherence to best practice January 2014 to December 2018. Values given as mean percent adherence to fracture specific guideline recommendation.FNF, femoral neck fracture,OTA, Orthopaedic Trauma Association.

to hospitals without such a programme (OR 1.16 (95% CI 1.06 to 1.27); p = 0.002). The effect of hospital treatment volume on adherence to guideline recommendations expressed by the term "best practice" varied significantly; with high volume hospitals as reference, both intermediate-high and low volume hospitals adhered significantly better to best practice (OR 1.08 (95% CI 1.02 to 1.14); p = 0.010, and OR 1.19 (95% CI 1.08 to 1.31); p < 0.001 respectively), whereas intermediate low volume hospitals underperformed (OR 0.82 (95% CI 0.76 to 0.87); p < 0.001). Table V also shows a gradual improvement in adherence to guidelines over the period studied.

Table V. Factors influencing best practice.

Factor	Patients, n	Best practice, n (%)	OR (95% CI)	p-value
Orthogeriatric service				
Yes	12,340	6,779 (54.9)	1.01 (0.96 to 1.06)	0.740
No	15,981	8,759 (54.8)	Reference	
Dedicated hip fracture unit				
Yes	10,925	6,089 (55.7)	1.06 (1.01 to 1.11)	0.025
No	17,396	9,449 (54.3)	Reference	
Separate orthopaedic ward				
Yes	24,777	13,542 (51.5)	0.94 (0.88 to 1.01)	0.086
No	3,544	1,996 (56.3)	Reference	
Hospital hip fracture programme				
Yes	26,323	14,509 (55.1)	1.16 (1.06 to 1.27)	0.002
No	1,998	1,029 (51.5)	Reference	
Total hip fracture volume of hospital 2014 to 2018				
High (868 to 2,025)	13,388	7,366 (55.0)	Reference	
Intermediate high (551 to 839)	7,754	4,402 (56.8)	1.08 (1.02 to 1.14)	0.010
Intermediate low (373 to 541)	5,100	2,540 (49.8)	0.82 (0.76 to 0.87)	< 0.001
Low volume (66 to 296)	2,079	1,230 (59.2)	1.19 (1.08 to 1.31)	< 0.001
Year of surgery				
2014	5,635	2,850 (50.6)	Reference	
2015	5,742	3,036 (52.9)	1.10 (1.02 to 1.18)	0.013
2016	5,806	3,085 (53.1)	1.11 (1.04 to 1.20)	0.004
2017	5,618	3,276 (58.3)	1.38 (1.28 to 1.49)	< 0.001
2018	5,52	3,291 (59.6)	1.45 (1.35 to 1.57)	< 0.001
RHA				
South-Eastern Norway	16,347	8,692 (53.2)	Reference	
Western Norway	5,194	2,877 (55.4)	1.09 (1.03 to 1.16)	0.006
Central Norway	4,150	2,594 (62.5)	1.50 (1.39 to 1.60)	< 0.001
Northern Norway	2,630	1,375 (52.3)	0.97 (0.89 to 1.06)	0.488

CI, confidence interval; OR, odds ratio; RHA, regional health authority.

There were also significant differences between the four regional health authorities (RHAs). With the most populated region (South-Eastern Norway RHA) as reference, Western Norway RHA and Central Norway RHA adhered significantly better to best practice (OR 1.50 (95% CI 1.39 to 1.60); p < 0.001, and OR 1.09 (95% CI 1.03 to 1.16); p = 0.006 respectively), whereas Northern Norway RHA did not differ significantly.

Consequences of deviation from guidelines. Guideline-recommended treatment and subsequent outcomes are presented in Table VI. Delayed surgery exceeding the recommended 48 hours increased 365 day mortality (OR 1.13 (95% CI 1.05 to 1.22); p = 0.001). Years of experience of surgeons did not affect any of the three outcome measures. For undisplaced FNFs, non-adherence to the recommended screw fixation reduced the risk of reoperation substantially (OR 0.34 (95% CI 0.21 to 0.55); p < 0.001). Patients with displaced FNF receiving treatment alternatives other than the recommended arthroplasty had a statistically significantly higher 30 day mortality rate (OR 1.29 (95% CI 1.03 to 1.62); p = 0.030), a higher 365 day mortality rate (OR 1.45 (95% CI 1.22 to 1.72); p < 0.001) and a higher 365 day reoperation rate (OR 4.61 (95% CI 3.73 to 5.71); p < 0.001). Patients treated with arthroplasty without the recommended cemented stem had a statistically significant higher 365 day reoperation rate (OR 1.23 (95% CI 1.02 to 1.48); p = 0.030). Patients with trochanteric fractures not treated with the recommended SHS had a significantly lower 365 day mortality rate (OR 0.85 (95% CI 0.75 to 0.98); p = 0.023). For inter- and subtrochanteric fractures the risk of reoperation increased significantly if recommended treatment with IMN was not employed (OR 1.54 (95% CI 1.10 to 2.16); p = 0.012).

Discussion

Our study demonstrates substantial hospital variation in adherence to evidence-based guidelines used for treatment of hip fractures in Norway. Further findings are that best practice can be ascribed to in-hospital factors and that the variation has significant negative consequences for patients in the form of increased mortality rates at 30- and 365-day post-treatment and in reoperation rates. On the other hand, adherence, expressed by the term best practice, improved significantly over the five-year study period for all fracture types except for trochanteric fractures. Treatment variation and non-adherence were

Table VI. Treatment outcome according to seven guideline recommendations and according to the best practice.

		Mortality 30 days			Mortality 365 days			Revision 365 days		
Outcome	**Total**	**n (%)**	**OR (95% CI)**	**p-value**	**n (%)**	**OR (95% CI)**	**p-value**	**n (%)**	**OR (95% CI)**	**p-value**
Surgery within 48 hours										
Yes	23,390	1,969 (8.4)	Reference		5,860 (25.1)	Reference		1,168 (5.0)	Reference	
No	4,931	477 (9.7)	1.04 (0.93 to 1.16)	0.499	1,427 (28.9)	1.13 (1.05 to 1.22)	0.001	262 (5.3)	1.06 (0.92 to 1.22)	0.405
Surgeon has > 3 years experience										
Yes	23,815	2065 (8.7)	Reference		6,091(25.8)	Reference		1,171 (5.0)	Reference	
No	4,686	381 (8.1)	0.97 (0.86 to 1.09)	0.573	1,196 (25.5)	1.04 (0.96 to 1.12)	0.380	259 (5.5)	1.12 (0.98 to 1.29)	0.100
Screw fixation (Garden 1 to 2)										
Yes	3,747	224 (6.0)	Reference		846 (22.6)	Reference		338 (9.0)	Reference	
No	589	46 (7.8)	1.09 (0.77 to 1.55)	0.619	160 (27.2)	1.05 (0.84 to 1.29)	0.687	19 (3.2)	0.34 (0.21 to 0.55)	<0.001
Arthroplasty (Garden 3 to 4)										
Yes	16,219	1,328 (8.2)	Reference		3,805 (23.5)	Reference		678 (4,2)	Reference	
No	770	111 (14.4)	1.29 (1.03 to 1.62)	0.030	276 (35.8)	1.45 (1.22 to 1.72)	<0.001	124 (16,1)	4.61 (3.73 to 5.71)	<0.001
Cemented stem if arthroplasty										
Yes	13,017	1,097 (8.4)	Reference		3,128 (24.0)	Reference		523 (4.0)	Reference	
No	3,202	231 (7.2)	0.90 (0.77 to 1.05)	0.184	677 (21.1)	0.91 (0.83 to 1.01)	0.082	155 (4.8)	1.23 (1.02 to 1.48)	0.030
SHS (Trochanteric AO/OTA A1)										
Yes	3,783	348 (9.2)	Reference		1,091 (28.8)	Reference		96 (2.5)	Reference	
No	1,763	167 (9.5)	1.04 (0.85 to 1.27)	0.701	462 (26.2)	0.85 (0.75 to 0.98)	0.023	43 (2.4)	0.96 (0.67 to 1.39)	0.842
IMN (Intertrochanteric AO/ OTA A3+ Subtrochanteric)										
Yes	2,072	173 (8.4)	Reference		506 (24.4)	Reference		113 (5.5)	Reference	
No	670	67 (10.0)	1.14 (0.84 to 1.56)	0.400	189 (28.2)	1.17 (0.95 to 1.45)	0.139	54 (8.1)	1.54 (1.10 to 2.16)	0.012

*Logistic regression analysis.
CI, confidence interval; IMN, intramedullary nail; OR, odds ratio; OTA, Orthopaedic Trauma Association; SHS, sliding hip screw.

notable although 86% of hospitals (n = 37) reported that they had a local, hospital-based, hip fracture programme.

We acknowledge that it is good medical practice to deviate from guidelines in specific clinical settings, if deviation can be substantiated. However, although the non-adherence rates demonstrated in this study may appear not to be substantial, deviation still represents a significant number of patients receiving less-than-optimal treatment. As an example, an adherence rate of 80% in the use of a cemented hip prosthesis means that more than 3,000 patients in Norway in the five year study period did not receive optimal care. We argue that deviation cannot be explained by rational clinical judgment alone, particularly because we have excluded combined (complex) fractures where variation and treatment according to surgeon discretion could be expected.

Evidence-based guidelines are in principle valid at the time of publication and must be revised when significant new scientific data have accrued. An example of this is that the SIGN guideline has now been withdrawn for revision. We would argue that there has been no paradigm shift in hip fracture treatment policies over the five-year study period, which may explain the relatively high non-adherence rates.

A striking feature is that individual hospitals did comply with guidelines for some items (time of surgery, competence) and fracture types, but at the same time demonstrated significant non-adherence and deviation for others. This explains the relatively low adherence rate when all hip fractures were evaluated as a group. Further, some hospitals were at odds with long-established and scientifically strong evidence. An example of this is the use of uncemented prosthesis stems.[17]

Non-adherence to guidelines is not a unique Norwegian phenomenon. A Dutch study showed that 74% of treatment for FNF complied with established national guidelines.[18] They did not study structural components of care nor geographical variation in adherence. Data from the British National Hip Fracture Database also have shown wide disparities and poor adherence to guidelines in the use of total hip arthroplasty for hip fractures.[19] Inconsistent compliance with guidelines poses a significant risk of inequality in treatment and poor outcomes.

Consequently, our findings strongly suggest that the observed variation mostly depends on providers and their hospital-specific, probably unwritten, treatment preferences. A hospital "surgical signature", as described by Birkmeyer et al,[20] probably reflects hospital-specific traditions due to regional training and surgeon-specific attitudes and beliefs as to treatment policy, which override established scientific evidence and formal national guidelines. Bhandari and Swiontkowski[2] have also shown that surgeons disagree on the optimal treatment principle (arthroplasty or internal fixation) in patients aged 60 to 80 years with FNF and that surgeons' personal preferences and beliefs probably have a major impact on the choice of treatment.

It is a challenge to explain the treatment volume and regional effects on adherence to best practice in a logical or clinical context. Some of the effects may be explained by an uneven distribution of hospitals favouring a non-cemented prosthesis stem in volume groups and regional categories. Certain structural elements of the hospitals may also contribute. Considering all information as a whole, we conclude that treatment practice in individual hospitals is the main cause of non-adherence.

Grove et al[21] have explored different drivers of variation in orthopaedic surgery. They argued that formal codified knowledge such as evidence-based guidelines has a little influence on decision-making. They concluded that treatment decisions are more driven by socialized knowledge spread between colleagues, particularly influenced by professional meetings and conferences.[21] Timmermans[22] also emphasizes the importance of clinical autonomy, which takes precedence over guidelines. Surgeon autonomy and informal paths of knowledge may partly explain the marked variation in adherence.

The main strength of this study is that it is population-based with a high inclusion rate and a high degree of completeness of the data from the NHFR. Reports to the registry are completed directly after surgery, which ensures high accuracy of the information. Subsequently, the NHFR provides high-quality information on hip fracture treatment in Norway.

A limitation is that there has been an underreporting of reoperations in the NHFR.[4] Reporting of reoperations probably does not differ between fracture groups. Therefore, more complete data would probably have supported and strengthened our findings, particularly the effects on outcomes (Table VI). We also acknowledge that the use of the ASA grade to express preoperative physical status may not fully characterize health status of this patient group. On the other hand, we argue that adjustment for health status of the patients using the ASA grade is far better than no adjustment at all. There may also be factors other than the variables included in this study that may influence the choice of treatment, and that may legitimize a treatment deviating from guideline recommendations.We acknowledge that concluding summary treatment recommendations based on five evidence-based guidelines might be challenged. However, we would argue that the recommendations summarized in Table I were homogeneous across the guidelines and that the discrepancies we encountered were of minor importance.

There is substantial variation in the treatment of hip fractures in Norway. Adherence to guidelines has gradually improved over the five-year study period, but in 2018 only 59% of patients received best practice treatment. Non-adherence had a negative effect on patient outcomes. Steps must be taken to disseminate knowledge on best practice and consequences of non-adherence, and to improve non-compliance and reduce the importance of surgeons' personal preferences in treatment decisions.

Take home message

- Substantial variation in hip fracture treatment in Norway, despite established evidence-based guidelines.
- Deviation from best practice has negative consequences for patient outcomes.
- Dissemination of information on best practice through guidelines is challenging.

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Ethical review statement:
- The project was approved by the Northern Norway Regional Committee for Medical and Health Research Ethics and was exempted from the duty of confidentiality (REK 2018/1955). A data protection integrity assessment was compiled according to the EU General Data Protection Regulation (GDPR).

BJO

HIP

Waiting time for hip fracture surgery: hospital variation, causes, and effects on postoperative mortality

DATA ON 37,708 OPERATIONS REPORTED TO THE NORWEGIAN HIP FRACTURE REGISTER FROM 2014 TO 2018

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Aims

This study aimed to describe preoperative waiting times for surgery in hip fracture patients in Norway, and analyze factors affecting waiting time and potential negative consequences of prolonged waiting time.

Methods

Overall, 37,708 hip fractures in the Norwegian Hip Fracture Register from January 2014 to December 2018 were linked with data in the Norwegian Patient Registry. Hospitals treating hip fractures were characterized according to their hip fracture care. Waiting time (hours from admission to start of surgery), surgery within regular working hours, and surgery on the day of or on the day after admission, i.e. 'expedited surgery' were estimated.

Results

Mean waiting time was 22.6 hours (SD 20.7); 36,652 patients (97.2%) waited less than three days (< 72 hours), and 27,527 of the patients (73%) were operated within regular working hours (08:00 to 16:00). Expedited surgery was given to 31,675 of patients (84%), and of these, 19,985 (53%) were treated during regular working hours. Patients classified as American Society of Anesthesiologists (ASA) classes 4 and 5 were more likely to have surgery within regular working hours (odds ratio (OR) 1.59; p < 0.001), and less likely to receive expedited surgery than ASA 1 patients (OR 0.29; p < 0.001). Low-volume hospitals treated a larger proportion of patients during regular working hours than high volume hospitals (OR 1.26; p < 0.001). High-volume hospitals had less expedited surgery and significantly longer waiting times than low and intermediate-low volume hospitals. Higher ASA classes and Charlson Comorbidity Index increased waiting time. Patients not receiving expedited surgery had higher 30-day and one-year mortality rates (OR 1.19; p < 0.001) and OR 1.13; p < 0.001), respectively.

Conclusion

There is inequality in waiting time for hip fracture treatment in Norway. Variations in waiting time from admission to hip fracture surgery depended on both patient and hospital factors. Not receiving expedited surgery was associated with increased 30-day and one-year mortality rates.

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Introduction

A hip fracture in elderly people is associated with a substantially increased risk of death compared to the general population, and with subsequent 30-day mortality of around 8%.[1] Prolonged waiting time from fracture to surgery increases mortality.[2,3] On the other hand, accellerated surgery within six hours of diagnosis did not reduce postoperative mortality.[4] Pincus et

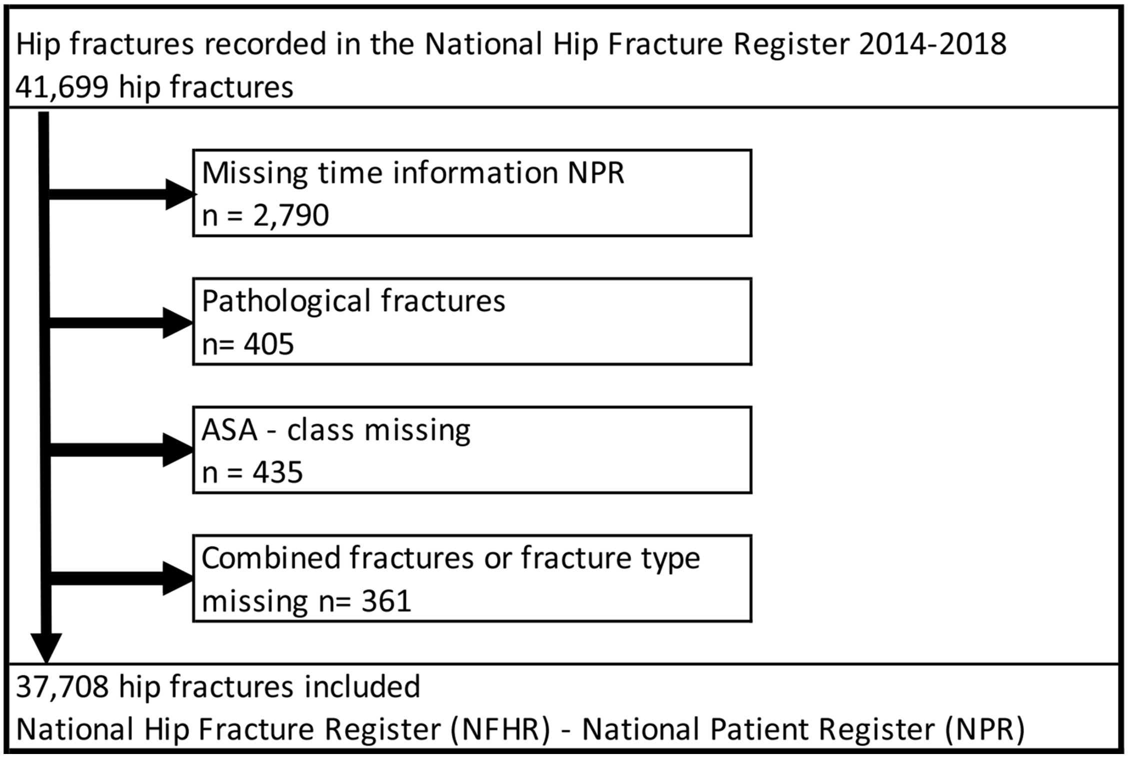

Fig. 1

Flow chart patient selection Hip fractures recorded in the National Hip Fracture Register from 2014 to 2018.

al[2] identified a potential threshold for defining higher risk related to waiting time at 24 hours.

Evidence-based guidelines from the National Institute of Health and Care Excellence (NICE) and the American Academy of Orthopaedic Surgeons recommend the shortest possible waiting time,[5,6] and advocate performing surgery within 36 and 48 hours of admission, respectively. The Norwegian multidisciplinary guidelines (2018) concur with this view and recommend surgery preferably within 24 hours, or at least within 48 hours after admission.[7] The National Hip Fracture Database (NHFD) in the UK reports "prompt surgery", defined as surgery on the day of or after admission, as a key performace indicator (KPI) in order to standardize and improve patient care.[8]

This study aimed to describe the temporal distribution of preoperative waiting time for surgery in patients with a hip fracture in Norway, particularly the proportion of patients receiving treatment within and outside regular working hours (08:00 to 16:00), receiving treatment within recommended waiting time, and having prompt (expedited) surgery. Further, we analyzed patient- and system-related factors affecting waiting time, and assessed potential effects on mortality of extended waiting time for surgery.

Methods

This is a national (5.3 million inhabitants in 2018) retrospective analysis of prospective data, based on linked data from the Norwegian Hip Fracture Register (NHFR) and the Norwegian Patient Registry (NPR). Patients' unique national identification number enables precise coupling of data from these two registries.

National Hip Fracture Register. The NHFR has collected data on all hip fracture patients operated in Norwegian hospitals since 2005.[9] Total hip arthroplasty (THA) as primary treatment is recorded in the Norwegian Arthroplasty Register and subsequently imported to the NHFR. Data from the NHFR were used to identify patients, and for retrieval of basic information on sex, age, American Society of Anesthesiologists (ASA) class, hospital identification, fracture type, type of operation, and grouping on surgeon experience (i.e. more than three years' experience of fracture surgery). Completeness of reporting to the NHFR is evaluated regularly, and was 88.2% for osteosynthesis, 94.5% for hemiarthroplasties, and 87.8% for THAs from 2015 to 2016.[10] Date of death was retrieved from the National Population Register.

Characterization of hospitals. All 43 hospitals treating hip fractures in Norway were included. Hospital characteristics and organization of hip fracture care (separate ward, dedicated hip fracture unit, hip fracture programme or orthogeriatric service) were obtained from a national survey of hospitals as part of this research programme.[11] The hospitals were grouped in quartiles by hip fracture surgery volume in the inclusion period.

Table I. Baseline patient characteristics.

Variable	Data
Study population, n	37,708
Sex, n (%)	
Females	25,586 (67.9)
Males	12,122 (32.1)
Median age, yrs (IQR)	83 (76 to 90)
Females	84 (78 to 91)
Males	80 (72 to 89)
ASA class, n (%)	
1	1,304 (3.5)
2	12,483 (33.1)
3	21,074 (55.9)
4 and 5	2,847 (7.5)
Charlson Comorbidity Index, n (%)	
0	26,027 (69.0)
1 to 2	8,309 (22.0)
3 to 4	2,160 (5.7)
5	1,212 (3.2)
Fracture type, n (%)	
Undisplaced femoral neck fracture - garden 1 to 2	4,877 (12.9)
Displaced femoral neck fracture - garden 3 to 4	17,293 (45.9)
Basocervical	1,070 (2.8)
Trochanteric AO/OTA A1	5,664 (15.0)
Trochanteric AO/OTA A2	5,919 (15.7)
Intertrochanteric AO/OTA A3	905 (2.4)
Subtrochanteric	1,980 (5.4)
Treatment type, n (%)	
Two or three parallel screws	5,367 (14.2)
Arthroplasty	16,725 (44.4)
Sliding hip screw	8,471 (22.5)
Intramedullary nailing	6,656 (17.7)
Other	489 (1.3)

AO, Arbeitsgemeinschaft für osteosynthesefragen; ASA, American Society of Anaesthesiologists; IQR, interquartile range; OTA, Orthopaedic Trauma Association.

Table II. Hospital and structural characteristics for 37,708 hip fracture patients.

Variable	n = 37,708, n (%)
Surgeons' experience in fracture surgery	
< 3 years	5,145 (13.6)
> 3 years	29,584 (78.5)
Missing	2,979 (7.9)
Hospital volume groups	
Quartile 4 (range 1,128 to 2,639)*	18,006 (47.8)
Quartile 3 (range 746 to 1,124)*	10,074 (26.7)
Quartile 2 (range 524 to 740)*	6,913 (18.3)
Quartile 1 (range 83 to 367)*	2,715 (7.2)
Hospital characteristics	
Orthogeriatric service	
Yes	16,632 (44.1)
No	21,077 (55.9)
Hip fracture programme	
Yes	34,978 (92.8)
No	2,730 (7.2)
Dedicated hip fracture unit	
Yes	15,296 (40.6)
No	22,412 (59.4)
Separate orthopaedic ward	
Yes	33,048 (87.6)
No	4,660 (12.4)

*Range in hospital volume groups is total volume 2014 to 2018 for hospitals in quartile.
AO, Arbeitsgemeinschaft für osteosynthesefragen; OTA, Orthopaedic Trauma Association.

Administrative data. Administrative data from all hospitals and other specialist healthcare providers are reported to the NPR monthly including dates and exact times for admission, discharge and surgical interventions. Furthermore, data on all in- and outpatient contacts, including ICD-10 diagnoses,[12] from 1 January 2013 to 31 December 2019 were obtained.

Comorbidity using the Charlson Comorbidity Index (CCI) was calculated from NPR data.[13] The CCI has been validated for use in Norway.[14]

Waiting time in hours from admission to start of surgery was calculated. In addition, we categorized waiting time according to the UK NHFD definition, i.e., surgery on the day of or after admission, in this paper expressed as expedited surgery. The number of days waiting for surgery was calculated as the difference between the dates of surgery and admission and is given as day 0 (admission day), 1 or 2, and from day three onwards as day 3+. Time of surgery was further categorized as daytime surgery (within regular working hours), afternoon/evening surgery (after regular working hours with reduced surgical capasity; 16:00 to 24:00), and night surgery (normally reserved for emergency surgery only; 00:00 to 08:00).

To explore the effect of delaying surgery from the afternoon and night the day after admission (day 1) to daytime on the following day (day 2), we defined two patient groups: one group operated between 16:00 (day 1) and to 08:00 (day 2). The second group was operated on the following day (day 2) in daytime (08:00 to 16:00).

By 31 December 2019, the NHFR had compiled data on 41,699 fractures, admitted from 1 January 2014 to 31 December 2018 (Figure 1). Patients with missing information at time of admission or operation (n = 2,790; 6.7%), and patients with pathological fracture (n = 405; 1.0%), missing information on ASA class (n = 435; 1.0%), and combined fracture types or missing information on fracture type (n = 361; 0.9%) were excluded, leaving 37,708 (90.4%) fractures for analyses (Figure 1), made up of 25,586 females (67.9%) and 12,122 males (32.1%), with a median age of 83 years (interquartile range (IQR) 76 to 90). In analysis of mortality, patients suffering from a contralateral hip fracture within the observation time (minimum one year) were excluded (n = 938/37,708). Baseline patient characteristics are given in Table I and hospital and system characteristics are presented in Table II.

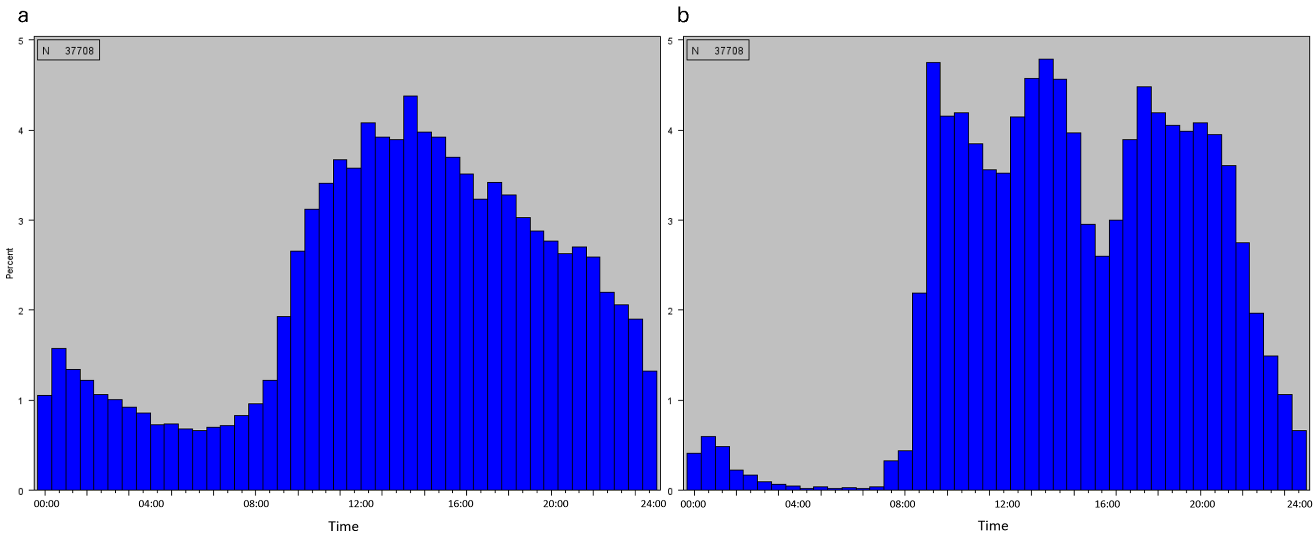

Fig. 2

Time of admission a) and time of surgery and b) for 37,708 patients.

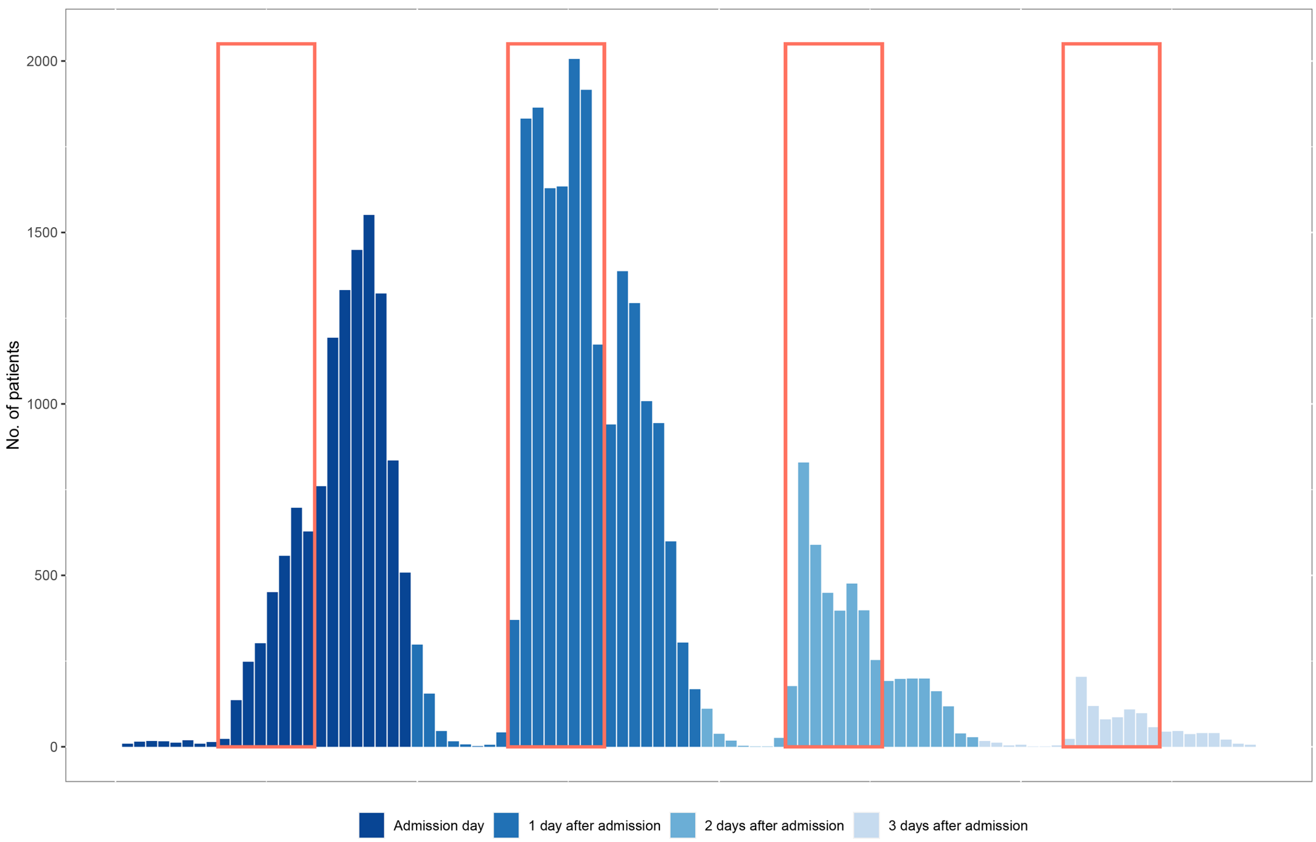

Fig. 3

Temporal distribution of time of surgery after admission. Red boxes give normal working hours (08:00 to 16:00).

Statistical analysis. The analyses were performed using SAS/STAT for Windows v. 8.2 (SAS Institute, USA). Continuous variables are presented as medians and IQRs. Categorical variables are presented as absolute numbers and percentages. Differences between categorical variables were analyzed using multiple logistic regression, adjusted for sex, age, and ASA class, unless stated otherwise. Age-dependent risk of death at 30 days and 365 days after surgery was estimated by logistic regression analysis. Comparison between groups and differences in means of waiting time before surgery was evaluated by analysis of variance (ANOVA) with Bonferroni corrections,

Table III. Patient-related factors influencing daytime and expedited surgery.

Variable	n	Daytime/working hours, n (%)	Logistic regression, OR (95% CI)	p-value*	Expedited surgery, n (%)	Logistic regression, OR (95% CI)	p-value*
ASA class							
1	1,304	614 (47.1)	Ref	Ref	1,169 (89.7)	Ref	Ref
2	12,483	6,447 (51.6)	1.27 (1.13 to 1.43)	< 0.001	10,946 (87.7)	0.71 (0.59 to 0.86)	= 0.001
3	21,074	11,142 (52.9)	1.37 (1.21 to 1.54)	< 0.001	17,485 (83.0)	0.47 (0.39 to 0.57)	< 0.001
4 and 5	2,847	1,607 (56.4)	1.59 (1.38 to 1.83)	< 0.001	2,143 (75.3)	0.29 (0.24 to 0.36)	< 0.001
Charlson Comorbidity Index							
0	26,027	13,554 (52.1)	Ref	Ref	22,152 (85.1%)	Ref	Ref
1 to 2	8,309	4,456 (53.6)	1.07 (1.01 to 1.12)	= 0.013	6,885 (82.9)	0.85 (0.80 to 0.91)	< 0.001
3 to 4	2,160	1,152 (53.3)	1.05 (0.96 to 1.15)	= 0.246	1,733 (80.2)	0.73 (0.65 to 0.81)	< 0.001
5	1,212	648 (53.5)	1.06 (0.94 to 1.19)	= 0.357	973 (80.3)	0.73 (0.63 to 0.84)	< 0.001
Fracture type							
Displaced FNF - garden 3 to 4	17,293	10,036 (58.0)	Ref	Ref	14,175 (82.0)	Ref	Ref
Undisplaced FNF - garden 1 to 2	4,877	2,176 (44.6)	0.58 (0.55 to 0.62)	< 0.001	4,148 (85.0)	1.21 (1.11 to 1.32)	< 0.001
Basocervical	1,070	527 (49.3)	0.70 (0.62 to 0.79)	< 0.001	929 (86.8)	1.49 (1.24 to 1.78)	< 0.001
Trochanteric AO/OTA A1	5,664	2,686 (47.4)	0.65 (0.62 to 0.69)	< 0.001	4,851 (85.7)	1.32 (1.21 to 1.43)	< 0.001
Trochanteric AO/OTA A2	5,919	2,909 (49.2)	0.70 (0.66 to 0.74)	< 0.001	5,098 (86.1)	1.37 (1.26 to 1.49)	< 0.001
Intertrochanteric AO/OTA A3	905	437 (48.3)	0.67 (0.59 to 0.77)	< 0.001	780 (86.2)	1.39 (1.15 to 1.69)	< 0.001
Subtrochanteric	1,980	1,039 (52.5)	0.80 (0.72 to 0.88)	< 0.001	1,762 (90.0)	1.78 (1.54 to 2.07)	< 0.001
Treatment type							
Arthroplasty	16,725	9,757 (58.3)	Ref	Ref	13,629 (81.5)	Ref	Ref
2 or 3 parallel screws	5,367	2,418 (45.1)	0.58 (0.54 to 0.61)	< 0.001	4,631 (86.3)	1.41 (1.29 to 1.55)	< 0.001
Sliding hip screw	8,471	3,970 (46.9)	0.63 (0.60 to 0.66)	< 0.001	7,247 (85.6)	1.35 (1.26 to 1.46)	< 0.001
Intramedullary nailing	6,656	3,427 (51.5)	0.76 (0.72 to 0.80)	< 0.001	5,809 (87.3)	1.57 (1.44 to 1.70)	< 0.001
Other	489	238 (48.7)	0.67 (0.56 to 0.80)	< 0.001	427 (87.3)	1.60 (1.22 to 2.10)	< 0.001

*Logistic regression analyses adjusted for sex, age and ASA class, except analyses on American Society of Anesthesiologists and Charlson Comorbidity Index where American Society of Anesthesiologists class is excluded.
ASA, American Society of Anesthesiologists; CI, confidence interval; FNF, femoral neck fracture; OR, odds ratio; OTA, Orthopaedic Trauma Association.

Table IV. Hospital- and system-related factors influencing daytime and expedited surgery.

Variable	n	Daytime/working hours, n (%)	Logistic regression, OR (95% CI)	p-value*	Expedited surgery	Logistic regression, OR (95% CI)	p-value*
Surgeon's experience in fracture surgery							
> 3 years	29,584	15,565 (52.6)	Ref		24,967 (84.4)	Ref	Ref
< 3 years	5,145	2,240 (43.5)	0.70 (0.66 to 0.74)	< 0.001	4,447 (86.4)	1.11 (1.04 to 1.19)	= 0.003
Missing	2,979	N/A	N/A	N/A	N/A	N/A	N/A
Hospital volume groups							
High volume (quartile 4)	18.006	9,712 (53.9)	Ref	Ref	14,570 (80.9%)	Ref	Ref
Intermediate-high volume (quartile 3)	10,074	4,925 (48.9%)	0.81 (0.78 to 0.86)	< 0.001	8,591 (85.3%)	1.39 (1.30 to 1.49)	< 0.001
Intermediate-low volume (quartile 2)	6,913	3,555 (51.4)	0.90 (0.85 to 0.95)	< 0.001	6,180 (89.4)	2.05 (1.88 to 2.23)	< 0.001
Low volume (quartile 1)	2,715	1,618 (59.6)	1.26 (1.16 to 1.37)	< 0.001	2,402 (88.5)	1.83 (1.62 to 2.07)	< 0.001
Orthogeriatric service							
Yes	16,631	8,820 (53.0)	Ref	Ref	13,940 (83.3)	Ref	Ref
No	21,077	10,990 (52.1)	0.97 (0.93 to 1.01)	= 0.110	17,803 (84.5)	1.04 (0.96 to 1.10)	= 0.157
Hip fracture programme							
Yes	34,978	18,320 (52.4)	Ref	Ref	29,273 (83.7)	Ref	Ref
No	2,730	1,490 (54.6)	1.10 (1-02 to 1.19)	= 0.020	2,470 (90.5)	1.84 (1.62 to 2.10)	< 0.001
Dedicated hip fracture unit							
Yes	15,296	8,441 (55.2)	Ref	Ref	12,562 (82.1)	Ref	Ref
No	22,412	11,369 (50.7)	0.84 (0.80 to 0.87)	< 0.001	19,181 (85.6)	1.30 (1.23 to 1.38)	< 0.001
Separate orthopaedic ward							
Yes	33,048	17,355 (52.5)	Ref	Ref	27,549 (83.4%)	Ref	Ref
No	4,660	2,455 (52.7)	1.01 (0.95 to 1.08)	= 0.721	4,194 (90)	1.78 (1.61 to 1.96)	< 0.001

*Logistic regression analyses were adjusted for sex, age, and American Society of Anesthesiologists class.
ASA, American Society of Anesthesiologists; CI, confidence interval; N/A, not applicable; OR, odds ratio.

and the corrections were justified due to the non-normal distribution of the observations. Association between volume and proportion treated expedited was evaluated by a linear regression model. Significance was set at 5% in all analyses.

Ethics, funding, and conflict of interest. The project was approved by the Northern Norway Regional Committee for Medical and Health Research Ethics and was exempted from the duty of confidentiality (REK 2018/1955). A data protection integrity assessment was compiled according

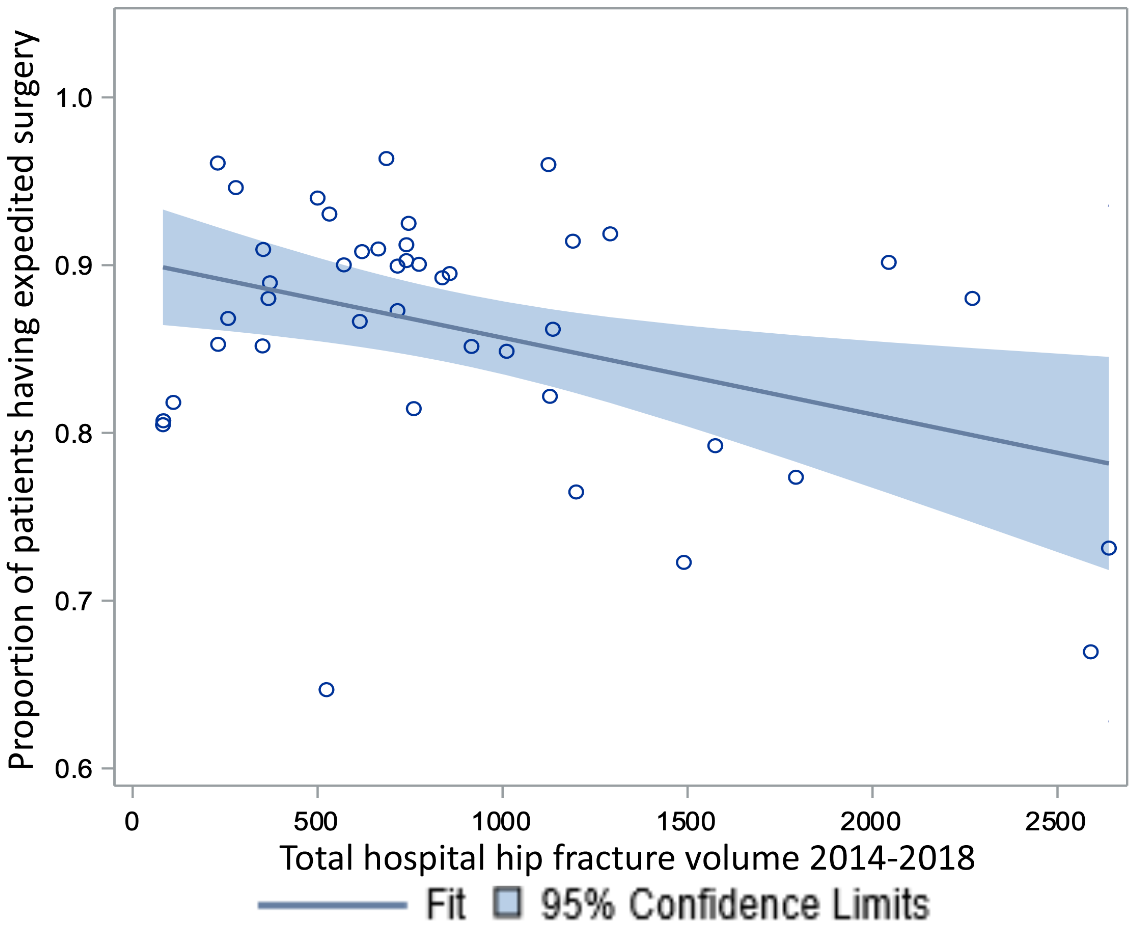

Fig. 4

Scatter plot and linear regression displaying proportion of patients having expedited surgery related to hip fracture volume.

to the EU General Data Protection Regulation (GDPR). The project was funded by the Northern Norway Regional Health Authority (HNF1482-19). The NHFR is financed by the Western Norway Regional Health Authority. No competing interests were declared.

Results

Time of admission and time of surgery. Admission time to hospital is illustrated in Figure 2a. Overall, 17,326 patients (46.0%) were admitted during daytime, 15,123 (40.1%) in the afternoon or evening, and 5,259 (14.0%) at night. Time for start of surgery on the day of operation, irrespective of waiting time, is shown in Figure 2b. In all, 19,810 patients (52.5%) were operated during daytime, while 16,972 (45.0%) were operated on in the afternoon or evening. Night-time surgery was rarely performed (n = 926; 2.5%).

Distribution of time of surgery related to waiting time. The temporal distribution of time of surgery after admission is illustrated in Figure 3. A total of 12,103 of patients (32.1%) were operated on the day of admission (day 0), 19,640 (52.1%) the day after admission (day 1), 4,901 (13.0%) on day 2, and 1,064 (2.8%) on day 3 or later (day 3+). An increasing proportion were operated during daytime and regular working hours for every day that passed: 3,042 (25%) on day 0, 12,424 (63%) on day 1, and 3,568 (73%) on day 2 and day 3+. Overall, 288 patients (27%) operated on day 3+ had afternoon/evening or night surgery, and 243 surgeries (4%) took place at night-time from day 2 and onwards.

Patient-related factors and timing of surgery. High-risk patients (i.e. higher ASA class) were more often treated during daytime (Table III). Displaced femoral neck fractures (FNFs) were more likely to be treated during daytime and within regular working hours than all other fracture types. Arthroplasties were also more frequently performed in daytime than other procedures (Table III).

Both higher ASA class and CCI score reduced the likelihood of receiving expedited treatment (Table III). Subtrochanteric fractures were more likely to receive expedited surgery. Arthroplasties were less likely to receive expedited surgery than all other surgical procedures.

Hospital/system factors and timing of surgery. Less experienced surgeons operated fewer patients in daytime and within regular working hours, but a higher proportion within the period defined as expedited surgery

Table V. Differences in mean waiting time for surgery for specific groups analyzed with analysis of variance statistics.

Variable	n (%)	Mean	95% CI	p-values < 0.05 marked by *
Mean total waiting time	37,708	22 h 36 m		
ASA class				
1	1,304	Ref	Ref	
2	12,483	3 h 21 m	1 h 40 m to 5 h2 m	*
3	21,074	6 h 22 m	4 h 43 m to 8 h0 m	*
4/5	2,847	12 h5 m	10 h 16 m to 13 h 53 m	*
Charlson Comorbidity Index				
0	26,027	Ref	Ref	
Ref1 to 2	8,309	1 h20 m	38 m to 2 h1 m	*
3 to 4	2,160	3 h35 m	2 h22 m to 4 h48 m	*
5-	1,212	4 h3 7 m	3 h 1 m to 6 h 13 m	*
Fracture type				
Displaced FNF - garden 3 to 4	17,293	Ref	Ref	
Undisplaced FNF - garden 1 to 2	4,877	- 1 h 56 m	-2 h57 m to - 55 m	*
Basocervical	1,070	- 1 h 40 m	-3 h38 m to 19 m	
Trochanteric AO/OTA A1	5,664	- 2 h 21 m	- 3 h 19 m to - 1 h 24 m	*
Trochanteric AO/OTA A2	5,919	- 2 h 49 m	- 3 h 46 m to - 1 h 53 m	*
Intertrochanteric AO/OTA A3	905	- 2 h 34 min	- 4 h 43 m to - 27 m	*
Subtrochanteric	1,980	- 4 h 22 m	- 5 h 52 m to - 2 h 53 m	*
Treatment type				
Arthroplasty	16,725	Ref	Ref	
2/3 parallel screws	5,367	- 2 h 54 m	- 3 h 48 m to - 1 h 59 m	*
Sliding hip screw	8,471	- 2 h 22 m	- 3 h 8 m to - 1 h 35 m	*
Intramedullary nailing	6,656	- 3 h 49 m	- 4 h 39 m to - 2 h 59 m	*
Other	489	- 3 h 51 m	- 6 h 31 m to - 1 h 12 m	*
Hospital volume groups - increasing volume				
Quartile 4	18,006	Ref	Ref	
Quartile 3	10,074	10 m	- 1 h 4 m to 1 h24 m	
Quartile 2	6,913	- 3 h 31 m	- 4 h 42 m to - 2 h 21 m	*
Quartile 1	2,715	- 4 h 54 m	- 6 h 1 m to - 3 h 47 m	*

The minus sign indicates a shorter waiting time than the reference value. In ANOVA analyses, the test show if variance is of such degree that the p-value is below a pre-set value -<0.05.
AO, Arbeitsgemeinschaft für osteosynthesefragen; CI, confidence interval; FNF, femoral neck fracture; IQR, interquartile range; OTA, Orthopaedic Trauma Association.; SD, standard deviation.

(Table IV). There was a significant trend that high volume hospitals had a lower proportion of patients treated with expedite surgery than low volume hospitals ($r^2 = 0.1528$; df = 41; mean square error 0.0048) (Figure 4).

An orthogeriatric service unit did not increase the proportion of patients having surgery within regular working hours or as expedited surgery. A dedicated hip fracture unit increased the proportion of patients having a daytime operation, but reduced the proportion having expedited surgery. A separate orthopaedic ward reduced the proportion of patients having expedited surgery (Table IV).

Differences in mean waiting time. Waiting time increased significantly with higher ASA classes and increasing CCI (Table V). Displaced FNFs treated with arthroplasty had statistically significantly longer waiting times than all other fractures and treatment types, except basocervical fractures (Table V). High-volume (Q4) hospitals had significantly longer waiting times than low volume (Q1) and intermediate low-volume (Q2) hospitals. Low-volume (Q1) hospitals had almost five hours shorter waiting time (Table V).

Consequences of the timing of surgery. In unadjusted logistic regression analyses, non-expedited surgery resulted in higher 30-day and one-year mortality rates compared to expedited surgery (OR 1.19; 95% confidence interval (CI) 1.08 to 1.31; p < 0.001, and OR 1.13; 95% CI 1.06 to 1.20; p < 0.001, respectively). Working hours surgery on day 2 increased 30-day and one-year mortality compared to afternoon/evening/night surgery on day 1 in unadjusted analyses (Table VI). Adjusting for age, sex, and ASA class resulted in insignificant effects on mortality, whereas analyses adjusted for age, sex and CCI demonstrated that not receiving expedited surgery resulted in higher mortality rates. Figure 5 illustrates the effect on 30-day mortality for each ASA class and CCI group related to age. There was a statistically significant higher 30-day mortality rate for

Table VI. The effect of expedite surgery and a subgroup analysis comparing surgery in the afternoon/night of day one with daytime surgery day two 30-day and one-year mortality.

			Adjusted for					
Effect	**Unadjusted, OR (95% CI)**	**p-value***	**Age/sex, OR (95% CI)**	**p-value***	**Age/sex/ASA, OR (95% CI)**	**p-value***	**Age/sex/CCI, OR (95% CI)**	**p-value***
Afternoon/night day 1 vs daytime day 2								
30-day mortality								
Expedite surgery								
Yes	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
No	1.19 (1.08 to 1.31)	< 0.001	1.19 (1.08 to 1.32)	= 0.001	0.99 (0.89 to 1.10)	= 0.841	1.16 (1.05 to 1.29)	= 0.004
Afternoon/night day 1 vs daytime day 2								
Day 1	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Day 2	1.22 (1.05 to 1.41)	= 0.008	1.26 (1.08 to 1.46)	= 0.003	1.08 (0.93 to 1.27)	= 0.306	1.22 (1.05 to 1.42)	= 0.010
One-year mortality								
Expedite surgery								
Yes	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
No	1.13 (1.06 to 1.20)	< 0.001	1.14 (1.06 to 1.22)	< 0.001	0.96 (0.89 to 1.03)	= 0.243	1.10 (1.02 to 1.17)	= 0.011
Day 1	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Day 2	1.10 (1.00 to 1.21)	= 0.047	1.14 (1.03 to 1.26)	= 0.010	1.01 (0.91 to 1.12)	= 0.857	1.10 (1.00 to 1.22)	= 0.057

*All analyses are logistic regressions. Adjustments stated in column heading.
ASA, American Society of Anesthesiologists; CCI, Charlson Comorbidity Index.; CI, confidence interval; OR, odds ratio.

non-expedited surgery than for expedited surgery in all CCI groups (OR 1.16; 95% CI 1.05 to 1.29; p = 0.004). All analyses were carried out by logistic regression, with adjustment stated in each analyses.

Discussion

The waiting time issue has been adressed using three indicators; waiting time in hours, surgery within regular working hours, and the UK KPI indicator expedited surgery (prompt surgery). Patient comorbidity, expressed as both higher ASA class and CCI score, increased waiting time. Similarly, fracture type and surgical procedure affected waiting time. Displaced FNF and treatment with arthroplasty prolonged waiting time, but at the same time increased the probability of surgery within regular working hours. We hypothesize that specialized surgeons performed the arthroplasties, especially THAs, in working hours. Other treatment alternatives may be considered less technically demanding, and require less surgical experience.

Compared to arthroplasties, other fracture treatments more frequently were performed outside regular working hours, and were more often performed by less experienced surgeons.

The high-volume (Q4) hospital group had significantly longer waiting times and a lower proportion of patients treated during regular working hours than Q1 to Q3 volume groups. The larger hospitals should have resources and staff to perform surgery for a longer period of the day. Recently Nilsen et al[15] demonstrated that strained hospital resources, increased waiting time to surgery by 20% and led to a 20% higher 60-day mortality. This supports our contention that hip fracture patients are not prioritized in hospital management.

Waiting time is a modifiable risk factor. Reimbursement schemes introduced to encourage expedited surgery have been followed by reduced preoperative waiting time.[16] Introduction of the Best Practice Tariff (BPT) in the UK reduced preoperative waiting time and one-year mortality rate.[17] Some hospitals have restructured fracture care for elderly people but with inconclusive effects.[18–20] The paradoxical effect on waiting time by system factors changes as demonstrated here, is a finding we cannot explain. Currently, there is no professional consensus nor high-level scientific evidence for the effectiveness of system changes. Despite the inconclusive scientific literature, optimalization of patient pathways with a focus on reducing unnecessary waiting should have high priority in day-to-day management.

Comorbidity was a factor in delayed surgery, but was also an independent predictor of postoperative mortality. Our interpretation is that the increased mortality we

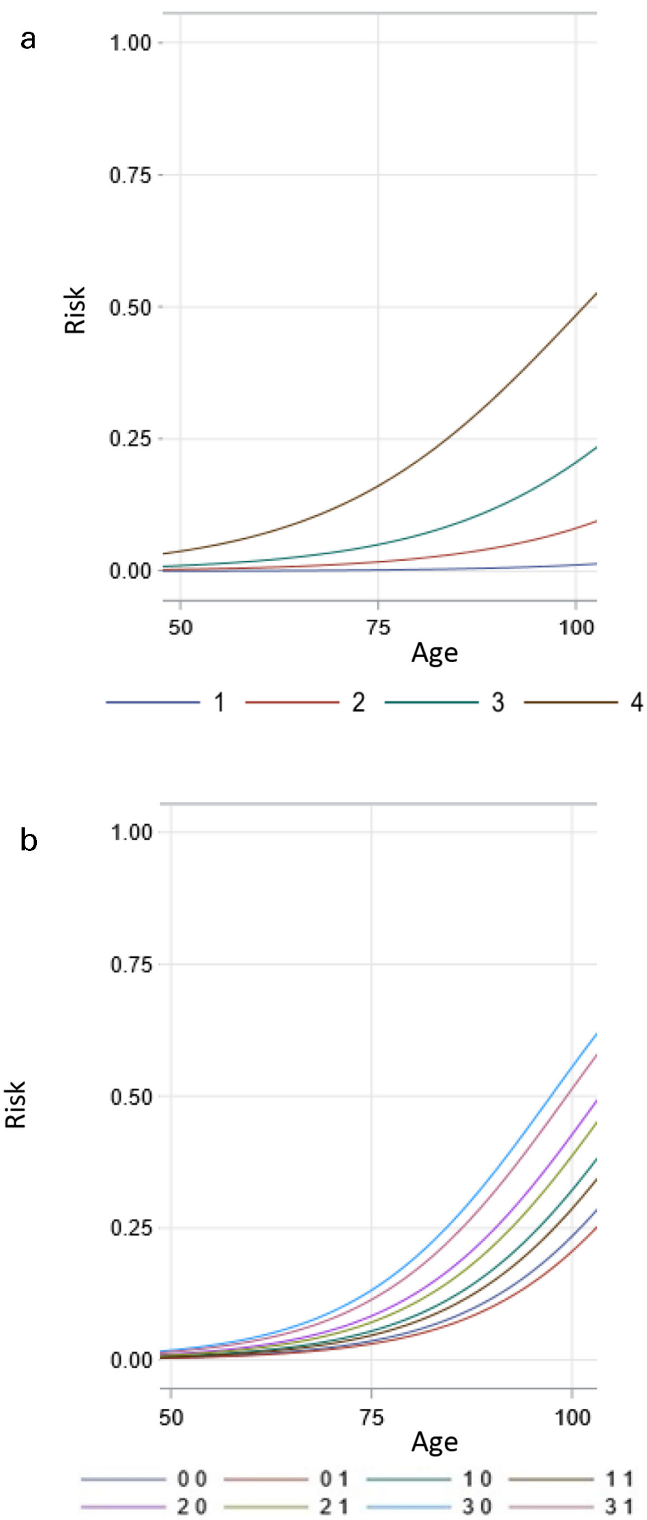

Fig. 5

Mortality at 30 days postoperatively related to age of patients.

observed when waiting time was prolonged was explained by a delay in surgery for patients with greater comorbidity. Consequently, there is a balance between preoperative optimization of the patient and increasing waiting time.[21] Waiting an extra night was associated with increased mortality in the postoperative period. An extra night may improve the fitness of patients with significant comorbidities but at the potential expense of a higher mortality, and increases patient's discomfort by waiting immobilized.

In a narrative literature review, Lewis et al[21] documented that ASA class was a consistent predictor of 30-day mortality, while CCI expresses more underlying chronic diseases and pre-fracture function which also affects mortality. However, others have shown a low predictive power of comorbidity indicies for mortality after hip fractures treated with arthroplasty.[22] Recently, Narula et al[23] has shown, in a retrospective study, that the Clinical Frailty Scale (CFS) was a good predictor of mortality for hip fracture patients. CFS can not be estimated based on routine administrative data but CFS data should be recorded in future prospective studies.

The increased postoperative death rate associated to treatment delay both in medically fit and unfit patients[21] are not substantial but in line with findings in other studies.[2,3,24] A support for the notion that delay is associated with increased mortality is the subgroup analysis comparing day 1/afternoon and evening surgery and surgery day two/working hours operations. Although the negative effect of treatment delay on mortality is relatively small, a more focused professional attention on delay as a health issue problem, could rectify this problem.

Both from a patient and health policy perspective, variations in waiting time for surgery is unwarranted healthcare inequality. Any contrast in hospital waiting time must be considered unwarranted. We conclude that expedited surgery, as used in the UK, is a better indicator than hours of waiting, embracing both the aspects of time and patient discomfort.

Strengths and limitations. The main strengths of the study are the large study population and the inclusion of all hospitals in Norway routinely treating hip fractures. We were not able to prove causality, although an association between mortality (or survival) and treatment delay has been documented. We acknowledge that pre-hospital waiting time was not included in our analysis. A previous study from the NHFR has shown that the median time from fracture to admission is six hours.[3] Given a mean in-hospital waiting time of 23 hours in this study, we find it unlikely that the addition of pre-hospital waiting time would have led to different results and changed our conclusions.

The findings in this study clearly indicate inequity in waiting time for hip fracture treatment in Norway. Variations in waiting time from admission to hip fracture surgery depended on both patient and hospital factors. Not receiving expedited treatment was associated with increased 30-day and one-year mortality rates. Further studies should address why such differences occur and whether specific patient groups should be prioritized differently.

Take home message

- There is a substantial variation in waiting time for surgery after admission.
- Both patient and hospital factors affect waiting time.
- Prolonged waiting time for surgery increases 30-day and one-year mortality.

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2018/1955). A data protection integrity assessment was compiled according to the EU General Data Protection Regulation (GDPR).

■ TRAUMA

Modifiable and non-modifiable risk factors in hip fracture mortality in Norway 2014 to 2018

A LINKED MULTIREGISTRY STUDY

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Aims
This study aimed to identify risk factors (patient, healthcare system, and socioeconomic) for mortality after hip fractures and estimate their relative importance. Further, we aimed to elucidate mortality and survival patterns following fractures and the duration of excess mortality.

Methods
Data on 37,394 hip fractures in the Norwegian Hip Fracture Register from January 2014 to December 2018 were linked to data from the Norwegian Patient Registry, Statistics Norway, and characteristics of acute care hospitals. Cox regression analysis was performed to estimate risk factors associated with mortality. The Wald statistic was used to estimate and illustrate relative importance of risk factors, which were categorized in modifiable (healthcare-related) and non-modifiable (patient-related and socioeconomic). We calculated standardized mortality ratios (SMRs) comparing deaths among hip fracture patients to expected deaths in a standardized reference population.

Results
Mean age was 80.2 years (SD 11.4) and 67.5% (n = 25,251) were female. Patient factors (male sex, increasing comorbidity (American Society of Anesthesiologists grade and Charlson Comorbidity Index)), socioeconomic factors (low income, low education level, living in a healthcare facility), and healthcare factors (hip fracture volume, availability of orthogeriatric services) were associated with increased mortality. Non-modifiable risk factors were more strongly associated with mortality than modifiable risk factors. The SMR analysis suggested that cumulative excess mortality among hip fracture patients was 16% in the first year and 41% at six years. SMR was 2.48 for the six-year observation period, most pronounced in the first year, and fell from 10.92 in the first month to 3.53 after 12 months and 2.48 after six years. Substantial differences in median survival time were found, particularly for patient-related factors.

Conclusion
Socioeconomic, patient-, and healthcare-related factors all contributed to excess mortality, and non-modifiable factors had stronger association than modifiable ones. Hip fractures contributed to substantial excess mortality. Apparently small survival differences translate into substantial disparity in median survival time in this elderly population.

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Introduction
Excess mortality observed after hip fracture treatment may persist for years.[1] The extent and magnitude of this long-term excess mortality is still debated.[1,2]

Mortality rates are influenced by various factors. Sheehan et al[3] identified 39 patient- and healthcare system-related factors that could be associated with post-hip fracture mortality. Others have emphasized the importance of socio-cultural risk factors (financial and educational status of patients, and residence factors such as living alone/cohabiting and urban/rural dwelling), and structure and processes of healthcare (pre- and in-hospital delay, hospital status, and in-hospital services).[1,2,4-7] Such information leads to the

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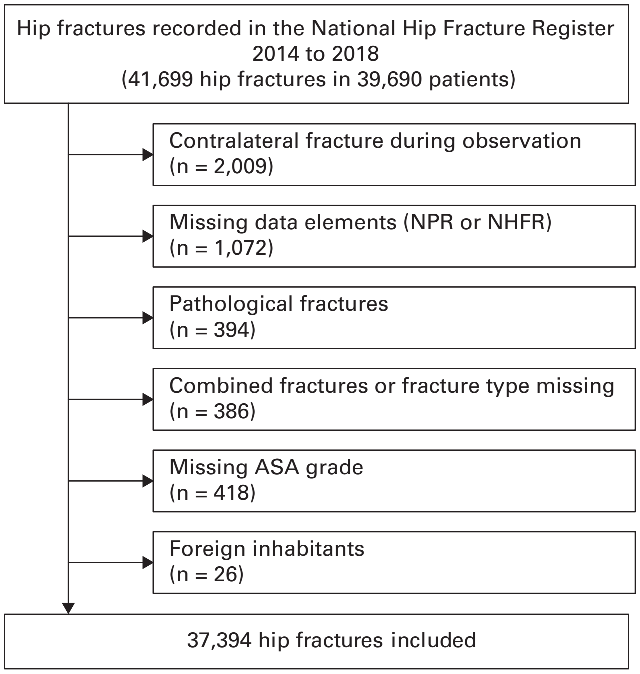

Fig. 1

Flowchart of patient selection. ASA, American Society of Anesthesiologists; NFHR, National Hip Fracture Register; NPR, National Patient Register.

question of the relative value of individual risk factors associated with mortality. Interventions on patient factors or rectifying shortcomings in the healthcare system must be based on measures of high feasibility and impact. Identifying the most important risk factors to address requires comprehensive analyses using multiple linkable data sources. This allows examination of many subsets of data in a single analysis.

The aim of this study was to identify risk factors associated with increased mortality using patient characteristics, healthcare system factors, and socioeconomic data. Secondly, we aimed to identify the relative importance of risk factors to assess the feasibility of potential interventions. Finally, we explored mortality and survival following hip fracture treatment, with particular emphasis on the mortality pattern related to an age- and sex-matched reference population.

Methods

This is a population-based national prospective study based on linked data from the Norwegian Hip Fracture Register (NHFR), the Norwegian Patient Registry (NPR), and socioeconomic data from Statistics Norway (SN). In all these databases, patients are identified with a unique 11-digit national identification number which enables data coupling. The term 'hip fracture' denotes patients with femoral neck fracture (FNF; International Classification of Diseases (ICD)-10 code S72.0), trochanteric fracture (ICD-10 code S72.1), or subtrochanteric fracture (ICD-10 code S72.2).[8]

The NHFR has collected data on almost all hip fracture patients admitted to hospitals in Norway since 2005.[9] Information on patient characteristics (age, sex, American Society of Anesthesiologists (ASA) grade,[10] date of death), fracture type, and treatment (type of treatment and experience-level of the surgeon (more or less than three years of experience in fracture surgery)) were extracted from the NHFR. Information on hip fracture patients treated with a total hip arthroplasty (THA) is primarily registered in the Norwegian Arthroplasty Register and subsequently imported to the NHFR. Completeness of reporting to the NHFR in 2015 to 2016 was 88.2% for osteosyntheses, 94.5% for hemiarthroplasties, and 87.8% for total hip arthroplasties.[9]

All hip fractures recorded in the NHFR from 1 January 2014 to 31 December 2018 were eligible. We identified all inpatient and outpatient episodes from 1 January 2013 to 31 December 2019 (i.e. at least one year before and after the index event), along with information on diagnosis, time of admission, medical procedures, and migration from the NPR. ICD-10 codes in the NPR were used to categorize patients according to the Charlson Comorbidity Index (CCI).[11] NPR also provided times of admission and procedures, which facilitated calculation of in-hospital waiting time for surgery, and identified patients treated with expedited surgery (within the day following admission).[12,13] Combining information on fracture type and treatment from the NHFR and waiting time from the NPR, we defined recommended surgical treatment within 48 hours of admission as best practice (according to national guidelines).[14]

We collected demographic information (marital status and household type) and socioeconomic data (household income, highest completed education level, and residential status) from Statistics Norway (SN). Patients' residential status was defined as living alone, cohabitant, or living in a healthcare facility. Household income, defined as income the year prior to injury in Norwegian kroner (100 NOK is approximately €10), was categorized into quartiles of income. Educational status was grouped in three levels according to the International Standard of Classification of Education:[15] low (lower secondary education), medium (upper secondary to short-cycle tertiary education), and high (bachelors level and beyond).

The populations of the municipalities where the patients lived at the time of fracture were defined as small (< 5,000 inhabitants), medium (5,000 to 19,999), or large (≥ 20,000). The number of inhabitants and number of deaths were supplied by SN in sex-specific five-year age groups. This information was used to estimate age- and sex-standardized mortality rates.

All 43 hospitals in Norway routinely treating hip fractures responded to an online survey designed for this study describing hospital characteristics i.e. organization of hip fracture care (dedicated orthopaedic ward, dedicated unit for hip fracture patients, or interdisciplinary care including an orthogeriatric service). The hospitals were ranked and categorized by patient volume in the five-year period using quartile groups (Q1 to Q4) and grouped according to their ownership affiliation to a regional health authority (RHA).

The NHFR compiled data on 41,699 hip fractures in 39,690 patients admitted in the five-year period from 2014 to 2018. The exclusions and their reasons are shown in Figure 1. The median follow-up time was 748 days (interquartile range (IQR) 287 to 1,209).

Table I. Patient descriptive characteristics.

Characteristic	Total	Survivors	Deceased
Total, n	37,394	22,281	16,113
Mean age, yrs (SD)	80.2 (11.4)	76.3 (12.2)	84.8 (8.4)
Sex, n (%)			
Female	25,251 (67.5)	15,867 (69.9)	10,384 (64.4)
Male	12,143 (32.5)	6,414 (30.1)	5,729 (35.6)
Comorbidities			
ASA grade, n (%)			
1	1,340 (3.6)	1,281 (6.0)	59 (0.4)
2	12,486 (33.4)	9,347 (43.9)	3,139 (19.5)
3	20,694 (55.3)	10,025 (47.1)	10,669 (66.2)
4	2,819 (7.5)	619 (2.9)	2,200 (13.7)
5	55 (0.2)	9 (0.04)	46 (0.3)
CCI, n (%)			
0	25,745 (68.9)	16,003 (75.2)	9,742 (60.5)
1 to 2	8,259 (22.1)	4,158 (19.5)	4,101 (25.5)
3 to 4	2,172 (5.8)	806 (3.8)	1,366 (8.5)
≥ 5	1,218 (3.3)	314 (1.5)	904 (5.6)
Socioeconomic factors			
Median household income, NOK (IQR)	261,610 (187,417 to 335,803)		
Household income quartile, n (%)*			
Q1	9,317 (25.0)	4,256 (20.1)	5,061 (31.5)
Q2	9,335 (25.0)	5,021 (23.7)	4,314 (26.8)
Q3	9,333 (25.0)	5,260 (24.8)	4,073 (25.3)
Q4	9,335 (25.0)	6,694 (31.5)	2,641 (16.4)
Highest level of education, n (%)			
Low	16,034 (42.9)	8,407 (39.5)	7,627 (47.3)
Medium	16,320 (43.6)	9,575 (45.0)	6,745 (41.9)
High	5,040 (13.5)	3,299 (15.5)	1,741 (10.8)
Residential status, n (%)†			
Residing alone	17,791 (47.6)	9,944 (46.8)	7,847 (48.7)
Cohabitant	15,786 (42.3)	10,288 (48.4)	5,498 (34.1)
Living in a healthcare facility	3,771 (10.1)	1,014 (4.8)	2,757 (17.2)
Fracture type, n (%)			
Displaced FNF (Garden 3 to 4)	17,157 (45.9)	10,098 (47.5)	7,059 (43.8)
Undisplaced FNF (Garden 1 to 2)	4,805 (12.9)	2,995 (14.1)	1,810 (11.2)
Basocervical	1,056 (2.8)	548 (2.6)	508 (3.2)
Trochanteric AO/OTA A1	5,610 (15.0)	2,850 (13.4)	2,760 (17.1)
Trochanteric AO/OTA A2	5,865 (15.7)	3,084 (14.5)	2,781 (17.3)
Subtrochanteric	2,004 (5.4)	1,202 (5.7)	802 (5.0)
Intertrochanteric AO/OTA A3	897 (2.4)	504 (2.4)	393 (2.4)

*Data missing for 74 patients.
†Data missing for 46 patients.
ASA, American Society of Anesthesiologists; CCI, Charlson Comorbidity Index; FNF, femoral neck fracture; IQR, interquartile range; OTA, Orthopaedic Trauma Association; SD, standard deviation.

Statistical analysis. The analyses were performed using SAS/STAT for Windows v. 8.2 (SAS Institute, USA). Continuous variables are presented as means and standard deviations (SDs), and categorical variables as frequencies and percentages.

A Cox regression model was used to assess the association between available covariates and mortality. Covariates were specified a priori. The assumption of proportional hazards was assessed by inspection of Kaplan-Meier (KM) survival curves for categorical variables. Time-dependent continuous and categorical covariates were generated by interaction between covariates, and a function of time was included followed by a test of proportionality using the PROC PHREG procedure in SAS.[16] Time-dependent covariates were entered into the Cox model whenever the proportional hazards assumption was violated. Potential non-linear association between survival and the continuous variable age was assessed by including age as a second-order polynomial into the model.[17] The results are presented as hazard ratios (HRs) with corresponding 95% confidence intervals (CIs) and p-values. For time-dependent variables, regression coefficients and standard errors are presented. All statistical tests were two-sided and results with p-values < 0.05 were considered statistically significant.

The Wald chi-squared statistic,[18] assessing the strength of association between each covariate and mortality in the Cox regression model, was used in combination with degrees of

Table II. Hospital and system descriptive characteristics.

Characteristic	Total	Survivors	Deceased
Hip fracture volume 2014 to 2018, n (%)			
Low	2,715 (7.3)	1,541 (7.2)	1,174 (7.3)
Intermediate low	6,738 (18.0)	4,003 (18.8)	2,718 (16.9)
Intermediate high	10,057 (26.9)	5,677 (26.7)	4,397 (27.3)
High	17,884 (47.8)	10,060 (47.3)	7,824 (48.6)
Dedicated orthopaedic ward, n (%)	32,794 (87.7)	18,576 (87.3)	14,218 (88.2)
Dedicated hip fracture unit, n (%)	14,889 (39.8)	8,466 (39.9)	6,423 (39.9)
Orthogeriatric services, n (%)	16,594 (44.4)	9,558 (44.9)	7,036 (43.7)
Waiting time in hospital, n (%)*			
Q1	8,961 (25.0)	5,217 (25.5)	3,744 (24.3)
Mean, hrs (SD)	6.3 (3.0)		
Q2	8,962 (25.0)	5,207 (25.5)	3,755 (24.4)
Mean, hrs (SD)	16.2 (3.0)		
Q3	8,965 (25.0)	5,093 (24.9)	3,872 (25.1)
Mean, hrs (SD)	23.9 (2.5)		
Q4	8,959 (25.0)	4,916 (24.1)	4,043 (26.2)
Mean, hrs (SD)	46.2 (29.2		
Expedited surgery, n (%)			
Yes	30,185 (84.2)	17,970 (84.4)	13,490 (83.7)
No	5,662 (15.8)	3,311 (15.6)	2,623 (16.3)
Regional Health Authority, n (%)			
Northern	3,365 (9.0)	1,942 (9.1)	1,423 (8.8)
Central	5,344 (14.3)	3,082 (14.5)	2,262 (14.0)
Western	7,079 (18.9)	4,015 (18.9)	3,064 (19.0)
South-Eastern	21,606 (57.8)	12,242 (57.5)	9,364 (58.1)
Municipality population, n (%)			
Small	4,866 (13.0)	2,753 (12.9)	2,113 (13.1)
Medium	10,112 (27.0)	5,826 (27.4)	4,286 (26.6)
Large	22,416 (60.0)	12,702 (59.7)	9,714 (60.3)
Treatment			
Surgical treatment, n (%)			
2 or 3 parallel screws	5,328 (14.3)	3,415 (16.1)	1,913 (11.9)
Arthroplasty	16,547 (44.3)	9,604 (45.1)	6,943 (43.1)
Sliding hip screw	8,511 (22.8)	4,272 (20.1)	4,239 (26.3)
Intramedullary nail	6,523 (17.4)	3,722 (17.5)	2,801 (17.4)
Other	485 (1.3)	268 (1.3)	217 (1.4)
Best practice, n (%)	15,765 (42.2)	9,055 (42.6)	6,710 (41.6)
Experienced surgeon, n (%)	29,252 (78.2)	16,291 (76.6)	12,961 (80.4)

*Data missing for 1,547 patients.
SD, standard deviation.

freedom (df) to quantify the strength of association of covariates in the model (Wald χ^2 – df).

We inspected the survival pattern for relevant covariates using KM survival curves. Median survival times in days with 95% CI were estimated based on the KM analyses.

In addition, we compared patient mortality with the expected rate of death in a reference population standardized by age and sex. Based on information from SN on deaths in sex-specific five-year age groups in the Norwegian population, we calculated expected mortality rates using the indirect standardization method. Standardized mortality ratios (SMRs) were estimated monthly after fracture during the first year, and annually for the

Table III. Patient and system characteristics and effects on mortality.

Characteristic	RC (SE)	p-value*
Sex†		
Male	Reference	
Female	0.67 (0.05)	< 0.001
Sex × Log(T)	-0.09 (0.009)	< 0.001
ASA grade†		
1	Reference	
2	1.68 (0.15)	< 0.001
3	2.86 (0.17)	< 0.001
4/5	4.01 (0.19)	< 0.001
ASA × Log(T)	-0.10 (0.008)	< 0.001
	HR (95% CI)	
Age	1.060 (1.058 to 1.062)	< 0.001
CCI		
0	Reference	
1	1.34 (1.29 to 1.39)	< 0.001
2	1.70 (1.60 to 1.80)	< 0.001
3	2.94 (2.73 to 3.16)	< 0.001
Socioeconomic factors		
Household income‡		
Q1	1.16 (1.07 to 1.26)	< 0.001
Q2	1.18 (1.09 to 1.27)	< 0.001
Q3	1.09 (1.04 to 1.15)	0.001
Q4	Reference	
Highest level of education		
Low	Reference	
Medium	0.93 (0.89 to 0.96)	< 0.001
High	0.86 (0.81 to 0.91)	< 0.001
Residential status		
Residing alone	Reference	
Cohabitant	1.04 (0.97 to 1.11)	0.260
Living in a healthcare facility	1.95 (1.86 to 2.04)	< 0.001
Municipality population		
Small	0.97 (0.92 to 1.03)	0.287
Medium	1.01 (0.97 to 1.05)	0.777
High	Reference	
Fracture type		
Displaced FNF (Garden 3 to 4)	Reference	
Undisplaced FNF (Garden 1 to 2)	1.02 (0.97 to 1.08)	0.498
Basocervical	1.18 (1.08 to 1.30)	0.001
Trochanteric AO/OTA[20] A1	1.15 (1.10 to 1.21)	< 0.001
Trochanteric AO/OTA A2	1.11 (1.05 to 1.16)	< 0.001
Subtrochanteric	0.98 (0.90 to 1.05)	0.510
Intertrochanteric AO/OTA A3	1.01 (0.91 to 1.12)	0.918
Hospital characteristics		
Regional Health Authority		
Northern	0.97 (0.91 to 1.03)	0.265
Central	0.85 (0.81 to 0.89)	< 0.001
Western	0.93 (0.89 to 0.97)	0.002
South-Eastern	Reference	
Hip fracture volume		
Low	0.96 (0.90 to 1.04)	0.331
Intermediate low	0.91 (0.86 to 0.95)	< 0.001
Intermediate high	0.95 (0.91 to 0.99)	0.013
High volume	Reference	
Dedicated orthopaedic ward		
No	Reference	
Yes	1.02 (0.96 to 1.08)	0.568

Continued

Table III. Continued

Characteristic	RC (SE)	p-value*
Dedicated hip fracture unit		
No	Reference	
Yes	0.99 (0.95 to 1.04)	0.770
Orthogeriatric services		
No	Reference	
Yes	0.95 (0.91 to 0.99)	0.008
Waiting time in hospital§		
Q1	Reference	
Q2	0.96 (0.92 to 1.01)	0.102
Q3	0.96 (0.91 to 1.00)	0.047
Q4	0.97 (0.92 to 1.03)	0.347
Expedited surgery		
Yes	Reference	
No	1.02 (0.96 to 1.09)	0.514
Best practice		
No	Reference	
Yes	1.00 (0.96 to 1.04)	0.973
Experienced surgeon		
No	Reference	
Yes	1.05 (1.00 to 1.10)	0.047

*Multivariate Cox regression model with all variables included in each analysis.
†As the proportional hazards assumption was not fulfilled for sex and ASA grade, those variables were entered the model as time dependent variables.
‡Data missing for 74 patients.
§Data missing for 1,547 patients.
ASA, American Society of Anesthesiologists; CCI, Charlson Comorbidity Index; CI, confidence interval; FNF, femoral neck fracture; HR, hazard ratio; IQR, interquartile range; OTA, Orthopaedic Trauma Association; RC, regression coefficient; SE, standard error.

remaining observation period. We also calculated SMRs stratified by sex.

Results

Characteristics. Mean age was 80.2 years (SD 11.4), 67.5% were female (n = 25.251) (Table I). Most patients were classified as ASA grades 3 to 5 (63.0%; n = 23,568), 31.2% had a CCI of 1 or above (n = 11,649). Median household income was NOK 261,610, 47.6% of patients lived alone (n = 17,791), and 86.5% had achieved a medium or high education level (n = 21,360). Most patients had a FNF (58.8%); 45.9% had a displaced (Garden type 3 to 4) fracture.[19]

The ten hospitals with highest volumes treated 47.8% of the patients (n = 17,884; Table II). Most patients were treated in an orthopaedic ward (87.7%; n = 32,794), 39.8% (n = 14,889) in a dedicated hip fracture unit, and 44.4% received treatment in a hospital with an orthogeriatric service (n = 16,594). The mean waiting time from admission to surgery was 23.3 hours (SD 20.9) and 84.2% (n = 30,185) received expedited surgery (within the day after admission). Arthroplasty was provided to 44.3% of the patients (n = 16,547) and 74.2% (n = 16,296) of the FNFs, while the remainder received osteosynthesis.

Mortality risk. Table III presents results of the multivariate Cox regression analysis. The age effect on mortality was notable, with a HR of 1.06 (95% CI 1.058 to 1.062) for a one-year increment in patient age; a rate of 6% higher mortality per year. Sex was a time-dependent variable and females had a lower

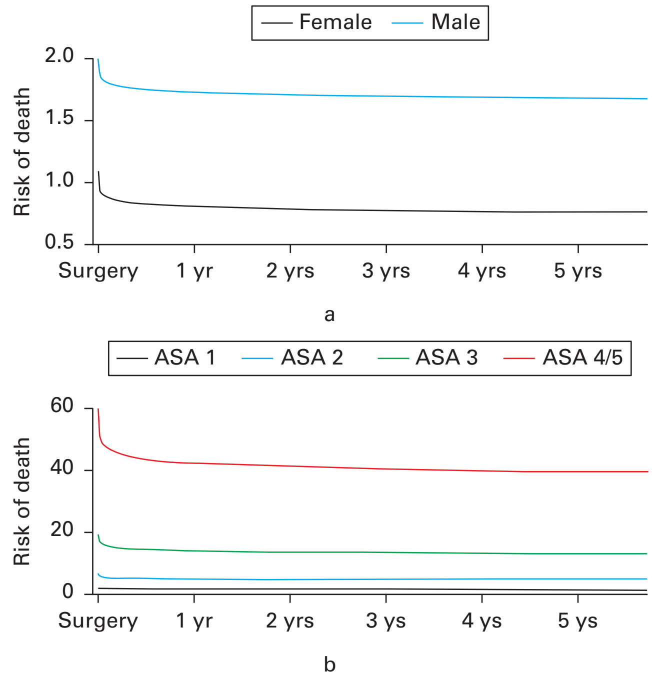

Fig. 2

Time-dependent risk. a) Sex; b) American Society of Anesthesiologists (ASA) grade. Mortality as a function of time for the time-dependent variables.

mortality than males in the immediate postoperative period, but this levelled off and stabilized after the first few weeks following surgery (Figure 2a). ASA grade was also a time-dependent risk factor. The risk of mortality was stable over time for ASA grade 1 and 2, but rapidly decreased the first two months after surgery for ASA grades 4 and 5 and less rapidly for ASA grade 3. The risk remained higher for ASA grades 2, 3, and 4 + 5 compared to ASA grade 1 (Figure 2b).

Mortality increased with higher CCI groups (Table III). Relatively low household income was associated with increased mortality, with the highest mortality in the lowest income groups compared to the highest group (Q1 HR 1.16 (95% CI 1.07 to 1.26) and Q2 HR 1.18 (95% CI 1.09 to 1.27)). Higher level of education reduced mortality, with a HR of 0.93 (95% CI 0.89 to 0.96) for medium and 0.86 (95% CI 0.81 to 0.91) for high level education compared to low education level. Patients living in healthcare facilities had a higher mortality (HR 1.95 (95% CI 1.86 to 2.04)), but no protective effect was observed for the cohabiting group.

Compared with displaced FNFs, we found that basocervical (HR 1.18 (95% CI 1.08 to 1.30)) and trochanteric fractures (AO/OTA A1 (HR 1.15 (95% CI 1.10 to 1.21)) and A2 (HR 1.11 (95% 1.05 to 1.16))) were associated with increased mortality. Mortality was significantly lower in the Central (HR 0.85 (95% CI 0.81 to 0.89)) and Western (HR 0.93 (95% CI 0.89 to 0.97)) RHAs compared to the South-Eastern and Northern RHAs. Compared to high- and low-volume hospitals, intermediate low-volume (HR 0.91 (95% CI 0.86 to 0.95)) and intermediate high-volume (HR 0.95 (95% CI 0.91 to 0.99)) hospitals had a statistically significant lower mortality. Expedited surgery was

Table IV. Statistical significant risk factors for mortality ranked after strength of association.

Factor	Wald's χ^2 – df	df	p-value
Non-modifiable risk factors			
Age	2,947.6	1	< 0.001
ASA	1,941.1	3	< 0.001
CCI	1,062.2	3	< 0.001
Residential status	859.5	2	< 0.001
Sex	578.5	1	< 0.001
Fracture type	46.0	6	< 0.001
Regional Health Authority	43.6	3	< 0.001
Level of education	32.5	2	< 0.001
Household income	15.4	3	< 0.001
Modifiable risk factors			
Hospital hip fracture volume	13.4	3	0.001
Orthogeriatric services	6.4	1	0.007
Experienced surgeon	3.3	1	0.037
Waiting time in hospital	1.7	3	0.198

ASA, American Society of Anesthesiologists; CCI, Charlson Comorbidity Index.

not associated with mortality, whereas mortality was relatively higher when the surgeon was experienced (HR 1.05 (95% CI 1.00 to 1.10)).

Relative importance of risk factors. We ranked non-modifiable patient-related factors and modifiable (healthcare system) factors in descending order according to Wald χ^2 – df (Table IV). Age, risk (ASA), and comorbidity (CCI) indices were most strongly associated with mortality. Of the modifiable factors, hospital hip fracture volume and presence of orthogeriatric services had the strongest association with mortality. The strength of the associations differed substantially, and modifiable factors appeared to have a lower impact than non-modifiable factors.

Mortality rates. The crude cumulative mortality (Figure 3a) was 22.6% in the first year, 33.5% in the second year, and subsequently 44.4%, 54.6%, 63.6%, and 69.1% after three, four, five, and six years, respectively. Based on the standardized reference population, the corresponding expected cumulative mortality rates were 6.4%, 12.1%, 16.8%, 20.8%, 24.4%, and 27.9%, respectively. The expected mortality rate was similar for females and males in the first year, but after six years females had a 6% higher expected mortality than men. Expressed as SMR, excess mortality among hip fracture patients (Figure 3b) was at 10.92 the first month, 3.53 after one year, and 2.48 after six years. Male patients had higher excess mortality (SMR) than females, most notably in the first 12 months following treatment (Figure 3b).

Survival pattern and median survival. The KM survival curves for categories of the statistically significant covariates are shown for non-modifiable factors in Supplementary Figure a and for modifiable healthcare factors in Supplementary Figure b.

To further assess and illustrate the differences in survival related to these covariates, we calculated median survival (Table V) and found substantial differences, particularly for covariates expressing patient factors. Regarding ASA grades 1 and 2, in household income Q4, and in highest education level, the median survival exceeded the observation period of six years. Undisplaced FNFs had a median survival of 1,952 days (IQR 1,820 to 2,074) versus 1,214 days (IQR 1,142 to 1,269) for trochanteric (AO/OTA A1)[20] fractures. Median survival differed by up to 12 months between categories in the waiting time covariate (Q1 vs Q4) and between experienced and inexperienced surgeons (Table V).

Discussion

This large population-based and linked multiregistry study suggests that hip fracture patients have substantially higher mortality compared to a standardized (by age and sex) reference population. Patient, socioeconomic, and healthcare factors all contribute to increased mortality. Patient and socioeconomic risk factors (non-modifiable factors) showed a stronger association with mortality than healthcare-related (modifiable) ones. Apparently small but significant survival differences translate into substantial disparity in median survival time in this elderly population.

Several studies have pointed out the limitations in many mortality/survival studies due to the restricted number of included covariates,[1,3,4] thus introducing an element of residual confounding. Based on a national hip fracture population in Norway and a wider range of covariates (n = 18), we argue that this study gives a more complete picture of factors affecting mortality and survival in hip fracture patients.

The review by Sheehan et al[3] identified 35 patient and nine system factors associated with mortality in hip fracture patients. Socioeconomic factors were not addressed in any of the 56 identified studies. Åhman et al[4] reported on a retrospective cohort study of a Swedish hip fracture population, but provided few system variables and no socioeconomic data. Quah et al[7] introduced a deprivation factor but could not document an association between deprivation and mortality. We added three socioeconomic and six healthcare system elements, including variables related to the organization of hip fracture care.

Using Wald statistics as a surrogate marker of relative importance, we document that non-modifiable factors such as age, sex, and comorbidity (CCI and ASA) were most strongly associated with mortality. It is noteworthy that several socioeconomic variables had a stronger association with mortality than patient-related factors and some system-related factors (hip fracture volume, waiting time in hospital, orthogeriatric service). Cao et al[5] recently published a retrospective observational study including 134,915 patients reported to the Swedish National Hip Fracture Register and concluded, as we did, that non-modifiable factors were the dominating risk factors.

Kristensen et al[6] and Quah et al[7] demonstrated an association between socioeconomic factors and 30-day mortality after hip fractures. In both studies, global indices were used to characterize socioeconomic or deprivation status, respectively. We found that low level of education and household income were associated with increased mortality. A difference in median survival exceeding two years between the lowest and highest level of education is a considerable time span in this elderly population. The residential status effect documented here is caused by patients living in healthcare facilities, and therefore easy to explain. Kristensen et al[6] did not find that cohabitation status was of significance. They did not, however, place patients living in healthcare facilities in a separate group.

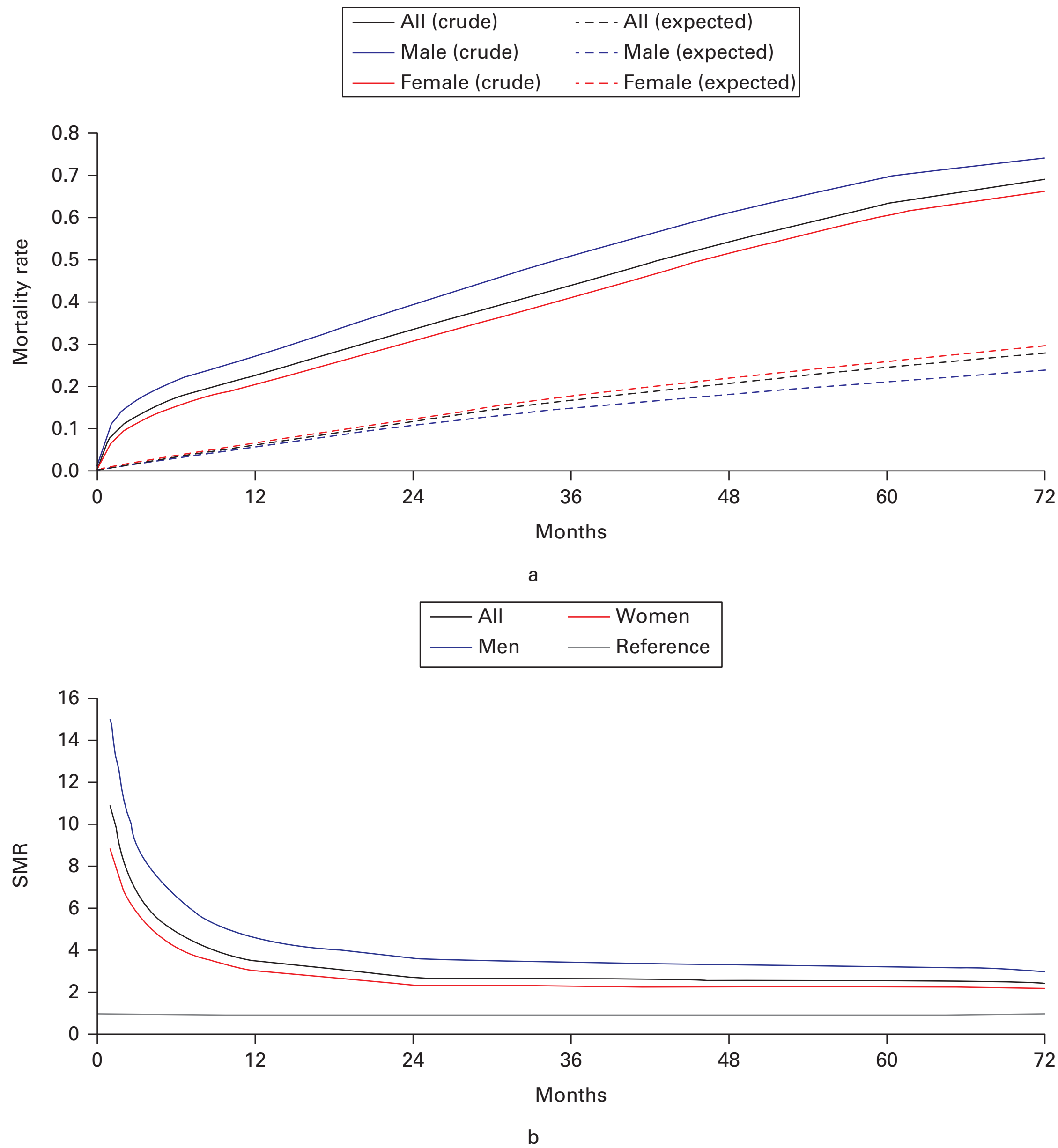

Fig. 3

Mortality rates and standardized mortality ratio (SMR) after hip fractures compared to a reference population. a) Mortality rates; b) SMR. Mortality rates as a function of time. Crude (observed) mortality represents the proportion of deaths in the study population. Expected mortality is the age- and sex-standardized mortality in the reference population.

Haentjens et al,[2] in a meta-analysis tailored to the white USA population, showed a five- to eight-fold excess mortality the first three months after hip fractures with a possible persisting excess mortality up to ten years. However, they could not directly attribute the excess mortality to the hip fracture. Our study concurred with these findings; the highest mortality rates and SMRs were observed in the first few months after surgery. A substantial drop in SMRs was noted the first year, but SMRs remained higher than one for up to six years. We argue that excess mortality measured by SMR is a strong indicator of the consequences of a hip fracture.

This study presented several new findings. Patients operated on by an experienced surgeon had increased mortality. In an earlier study,[21] we showed no significant difference in 30-day or one-year mortality between patients operated on by surgeons with approximately three years of surgical experience. Possible explanations might be the selection of frail and high-risk patients to be treated by experienced surgeons, and the fact that patients treated with arthroplasty are preferentially operated on by more experienced surgeons and wait longer than other patients.[12]

Orthogeriatric assessment is recommended to improve functional outcomes,[14] and has been shown to reduce mortality in

Table V. Median survival after hip fracture.

Patient factors		System and hospital factors	
Characteristic	**Median survival, days (95% CI)**	**Characteristic**	**Median survival, days (95% CI)**
Sex		**Regional Health Authority**	
Female	1,578 (1,540 to 1621)	Northern	1,554 (1,412 to 1,662)
Male	1,262 (1,212 to 1,320)	Central	1,530 (1,462 to 1,638)
ASA grade		Western	1,473 (1,393 to 1,544)
1	1,792.9 (7.7)*	South-Eastern	1,459 (1,419 to 1,500)
2	1,672.0 (7.2)*	**Hip fracture volume**	
3	1,063 (1,039 to 1093)	Low	1,552 (1,473 to 1,627)
4 + 5	33 (8 to 67)	Intermediate low	1,601 (1,535 to 1,695)
CCI		Intermediate high	1,449 (1,384 to 1,527)
0	1,775 (1,729 to 1,820)	High	1,425 (1,391 to 1,470)
1	1,147 (1,095 to 1,196)	**Orthogeriatric services**	
2	693 (628 to 761)	No	1,473 (1,434 to 1,509)
3	268 (218 to 327)	Yes	1,496 (1,440 to 1,541)
Household income†		**Waiting time in hospital§**	
Q1	1,057 (1,025 to 1,095)	Q1	1,603 (1,530 to 1,685)
Q2	1,307 (1,257 to 1,362)	Q2	1,560 (1,479 to 1,635)
Q3	1,452 (1,398 to 1,524)	Q3	1,473 (1,414 to 1,530)
Q4	1,586.7 (9.3)*	Q4	1,342 (1,288 to 1,397)
Highest level of education		**Experienced surgeon**	
Low	1,284 (1,243 to 1,319)	No	1,788 (1,715 to 1,841)
Medium	1,556 (1,516 to 1,626)	Yes	1,402 (1,370 to 1,432
High	1,444.6 (12.5)*		
Residential status‡			
Residing alone	1,417 (1,38 to 1464)		
Cohabitant	1,992 (1,935 to 2,074)		
Living in a healthcare facility	455 (417 to 497)		
Fracture type			
Displaced FNF (Garden 3 to 4)	1,570 (1,508 to 1,623)		
Undisplaced FNF (Garden 1 to 2)	1,952 (1,820 to 2,074)		
Basocervical	1,364 (1,233 to 1,493)		
Trochanteric AO/OTA A1	1,214 (1,142 to 1,269)		
Trochanteric AO/OTA A2	1,260 (1,210 to 1,317)		
Subtrochanteric	1,705 (1,500 to 1,962)		
Intertrochanteric AO/OTA A3	1,507 (1,286 to 1,650)		

*Data presented as mean (standard error).
†Data missing for 74 patients.
‡Data missing for 46 patients.
§Data missing for 1,547 patients.
ASA, American Society of Anesthesiologists; CCI, Charlson Comorbidity Index; FNF, femoral neck fracture; IQR, interquartile range; OTA, Orthopaedic Trauma Association.

FNFs receiving arthroplasty by Roberts et al.[22] In this study, orthogeriatric services were associated with lower mortality, all fracture types included.

In a systematic review, Abrahamsen et al[1] found that increased mortality might be elevated for years after injury, particularly for males. In our study, males had a more pronounced, time-dependent, crude mortality rate, particularly in the first year, while expected mortality for males was surprisingly lower than for women. This observation is not fully explored in this paper, but we note that the male hip fracture population is a mean four years younger than the female group. Consequently, the female and male patients are not identical in basic characteristics.

This observational study included approximately 90% of the Norwegian hip fracture population, allowing for inclusion and analysis of a high number of factors. We have also coupled patient-identifiable information from three national registries and have therefore widened the scope of the analyses. The findings related to socioeconomic parameters and healthcare system characteristics are new. We also argue that the introduction of Wald statistics to enhance understanding of the importance of covariates and their effect on mortality provides additional and useful insight. Further, the mortality and survival analyses gave new information on survival patterns.

We acknowledge that we have studied associations between mortality and individual covariates and have not documented causality. On a similar note, we cannot provide information on the biological mechanisms explaining why some variables were significantly associated with mortality. Outcome measures other than mortality are equally important for geriatric patients, and further studies should other outcome measures, particularly frailty and patient-reported outcome measures.

In summary, patient-related factors (age, fracture type, comorbidity, socioeconomic status, and residential status) and system-related factors (waiting time and hospital volume) were shown to have an impact on mortality. In addition, some unexpected associations were identified including a significant although modest the impact of orthogeriatric assessment, a negative effect of surgeon experience, and the sex disparity. Further experimental and observational multiregistry studies are required to corroborate findings in this study.

Take home message

- Patient-, socioeconomic-, and healthcare-related factors contributed to excess mortality.
- Non-modifiable risk factors were more important than modifiable ones.
- Small but significant survival differences translate into substantial disparity in median survival time.

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Supplementary material

Kaplan-Meier survival patterns curves for categories of the statistically significant covariates in Table III are shown for non-modifiable factors in Supplementary Figure a and for modifiable factors in Supplementary Figure b

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J-E. Gjertsen: Conceptualization, Investigation, Visualization, Writing – original draft, Writing – review & editing.
E. Stensland: Conceptualization, Data curation, Supervision, Writing – review & editing.
J. Saltyte-Benth: Methodology, Data curation, Formal analysis, Visualization, Writing – review & editing.
O. Soereide: Conceptualization, Methodology, Supervision, Investigation, Validation, Writing – original draft, Writing – review & editing.

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Supplementary Material

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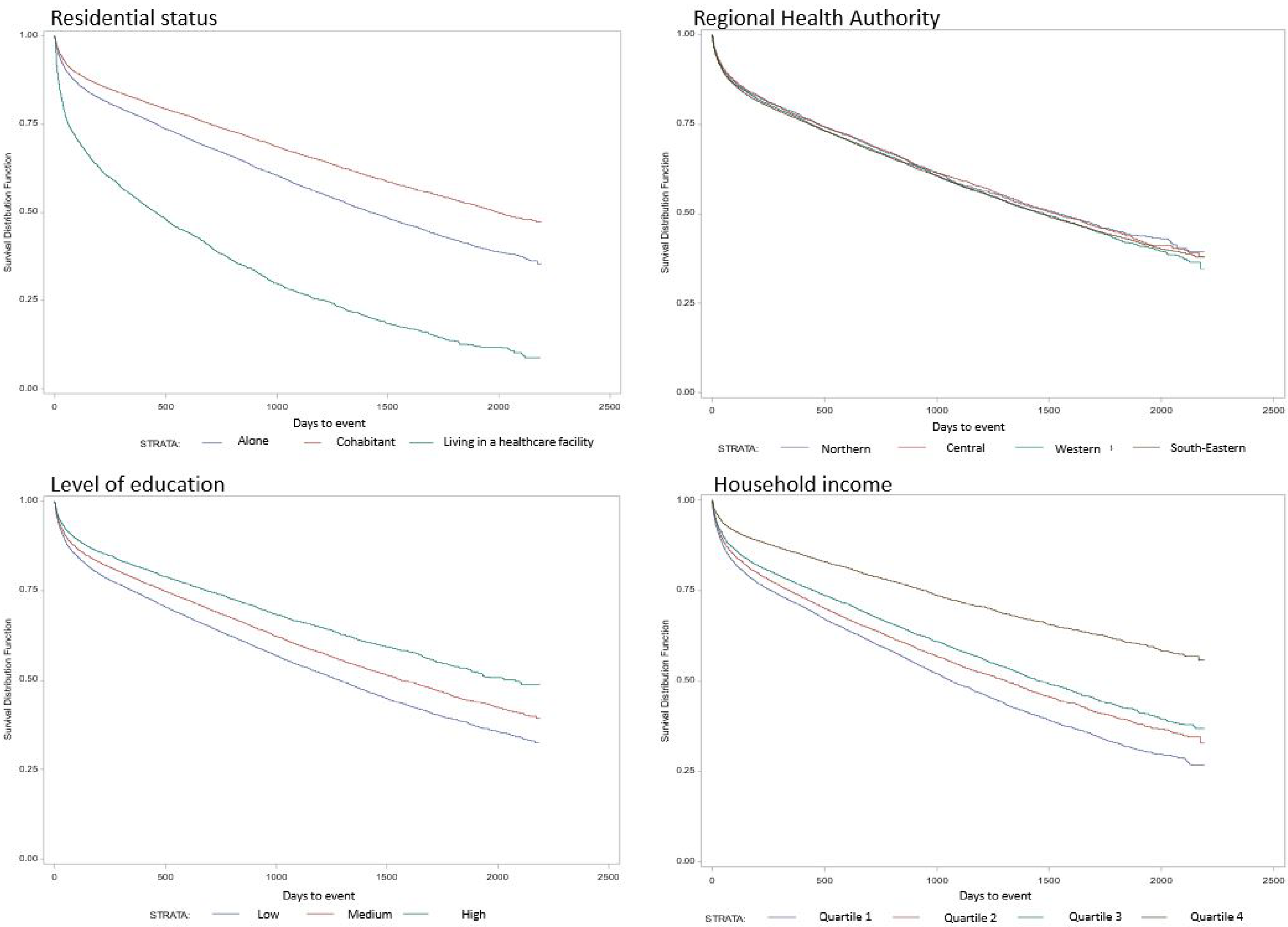
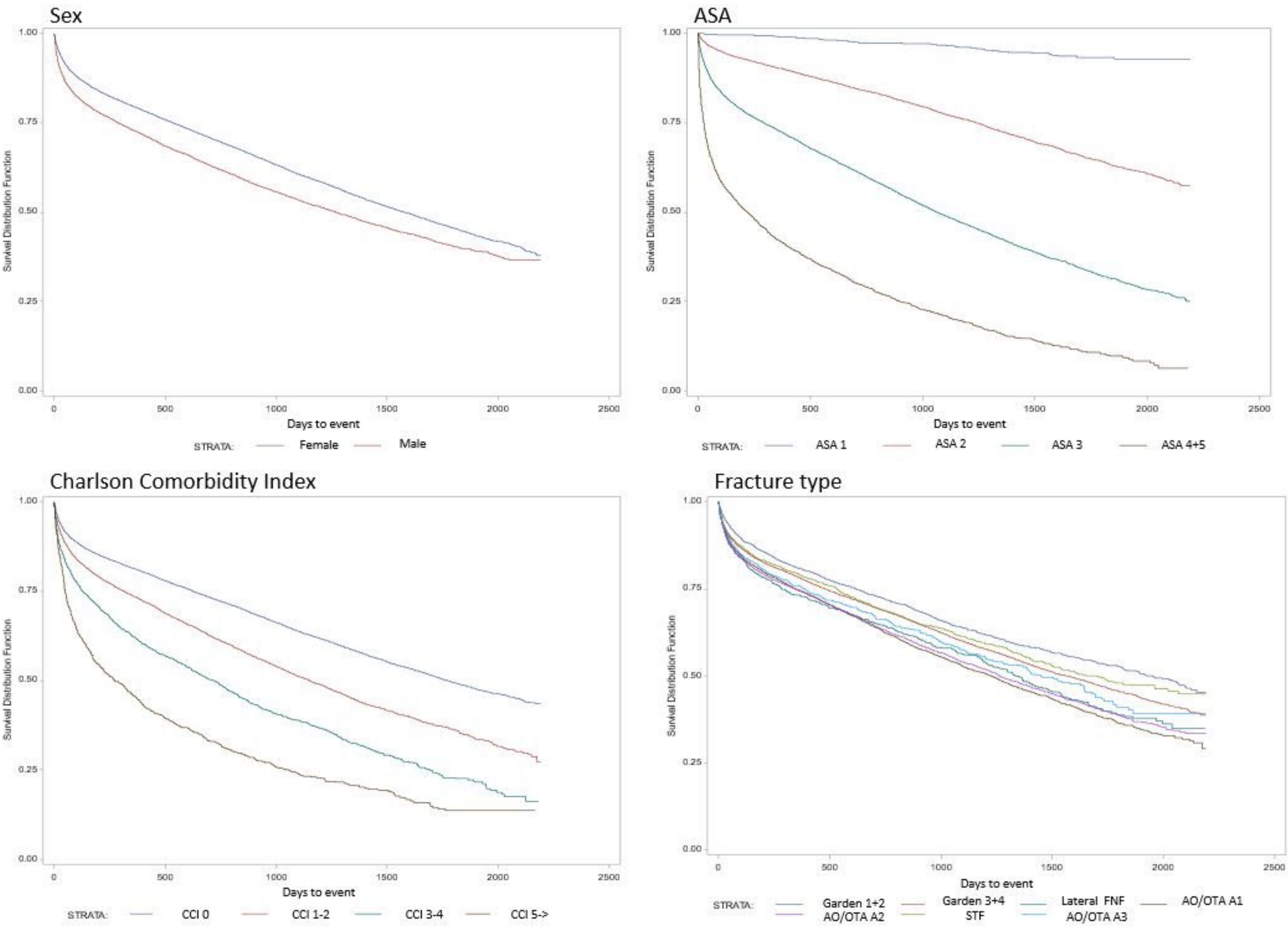
Fig. a Kaplan-Meier curves illustrating differences in survival related to defined patient factors (non-modifiable). AO/OTA, Arbeitsgemeinchaft in Osteosynthesefragen/Orthopaedic Trauma Association; ASA, American Association of Anesthesiologists; FNF, femoral neck fracture; STF, subtrochanteric fracture.




Sex
Survival Distribution Function
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0.50
0.25
0.00
0
500
1000
1500
2000
2500
Days to event
STRATA:
Female
Male
ASA
Survival Distribution Function
1.00
0.75
0.50
0.25
0.00
0
500
1000
1500
2000
2500
Days to event
STRATA:
ASA 1
ASA 2
ASA 3
ASA 4+5
Charlson Comorbidity Index
Survival Distribution Function
1.00
0.75
0.50
0.25
0.00
0
500
1000
1500
2000
2500
Days to event
STRATA:
CCI 0
CCI 1-2
CCI 3-4
CCI 5->
Fracture type
Survival Distribution Function
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0.75
0.50
0.25
0.00
0
500
1000
1500
2000
2500
Days to event
STRATA:
Garden 1+2
Garden 3+4
Lateral FNF
AO/OTA A1
AO/OTA A2
STF
AO/OTA A3

Fig. b. Kaplan Meier curves illustrating differences in survival related to defined system factors (modifiable). AO/OTA, Arbeitsgemeinchaft in Osteosynthesefragen/Orthopaedic Trauma Association; ASA, American Association of Anesthesiologists; FNF, femoral neck fracture; STF, subtrochanteric fracture.