Hip fracture in Denmark:
Quality of in-hospital care and clinical outcomes

PhD Thesis

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Acknowledgements

Being engaged into this research for the last three years has been an enjoyable and learning experience. I am deeply indebted to a number of people, who have made this work possible. First, I would like to express my deepest appreciation to my main supervisor, Søren Paaske Johnsen, for his never-failing trust in me, for always providing thoughtful and constructive feedback, for sharing extensive knowledge of clinical epidemiology, and for supporting me on the way to become an independent researcher. A special thanks goes to Theis Muncholm Thillemann, for introducing me to research at the very beginning, for valueable support to launch the PhD, for your constructive comments, and our always inspiring discussions. Kjeld Søballe, thank you for believing in my project and inviting me to the Clinical Orthopaedic Research Group of Aarhus University Hospital.

I warmly thank Birgitte Bigom Nielsen, Gerhardt Teichert and Regional Hospital Horsens for believing in my project and supporting me through the years. Without your financial support and encouragement, I would not have had the privilege to pursue this opportunity to do become a fulltime researcher. Furthermore, this PhD was funded by the Health Research Fund of Central Denmark Region, the Gurli and Hans Friis Foundation, and the Family Hede Nielsens Foundation. I am very grateful for this financial support, which gave me the optimal conditions to work on my PhD study. My appreciation also goes to The Department of Clinical Epidemiology for providing a unique and stimulating working environment throughout this PhD study. It has been very valuable to draw on the departments knowledge and experience within healthcare and epidemiology.

Thanks also to David Goodman and Anna Tosteson for hosting me during my stay abroad at the Dartmouth Institute and for our collaboration. I appreciate the optimistic comments and support in doing research in healthcare variation. Furthermore, I want to express my other co-authors Rikke Søgaard and Alma Becic Pedersen for their important contributions to the studies in this PhD. I am also grateful to biostatician Henrik Nielsen, biostatician Morten Frydenberg, librarian Karin Velbæk and Line Jensen for providing skilful assistance within biostatistics, littearture search and English proofreading.

To my colleagues at both Research Center Horsens and Department of Clinical Epidemiology; thank you for sharing your knowledge and making the departments a dynamic and nice place to work. Special thanks go to my office mates and mentor; Jens Sundbøl, Sigrún Alba Jóhannesdóttir Schmidt, Gitte Boier Tygesen, and Louise Grode, as well as my mentor, Anne Mette Falstie-Jensen for helping me with everything and for all our discussions, which have made the PhD time much more fun.

Finally, my sincere gratitudes go to my lovely family; Jesper and our children Jakob and Julie, my mother Birthe Jensen and mother-in-law Inge Sørensen for never-failing support, when I was busy with deadlines or traveling. Without your support and encouragement, I would not have made it to the end.

Horsens, February, 2017
Pia Kjær Kristensen

Thesis papers

Paper I

Kristensen PK, Thillemann TM, Søballe K, Johnsen SP. Are process performance measures associated with clinical outcomes among patients with hip fractures? A population-based cohort study. Int J Qual Health Care. 2016 28(6):698-708

Paper II

Kristensen PK, Søgaard R, Thillemann TM, Søballe K, Johnsen SP. Is high quality of care associated with higher costs? – a nationwide cohort study among hip fracture patients. Submitted to BMJ Qual Saf

Paper III

Kristensen PK, Thillemann TM, Søballe K, Johnsen SP. Can improved quality of care explain the success of the orthogeriatric units? A population-based study. Age Ageing 2016 45(1):66-71

Paper IV

Kristensen PK, Thillemann TM, Pedersen AB, Søballe K, Johnsen SP. Socioeconomic inequality in clinical outcome among hip fracture patients: A nationwide cohort study. Osteoporos Int 2017 28(4):1233-1243

List of abbreviations

ADL	:	Activities of daily living
BMI	:	Body mass index
CI	:	Confidence intervals
CCI	:	Charlson Comorbidity Index
CRS	:	Civil Registration System
DMHFR	:	Danish Multidisciplinary Hip Fracture Registry
DNPR	:	The Danish National Patient Registry
DRCD	:	Danish Reference Cost Database
HR	:	Hazard ratio
IQR	:	Intra quartile range
LOS	:	Length of stay
NICE	:	National Institute For Health and Care Excellence
NOMESCO	:	Nordic Medico-Statistical Committee
OR	:	Odds ratio
RCT	:	Randomised controlled trial
RR	:	Relative risk
TTS	:	Time to surgery
US	:	United States
UK	:	United Kingdom

CONTENT

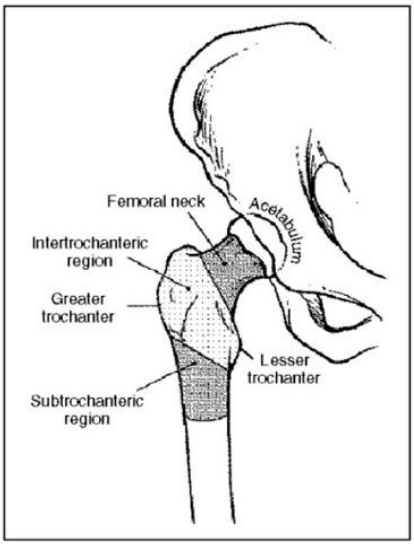
1. INTRODUCTION

Hip fracture is the leading cause of accident-related mortality in older people, and 50% of patients who survive a hip fracture never return to their previous functional level[1-4]. Besides serious individual implications, hip fracture is also associated with substantial health costs[5-8]. Substantial unexplained variation in hip fracture outcome exists[9-11]. Continuous monitoring and improvement of care are therefore a global need[12]. In the last decades, both national and international clinical guidelines for hip fracture care have been developed to ensure a consistent evidence-based treatment. However, the evidence is very sparse regarding whether adherence to guideline recommendations in routine clinical settings is associated with better patient outcome. Denmark hosts a large number of national clinical quality registries, established with the aim of monitoring and improving clinical practice and patient outcomes for a range of diseases, including hip fracture[13]. The clinical quality registry for patients with hip fracture – The Danish Multidisciplinary Hip Fracture Registry (DMHFR) — contains detailed information on the provided care, patient characteristics, and outcomes. By combining this information with data from other population-based registries, this thesis aims to identify links among structure, processes, outcome, and potential inequalities in care.

1.1 Definition and diagnosis of hip fracture

Hip fracture is defined as a fracture in the edge of the femoral head and 5 cm below the minor trochanter. Generally, hip fractures are divided into two main groups: intra-capsular and extra-capsular. Intra-capsular fractures, also called femoral neck fractures, are located above the insertion of the hip joint capsule whereas extra-capsular fractures are located below the insertion. Femoral neck fractures can be displaced or nondisplaced (femoral head is in normal or near-normal alignment on x-rays). The extra-capsular fractures are further divided into intertrochanteric fractures and subtrochanteric fractures (Figure 1)[14].

Figure 1. Picture of the femoral bone and pelvis[14]



The term 'pertrochanteric fractures' is also used and refers to extra-capsular fractures in the intertrochanteric region. The most common hip fracture in Denmark is the femoral neck fracture (48%)

followed by pertrochanteric fracture (42%)[15]. Patients with hip fracture are often admitted through the emergency department because of a fall. The clinical symptoms may include pain, a shorter and more outward turning leg on the injured side, and not being able to move, turn, or lift the affected leg. Hip fractures are diagnosed on the basis of clinical findings and x-rays.

1.2 Hip fracture rates and risk factors

Hip fracture occurs mostly in elderly people because of a combination of lower bone density and an increased tendency to fall due to neuromuscular dysfunction and reduced muscular strength[5, 16]. Women lose bone mineral density faster than men because of menopause and have a longer life expectancy. Consequently, hip fracture occurs more often among women[2, 17].

The incidence rates of hip fracture in Denmark from 1987 to 2010 per 10,000 person years were 68 for women and 28 for men[18]. There is remarkable variation in age-standardised rates for hip fracture world-wide[9, 19]. The median age-standardised rates of hip fracture are highest in the Nordic countries, the rest of Europe, and North America while Africa has the lowest rate[3]. The incidence rate has been rising since the 1980s but is now stabilising or decreasing in the Nordic countries, the rest of Europe, and North America[19-21]. In Denmark and Canada, a decline in the number of hip fractures has been observed despite increasing life expectancy[20, 21]. In Denmark, the incidence rates have declined by 20% in men and 22% in women in the period between 1997 and 2006[21]. However, this decreasing trend does not appear to reflect a global pattern and may level off[22]. Recent evidence from Denmark and Sweden examining the incidence rate up to 2010 suggests an increase in hip fracture incidence in the coming decades due to more comorbidity for birth cohorts born after the 1930s[18]. Even though the age-standardised incidence rate is decreasing in some countries, the worldwide population ageing means an increasing prevalence of hip fracture[22]. In 2000, the worldwide estimated number of persons with first-time hip fracture was 1.6 million; this number is predicted to increase to 4.5–6.5 million by 2050[23, 24].

1.3 Treatment, care, and rehabilitation

The majority of hip fractures are treated with surgery to establish a normal anatomic position for optimal healing and early mobilisation[25]. The type of surgery is based on the location of the fracture, bone quality, comminution, and displacement of the fracture[14]. Femoral neck fractures can disrupt the blood supply to the femoral head, especially if the fracture is displaced, and are therefore associated with healing complications, including avascular necrosis and secondary osteoarthritis. Femoral neck fractures are treated with either internal fixation or prosthetic replacement (hemi-arthroplasty or total arthroplasty)[26]. Pertrochanteric fractures are treated by internal fixation with a sliding hip screw or similar device[14]. Subtrochanteric fractures are often treated with a long intramedullary nail and with a hip screw.

The postoperative care for hip fracture patients is complex and multidisciplinary, involving the emergency department, orthopaedic department, rehabilitation services, other health services in the community, and end-of-life care services[27]. This care therefore relies on close collaboration among anaesthetists, orthopaedic surgeons, geriatricians, and nursing and physiotherapy teams. Several guidelines for treatment, care, and rehabilitation of hip fracture patients exist, including those of the National Institute for Health and Care Excellence (also known as NICE) published in 2011[28], the British Orthopaedic Association and British Geriatrics Society's Blue Book published in 2007[29], and the guidelines of the

Association of Anaesthetists of Great Britain and Ireland published in 2011[30]. All guidelines recommend fast return to pre-fracture level of function through implementation of specific recommendations for surgery, early mobilisation, sufficient nutrition, pain treatment, and rehabilitation. Also described are preventive initiatives, aimed at reducing the risk of complications such as pressure ulcers, thromboembolism, and recurrent fractures.

Hip fracture patients are frequently hospitalised for several days because of pain and comorbidity and functional decline in activities of daily living (ADL), but they often do not reach pre-fracture physical level before hospital discharge. The median time to recovery of ADL functions is 6 months but ranges from 4 to 11 months[31], and some hip fracture patients do not regain their pre-fracture level of mobility[32-34]. In the United States (US), the majority of hip fracture patients are discharged to rehabilitation facilities whereas hip fracture patients in Denmark and most other European countries receive acute care and rehabilitation at the hospital and are then discharged home; the municipality is responsible for the rehabilitation.

1.4 Clinical outcomes

Mortality after hip fracture is substantial. The highest mortality occurs immediately after the fracture, and the short-term mortality within 1 months varies between and within countries, ranging from 2.3% to 13.9% [35-39]. About one third of patients will die within the first year[40, 41]. In the Nordic countries, the 1-year mortality rate is 4.6 fold higher for men and 2.8 fold higher for women than expected for the general population at the same age[37, 42]. Furthermore, a French study including 371,191 age-, sex-, and comorbidity-matched patients who underwent elective hip replacement found a relative risk (RR) of 5.88 (95% confidence interval (CI): 5.26–6.58) for in-hospital mortality after hip fracture surgery compared to patients undergoing elective hip replacement[43]. The most common causes of death are cardiovascular disease, pneumonia, and cancer[44].

Length of stay (LOS) is frequently used as a health outcome and a proxy for the financial impact of an intervention. Substantial variation in LOS exists among countries because of the major differences in organisation of the rehabilitative services across healthcare systems. LOS has furthermore been reduced in many healthcare systems because of financial incentives, e.g., reductions in the numbers of hospital beds and implementation of diagnosis related group–based reimbursement, where the hospital receives a greater reimbursement based on the patient's surgery than for the patient's LOS[45].

A large proportion of patients surviving the index admission for hip fracture are acutely readmitted within 30 days after discharge; studies report readmission rates between 8.3% and 18.3% within 30 days[46-50]. The main reasons for readmission are medical problems, including respiratory diseases (mainly pneumonia), diabetes, atrial fibrillation, and urinary tract infection[46, 49, 50]. Orthopaedic causes for readmission represent less than 20% of readmissions and are mainly new fractures, surgical site infection, and hip arthroplasty dislocation[49]. Hip fracture patients are therefore often readmitted to departments other than orthopaedic departments. Despite the high readmission rate, marked variation has been reported in readmission rates among hospitals in the US, which could not be explained by differences in patient characteristics[51].

Hip fracture is also a major source of healthcare expenditure[1]. A wide variability in hospital costs has been reported, ranging from EUR 6405 to EUR 20730 for the index admission and between EUR 7782 and EUR 25792 for 1-year costs[52-55].

In summary substantial variation exists for hip fracture outcome, e.g., mortality, LOS, readmission, and hospital costs. The variation may be traced to differences in patient case mix or medical services, including the quality of the healthcare provided.

1.5 Patient case mix

In addition to fracture severity[56-58], the prognosis after hip fracture is related to a range of patient characteristics, such as age, sex, comorbid disease, nutritional status, and pre-fracture functional status[59-65]. Socioeconomic status may also play a role because those with low socioeconomic status often experience higher morbidity and higher mortality compared to those with high socioeconomic status[66]. An unhealthy lifestyle – e.g., poor diet with low calcium intake, smoking, physical inactivity, high alcohol intake, and poor housing among disadvantaged persons – may increase vulnerability in connection with a hip fracture. Furthermore, chronic diseases, such as diabetes, cardiac dysfunction, and obstructive lung disease are associated with increased mortality after hip fracture and are more prevalent in persons with low socioeconomic status[67, 68]. Other factors involving health services provided and social support from relatives may also play a role[69-75].

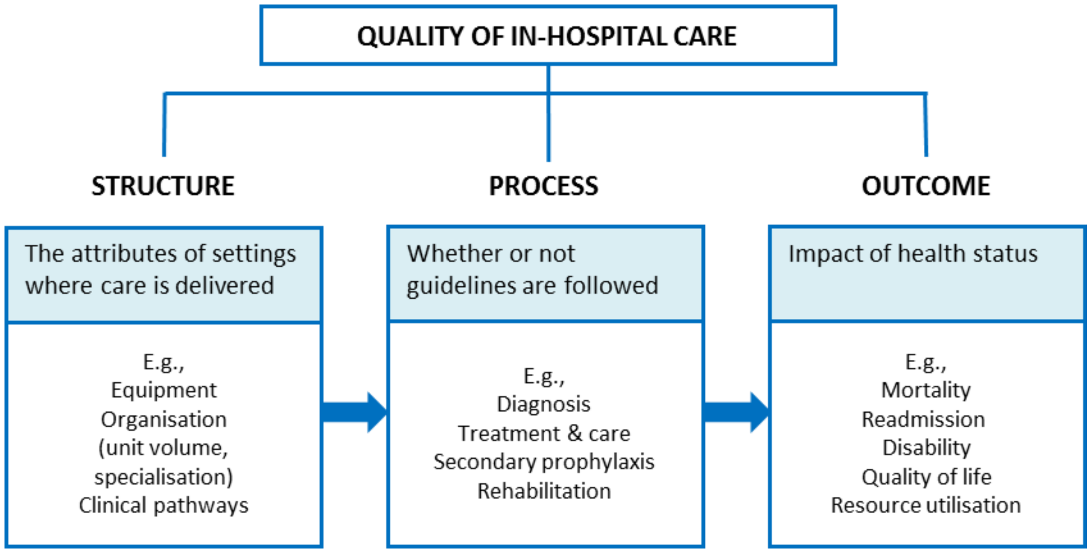
1.6 Quality of healthcare

Quality of healthcare remains a major challenge with inadequate levels of care and unexplained variation in care, costs and patient outcomes being observed across health care systems. Recent studies in both Europe and the US has shown unwarranted variation, as not all relevant patients receive the relevant evidence-based care (underuse), whereas other patients receive unnecessary care (overuse) or wrong care (misuse)[76, 77]. In the light of the rising costs and increasing treatments demands of aging populations and new biomedical advances, unwarranted variation in healthcare services have to be eliminated or at least substantially reduced. Health care systems therefore need to improve not only productivity but also quality of care and patient safety at similar or less costs in order to ensure public health[78, 79]. The first prerequisite for improving quality is information on the current quality of care. Methods for measurement of quality of care have therefore been the agenda in most health care systems and hip fracture has often been among the first disease areas to be given priority.

1.6.1 Donabedian model for quality

A wide range of strategies have been applied to define and assess quality of care. The most widely used approach has been Donabedian's model for quality. The Donabedian model characterises quality of healthcare according to structure, process, and outcome (Figure 2)[80]. Care structure is defined as the infrastructure of the healthcare services, and the capacity to provide high quality care. Care processes are healthcare provider performance on processes recommended in clinical guidelines. Outcome is the impact of care on the patient´s health status[81]. The three dimensions of quality supplement each other and will in theory interact, so that a care structure affects the patient outcome through care processes and variation in care processes may be explained by lack of structure to ensure compliance with the processes, which in turn will affect patient outcome.

Figure 2. Modified Donabedian model for quality [80]



1.6.2 Quality measurement

Structural performance measures assess the characteristics of a care setting e.g. facilities, equipment, capacity and clinical pathways within hip fracture care[82, 83]. However, the structural performance measures cannot measure the actual quality received or improvement in outcome. An example: different types of clinical pathways for hip fracture patients could not be linked with lower mortality according to a meta-analysis from 2009 by Neuman et al[84] and recent studies[85-88]. However, it is important to assess the structural dimension of quality because it affects the possibilities to deliver processes of care, e.g., high hospital capacity has been shown to be associated with higher 30-day mortality due to a lower process performance[15]. Other organisational chacteristics such as specialisation may also impact the quality of care. A widely implemented model within hip fracture care is the orthogeriatric collaboration, which was developed in the UK in the late 1950s by Devas and colleagues, with the purpose of dealing better with pre-existing comorbidity, preventing potential complications, and achieving better survival and physical function[89-91]. However, we do not know whether this organisational model has advantages when it comes to providing effective care processes.

Process performance measures within hip fracture care in Denmark reflect key recommendations from the national guidelines that reflect both multidisciplinary efforts in care and the feasibility of collecting data in a routine setting. A multidisciplinary expert panel consisting of a physician, nurses, physiotherapists, and an occupational therapist has selected the process performance measures based on the obtainable scientic evidence. Process performance measures have the advantage that they give providers clear actionable feedback to improve quality if they are effective. However, if the evidence is lacking for the process performance measures’s association with outcome, we do not know whether the process performance measures actually can contribute to the clinical outcome. The evidence for the process performances measure relation to clinical outcomes is therefore crucial.

Outcome performance measures assess the intended or unintended effect of care processes. The outcome performance measures are often the goal of care and the performance measure patients and politicians are most interested in. A common outcome performance measures within hip fracture care in recent years has been the risk-adjusted 30-day mortality[92]. But also readmission and LOS has been measured among hip fracture patients. However, if only outcome performance measures are assessed it can be difficult to examine whether the quality of care has been improved as many factors, including factors beyond the control of the health care system, e.g. the severity of the underlying disease, comorbidity and the patients life style.

1.6.3 Continuous monitoring of hip fracture care

With the aim of monitoring the quality of hip fracture care, a number of quality registries have been established in the European countries, including Finland (PERFormance, Effectiveness and Cost of Treatment episodes), Sweden (Rikshöft), the United Kingdom (UK) (the National Hip Fracture Database), Italy (Regional Outcome Evaluation Program in the Lasio region), Norway (The Norwegian Hip Fracture Registry), and Denmark (DMHFR)[13, 93-97]. However, many of these registries mainly monitor outcome performance measures, e.g., mortality and readmissions at the hospital level, and lack monitoring of process performance measures. An exception is the DMHFR and the National Hip Fracture Database in the UK, which contain valuable information on process performance measures according to clinical guideline recommendations. These registries therefore offer the possibility of directly monitoring changes in care over time.

Knowledge about healthcare performance is essential for ensuring effective and systematic quality improvement, including elimination of unwarranted variation in care and patient outcome. However, the full potential for improvement can be achieved only if the links among structure, process, and outcome are transparent and well-understood in care.

1.7 Search strategy

A search strategy was performed primarily aimed at identifying evidence regarding the following questions:

- Are process performance measures reflecting guidelines associated with 30-day mortality, LOS, readmission within 30 days after discharge, or hospital costs?
- Is admission to a department with orthogeriatric organisation associated with fulfilment of process performance measures, time to surgery (TTS), 30-day mortality, or LOS?
- Is socioeconomic status associated with fulfilment of process performance measures, TTS, 30-day mortality, LOS, or readmission within 30 days after discharge?

A systematic search was performed in the electronic databases PubMed, CINAHL, and EMBASE for studies published up to December 2016. Initially, nine search strings regarding hip fracture, quality of care, orthogeriatric, socioeconomic status, mortality, LOS, TTS, readmission, and hospital costs were used and searched individually. Each search string consisted of Medical Subject Headings with no time limit and keywords with time limit from 2015 and onward. Truncations were used when relevant. The search terms within each string were combined with 'OR'. The nine search strings were then combined in different ways to answer the different research questions (e.g., "Hip fracture" AND "Quality of care" AND "Mortality"; please see the supplemental appendix for search terms and combinations). The search was limited to include publications in English, Danish, German, Swedish, and Norwegian. Overall, the literature search resulted in 4678 hits. From these, 745 relevant titles were identified of which 246 duplicates were excluded. After reading the abstracts of the 499 remaining titles, we excluded 369 publications. Following a review of 130 full-text articles, 67 publications were included. Furthermore, the reference lists for the included studies were hand-searched, but no further studies were identified.

1.8 Process performance measures and clinical outcomes and costs

Eight studies have examined the association between fulfilment of process performance measures and clinical outcomes and costs among hip fracture patients using individual level data[75, 94, 98-103]. The studies are described in Table 1. The majority of studies had a sample size below 600 hip fracture patients, but one study had a sample size of 6266[75]. There was one randomised controlled trial (RCT)[101] whereas the rest were observational studies. Process performance measures were in some studies analysed at the individual level[75, 98, 99, 101], but other studies examined composite process performance measures at the hospital level[94, 100, 102, 103].

The cohort studies using a composite score of the process performance measures all found lower 30-day mortality for fulfilment of the composite score[75, 99], but a precise estimate was reached only in the study by Nielsen et al[75]. Few of the studies examined the association between fulfilment of individual process performance and mortality[75, 98, 103]. Process performance measures reflecting basic care processes within mobilisation, pain treatment, and prevention of future fractures have been associated with lower 30-day mortality in a cohort study[75]. In contrast, a cohort study by Siu et al concluded that none of the process performance measures within mobilisation and pain treatment were associated with lower in-hospital mortality[98]. However, none of the estimates were reported in that paper, and the study may have been affected by random error due to the relatively low sample size of 554 hip fracture patients. Intravenous line use and antibiotics use were linked with lower in-hospital mortality in a study comparing differences in care processes provided at Japanese hospitals and US hospitals[103]. However, no confounder adjustment was performed in that study, and both the different healthcare organisation and the differences in patient characteristics between the two countries could have explained the differences in hospital mortality[103].

Four of the studies examined the association between process performance measures and LOS[94, 99, 101, 102]. A composite score based on the best practice tariff criteria was reported to be associated with 3–5 days shorter LOS in two before-and-after studies[94, 102]. In contrast, the cohort study by Khan et al, examining the same composite score, found no association with LOS[99]. In the RCT, mobilisation within 48 postoperative hours was shown to reduce LOS by 2 days[101]. No other studies appear to have reported on the association between individual care processes and LOS.

Lower risk for readmission within 2 months was associated with a 9-item composite score in the cohort study by Siu et al[98]. These authors concluded that none of the individual processes were associated with readmission after adjustment, but neither the estimates nor the absolute difference in readmission for the 9-item composite score were reported in the study[98]. In contrast, a clinical audit by Laudicella et al indicated that low-cost hospitals were associated with both higher performance on care process within mobilisation, pain treatment, and prevention of future fractures and a lower readmission rate within 28

Table 1: Identified studies on the association between fulfilment of process performance measures and clinical outcome and costs

Author, country	N, patients	Year	Study design	Process performance measures	Main findings	Adjustment
Siu AL 2006 US [98]	554 patients treated with surgery from 4 hospitals.	1997–1998	Cohort	1) Timing of surgery 2) Clinical stability before surgery 3) Use of anticoagulants 4) Type of anticoagulants 5) Use of prophylactic antibiotics 6) Removal of urinary catheters 7) Mobilisation to a chair within three days 8) Mobilisation beyond chair within three days 9) Physical therapy within three days 10) Days of moderate or severe pain within five days 11) Days of moderate or severe pain within five days with no or only slight relief 12) Avoidance of restraints 13) Stability at discharge	Individual processes performance measures: No estimates were described 9-item composite quality measure: ↓Readmission risk for receiving 9-item composite measure: No absolute values, adjusted HR=0.95 (95% CI: 0.91–0.98) Imprecise ↓in-hospital mortality: No absolute values Adjusted HR= 0.95 (95% CI: 0.90–1.00)	Sex, residence, dementia, hospital, displace fracture
Oldmeadow LB, 2006, Australia [101]	60 patients	2004	RCT	Mobilisation within 48 hours post operatively	↓LOS: 9.3 days vs. 11.4	–
Nielsen KA 2009, Denmark [75]	6,266 patients ≥ 65 years	2005–2006	Cohort	1) Early assessment of the patients nutritional risk (within 2 days) 2) Systematic pain assessment 3) Assessment of ADL before fracture 4) Assessment of ADL before discharge 5) Initiation of treatment to prevent future osteoporotic fractures	Nutritional risk: Imprecise ↓30-day mortality for fulfilment: 9.3% vs 10.8%, adjusted OR=0.98 (95% CI: 0.77–1.19). Pain assessment: ↓30-day mortality for fulfilment: 5.7% vs 9.3%, adjusted OR= 0.72 (95% CI: 0.52–1.00). Assessment of ADL pre: ↓30-day mortality for fulfilment: 7.6% vs.16.0%, adjusted OR= 0.54 (95% CI: 0.39–0.76). Assessment of ADL post: ↓30-day mortality for fulfilment: 5.5% vs. 19.0%, adjusted OR= 0.28 (95% CI: 0.21–0.37). Anti-osteoporotic treatment: ↓30-day mortality for fulfilment: 6.5% vs. 10.7%, adjusted OR= 0.64 (95%	Age, sex, CCI, residence, type of fracture, fracture displacement, ASA-score, TTS and type of surgery

					CI:0.48–0.85) None indicators vs. all indicators: 19.7% vs. 3.1%, OR=0.18 (95% CI: 0.09–0.36)	
Kondo A US, Japan, 2012 [103]	492 patients ≥65 years from 3 hospitals from Japan and two hospitals from US	2005–2007	Cohort	1. Delay of getting out of bed: 2.5 days in Japan vs. 1.6 day in US 2. Days continuous intravenous line use: 5.6 days in Japan vs. 6.8 days in US 3. Days of antibiotics use: 8.8 days in Japan vs. 2.8 days in US	7.4% died in Japan vs. 13.8% in US ↑In-hospital mortality for more days before getting out of bed: HR=1.24 ↑In-hospital mortality for more days of continuous intravenous line use: HR= 1.06 ↑In-hospital mortality for more days with antibiotics use: HR= 1.09	–
Patel 2013, UK [94]	372 patients	2009–2010	Before and after	Best Practice Tariff (BPT) processes[1]	↓TTS for BPT achievers: 26.8 hours vs. 24 hours ↓LOS for BPT achievers: 14 days vs. 9 days Imprecise ↓in-hospital mortality for BPT achievers 7.4% vs. 5% ↑cash settlement for the hospital The best practice tariff was met in 45.3% vs. 70.3%	–
Laudicella, 2013, UK [100]	20 cases from 149 hospitals	2006–2010	Clinical audit	Examining hospital cost association with outcome and fulfilment of the following processes: 1) Cognitive functions assessed within 72 hours from surgery 2) Attend an after discharge exercise program 3) Home assessed for potential hazards 4) Mobilisation within 24 hours. 5) Appropriate analgesia within 60 min of admission 6) Document lying and standing blood pressure readings. 7) Written information on fall prevention.	Neutral 30-day in-hospital mortality for lowest cost quartile compared to highest cost quartile: 7% vs. 8%, Adjusted OR= 1.00 (95% CI: 0.93–1.07) High cost hospitals compared to low costs hospitals: ↑Assessment of cognitive function: 33.4% vs. 23.5% ↑Post-discharge exercise program: 61.8% vs. 37.9% ↑Have the home assessed for potential hazards: 50.8% vs.30.0%. ↓Mobilisation within 24 hours: 71.4% vs 75.1% ↓Analgesia within 60 minutes: 62.2% vs.69.6% ↓Documented lying and standing blood pleasure readings: 35.3% vs. 40.3% ↓Provide written information on fall prevention: 11.5% vs. 18.4% ↓Readmission within 28 days: 11.7% vs. 13.4% ↓30-day mortality: 7% vs. 8%	Adjusted for age, sex, comorbidity, small area income deprivation and type of surgery

Khan 2014, UK [99]	516 patients ≥60 years. Exclusion of patients with pathological or non-fragility fractures	2008–2011	Cohort: Pre –BPT BPT achievers BPT fails	BPT processes[1] plus Mental test scores	Imprecise ↓30-day mortality 6.9% for Pre-BPT vs. 4.9% for BPT achievers vs. 6.9% for non-achievers of BPT . Neutral LOS between BPT achievers and BPT non-achievers: 18 days vs. 18 days. ↓LOS between Pre-BPT vs. BPT achievers: 23 days vs. 18 days	–
Hawkes D, 2015, UK [102]	541 patients ≥60 years. Exclusion of patients with pathological or non-fragility fractures	2012–2014	Before and after	BPT processes[1] plus Mental test scores	↓TTS: 41% had surgery within 48 hours vs. 78% ↓LOS: 18 days vs. 15 days ↑Reimbursement	–

Abbreviations: HR= Hazard ratio, OR= Oddsratio, 95% CI= 95% confidence interval, TTS= time to surgery, LOS= length of stay, ADL= Activities of daily living, UK= United Kingdom, US= United States

1. BPT processes (Best Practice Tariff): 1)Surgery within 36 hours, 2)Admission under joint care of a consultant geriatrician and a consultant orthopedic surgeon 3)Admission using a multidisciplinary assessment protocol agreed by geriatric medicine, orthopedic surgery and anesthesia, 4)Perioperative assessment by geriatrician within 72 hours of admission to the accident and emergency department, 5)Geriatrician-directed multiprofessional rehabilitation, 6) Fracture-prevention assessments (falls and bone protection)

days after discharge[100]. Yet this group also found the highest readmission rate in high-costs hospitals, which had a higher performance on the process performance measures: assessment of cognitive functions within 72 hours from surgery, post-discharge exercise program, and home visits with the purpose of assessing the home for potential hazards[100].

The study by Khan et al examined a composite measure association with costs, although they examined only reimbursement cost. The study by Laudicella et al examined the association between hospital cost and process performance measures, but they found no clear relationship between average hospital costs and the overall composite measure[100]; however, any true differences may have been obscured by their hospital-aggregated data. Furthermore, Laudicella et al did not examine the association between individual process performance measures and costs.

1.8.1 Summary of existing studies

In summary, the evidence regarding the association between both individual process performance measures and composite scores association with clinical outcomes is sparse and inconclusive. It therefore remains unknown whether fulfilment of the individual process performance measures, reflecting guideline recommended care, is associated with 30-day mortality, LOS, and acute readmission within 30 days after discharge. Furthermore, it is unknown whether fulfilment of the process performance measures is possible without increasing hospital costs.

1.9 Orthogeriatric organisation

The literature search identified 36 studies and 8 reviews[104-111] with or without meta-analyses for the orthogeriatric organisational model. The six meta-analyses, however, had several shortcomings[104, 105, 107-109, 111]. First, nearly all meta-analyses included different organisational models and failed to reach a conclusion regarding in-hospital mortality (except the meta-analysis by Grigoryan et al)[104, 105, 108, 109, 111]. Second, four meta-analyses included only RCT studies[104, 105, 108, 111], all characterised by relatively small sample sizes and inclusion of selected patients with a low mortality risk. The results may therefore not be generalised to the general hip fracture population. Third, substantial heterogeneity in study findings was reported among the included studies.

Table 2 provides an overview of the 36 identified studies. The orthogeriatric organisation differed among the studies from a geriatric consultative service to a multidisciplinary team with a geriatrician, an orthopaedic surgeon, nurses, physiotherapists, and occupational therapists. An existing framework of four main models has been used to characterise the studies in Table 2[106, 112].

- Model 1: The geriatric consultative service on request was examined in two RCTs[113, 114].
- Model 2: The consultative geriatric service was investigated in two RCTs[115, 116], one cohort study[117], and five before-and-after studies[118-122].
- Model 3: A multidisciplinary team based in the medical department was examined in four RCTs[123-126], two cohort studies[127, 128], and one before-and-after study[129].
- Model 4: A multidisciplinary team based in the orthopaedic department was investigated in three RCTs[130-132], five cohort studies[133-137], and eleven before-and-after studies[138-148].

Table 2: Identified studies on the association between orthogeriatric organisation and fulfilment of process performance measures and clinical outcome according to the orthogeriatric model

Author, country	N, patients	Year	Study design	Model	Main findings	Adjustment
Kennie DC, 1988, UK [113]	108 women ≥65 years	18 months inclusion period	RCT	1	↓LOS: 41 median days vs. 24 median days	–
Naglie G, 2002, Canada [114]	279 patients ≥70 years	1993–1997	RCT	1	↑LOS: 29.2 days vs 20.9 days	–
Antonelli Incalzi R, 1993, Italy [118]	503 patients ≥70 years	1985–1995	Before-and-after	2	↓LOS: 26.2 days vs 32.9 days	–
Swanson CE, 1998, Australia [115]	71 patients	1994–1995	RCT	2	↓LOS: 21 days vs 32.5 days	age, sex, pre-trauma functional levels, pre-trauma comorbidity and postsurgical complication
Marcantonio ER, 2001, US [116]	126 patients ≥65 years	Not mention	RCT	2	Neutral LOS: 5 days vs 5 days	–
Khan R, 2002, UK [119]	745 patients>60 years	1992–1996	Before-and-after	2	Neutral LOS: 26.14 days vs. 26.88 days	–
Fisher AA, 2006, Australia [120]	951 patients ≥60 years	1995–1997	Before-and-after	2	Neutral LOS: 10.8 days vs. 11.0 days ↑Anti-osteoporotic treatment: 11.8% vs. 14.0%	–
Cogan L, 2010, Ireland [121]	201 patients ≥65 years	2001–2006	Before-and-after	2	Imprecise ↑LOS: 23.1 days vs. 30.3 days ↑ osteoporosis medication: Bisphosphonate 1% vs. 54% Co-prescription of calcium: 2% vs. 60%	–
Deschodt M, 2011, Belgium [117]	171 patients ≥65 years	2010	Cohort	2	Imprecise ↓LOS: 11.1 vs. 12.4 days	–
Suhm N, 2014, Switzerland [122]	493 ≥65 years	2007–2011	Before-and-after	2	↓LOS: 11.3 days vs 8.6 days, adjusted HR = 1.73 (95% CI: 1.43–2.09) ↑TTS : 27.9 hours vs. 30.9 hours, HR = 0.96 (95% CI: 0.94–0.98) Neutral 30-day mortality: 6% vs. 6%	Age, sex, CCI, residential status, TTS and in-hospital complications
Gilchrist WJ, 1988, UK [125]	222 women ≥65 years	1984–1986	RCT	3	Imprecise ↓LOS: 44 days vs. 47.7 days	–
Huusko TM, 2000, Finland [126]	243 demented independently	1994–1998	RCT	3	Imprecise ↑LOS for normal scores: 85 days vs. 67 days ↓LOS for mild dementia: 29 days vs 46 days	Stratified analysis for dementia score

	living patients ≥65 years				↓LOS for moderate dementia: 47 days vs. 147 days Imprecise ↓LOS for severe dementia: 26 days vs. 42 days	
Stenvall M, 2007, Sweden [123]	199 patients ≥70 years	2000–2002	RCT	3	↓LOS: 30 days vs 40 days	–
Miura LN, 2009, US [129]	163 patients ≥55 years	2001–2002	Before-and-after	3	↓LOS: 4.6 days vs 6.1 day ↓TTS: 50.5% had surgery within 24 hours vs 22.2%	–
Adunsky A, 2011, Israel [128]	3,114 patients admitted for surgery of extracapsular or intracapsular fracture	1999–2007	Cohort	3	Imprecise ↓30-day mortality: 1.9% vs. 3.0% adjusted HR= 0.58 (95% CI: 0.33–1.01)	Age, sex, comorbidtity, type of surgery, fracture number, TTS
Watne LO, 2014, Norway [124]	329 patients ≥65 years	2009–2012	RCT	3	↓LOS: 11 median days vs. 8 median days Imprecise ↓TTS: 26.2 hours vs. 23.9 hours	–
Nordström P, 2016, Sweden [127]	89,301 patients ≥50 years at 78 hospitals	2004–2012	Cohort	3	↓30-day mortality: 7.4% vs 7.1%, adjusted HR = 0.91 (95% CI: 0.85–0.97) ↑LOS: 2.4 days higher	Age, sex, living independently before fracture, walking ability, diagnoses (6 different), ASA score and type of surgery.
Khasraghi FA, 2005, US [138]	510 patients ≥65 years	1995–2000	Before-and-after	4	↓LOS: 5.7 days vs 8.1 day ↓TTS: 63% had surgery within 24 hours vs 35%	–
Vidan M, 2005, Spain [130]	321 patients >65 years	1997	RCT	4	Imprecise ↓LOS: 16 days vs. 18 days	–
Friedman SM, 2009, US [135]	314 patients ≥60 years	2005–2006	Cohort	4	↓LOS: 4.6 days vs. 8.3 days ↓TTS: 24.1 hours vs. 37.4 hours	–
Shyu YI, 2010, Taiwan [131]	162 patients >60 years. Chinese Barthel index >70	2001–2003	RCT	4	Neutral LOS: 10.12 days vs. 9.3 days ↑TTS: 35% had surgery within 24 hours vs. 43%	–
Gonzalez-Montalvo JI, 2010, Spain [132]	224 patients	2007	RCT	4	↓LOS: 14 median days vs. 20 median days ↓TTS: 5 days vs 6 days	–
Leung AH, 2011, Hong Kong [145]	548 patients >60 years	2004–2006	Before-and-after	4	↓TTS: 54.5 hours vs 45.0 hours ↓LOS: 10.8 days vs 9.3 days	–
Folbert ECE, 2012, Netherlands [146]	230 patients >65 years	2007–2008 2009–2010	Before-and-after	4	Neutral TTS: 93% vs. 95% had surgery within 48 hours Imprecise ↓LOS: 12 days vs. 11 days	–

Bhattacharyya R, 2013, UK [144]	523 patients ≥65 years	2010–2011	Before-and-after	4	Imprecise ↓LOS: 25 median days vs. 19.5 median days	–
Biber R, 2013, German [143]	283 patients >60 years treated with hemiarthroplasty	2009–2011	Before-and-after	4	↓LOS: 16.8 days vs. 13.9 days ↓TTS: 3.1 days vs. 2.1 days	–
Zeltzer J, 2014, Australia [133]	9,601 patients ≥65 years	2009–2011	Cohort	4	↑LOS: 26 days v 22 days ↓30-day mortality: 6.2% vs. 8.4%	Age, sex, CCI
Flikweert ER, 2014, Nederlands [140]	401 patients ≥60 years	2006–2011	Before-and-after	4	↓LOS: 11 median days vs 7 median days, adjusted ratio = 0.79 (95% CI: 0.70–0.88) Imprecise ↓30-day mortality: 5% vs 9%, adjusted OR = 0.56 (95% CI: 0.25–1.30)	Age, sex, living condition, ASA score
Lynch G, 2015, Australia [142]	798 patients >37 years	2005–2013	Before-and-after	4	↓LOS: 21.3 days vs. 5.9 days.	–
Middleton M, 2016, UK [139]	1,894 patients >60 years	2009–2013	Before-and-after	4	↓LOS: 27.5 days vs. 21.0 days ↓TTS: 41.8 hours vs. 27.2 hours ↓30-day mortality: 13.2% to 10.3%, adjusted OR=0.68	Age, sex, ASA score, mental test score.
Soong C, 2016, Canada [136]	571 patients ≥65	2009–2013	Cohort	4	↓LOS: 18.2 vs 11.9 days ↓TTS: 45.8 hours vs 29.7 hours ↑Initiation of surgery treatment: 55.8% vs.96.4%	–
Kalmet PH, 2016, Nederlands [137]	1,193 patients >50 years at 6 hospitals	2012	Cohort	4	↓LOS: 9.7 days vs. 12.0 days ↓TTS: 19.2 hours vs. 24.4 hours Neutral 30-day mortality: 6% vs 5%	–
Henderson CY, 2016; Irland [141]	454 patients ≥65 years	2009–2011	Before-and-after	4	↓LOS: 3.77 lower LOS ↑TTS: 73.7% vs. 61.9% had surgery within 48 hours.	–
Judge A, 2016, UK [148]	Eleven hospitals with 32,633 patients >60 years	1999–2011	Before-and-after	4	↓30-day mortality: 11.8% vs 7.1%, adjusted HR = 0.73 (95% CI: 0.65–0.82)	Age, sex
Stenqvist C, 2016, Denmark [147]	1,982 patients ≥65 years	2007–2011	Before-and-after	4	↓30-day mortality: 12.5% vs. 10.5%, adjusted OR= 0.66 (95% CI: 0.50–0.87) Stratified analysis: ↓30-day mortality: home-dwelling patients 12.2% vs. 6.8% Imprecise ↓30-day mortality: nursing home patients 25.6% vs. 21.6%	Age, sex, ASA score
Hawley S, 2016, UK [134]	33,152 patients >60 years at 11 hospitals	2003–2013	Cohort	3 & 4	↓30-day mortality: 11.8% vs. 7.1%, adjusted OR= 0.73 (95% CI: 0.65–0.82)	Age, sex

Abbreviations: HR= Hazard ratio, OR= Oddsratio, 95% CI= 95% confidence interval, TTS= time to surgery, LOS= length of stay, US= United States, UK= United Kingdom

1.9.1 Orthogeriatric organisation and process performance measures

The evidence is limited regarding the association between orthogeriatric organisation and fulfilment of process performance measures. Two studies examining model 2 found a higher chance for receiving anti-osteoporotic treatment[120, 121]. However, a before-and-after study also examining model 2 found longer TTS[122]. In contrast, both model 3 and model 4 have indicated an association with shorter TTS in cohort studies and RCTs[124, 129, 132, 135, 138, 143, 145]. Only the RCT by Shyu et al indicated increased TTS for patients receiving model 4[131]. Recently published cohort studies have supported these findings[136, 137, 139]. One study has indicated a lower proportion of patients undergoing surgery within 48 hours after implementation of model 4[141]. No study investigated whether the examined processes could be related to mortality.

1.9.2 Orthogeriatric organisation and clinical outcomes

The 30-day mortality has been investigated only in one study within model 2, and no association was found[122]. Within the multidisciplinary models, nine studies examined the association with 30-day mortality[127, 128, 133, 134, 137, 139, 140, 147, 148], but only three studies were available at the time of publication of paper III[128, 133, 140]. Within model 3, one cohort study indicated lower 30-day mortality, but the estimate was imprecise[149]. The recent cohort study by Nordström et al, however, confirmed lower 30-day mortality for model 3[127]. Within model 4, one cohort study and one before-and-after study indicated lower 30-day mortality, but the association was imprecise in the before-and-after study[140], and the cohort study reported only adjusted 30-day hospital mortality[133]. The five new studies, published after paper III, examining model 4 all found lower 30-day mortality[134, 137, 139, 147, 148].

Studies examining model 1 were inconclusive regarding the association with LOS[113, 114]. Similar findings were reported in the before-and-after studies examining model 2[119-122], but no difference in LOS was found in the RCT or the cohort study[116, 150]. In contrast, nearly all RCTs except for that by Huusko et al found reduced LOS for model 3[123-126]. Similarly, the majority of studies examining model 4 reported an association with shorter LOS[132, 135, 138, 140, 142, 143, 145]; however, most of these studies used a before-and-after design[138, 140, 142, 143, 145], which may be problematic, especially for LOS. RCTs or cohort studies with a comparison group within the same time period have indicated a more inconclusive association with LOS[130-133, 135], but recent cohort studies published after paper III have confirmed the shorter LOS for model 4. In contrast, a recent Swedish cohort study by Nordström et al investigating model 3 found remarkably longer LOS[127].

1.9.3 Summary of existing studies

Although the literature regarding orthogeriatric organisation is extensive, few studies have examined orthogeriatric models and their association with fulfilment of process performance measures. The daily geriatric consultative model is linked to a higher chance of receiving anti-osteoporotic medication whereas the multidisciplinary models are linked to lower TTS. However, the healthcare performance within other recommended focus areas in the current guidelines, such as early mobilisation, pain treatment, and rehabilitation, has not been investigated. The multidisciplinary models have been associated with lower 30-day mortality, especially in the recently published studies, but no clear association with LOS seems to exist. No studies had examined process performance measures as mediators in the association between orthogeriatric organisation and 30-day mortality.

1.10 Socioeconomic status

Table 3 provides an overview of the 16 identified studies regarding socioeconomic status. All of them used a cohort design, and the number of included patients ranged from 1529 to 485,595 hip fracture patients. The 30-day mortality was examined in six studies[151-156], but no studies examining 30-day readmission or LOS were identified. Nine studies were identified regarding the association between socioeconomic status and fulfilment of process performance measures[157-165]. Different socioeconomic markers were used, including income, ethnicity, education, cohabiting status, and insurance status. Furthermore, a composite score was used. The majority of the studies relied on area-based information about income and education but also examined individual-level data on income, ethnicity, education, cohabiting status, and insurance status.

1.10.1 Socioeconomic status and process performance measures

Elleven studies examined whether socioeconomic status was associated with processes[153, 155, 157-165]. Eight studies investigated individual-level data on race association with surgical procedures[158, 162], bone density testing[160], TTS[164], and aftercare[157, 159, 161]. All eight studies except that by Lee et al were performed in the US. African and Caucasian had an equal chance of receiving hip replacement and hip repair surgery[158, 162], but African patients had a longer TTS[164]. Furthermore, compared to Caucasian, African were less likely to be treated in extended-care facilities and more often had low-intensity physical therapy after discharge[157, 159, 161]. In a similar pattern, patients on Medicaid had longer TTS and were more likely to receive low-intensity physical therapy[157] and less institutional care[163] compared to patients on Medicare. Only Freburger et al examined household income association with care processes[163], and they found high household income to be associated with aftercare in rehabilitation facilities instead of nursing homes[163]. None of the 10 studies examined individual-level data on education or income, but five studies examined a composite score[153, 155, 160, 163, 165]. Two of these used an area-based composite score of education and income but found no association with receiving bone density testing or aftercare[160, 163]. In contrast, the two Italian studies by Barone et al and Colais et al both found low socioeconomic status to be associated with longer TTS and lower prevalence of delivery of interventions within 48 hours compared to patients with a higher status[153, 155]. In accordance a English study comparing provision of total hip arthroplasty among patients eligible according to the NICE criteria, found lower use of total hip arthroplasty among the most disadvantaged hip fracture patients[165]. In the study by Collais et al, the association between socioeconomic status and the proportion of patients who received intervention within 48 hours weakened over time simultaneously with lower 30-day mortality[155].

1.10.2 Socioeconomic status and clinical outcomes

Six studies examined 30-day mortality[151-156], of which four studies used an area-based composite score[153-156]. These four studies were all associated with higher 30-day mortality for low socioeconomic status compared to higher status[153-156], but in the UK studies, the estimates were imprecise after adjustment, and the absolute differences were below 2 percentage points[154, 156]. The Italian studies by Barone et al

Table 3: Identified studies on the association between socioeconomic status and fulfilment of process performance measures and clinical outcome

Author, country	N, patients	Population	Study design	Socio economic status	Main findings	Adjustment
Hoenig JH, 1996, US [157]	2,762 hip fracture patients ≥65 years from 297 hospitals	1981– 1986	Cohort	Race	Low-intensity physical therapy: 63% of African vs. 43% of non-African OR for African = 1.56 (95% CI: 1.04–2.34)	–
Lee AJ, 1998, UK [158]	1,529 hip fracture patients ≥65 years	1989	Cohort	Race	No difference in surgical procedure (hip replacement vs. hip repair) Adjusted Caucasian-African OR for hip repair = 1.07 (95% CI: 0.58–1.95) Adjusted Caucasian-African OR for hip replacement = 0.91 (95% CI: 0.43–1.91)	Age, sex, comorbidity, hospital characteristics, country/regional characteristics, Medicaid eligibility and distance traveled to hospital
Roberts SE, 2003, UK [152]	32,590 patients ≥65 years	1968– 1988	Cohort	Last main employment	↑30-day mortality OR= 1.34 (95%CI: 0.98–1.83) for ses level[1] III compared to ses level I/II OR= 2.47 (95% CI: 1.79–3.42) No absolute difference was reported	Age, sex
Ganesan K, 2005, US [159]	324,760 hip fracture patients ≥65 years	1990– 2000	Cohort	Race	↓Extended care-facilities for Hispanic compared to Caucasian (64% vs.72%) and for Asian/others compared to Caucasian (66% vs. 72%) OR for Hispanic = 0.74 (95% CI: 0.71–0.76) OR for Asians/others = 0.82 (95% CI: 0.79–0.85)	Age, sex, comorbidity, insurance, length of stay
Neuner JM, 2007, US [160]	35,681 women with hip fractures	2001– 2003	Cohort	Race Income (area based) Education (area based)	↓Bone density testing 6 months after hip fracture for African compared to Caucasian (6.3% vs. 4.6%, adjusted RR of 0.66 (95% CI: 0.50–0.88) and for Hispanic compared to Caucasian (6.3% vs. 4.6%, adjusted RR of 0.58 (95% CI: 0.39–0.87)	Age, state, comorbidity, area-based education & income
Nguyen-Oghalai TU, 2009, US [161]	34,203 hip fracture patients	2001– 2005	Cohort	Race	↑Discharged home to self-care for Hispanic compared to Caucasian 16.4% vs. 5.9%, adjusted OR of 3.2 (95% CI: 2.1–4.8) and for African compared to Caucasian 8.7% vs. 5.9%, adjusted OR of 1.4 (95% CI: 1.0–2.0)	Age, sex, year of admission, type of fracture, procedure, income, state assistance, hospital length of stay and comorbidity
Fanuele JC, 2009, US [162]	140,195 hip fracture patients	1999– 2003	Cohort	Race	No difference in surgical procedure in Caucasian compared to non-Caucasian 2.7% vs 2.8% had total hip arthroplasty 77.8% vs. 77.7% had hemiarthroplasty 26.9% vs. 26.9% had Internal fixation	Age, sex, CCI,

					2.9% vs. 3.4% has non-operative management	
Barone AP, 2009, Italy [153]	5,051 patients ≥65 years	2006– 2007	Cohort	City-specific index[2]	↑30-day mortality 7.7% vs 5.0%, adjusted RR= 1.51 ↓Interventions within 48 hours 2.8% vs. 9.0% adjusted HR= 0.32 ↑TTS: Adjusted median waiting time 7 days vs. 5 days.	Age, sex, comorbidity
Quah C, 2011, UK [154]	7,511 patients ≥65 years	1999– 2009	Cohort	The English Indices of Multiple Deprivation[3]	Log rank test for follow up to 30 days showed no significant difference in survival (10.1% vs. 11.1%)	–
Castronuovo E, 2011, Italy [151]	6,896 patients ≥65 years living in the Lazio region	2006	Cohort	Education: Marital status	Imprecise ↓30-day mortality for patients with >8 years of education compared to patients with <8 years of education 5.2% vs. 6.5 %, adjusted HR of 0.94 (95% CI: 0.67–1.30) ↑30-day mortality for not married patients 7.6% vs. 5.0%, adjusted HR= 1.56 (95% CI: 1.26–1.91)	Age, sex, type of fracture, comorbidity, hospital volume and elapsed time to surgery
Freburger JK, 2012, US [163]	64,065 patients ≥65 years from 411 hospitals	2005– 2006	Cohort	Insurance Household income Area-based	↓Discharge to institutional care vs discharge home for Medicaid patients compared to private insurance patients: OR=0.23 (95% CI: 0.18–0.30) ↓Home health care vs. self-care for Medicaid patients compared to private insurance patients: OR= 0.46 (95% CI: 0.30–0.70) ↑Nursing facility vs. rehabilitation facility for Medicaid patients compared to private insurance patients: OR= 2.03 (95% CI: 1.36–3.05) ↑Discharge to institutional care vs discharge home for patients with highest income compared to patients with lowest income: OR= 1.27 (95% CI:1.14–1.42) Home health care vs. self-care for patients with highest income compared to patients with lowest income: OR= 0.98 (95% CI: 0.79–1.22) ↑ Nursing facility vs. Rehabilitation facility for patients with highest income compared to patients with lowest income: OR= 1.27 (95% CI: 1.14–1.42)	–
Colais P, 2013, Italy [155]	11,581 patients ≥65 years	1. 2006–2007 2. 2009–2010	Cohort	City-specific index[2]	1.period: ↑30-day mortality for low ses compared to high ses: Adjusted percentage 9.54% vs 6.74% ↓ Interventions within 48 hours for low ses compared to high ses: Adjusted percentage 8.50% vs. 18.57%, adjusted RR=0.46	Age, sex, nutritional status, comorbidity

					↑TTS for low ses compared to high ses: adjusted median waiting time 8 days vs. 7 days 2.period: Neutral 30-day mortality for low ses compared to high ses: Adjusted percentage 7.37% vs. 7.20% ↓Interventions within 48 hours for low ses compared to high ses: 14.78% vs. 23.58%. Adjusted RR=0.63 ↑TTS for low ses compared to high ses: 6 days vs. 5 days	
Dy CJ, 2016, US [164]	197,290 hip fracture patients	1998– 2010	Cohort	Race Medicaid	↑TTS for Medicaid patients, African and Asian patients. OR for surgery after 2 days: OR for African = 1.49 (95% CI: 1.42–1.57) OR for Asian = 1.26 (95% CI: 1.16–1.37) OR for Others = 1.31 (95% CI: 1.25–1.38) OR for Medicaid = 1.17 (95% CI: 1.10–1.24) No absolute differences were reported, but 79.8% underwent surgery within 2 calendar days after admission.	Age, comorbidity, type of surgery, osteoporosis diagnosis present on admission, number of hospitals in hospital services area, number of beds at treating hospitals, urban/rural setting, teaching hospital, hospital volume, surgeon volume, area deprivation index
Thorne K, 2016, UK [156]	485,595 hip fracture patients ≥18 years	2004– 2011	Cohort	The English Indices of Multiple Deprivation[3]	↑30-day mortality for England: 8.5% vs. 9.7% adjusted OR of 1.19 (95% CI: 1.15–1.23) Imprecise ↑30-day mortality for Wales: 8.2% vs. 9.2%, adjusted OR of 1.14 (95% CI: 0.99–1.30)	Age, sex, comorbidities
Perry DC, 2016, UK [165]	114,119 patients ≥60 years with a non-pathological displaced intracapsular hip fracture	2011–2015	Cohort	The English Indices of Multiple Deprivation[3]	Among eligible patients according to NICE criteria ↓Total hip arthroplasty surgery for low ses compared to high ses: OR= 0.76 (95% CI: 0.66–0.88). Among non-eligible patients, ↓total hip arthroplasty surgery for low ses: OR= 0.64 (95% CI:0.55–0.77)	–

Abbreviations: HR= Hazard ratio, OR= Oddsratio, 95% CI= 95% confidence interval, TTS= time to surgery, LOS= length of stay, NICE=National Institute for Health and Care Committee, US= United States, UK= United Kingdom, ses= socioeconomic status

1. Socioeconomic status was based on husband's occupation for married women and the woman's own occupation if she was single, divorced, or widowed. socioeconomic status level I: Professional occupation, socioeconomic status level II: Managerial and technical occupations, socioeconomic status level III: Skilled occupations, socioeconomic status level IV: Partly-skilled, socioeconomic status level V: Unskilled occupations.
2. City-specific index based on education, occupation, crowding, immigration, family composition and home ownership
3. The English Indices of Multiple Deprivation based on area based indicators of income, employment, health, education, living environment and crime which are weighted

and Colais et al found an association after adjustment for age, sex, and comorbidity[153, 155], but Colais et al found no difference in 30-day mortality in the second study period[155]. Only two studies have investigated education, marital status, and last main employment as separate markers of socioeconomic status[151, 152]. Education above 8 years and marriage were both associated with lower 30-day mortality among 6896 hip fracture patients in an Italian study by Castronuovo et al, but the association was quite imprecise in the adjusted analyses[151]. Similarly, a study by Roberts et al found increased 30-day mortality for those whose last main employment was classified as unskilled[152].

1.10.3 Summary of existing studies

Studies have indicated that inequality in healthcare performance may exist, but the existing evidence is mainly from US studies examining ethnic differences. Only four studies have evaluated the association of family income with receiving care processes, but these studies all used area-based data on family income, and the process performance measures examined did not reflect current guidelines on hip fracture care. Only one study examined surgical procedure according to NICE guidelines, but potential differences in care and rehabilitation processes were lacking. None of the existing studies addressed whether differences in care may be a potential mediator of an association between low socioeconomic status and higher mortality after hip fracture. The association between socioeconomic status and 30 day-mortality has been examined mainly using composite measures of socioeconomic status relying on area-based data. Only one study has examined education and cohabiting status association with 30-day mortality. The role of different markers of socioeconomic status has therefore not been investigated. Furthermore, socioeconomic status association with other clinical outcomes including LOS and readmission is unknown.

2. AIMS AND HYPOTHESIS

The overall aim for the studies included in this thesis was to examine links between the organisation of hip fracture care (i.e. orthogeriatric organisation), fulfilment of process performance measures reflecting clinical guideline recommendations for in-hospital hip fracture care, inequality in care, clinical outcomes and costs. In paper I and paper II, the aim was to examine whether individual and composite scores of the process performance measures were associated with 30-day mortality, LOS, readmission within 30 days after discharge, and hospital costs. Paper III aimed at identifying whether orthogeriatric organisation was associated with fulfilment of process performance measures, 30-day mortality, TTS, and LOS. In paper IV, the aim was to examine whether the patients' socioeconomic position was associated with 30-day mortality, acute first time readmission within 30 days after discharge, fulfilment of process performance measures, TTS, and LOS. The specific hypotheses were as follows:

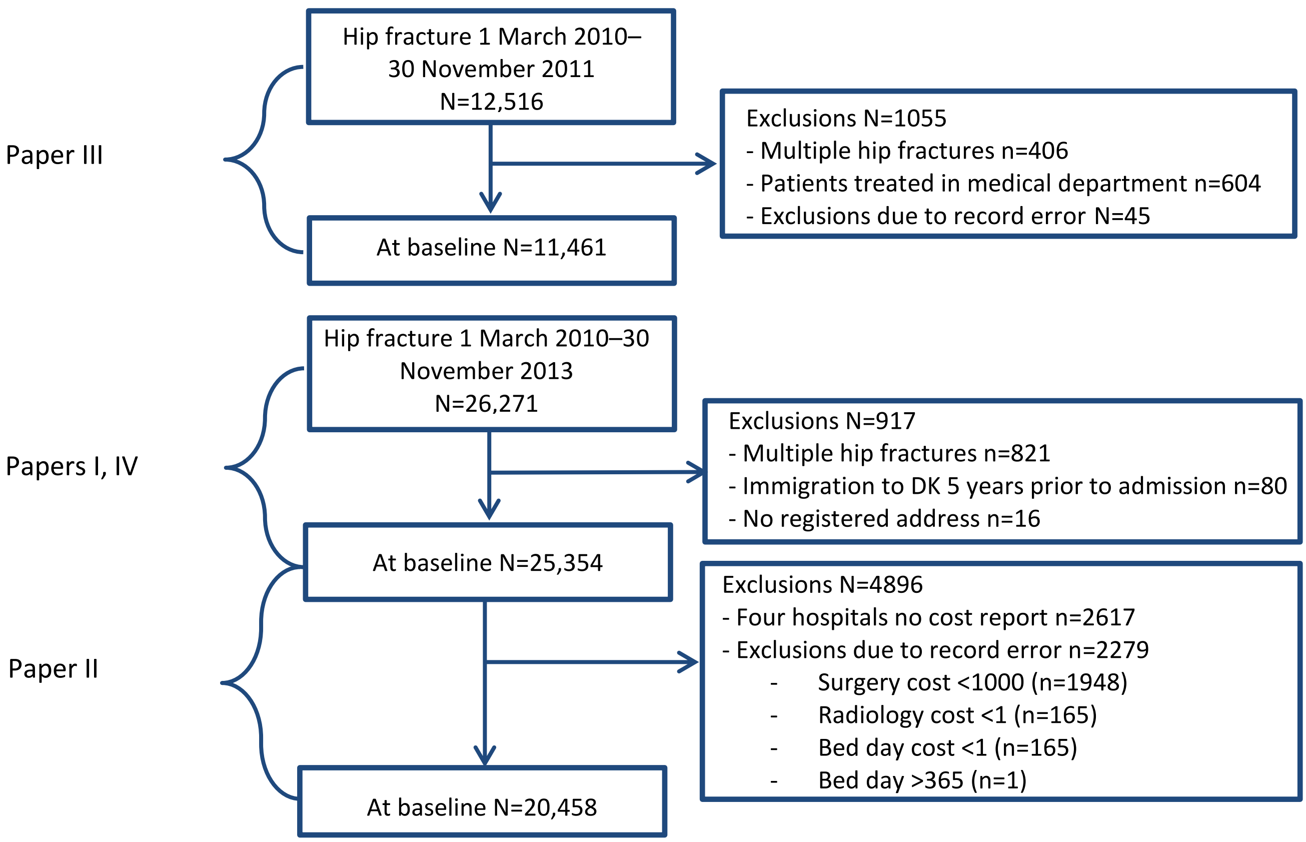
- Fulfilment of process performance measures is associated with lower 30-day mortality, shorter LOS, a lower risk of acute readmission within 30 days after discharge, and higher hospital costs (paper I and paper II).
- Admission to an orthogeriatric unit is associated with higher fulfilment of process performance measures, shorter TTS, lower 30-day mortality, and longer LOS (paper III).
- Low socioeconomic status is associated with lower fulfilment of process performance measures, longer TTS, higher 30-day mortality, and longer LOS (paper IV).

3. METHODS

3.1 Study design and study population

The four studies were designed as population-based cohort studies based on medical and administrative databases, covering the entire Danish population of 5.5 million inhabitants (2010) using the unique civil registration number assigned to all residents since 1968[166, 167]. Denmark has tax-financed healthcare, which includes free access to hospital treatment. In Denmark, hip fracture patients are treated at the nearest public hospital without prior triage. All four studies were based on cohorts of hip fracture patients identified in the DMHFR. Figure 3 shows a flowchart of the patients included in the studies.

Figure 3. Flowchart for patients included in the studies



The orthogeriatric study was the first study conducted and based on hip fracture patients registered with a discharge diagnosis between 1 March 2010 and 30 November 2011 (N=12,516) linked with the Danish National Registry of Patients and the Danish Civil Registration System. Reasons for exclusion included occurrence of a second fracture in the study period (n=406), erroneously recorded data (n=45), and transfer to a geriatric unit after surgery (n=604), which left 11,461 patients for analysis in paper III. Characteristics of the study population are described in paper III in the Supplementary Table S1.

The other studies included patients with a discharge date between 1 March 2010 and 30 November 2013 (N=26,271). This cohort was linked with the Danish National Registry of Patients, the Danish Civil

Registration System, and the income-, population-, and education registry in Statistics Denmark. Reasons for exclusion included occurrence of a second fracture in the study period (n=821), immigration within the last 5 years before the hip fracture (n=80), and patients without a registered address (n=16), which left 25,354 patients for analysis in paper I and paper IV. The characteristics of the cohort are described in paper I in Table 1.

In paper II, a total of 22,737 patients had been treated at a hospital, which had composed a cost report for the years in question (2010–2014). These patients were linked with the Danish Reference Cost Database (DRCD). Exclusions were performed according to 2279 patients with erroneously recorded data (e.g., no radiology, surgery, or bed day cost). A total of 20,458 hip fracture patients were available for analysis. The description of the study population is available in paper II in Appendix 1.

3.2 Data sources

3.2.1 The Danish Multidisciplinary Hip Fracture Registry

The DMHFR was established in 2003 to document and improve in-hospital quality of care among patients at age 65 years or above with hip fracture (including medial, pertrochanteric, or subtrochanteric femoral fractures). The registry contains patient-level data on whether patients received specific process performance measures related to in-hospital management of patients with hip fracture and sociodemographic and clinical characteristics. The process performance measures mirror recommendations from the national multidisciplinary clinical guideline for in-hospital care for hip fracture patients. A multidisciplinary expert panel composed of experienced physicians, nurses, and therapists selected the process performance measures based on scientific evidence and the feasibility of data collection. Data are prospectively collected for each patient from the time of hospital admission by the health professionals and recorded in electronic health records, which on a daily basis upload the information to the registry. Project participation is mandatory for all Danish hospital departments treating hip fracture. To ensure validity and completeness of data, regional clinical audits are carried out every 3 months, and national clinical audits with risk-adjusted 30-day mortality take place once a year[13, 168].

3.2.2 The Danish National Registry of Patients

The Danish National Registry of Patients (DNRP) provides information on all non-psychiatric hospital inpatient admissions since 1977 and on all outpatient clinic and emergency room visits since 1995. Each hospital discharge or outpatient visit is recorded with one primary diagnosis and up to 19 secondary diagnoses by the discharging physician. The diagnoses are classified according to the eighth revision of International Classification of Diseases Danish version until the end of 1993 and tenth revision thereafter[169]. The Nordic Medico-Statistical Committee (known as NOMESCO) is used for classification of surgical procedures from 1996. The DNRP furthermore includes dates and times of any hospital contact and serves as a basis for hospital reimbursement. The registry is updated daily[170]. The registry was used to compute the Charlson Comorbidity Index (CCI) based on all patient contacts within the previous 10 years. In addition, the time and date registrations were used to calculate TTS, LOS, and readmission.

3.2.3 The Danish Civil Registration System

The Danish Civil Registration System (CRS), established in 1968, contains information on sex, dates of birth and death, place of residence, marital status, and dates of emigration and immigration, with daily updates. Accurate and unambiguous linkage of all registries is made possible by the unique Central Personal Registration (CPR) number assigned by the CRS to all Danish citizens at birth and to residents upon immigration. The validity of the data is considered to be high due to the fact that registration is mandatory by law and used for administrative purposes, including taxation[171, 172]. The registry was used to obtain complete follow-up data on 30-day mortality. Additionally, date and destination of emigration and migration and cohabiting status were obtained.

3.2.4 The Danish Reference Cost Database

In 2005, the DRCD was established to serve as a basis for calculating the national Diagnosis Related Groups for reimbursement. The database collects individual-level information on financial costs and activities. A financial employee at each hospital performs a cost report at the end of the financial year, which distributes costs from administrative costs, electricity, heating, technical maintenance, cleaning, and activities from transversal departments to the individual patient. The aim is to distribute the cost to departments with identifiable patient activity. The costs are allocated to the individual patient based on a point system and data on activities, procedures, and bed days/visits from the patient administrative systems. When all costs are distributed to the relevant departments, the average cost per activity is calculated, and costs for the individual patient could be summed up. The total patient cost is therefore calculated from bed costs from the department and activities costs from transversal departments. The database was used to obtain information on use of resources and cost within the index admission and first year. The database is updated once a year.

3.2.5 Income, population, and education registry in Statistics Denmark

Statistics Denmark has several registries, including the registry for income and transfer payments, the population registry, and the registry for education, which provides a statistical overview for both the individual citizen and the entire Danish population. The population registry includes data on migrant status and residence while the income registry contains information on income for both the individual and for the household[173, 174]. The registry for education contains dates and type of education including highest obtained education. The registry has 97% complete education information on the population born from 1945 onward whereas the completeness is substantially lower for citizens born before 1945[175]. The three registries are updated annually. The registries were used to obtain data on highest obtained education, family income, and migrant status.

3.3 Definitions of variables

3.3.1 Process performance measures

The quality of in-hospital care was measured using process performance measures, defined in Table 4. These measures are obtained from the DMHFR and reflect the national clinical guidelines for hip fracture care. Via detailed written instructions, health professionals assessed whether the individual patient was eligible for systematic pain assessment, mobilisation within 24 hours, basic mobility assessment, and a post-discharge rehabilitation program. A contraindication for systematic pain assessment could be dementia that may prevent the hip fracture patient from reporting pain using a visual analogue scale or other systematic pain scales. The number of patients in the analysis of the individual process performance measure association with outcomes may therefore vary.

Table 4. Definition of the process performance measures and fulfilment

Process performance measures	Proportion %	(N)	Definition
Systematic pain assessment			
No	18.2	(3,556)	
Yes	81.8	(16,024)	*Measured daily by a visual analogue scale or a numeric rating scale at rest and during mobilisation* [176].
Lack of indication[1]		(5,774)	
Mobilised within 24 hours postoperatively			
No	22.4	(5,354)	
Yes	77.6	(18,526)	*Defined as assisting the patient from bedrest to walking or rest in a chair.*
Lack of indication		(1,474)	
Basic mobility assessment before fracture			
No	20.3	(715)	
Yes	79.7	(2,807)	*Measured at admission by a validated test such as Cumulated Ambulation Score, Barthel 20, Functional Recovery score, or New Mobility score* [177-179].
Lack of indication		(21,832)	
Basic mobility assessment at discharge			
No	25.3	(5,986)	
Yes	74.7	(17,655)	*Measured prior to admission by a validated test such as Cumulated Ambulation Score, Barthel 20, Functional Recovery score, or New Mobility score* [177-179].
Lack of indication		(1,713)	
Post discharge rehabilitation program			
No	5.0	(1,094)	
Yes	95.0	(21,438)	*Including assessment of ADL with a validated test before the fracture and again before discharge.*
Lack of indication		(2,822)	
Anti-osteoporotic medications			
No	10.7	(2,702)	
Yes	89.3	(22,652)	*Initiation of treatment with anti-osteoporotic medications.*
Prevention of future fall accidents			
No	10.7	(4,763)	
Yes	89.3	(20,591)	*Including a fall risk assessment to account for coexisting medical conditions, medication, functional disability, symptoms from the central nervous system and musculoskeletal system, and cardiopulmonary status.*

Abbreviations: ADL= activities of daily living, N=number

1. Lack of indication: Patients were classified as eligible or ineligible for each individual process depending on whether the hospital staff identified contraindications (e.g., dementia that disabled the patients from reporting their level of pain during mobilisation).

Performance on the processes of care was reported individually as a percentage in all studies. The total number of patients is the denominator, and the numerator is the number of patients who had the process performance measures according to the medical record. Furthermore, a composite score for fulfilment of the process performance measure was used in papers I and II. The composite score was the percentage of all relevant process performance measures given to the patients, calculated as the ratio between the sum of the numerators for each process performance measure given and the sum of the denominators of the process performance measures relevant for the patient. The composite score was divided into three categories (0–50%, 50–75%, and 75–100%). The categorisation was chosen pragmatically to ensure a reasonable number of patients in each group. In paper IV, quality of in-hospital care was also assessed using an all-or-none indicator of whether the patient had received all the relevant process performance measures [180]. In paper III, only six process performance measures were examined because the basic mobility assessment before fracture did not become mandatory until 2012. In papers I, II, and IV, seven process performance measures were examined. The process performance measures were included as exposures in paper I and paper II. In the studies considering orthogeriatric organisation (paper III) and socioeconomic status (paper IV), the processes were included as (1) separate outcomes and (2) potential mediators on the pathway leading to 30-day mortality.

3.3.2 Orthogeriatric organisation

In paper III, the patient population was divided according to whether the patients were admitted to a traditional orthopaedic department with medical and geriatric services upon request or whether the patients were admitted to an orthogeriatric unit settled in the orthopaedic department (model 4). The presence of the orthogeriatric units in Denmark was mapped according to a report from the Danish Geriatric Society[181]. Furthermore, a questionnaire regarding orthogeriatric treatment of hip fracture patients stratified on calendar time was distributed to all department managements.

3.3.3 Socioeconomic status

Four markers of socioeconomic status were used in paper IV: highest obtained education, mean family income, cohabiting status, and migrant status. Information regarding highest obtained education and mean family income was obtained from the education and income registry from Statistics Denmark. To ensure comparison with other studies, the highest obtained education was classified as low level (none or elementary school completed), medium level (more than elementary school completed), or high level (university degree completed). Mean family income for a patient was defined as the average family income during a 5-year period before the fracture, taking into account changes in number of persons in the household due to, e.g., a death or divorce in the family. The average 5-year family income was categorised into terciles of increasing family income. Information on cohabiting status was obtained from the CRS and was categorised as living with a partner or living alone irrespective of marital status. Ethnicity was obtained from the population registry. Immigration status was categorised as non-immigrant or immigrant, including their descendants. The limited number of migrants in the study population limited further subclassifications by country of origin.

3.3.4 30-day mortality

In papers I, III, and IV, follow-up started on the day of hospital admission for hip fracture or the date of hip fracture (if occurring during hospitalisation for another disease). Follow-up continued for 30 days or until death from any cause. Deaths occurring in-hospital or post-discharge were both included. Information on 30-day mortality was obtained from the CRS.

3.3.5 Time to surgery

TTS was calculated as the difference in hours from admission date and time and the date and admission time for surgery (papers III and IV). Information on TTS was obtained from the Danish National Patient Registry (DNPR).

3.3.6 Length of stay

LOS was defined as the time from admission with a hip fracture or hip fracture occurrence if the patient already was hospitalised to the date of discharge to the patient's own home or a nursing home, or death. Transfers between departments were linked, and all consecutive days spent were added to compute the LOS. The number of bed days within the first year (paper II) included hospitalisation for all causes during the first year after admission for hip fracture. The information on LOS (papers I, III, IV) was obtained from the DNPR whereas bed day use within the first year was obtained from the DRCD (paper II).

3.3.7 Acute readmission

Acute readmission was defined as first time acute readmission and included all-cause acute admission to any hospital with at least one overnight stay (papers I, IV). Admissions due to elective procedures were not included. Admission within 24 hours from discharge from the index admission was linked to index admission and therefore was not counted as readmission. Data on admissions and discharges were obtained from the DNPR.

3.3.8 Hospital costs

In paper II, hospital costs were defined as the sum of costs for the resources used by the individual hip fracture patient, including both orthopaedic and non-orthopaedic diseases. Using the general consumer price index, all costs were inflated to the common price year of 2014. Furthermore, costs were converted into EUR by using a fixed exchange rate (7.45 DKK=1 EUR). Thereafter, costs were summed up within seven main areas: radiology, surgery, and anaesthesia; further diagnostic procedures; further treatment or therapy; bed days; and outpatient services. Total costs then were calculated, and two follow-up periods were investigated: costs within the index admission and costs within the first year. For both endpoints, the day of admission was the start time-window. Further classification within the individual cost areas, e.g., separation of surgery and anaesthesia, was not realistic due to different plans of distribution of costs at the hospitals.

3.3.9 Covariates

A priori, on the basis of the scientific evidence, a number of patient- and hospital-level characteristics with known impact on 30-day mortality, TTS, LOS, acute readmission, and hospital costs were identified, including age, sex, comorbid diseases, nutritional status, functional status, ethnicity, cohabiting status, education, and income[59-65, 182]. Through the DMHFR and DNPR, we therefore extracted data on age (65–75, 75–85, >85 years), sex, body mass index (BMI) (<19, 20–25, >26), place of residence (own home, own home affiliated with an institution, institution), and CCI score (0, 1, 2, ≥3 points). Fracture severity, surgical treatment, and TTS could also be potential covariates[57, 58, 69-74]. Data on fracture type (femoral neck, pertrochanteric, subtrochanteric), type of surgery (osteosynthesis, hemi-arthroplasty, total hip arthroplasty), and fracture displacement (displaced, un-displaced) were obtained through the DMHFR, whereas TTS (<24, 24-48, >48 hours) was obtained from DNPR. Socioeconomic markers obtained from Statistics Denmark, including education (low, medium, high), family income (categorised into terciles of increasing income), cohabiting status (cohabitant, living alone), and migrant status (migrant, non-immigrant), were used in paper II. Family income and cohabiting status were included in paper I, but no socioeconomic indicators were included in paper III. At the hospital level, hip fracture patient volume (<151, 152–350, >350) and orthogeriatric organisation (orthopaedic, orthogeriatric) were included as potential covariates[15, 107, 183, 184].

3.4. Statistical analysis

Initially, the distribution of potential covariates was described according to each level of exposure in all studies. Second, the proportions (30-day mortality, acute readmission, quality of in-hospital care) or median (TTS, LOS) or mean (costs) of outcomes examined were calculated within each stratum of the exposure. Except for when fulfilment of process performance measures was the outcome (the binary regressions in papers III, IV), all associations were analysed using both univariate and multivariable regression techniques (see previous section on potential covariates). Covariates were not included in the analyses regarding an exposure association with fulfilment of process performance measures because they were direct measures of quality of care; i.e., only eligible patients were included in the analyses. Estimates were presented with 95% CIs.

To deal with missing data on BMI, fracture displacement, housing, TTS, and education, multiple imputations by chained equations (MICE procedure in Stata) were performed based on the missing-at-random assumption[185]. The number of imputations in the studies ranged from 20 to 25 datasets. Based on the distribution of the observed data, multiple values of, e.g., missing education, reflecting the uncertainty around the true value were estimated through different regression models[186]. Ordinal logistic regression was used for imputation of BMI, fracture displacement, housing, and education whereas linear regression was used for imputation of TTS. All analyses were performed with and without the imputed data (complete-case analysis). Histograms and probability plots indicated a right skewness in the distribution of TTS and LOS, so a natural log transformation was performed. Consequently, the results from the linear regression analyses regarding TTS and LOS are reported as ratios between geometric means. Patients who died under hospitalisation were excluded from the analyses with LOS and readmission. The different regression techniques used in the studies are presented in Table 5 and additional specifications are provided below.

3.4.1 Process performance measures and clinical outcomes and costs

Due to the hierarchical data structure with patients nested within hospitals, multilevel regression modelling was used in papers I and II[187, 188]. To take into account a potential correlation between the individual process performance measures, a mutually adjusted regression analysis with all process performance measures was then performed. Furthermore, the mortality analyses were repeated excluding patients who died in the hospital (paper I). In paper II, 10th and 90th percentiles for the costs according to each main cost category and total cost were examined within the two follow-up periods. Different transformations (natural log transformations and polynomials) of total cost were examined (paper II), as histograms and probability plots indicated a right skewness in the distribution of total hospital costs. Based on the log likelihood test, the natural log transformation was chosen.

3.4.2 Orthogeriatric organisation and process performance measures and clinical outcomes

All regression analyses in study II were performed as cluster analyses with robust variance estimates to account for potential clustering at hospital level. Given that fulfilment of the process performance measures was frequent, binary regression analyses were conducted when examining the association between orthogeriatric organisation and fulfilment of process performance measures. To investigate whether quality of in-hospital care acted as a mediator of the association between hip fracture unit setting and 30-day mortality, additional adjustment for the process performance measures was performed. To investigate whether the association between hip fracture settings and 30-day mortality differed by the patient's predicted risk of death at admission, the results were stratified by a mortality risk score. Multiple logistic regression condition on age, sex, housing, BMI, CCI, fracture type, and fracture displacement was used to predict each patient's mortality risk at admission.

3.4.3 Socioeconomic status and process performance measures and clinical outcomes

Following the crude and adjusted regression analyses described in Table 5, mutual adjustment for education, family income, cohabiting status, and migrant status was performed to examine the role of different markers of socioeconomic status. Furthermore, a subgroup analysis was conducted to investigate the combination of income and education. Patients with the same levels of education and income were categorised, e.g., patients with both low education and low income were one group called low socioeconomic status. Patients with divergent level of education and income, e.g., low education and high income, were excluded from these analyses.

Table 5. Overview of the methods used in the four studies in the thesis

	Data sources	Population	Exposure	Outcome	Statistical analysis
Paper I	The Danish Multidisciplinary Hip Fracture Registry Danish National Registry of Patients Danish Civil Registration System	25,354 patients with a discharge registered between 1 March 2010 and 30 November 2013	Seven individual process performance measures Composite quality measure	30-day mortality Length of stay Acute readmission	Multilevel logistic regression Multilevel linear regression with logarithm-transformed time Multilevel logistic regression
Paper II	The Danish Multidisciplinary Hip Fracture Registry Danish National Registry of Patients Danish Civil Registration System The Danish Reference Cost Database	20,458 patients with a discharge registered between 1 March 2010 and 30 November 2013 and treated at a hospital that has reported a cost report	Seven individual process performance measures Composite quality measure	Total hospital costs within index admission Total hospital costs within the first year	Multilevel linear regression with logarithm transformed costs
Paper III	The Danish Multidisciplinary Hip Fracture Registry Danish National Registry of Patients Danish Civil Registration System	11,461 patients with a discharge registered between 1 March 2010 and 30 November 2011	Admission to orthopaedic department or admission to multidisciplinary orthogeriatric unit based in the orthopaedic department	30-day mortality Quality of care Time to surgery Length of stay	Logistic regression with clusters Binary regression Linear regression with clusters and logarithm transformed time (time to surgery and length of stay)
Paper IV	The Danish Multidisciplinary Hip Fracture Registry Danish National Registry of Patients Danish Civil Registration System	25,354 patients with a discharge registered between 1 March 2010 and 30 November 2013	Education Family mean income Cohabiting status Migration status The combination of education and income	30-day mortality Quality of care Time to surgery Length of stay Acute readmission	Multilevel logistic regression Binary regression Multilevel linear regression with logarithm-transformed time (time to surgery and length of stay) Multilevel logistic regression

4. RESULTS

A summary of the main findings within the three areas of the thesis is provided in this section. Detailed descriptions and additional results are available in the appended papers.

4.1 Process performance measures and clinical outcomes and costs (papers I and II)

Both individual process performance measures and the composite score were associated with a lower risk of 30-day mortality and acute first time readmission within 30 days after discharge. The associations remained after adjustment for a range of prognostic factors (Tables 2–5, paper I). The association was weakened when excluding patients who died during hospitalisation, but the associations remained for most process performance measures (appendix 1, paper I). Table 6 presents the mutually adjusted estimates for 30-day mortality, LOS, and acute first-time readmission.

All process performance measures except fall prevention were still associated with lower 30-day mortality, but the estimates remained precise only for mobilisation within 24 hours postoperatively and receiving a post-discharge rehabilitation program. Four out of seven process performance measures were associated with a longer LOS, but the absolute difference was below one day. Only mobilisation within 24 postoperative hours was associated with a difference of a minimum one day in LOS. Five out of seven process performance measures were associated with lower risk for acute readmission; however, the estimates were precise only for systematic pain assessment, mobilisation within 24 postoperative hours, and receiving anti-osteoporotic medication. Indication of a dose-response relationship was furthermore found between the composite score and 30-day mortality (Table 3, paper I).

Table 6. Associations between the individual process performance measures and clinical outcomes

Process performance measures	Died %	Mutually adjusted OR for 30-day mortality (95% CI)		Median LOS in days	Mutually adjusted relative LOS (95% CI)		Readmission %	Mutually adjusted OR for first time readmission (95% CI)	
Systematic pain assessment									
No (ref.)	16.1			8.7			21.1		
Yes	6.8	0.91	(0.71–1.16)	8.8	1.05	(1.02–1.08)	16.9	0.86	(0.76–0.98)
Mobilised <24 hours postoperatively									
No (ref.)	15.4			9.8			20.7		
Yes	7.8	0.81	(0.69–0.94)	8.1	0.85	(0.84–0.87)	16.9	0.90	(0.82–0.99)
Basic mobility assessment at admission									
No (ref.)	18.2			7.1			16.1		
Yes	8.9	0.73	(0.50–1.05)	7.7	1.04	(0.99–1.09)	17.9	1.23	(0.97–1.57)
Basic mobility assessment at discharge									
No (ref.)	6.2			8.1			18.1		
Yes	4.8	0.88	(0.75–1.04)	8.6	0.92	(0.90–0.94)	17.8	0.97	(0.88–1.07)
Post-discharge rehabilitation program									
No (ref.)	11.1			8.0			20.5		
Yes	4.3	0.45	(0.36–0.57)	8.5	1.09	(1.05–1.12)	17.7	0.96	(0.82–1.12)
Anti-osteoporotic medication									
No (ref.)	19.5			8.8			21.4		
Yes	10.2	0.93	(0.72–1.21)	8.5	1.03	(1.00–1.06)	17.5	0.85	(0.73–0.99)
Prevention of future fall accidents									
No (ref.)	15.8			8.3			19.3		
Yes	10.1	1.24	(0.85–1.27)	8.5	1.05	(1.03–1.08)	17.5	1.10	(0.98–1.23)

Abbreviations: OR= oddsratio, 95% CI= 95% confidence interval, LOS= length of stay, ref= reference group

1. Mutually adjusted: age, sex, housing, BMI, CCI, type of fracture, fracture displacement, type of surgery, time to surgery, civil status, family income, hip fracture unit setting, and all process performance measures for their mutual adjustment.

Each process performance measure was associated with lower mean total costs (Table 7). The differences ranged between EUR277 and EUR3176 within the index admission. Even though the differences were small for some process performance measures, nearly all measures remained associated with lower total costs in the adjusted analyses. Mobilisation within 24 postoperative hours and receiving anti-osteoporotic medication were associated with the largest difference in total costs in the adjusted analysis. When taking into account all hospital costs within the first year, the difference in total costs dropped further. However, most of the process performance measures remained associated with lower total costs in the adjusted analyses (Table 2, paper II).

Table 7. The individual process performance measure and total hospital costs in euro within the index admission

	Mean total cost in euro	(p10–p90)[1]	Adjusted mean total cost in euro	Unadjusted ratio[2] (95% CI)		Adjusted ratio[3] (95% CI)	
Systematic pain assessment							
No (ref.)	13,783	(6,101–22,972)	15,365				
Yes	12,289	(6,471–19,234)	13,670	0.99	(0.97–1.01)	0.98	(0.97–0.98)
Mobilisation <24 hours postoperatively							
No (ref.)	14,474	(6,369–24,477)	16,038				
Yes	11,739	(6,248–18,172)	13,008	0.91	(0.89–0.92)	0.91	(0.91–0.92)
Basic mobility assessment at admission							
No (ref.)	12,198	(5,601–19,406)	15,558				
Yes	11,445	(5,878–17,463)	12,721	1.02	(0.98–1.07)	0.95	(0.94–0.95)
Basic mobility assessment at discharge							
No (ref.)	12,734	(6,399–20,346)	14,024				
Yes	11,874	(6,180–19,035)	13,077	0.93	(0.92–0.95)	0.99	(0.97–1.00)
Rehabilitation program							
No (ref.)	12,237	(5,398–23,292)	13,451				
Yes	11,960	(6,341–18,838)	13,147	1.05	(1.02–1.08)	1.01	(0.97–1.05)
Anti-osteoporotic medication							
No (ref.)	15,270	(6,045–25,966)	17,007				
Yes	12,094	(6,215–19,038)	13,469	0.93	(0.91–0.95)	0.94	(0.94–0.95)
Initiation of treatment to prevent future fall accidents.							
No (ref.)	13,292	(5,871–23,528)	14,822				
Yes	12,226	(6,280–19,123)	13,633	0.99	(0.98–1.01)	0.99	(0.98–0.99)

Abbreviations: ref= reference group, 95% CI= 95% confidence interval

1) P10–P90, range of data from 10th percentile to 90th percentile

2) Unadjusted ratio between geometric mean taking the hierarchical data structure into account

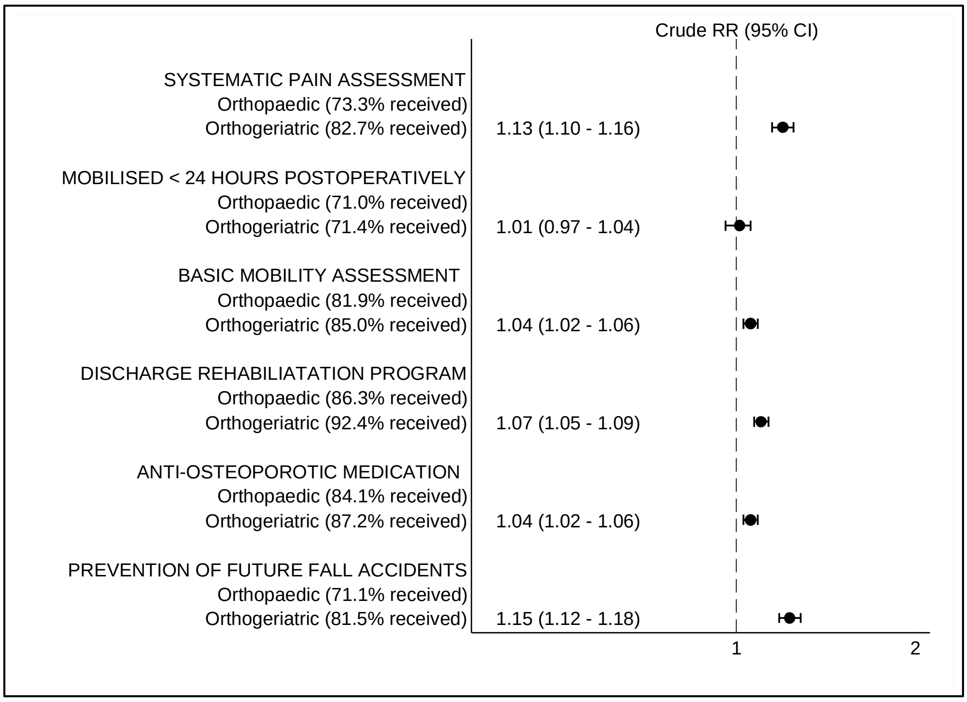
3) Adjusted for sex, age, CCI, BMI, type of fracture, fracture displacement, type of surgery, time to surgery, civil status, 5-year family mean income, highest obtained education, ethnicity, yearly unit hip fracture patient volume, and orthogeriatric organisation.

Table 3 in paper II presents the total hospital costs for the quality of care categories within the indexadmission and within the first year. Patients who received more than 75% of the process performance measures had a mean total cost of EUR 11,956 compared to EUR 15,141 for patients who received less than 50% of the processes within the indexadmission. Lower total cost was also found within the first year. The scatterplot in paper II did not indicate that a higher composite score was associated with higher costs. The differences between the quality of care categories were mainly driven by differences in further diagnostic services and more bed days for both follow-up periods (Table 4, paper II).

4.2 Orthogeriatric organisation and process performance measures and clinical outcomes (paper III)

The forest plot in Figure 4 shows the RR for receiving a process performance measure for a patient admitted to an orthogeriatric unit compared to a patient admitted to a traditional orthopaedic department. Admission to an orthogeriatric unit was associated with a higher RR for fulfilling five out of six process performance measures.

Figure 4. Forest plot presenting the RR for receiving the process performance measures for patients admitted to an orthogeriatric unit compared to patients admitted to an orthopaedic department



Admission to an orthogeriatric unit was associated with lower risk for 30-day mortality (12.0% vs. 9.4%, adjusted odds ratio (OR)=0.69, 95% CI: 0.54–0.88). The lower mortality among patients admitted to orthogeriatric units seems partly to have been driven by a higher portion of patients receiving the process performance measures, as the adjusted OR increased from 0.69 (95% CI: 0.57–0.84) to 0.80 (95% CI: 0.64–0.99) when adjusting for process performance measures received. Lower mortality rates among patients admitted to orthogeriatric units seemed to benefit hip fracture patients, independently of the patient mortality risk score at admission (Table 3, paper III). Admission to different hip fracture unit settings was not associated with TTS (22.0 hours vs 23.4 hours, adjusted relative time of 1.06, 95% CI: 0.89–1.26). However, a non-significantly longer LOS was observed among patients admitted to orthogeriatric units compared to patients admitted to orthopaedic departments (8.5 days vs 10.5 days, adjusted relative time of 1.18, 95% CI: 0.92–1.52).

4.3 Socioeconomic status and process performance measures and clinical outcomes (paper IV)

Table 8 shows the association between the four socioeconomic markers and 30-day mortality. In the unadjusted analyses, high education level, high family income, and not living alone were each associated with lower 30-day mortality whereas immigrants had lower 30-day mortality compared to non-immigrants (Table 8). However, the associations did not remain for immigrants and cohabiting patients in the adjusted analyses. Associations with high education level and high family income persisted but were less pronounced.

Table 8. Unadjusted and adjusted ORs of 30-day mortality for the four socioeconomic indicators

	Died % (n)		Unadjusted OR (95% CI)		Adjusted OR[1] (95% CI)		Mutually adjusted[2] OR (95% CI)	
Education								
Low (ref.)	10.0	(1,287/12,848)						
Middle	9.4	(521/5,566)	0.91	(0.82–1.02)	0.85	(0.76–0.95)	0.88	(0.78–0.99)
High	7.3	(208/2,849)	0.70	(0.60–0.81)	0.74	(0.63–0.88)	0.81	(0.68–0.96)
Income								
Low (ref.)	13.0	(1,099/8,451)						
Middle	11.9	(1,007/8,451)	0.90	(0.82–0.99)	0.93	(0.84–1.02)	0.94	(0.84–1.04)
High	8.6	(729/8,452)	0.62	(0.56–0.68)	0.77	(0.69–0.85)	0.80	(0.71–0.91)
Cohabiting status								
Single (ref.)	11.9	(2,091/17,569)						
Cohabiting	9.6	(744/7,785)	0.78	(0.72–0.85)	0.93	(0.84–1.03)	1.02	(0.91–1.14)
Migrant status								
Non-immigrants (ref.)	11.2	(2,752/24,570)						
Immigrants	10.6	(83/784)	0.92	(0.73–1.17)	0.95	(0.75–1.22)	0.98	(0.77–1.26)

Abbreviations: ref= reference group, n= number, OR= oddsratio, 95% CI= 95% confidence interval

1. Adjusted for sex, age, housing, fracture type, fracture displacement, type of surgery, body mass index, CCI, TTS, yearly unit hip fracture patient volume, and orthogeriatric organisation
2. Additionally adjusted for the four socioeconomic markers.

None of the individual socioeconomic markers were associated with lower risk for an acute first-time readmission (Table 3, paper IV). However, high income/high education was associated with lower risk for first-time acute readmission compared to the most disadvantaged patients (low education/low income) (16.9% vs 14.5%, adjusted OR=0.94, 95% CI: 0.91–0.97).

Table 9 presents the associations between the individual socioeconomic markers and potential mediators of the associations between disadvantaged patients and higher 30-day mortality. The healthcare services measured in this study were not associated with education, income, cohabiting status, or migration status. Adjustment for covariates did not alter the conclusion from crude associations (Tables 4–6, paper IV).

Table 9. Median time to surgery, median LOS, and the proportion of receiving all-or-none within each stratum of the socioeconomic indicators

	Median TTS in hours (IQR)		Median LOS in days (IQR)		All or none[2] %
Education					
Low	21.5	(14.9–33.0)	8.4	(5.8–12.3)	49.7
Middle	21.7	(15.2–34.0)	8.8	(6.0–13.0)	49.8
High	21.8	(14.9–34.4)	8.5	(5.8–11.9)	49.5
Income					
Low	21.8	(15.1–33.2)	8.5	(5.7–12.7)	47.4
Middle	21.3	(14.6–32.4)	8.5	(5.8–12.6)	49.3
High	21.6	(14.8–33.5)	8.5	(5.8–12.5)	50.2
Cohabiting status					
Single	21.5	(14.9–32.5)	8.6	(5.8–12.7)	49.0
Cohabiting	21.7	(14.8–34.2)	8.2	(5.8–12.1)	48.8
Migrant status					
Non-immigrants	21.5	(14.8–32.9)	8.5	(5.8–12.6)	49.0
Immigrants	22.6	(15.7–35.4)	8.7	(5.9–12.8)	47.0
Socioeconomic status[3]					
Low	21.9	(15.4–33.9)	8.4	(5.8–12.4)	47.9
Middle	21.4	(15.0–32.4)	9.0	(6.1–13.6)	51.3
High	21.4	(14.5–31.7)	8.5	(5.9–11.7)	50.9

Abbreviations: IQR= intra quartile range, TTS= time to surgery, LOS= length of stay

1. The proportion of patients who had all recommended process performance measures
2. Low socioeconomic status: low education and low income. Middle socioeconomic status: middle education and middle income. High socioeconomic status: higher education and high income.

5. DISCUSSION

5.1 Main findings

This thesis shows that receiving individual as well as a composite score of process performance measures was associated with lower 30-day mortality and lower risk for first time readmission within 30 days after discharge. Furthermore, early mobilisation was associated with shorter LOS. Receiving the process performance measures appears to be achievable without increasing the total cost of in-hospital care within the first year. Multidisciplinary care with involvement of orthopaedic surgeons and geriatricians based in the orthopaedic department was associated with lower 30-day mortality regardless of the patient´s mortality risk. The orthogeriatric care model was also associated with higher performance on five out of six process performance measures, which partially mediated the association between orthogeriatric organisation and lower 30-day mortality. The orthogeriatric organisation was not associated with time to surgery, but a non-significantly longer length of stay. Higher education level and family mean income were associated with lower 30-day mortality risk. Furthermore, a composite score of high education and high family income was associated with lower risk for acute first time readmission within 30 days after discharge compared to low education and low family income. The socioeconomic difference in patient outcome, seems not to be explained by differences in meeting process performance measures, because no differences in TTS, process performance measures, or LOS were found.

5.2 Comparison with existing studies

5.2.1 Process performance measures and clinical outcomes and cost

The scientific literature within this field is limited[75, 94, 98-101], especially with regard to individual-level analysis[75, 98, 99, 101]. A previous Danish cohort study by Nielsen et al examined the association between previously used process performance measures and 30-day mortality[75]. These authors found adjusted ORs for assessment of functional ability before fracture and prevention of future osteoporotic fractures that are in agreement with those obtained in our study. That study also examined systematic pain assessment and functional ability before discharge, but their estimates differed from those obtained in our study, with an OR of 0.28 (95% CI: 0.21–0.37) for assessment of functional ability after fracture compared to our OR of 0.78 (95% CI: 0.67–0.91). Furthermore, we found a stronger association for systematic pain assessment (OR=0.40 (95% CI: 0.35–0.45) compared to their OR of 0.72 (95% CI: 0.52–1.00). This difference may be explained by the correlation between the process performance measures in the studies because our mutually adjusted OR for systematic pain assessment increased to 0.91 (95% CI: 0.71–1.16). The absolute difference in 30-day mortality was smallest for pain assessment and most pronounced for assessment of functional ability in the study by Nielsen et al whereas we observed the opposite. These differences may therefore have affected the associations. To our knowledge, the association between systematic pain assessment, prevention of future osteoporotic fractures, and assessment of functional ability before fracture or before discharge with patient outcomes (including LOS and acute readmission) and total hospital costs has not previously been investigated.

Mobilisation within 24 hours after surgery was independently associated with a lower 30-day mortality, shorter LOS, and lower risk of acute readmission in our study. The association with shorter LOS is in accordance with the RCT by Oldmeadow et al, who found a 2.1 day reduction in LOS for patients mobilised within 24 hours postoperatively, which is comparable our estimate of 1.4 days[101]. No studies have investigated the association between mobilisation within 24 hours and 30-day mortality or readmission. However, in the cohort study by Siu et al, early mobilisation initiated on the first postoperative day was associated with improved function, survival, and lower readmission risk within 2 months, but the associations did not remain in the adjusted analyses[98]. A possible explanation for this outcome might be the lack of statistical power due to the relatively small study sample of 554 patients, but the point estimates for the individual processes were not reported in the study. Thus far, no studies appear to have examined the association between a post-discharge rehabilitation program and outcomes.

The association between the increasing composite process performance score and lower 30-day mortality is in line with existing evidence[75, 98, 99], even though it did not reach statistical significance in two of the previous studies[98, 99]. Also, our finding of a neutral association with LOS is in accordance with the previous UK study by Kahn et al examining an all-or-none indicator of best practice tariff criteria [99]. In contrast, two before-and-after studies found shorter LOS in the second period while simultaneously finding a better overall hospital fulfilment of process performance measures [94, 102]. This distinction may be due to the lack of comparability between the two time periods. For instance, Khan et al found shorter LOS when comparing the period before implementation of the best practice tariff criteria with the implementation period whereas no difference in LOS was found between those who met best practice tariff goals and those who did not meet all criteria within the implementation period[99]. No studies have investigated the association between a composite score and acute readmission within 30-days after discharge, but the study by Siu et al found an adjusted HR of 0.95 for acute readmission within 2 months for patients receiving a 9-item composite score[98], which is a weaker estimate than the OR for acute readmission of 0.78 (95% CI: 0.70–0.87) in our study. The difference can be explained in part by the fact that no patient predictors, such as clinical stability before surgery, were included in our composite score[98].

To our knowledge, no previous studies have examined the association between process performance measures and total hospital costs using individual-level data. Laudicella et al investigated the association between hospital costs and receiving process performance at hospital level but found no clear relationship[100]. However, the low-spending hospitals were characterised by a lower readmissions rate and lower 30-day mortality, which are in accordance with our findings[100].

5.2.2 Orthogeriatric organisation and process performance measures and clinical outcomes

Most previous studies, including both RCT and cohort designs, have indicated the orthogeriatric multidisciplinary model to be associated with a shorter TTS[124, 129, 132, 135, 138, 143, 145]. Similarly, three newly published cohort studies found the same association, which is in contrast to our relative TTS of 1.06 (95% CI: 0.89–1.26) for patients admitted to orthogeriatric units. These differences can be explained in part by the absolute differences in TTS among the studies, which range from hours to days[132, 189]. Indeed, studies investigating settings with relatively short TTS were less likely to find an association[131, 141, 189]. No studies were identified regarding the association between the multidisciplinary orthogeriatric care model and fulfilment of process performance measures, which potentially could drive the improvement in 30-day mortality. However, similar to our results, two studies have found an association between the geriatric consultative service and a higher chance of receiving anti-osteoporotic treatment[120, 121].

We found lower 30-day mortality for patients admitted to multidisciplinary orthogeriatric units based in the orthopaedic departments, which is in accordance with one before-and-after, one cohort study[133, 140] and four recently published cohort studies[134, 139, 147, 148]. Only one study by Kalm et al found no differences in 30-day mortality[137]. In addition, a recent cohort study by Nordström et al, investigating the multidisciplinary model in the medical department, found lower 30-day mortality[127]. An interesting finding in our work is that the multidisciplinary orthogeriatric model of care seems to benefit patients irrespective of their mortality risk at admission. These results are partially supported by those of Huusko et al, who investigated the association among patients with dementia, and those of Stenqvist et al using a before-and-after design [147, 190]. Stenqvist et al found a mortality rate of 25.6% before compared with 21.6% after implementation [147], but the result was very imprecise (only 78 nursing home residences were included).

In our study, patients admitted to orthogeriatric units had a longer LOS (8.5 vs. 10.5 days), which is in line with one previous RCT by Shyu et al and a cohort study by Zeltzer et al[131, 133]. In addition, a recent Swedish cohort study by Nordström et al found a 2.4 day longer LOS for patients admitted to multidisciplinary orthogeriatric units sited in medical departments[127]. In contrast, one earlier cohort study and one RCT found a shorter LOS[132, 135], which is additionally supported by five new cohort studies[136, 137, 139, 141, 189]. The inconsistent association with LOS among the studies comparing within the same time period is remarkable[131-133, 135-137]. It could be hypothesised that implementation of multidisciplinary orthogeriatric units in study settings such as the Nordic countries with a LOS below 10 days may not be associated with reduced LOS because of preceding work with continuity of care and optimisation.

5.2.3 Socioeconomic status and process performance measures and clinical outcomes

In contrast to the existing studies regarding socioeconomic status and processes, we found no differences in TTS[153, 155, 164] or fulfilment of process performance measures[153, 157, 159-161, 163-165] among disadvantaged patients. There are several possible explanations for this result. First, the majority of studies examined only race association with receiving of care in the US, which has a healthcare system very different from the Danish system. Second, Denmark has been working with clinical guideline–recommended care for hip fracture patients for over 12 years, which may especially have supported disadvantaged patients' receiving the recommended processes under admission[155, 191]. Third, the process performance measures reflect only relatively plain key recommended processes of in-hospital care. Differences may therefore exist within more complex interactional processes between patients and health professionals or within other areas, e.g., the care and rehabilitation in the community. It could be hypothesised that socially disadvantaged patients get less support from relatives when discharged from hospitals. Furthermore, these patients may have fewer resources to remain adherent to the rehabilitation program and the prescribed secondary prevention after discharge[192].

Education and family income were associated with higher 30-day mortality, which is partially in agreement with the findings of Castronuova et al in an Italian cohort study, where more than 8 years of education was associated with an adjusted HR for 30-day mortality of 0.94 (95% CI: 0.67–1.30)[151]. The strong association for mid-level and high-level education compared to low-level education (OR=0.85, 95% CI: 0.76–0.95) in our study was unexpected because of the tax-financed healthcare in Denmark. No Nordic publications were identified regarding the association between education and 30-day mortality; however, a Norwegian study by Omsland et al found a RR for 1-year mortality of 0.82 (95% CI: 0.77–0.87) for hip fracture patients with ≥13 years of education compared to patients with ≤9 years of education, which supports our results[193]. The

Italian study also examined marital status and found an adjusted HR of 1.56 (95% CI: 1.26–1.91) for unmarried patients compared to married patients, which is a stronger association than estimated in our study, which identified an OR of 0.93 (95% CI: 0.84–1.03) for cohabiting patients[151]. Relatives in Italy may to a large extent be responsible for the care of the hip fracture patient compared to Danish relatives, which could explain the stronger association in the Italian study. None of the identified studies examined the association with LOS or readmission.

The OR of 0.74 (95% CI: 0.63–0.88) for the association between a higher socioeconomic status and lower 30-day mortality is supported by previous literature. However, estimates in the previous studies are more extreme[152, 153], particularly in the study by Roberts et al, where an OR of 2.47 was found for lower versus higher socioeconomic status[152]. The stronger association may reflect their study's limited possibilities for adjusting for confounding, including comorbidity. The study by Barone et al did adjust for comorbidity, but the association still was stronger than because lower socioeconomic patients had an adjusted relative risk for 30-day mortality of 1.51 compared to those of higher socioeconomic status. This disparity may be explained by the fact that the authors of the Italian study obtained their socioeconomic status from area-based data, which could have carried a substantial risk of misclassification compared to a composite measure based on individual-level data, as used in our study.

In our literature search, no studies investigating socioeconomic markers or composite score association with LOS or acute readmission were identified. However, the similar LOS across different levels of socioeconomic status is somewhat surprising because of the higher comorbidity among lower status patients. A study by Nordström et al has recently shown that LOS after hip fracture below 10 days is associated with higher 30-day mortality[45]. Nordström et al did not, however, examine whether this association could vary among patients of lower and higher socioeconomic status. Hence, it could be hypothesised that early discharge increases the risk of complications and thereby death among those with a lower socioeconomic status.

5.3 Methodological considerations

5.3.1 Selection bias

All four studies used a population-based design with prospective data collection and nearly complete follow-up, which minimises the risk of selection bias. Nevertheless, some selection occurred both at baseline and during follow-up, which may have resulted in bias if the association between exposure and outcome is different for the patients in the study compared with those excluded.

It is mandatory for the hospital departments to report to the DMHFR, and the patients are included in the database from the DNRP-reported diagnosis and surgery codes for patients with proximal hip fracture without prior patient permission. Unfortunately, no nationwide validation of the hip fracture diagnosis code and surgery codes has been conducted, but a high predictive value for the presence of true surgical treated hip fracture exists in a regional pilot test[194]. Registration of the diagnosis code and surgery code for hip fracture took place before any of the outcomes of interest had occurred, and the potential selection of patients into the database is therefore considered not to be related to the outcome[195]. In paper II, a total of 2279 patients (9%) were excluded because of a record error in the DRCD. However, the exclusion did not seem to be related to the fulfilment of the process performance measures because fulfilment of the process performance measures in Table 1, paper II, was similar to that found for the 25,354 hip fracture patients in the other studies (Table 1). In contrast, the loss to follow-up due to mortality in paper II may have led to selection bias because of the potential relation to the exposure and the outcome. The higher number of deaths in the lowest quality of care category in paper II could have led to selection bias because of the reduced time to consume healthcare services, but such a bias would most likely have distorted the association towards the null. Furthermore, patients who died under admission will impact the LOS and the readmission risk in the studies; thus, only patients discharged alive were included in the analyses with LOS and acute readmission. Missing data is another potential selection problem, but we used multiple imputations, which based on the missing-at-random assumption, is expected to yield unbiased estimates[186].

5.3.2 Information bias

Incorrect registration of diagnosis, surgery, cohabiting status, education income, or immigration status in the registries is possible and may affect the accuracy of the data, but because data are collected prospectively, independently of any research question, this misclassification most likely would be unrelated to the outcome and therefore expected to yield a bias toward the null association[196]. In the DMHFR, detailed written instructions are available for reporting the data. Furthermore, regional and national audits are carried out at a minimum of once a year to ensure the validity of the data. Intentional misclassification of the fulfilment of the process performance measure is, however, a possibility because of the public disclosure of the annual reports, which often is used to benchmark hospitals. Nevertheless, this misclassification from gaming would most likely be unrelated to outcome and would therefore yield a bias toward the null. Categorisation of the multidisciplinary orthogeriatric organisation was based on a report from the Geriatric Society and a questionnaire regarding the existence of orthogeriatric care models in the years 2010 to 2013. Misclassification of the variables 30-day mortality, LOS, TTS, and registration of rehospitalisation and additional covariates are recorded on a daily basis, independently of the registration of the process performance measures and socioeconomic variables and thus would be non-differential. A differential misclassification of the covariate CCI is a possibility in study III, however CCI is a strong predictor for 30-day mortality for hip fracture patients, and patients admitted to orthogeriatric units may have more diagnoses recorded at discharge by the geriatrician than patients treated at an orthopaedic department. The misclassification of CCI may therefore be related to both exposure and outcome and would cause information bias in an adjusted analysis, but the unadjusted and adjusted OR for 30-day mortality yielded nearly identical estimates, so the information bias is expected to be low.

5.3.3 Confounding

Confounding is another potential limitation of our studies. In all studies, we adjusted for covariates identified a priori. The covariates were identified by a systematic search of the scientific literature for predictors for the outcomes of interest including 30-day mortality, TTS, LOS, short-term acute readmission, and hospital costs. For some of the potential covariates, we used proxy measures, e.g., housing instead of functional level. Furthermore, some of the variables, e.g., CCI, were categorised broadly, possibly resulting in residual confounding. However, this residual confounding has to be very large and differ among the exposure categories to influence the conclusions. Additional adjustment for specific diagnoses, such as diabetes and dementia, may have optimised the adjusted analysis, but the impact on the estimates is likely to be small due to several reasons. First, CCI is strongly associated with 30-day mortality; second, the CCI contains dementia and diabetes; and third, the unadjusted and adjusted estimates yielded nearly identical results.

Confounding by indication may also occur. In paper I, the clinician may have been less likely to offer the processes to frail patients near the end of life, which may have confounded the association due to the relation to exposure and outcome. However, the staff had the opportunity to consider the patient ineligible for the individual process performance measures, and a sensitivity analysis excluding all patients who died under admission did not change the direction of the association. In paper III, it could be argued that patients admitted to orthogeriatric units have a prognostic profile different from that of patients admitted to orthopaedic departments, but in Denmark, hip fracture patients are admitted to the nearest orthopaedic department without any triage according to health status or fracture severity.

Unmeasured and unknown confounding could have influenced the results. For instance, we did not have data on cognitive status, which could have allowed consideration of the level of dementia or delirium, which is associated with LOS and mortality after hip fracture[197]. In paper III, we did not include socioeconomic status as a covariate, but the orthogeriatric departments are located in both rural and urban areas and the impact is therefore considered limited. Other organisation differences at the hospital level may exist, but because of the multilevel regression analysis, unmeasured characteristics of the hospitals, which may be related to the outcome, were taken into account. Other predictors for the outcomes may exist that were not taken into account; however, if they were to confound the results, they would have to have been differentially distributed among the exposed groups and not correlated with the wide range of potential confounders for which we already adjusted.

5.3.4 Statistical considerations

All studies had a large sample size, which reduced the risk of random error. Most of the analyses yielded precise estimates represented with a narrow 95% CI, but some of the stratified analyses had relatively broad CIs, so these results should be interpreted with caution.

We have analysed the individual process performance measure, a composite measure, and an all-or-none measure association with outcomes. As adherence rates rise, a ceiling effect may occur, which makes it difficult to differentiate between high quality of care and low quality of care. The all-or-none indicator may therefore be more reliable measure because it raises the bar on performance[180]. Furthermore, the processes interact with each other, and exclusion of a process performance measure may vitiate the benefits of the other process performance measures. When examining quality of care as an outcome, binary regression models without adjustment were used because of the exclusion of patients, which were not relevant for the individual process performance measure.

We used multi-level linear regression with log-transformed LOS or TTS to analyse the outcomes TTS and LOS because we viewed them as continuous outcomes even though both factors can take only positive values. Another possibility was to treat TTS or LOS as duration and use time-to event models[198]. Both multi-level linear regression models had normally distributed residuals, and the distributional assumptions of ordinary least squares were fulfilled.

6. CONCLUSION

In conclusion, the thesis underlines the importance of meeting process performance measures reflecting clinical guideline recommendations for in-hospital care of hip fracture patients as this may lead to a lower 30-day mortality and lower risk for acute readmission without increasing the total hospital costs within the first year. The multidisciplinary orthogeriatric organisation based in the orthopaedic department was associated with lower 30-day mortality, which was partly explained by improved implementation of the process performance measures. All patients with hip fracture benefitted from the orthogeriatric organisation, but high-risk patients appeared to benefit most. High education and high family income were associated with a lower risk of 30-day mortality and acute readmission after hip fracture. However, the higher mortality was not mediated by differences in TTS, by whether patients received process performance measures, or by LOS, as no differences were found.

7. PERSPECTIVES

The studies of this thesis have highlighted the wide variation that exists in outcome for hip fracture patients treated with surgery in Denmark. The wide variation could not be explained by differences in patient characteristics but was highly associated with the organisation of care and whether the patients had received key recommendations according to clinical guidelines. This research has extended our knowledge regarding the fact that better organisation of healthcare and better achievement of guideline-recommended process performance measures improve outcome and has also indicated opportunities to obtain more value for the money within hip fracture care in Denmark.

These results indicate that orthopaedic departments that improve structures and processes will be likely to improve outcomes including mortality, readmission, and efficient use of limited resources. The identified associations are a step toward understanding how healthcare quality can be improved for patients with hip fracture, as it highlights potential focus areas. This research furthermore provides a potential framework for similar studies involving other patient groups.

Confirming the association between process performance measures and outcome is encouraging because this association points to a feasible avenue for improving patient outcome without increasing costs. Furthermore, it highlights the importance and value of receiving basic processes of treatment, nursing, and rehabilitation. These basic processes are under great pressure in modern healthcare because of expensive new technologies and medicine. Often, these new technologies and medicine have been implemented in healthcare based on the results of clinical trials. The evidence regarding fundamental processes of treatment, nursing, and rehabilitation is less well established, and their importance may therefore not always be fully acknowledged. The use in this thesis of epidemiology to study the effectiveness of these process performance measures underlines the importance of receiving these fundamental processes in routine practice. However, not all outcomes described in Donabedian's model were examined in our research. Outcome data on quality of life and ability to function in daily activities are not currently available in our routinely collected data. Further research into such associations is therefore warranted.

In the orthogeriatric study, the multidisciplinary orthogeriatric organisation model in Denmark was associated with higher fulfilment of the process performance measures and improved outcome for hip fracture patients. It is therefore an example of how an organisational model may promote the performance of healthcare professionals and improve the outcome. Other organisational changes may affect healthcare performance and outcome in a different manner. It is therefore crucial to continuously monitor and investigate the effect of new organisational models on process performance measures and outcomes if we want to improve the healthcare system.

The socioeconomic study provides additional evidence with respect to the existence of inequalities in health. Patients with a lower level of education had similar readmission rates compared to patients with a university degree, despite the fact that socially disadvantaged patients often suffer from multiple chronic diseases that make them high-risk patients for developing post-operative complications. In addition, a higher proportion of patients with a lower level of education died within 30 days compared to hip fracture patients with a university degree. Inequalities in healthcare benefits in the sector transition or in the primary health services may therefore exist. It is thus necessary to extend quality work to the local communities, which in recent years have been given an increasingly important role regarding treatment, nursing, and rehabilitation of hip fracture patients. The extent of the variation in overall performance of the healthcare system, e.g., sector crossings to the primary sector for elderly patients, and the possible implications of such variation have so far been sparsely assessed. Questions to be answered include: Which healthcare processes in the communities facilitate higher survival and better quality of life after hip fracture? Which organisational structure promotes these processes and leads to better outcomes? Do socioeconomically disadvantaged patients have the same access to primary healthcare? Without more insights, the recent reductions in LOS at hospitals and relocation of patients to be treated in the communities are in many ways comparable to the challenges faced by ancient explorers, who had to navigate the seas without a map. We therefore need data for the sector transition as well as for the primary health services to investigate healthcare processes and how healthcare should be organised to improve patient outcome and ensure maximal benefit from available resources.

8. SUMMARY

Hip fracture is among the most common causes for hospital admissions among the elderly with major implications for the individual patient and for the society due to a high mortality rate, functional decline among a high proportion of the survivors, and substantial health costs. National and international clinical guidelines for hip fracture care have been developed to promote evidence-based care, reduce variation in clinical practice and to ensure effective use of the available ressources. However, evidence is lacking for the impact of recommended care on clinical outcomes and healthcare costs. This thesis aims to examine links between the organisation of hip fracture care (i.e. orthogeriatric organisation), fulfilment of process performance measures reflecting clinical guideline recommendations for in-hospital hip fracture care, inequality in care, clinical outcomes and costs.

This thesis is based on nationwide cohort studies published in four papers. All studies used data from the Danish Multidisciplinary Hip Fracture Registry linked with other population-based studies including the National Registry of Patients, the Civil Registration System, the Danish Reference Cost Database, and population-, income- and education registries from Statistics Denmark. Patients with hip fractures were included from the time period between 1. Marts 2010 to November 30. 2013. The number of included hip fracture patients ranged from 11,461 to 25,354.

Paper I and II examined the association between fulfilment of process performance measures and clinical outcomes (i.e., 30-day mortality, length of stay and readmission within 30-day after discharge) and costs of hospital care. The process performance measures included systematic pain assessment, mobilization within 24 hours postoperative, basic mobility assessment before admission and discharge, post discharge rehabilitation program, anti-osteoporotic medication and prevention of future fall accidents. Fulfilling the individual as well as a composite score of process performance measures were associated with lower 30-day mortality and lower risk for acute readmission within 30 days after discharge. Mobilisation within 24 hours postoperative was also associated with shorter length of stay. Furthermore, fulfilment of the individual process performance measures and the composite score were also associated with lower total costs within the index admission. The association were weakened when taking into account all costs related to hospitalisations within the first year. However, most of the individual process performance measures as well as the composite score remained associated with lower costs.

Paper III examined the association between orthogeriatric organisation and fulfilment of process performance measures and clinical outcomes. The patient population was divided into patients admitted to orthogeriatric units and traditional orthopedic departments, respectively. The orthogeriatric unit had a multidisciplinary team comprising of a geriatrician, orthopaedic surgeon, nurses and physio- and occupational therapist, whereas the traditional orthopedic departments had geriatric or medical consultant service on request. Admission to orthogeriatric units was associated with a higher chance for fulfilling five out of six process performance measures and a lower 30-day mortality regardless of the patient´s mortality risk. The orthogeriatric organisation was not associated with time to surgery, but a non-significantly longer length of stay. Receiving the process performance measures was demonstrated to be a key mediator for the lower 30-day mortality at the orthogeriatric departments.

Paper IV examined the association between socioeconomic status including four socioeconomic markers (education, family mean income, cohabiting status and migration status) and clinical outcomes. Higher education and higher family income were associated with substantially lower 30 day mortality after hip fracture. Furthermore, a composite score of high education and high family income were associated with lower risk for acute readmission within 30 days after discharge. However, there were no socioeconomic differences in fulfilment of process performance measures, time to surgery and length of stay, which indicated that these factors were not important mediators of the socioeconomic inequalities in mortality.

In conclusion, the thesis underlines the importance of meeting process performance measures reflecting clinical guideline recommendations for in-hospital care of hip fracture patients as this may lead to a lower 30-day mortality and lower risk for acute readmission without increasing the total hospital costs within the first year. Furthermore, multidisciplinary orthogeriatric care was associated with lower 30-day mortality, which was partial mediated by a higher fulfilment of the process performance measures. Socioeconomic inequality in 30-day mortality and readmission exist among hip fracture patients in Denmark, however it seems not to be mediated of differences in time to surgery, fulfilment of process performance measures or length of stay.

9. DANSK RESUME

Hoftenære frakturer udgør en væsentlig samfundsmæssig udfordring på grund af høj dødelighed, høj forekomst af nedsat funktionsevne blandt de overlevende, samt store sundhedsøkonomiske omkostninger for samfundet. Nationale og internationale kliniske retningslinjer for behandling, pleje og rehabilitering af hoftebrudspatienter er blevet udviklet med henblik på at skabe en evidens-baseret praksis, reducere uønsket variation og opnå den mest effektive udnyttelse af faglige og økonomiske ressourcer. Effekten af at efterleve disse anbefalinger er dog kun belyst i meget begrænset omfang. Denne usikkerhed gælder både i forhold til patienternes kliniske outcome, f.eks. risiko for død eller genindlæggelse, samt i forhold til de sundhedsøkonomiske udgifter. Hovedformålet med denne ph.d.-afhandling var at undersøge sammenhænge mellem henholdsvis organisering af behandlingen (eksemplificeret ved orthogeriatriske afsnit), behandlingskvalitet (defineret som efterlevelse af anbefalinger fra den tværfaglige kliniske retningslinje for hospitalsbehandling af hoftenære frakturer), ulighed i behandling (eksemplificeret ved socioøkonomisk status) samt sygdomsudfald og hospitalsomkostninger.

Afhandlingen er baseret på populationsbaserede kohorte studier publiceret i fire artikler. Alle studierne anvendte data fra Dansk Tværfagligt Register for hoftenære lårbensbrud, Landspatientregisteret, Central Person Registeret, Omkostningsdatabasen og befolknings- , indkomst- og uddannelses registret fra Danmarks Statistik. Patienter med hoftenære frakturer blev inkluderet i tiden fra 1. marts 2010 til 30. november 2013. Antallet af inkluderede hoftebrudspatienter spændte fra 11.461 til 25.354.

Artikel I og II undersøgte sammenhængen mellem behandlingskvalitet og sygdomsudfald, inklusiv 30 dags dødelighed, indlæggelsestid og akut genindlæggelse indenfor 30 dage efter udskrivelse og hospitalsomkostninger. Behandlingskvalitet blev defineret som opfyldelse af en række procesindikatorer, som afspejler anbefalinger fra den nationale kliniske retningslinje inkl. systematisk smertescoring, postoperativ mobilisering indenfor 24 timer postoperativt, vurdering af basismobilitet før indlæggelse og før udskrivelse, udarbejdelse af genoptræningsplan samt iværksættelse af osteoporose- og faldpropylakse. Opfyldelse af individuelle procesindikatorer såvel som et aggregeret mål for behandlingskvalitet var alle associeret med lavere 30 dags dødelighed og en lavere risiko for akut genindlæggelse. Mobilisering indenfor 24 timer postoperativt var ligeledes associeret med kortere indlæggelsestid. Opfyldelse af indikatorerne og det aggregerede mål var ikke associeret med øgede hospitalsomkostninger og muligvis endda med lavere hospitalsomkostninger indenfor både primær indlæggelsen og indenfor det første år.

Artikel III undersøgte sammenhænge mellem ortogeriatrisk organisering og opfyldelse af procesindikatorer samt sygdomsudfald. Patientpopulationen blev inddelt efter om patienterne havde været behandlet på et ortogeriatrisk afsnit eller behandlet på en traditionel ortopædkirurgisk afdeling. De ortogeriatriske afsnit var kendetegnet ved et tværfagligt behandlingsteam bestående af geriater, ortopædkirurg, sygeplejersker, fysio- og ergoterapeuter, hvorimod de traditionelle ortopædkirurgiske afdelinger havde geriatrisk og medicinsk tilsyn på forespørgsel. Indlæggelse på et ortogeriatrisk afsnit var associeret med en højere opfyldelse af fem ud af seks procesindikatorer og en lavere 30 dags dødelighed uanset patients øvrige sundhedstilstand. Indlæggelse på et ortogeriatrisk afsnit var ikke associeret med ventetiden på operation, men vi fandt en længere indlæggelsestid, der dog ikke kunne afvises at kunne skyldes usikkerhed i datamaterialet. Den bedre opfyldelse af procesindikatorerne kunne delvis forklare den lavere 30 dags dødelighed for patienter indlagt på ortogeriatriske afsnit.

Artikel IV undersøgte sammenhænge mellem socioøkonomisk status (uddannelsesniveau, familie indkomst, samlivs status og migration status) og opfyldelse af procesindikatorer samt sygdomsudfald. Høj uddannelse og høj familieindkomst var associeret med lavere 30 dags dødelighed efter hoftenær lårbensbrud. Yderligere var et aggregeret mål for høj uddannelse og høj indkomst associeret med en lavere risiko for akut genindlæggelse indenfor 30 dage efter udskrivelse. Vi fandt dog ingen socioøkonomiske forskelle i forhold til ventetid til operation, opfyldelse af procesindikatorer eller indlæggelsestid, som kunne forklare den socioøkonomiske ulighed i dødelighed efter hoftenær lårbensbrud.

Sammenfattende viser ph.d. afhandlingen vigtigheden af patienter med hoftenær lårbensbrud behandles efter national kliniske retningslinje, da det sandsynligvis er forbundet med lavere 30 dags dødelighed og mindre risiko for akut genindlæggelse 30 dage efter udskrivelse. Derudover tyder det på, at den øgede behandlingskvalitet ikke er forbundet med ekstra hospitalsomkostninger. Ortogeriatrisk organisering fordrer i højere grad, at patienter med hoftebrud behandles efter national kliniske retningslinjer, hvilket sandsynligvis er en medvirkende årsag til den lavere 30 dags dødelighed for patienter behandlet på disse afsnit. Desuden tyder det på, at der er socioøkonomiske forskelle i 30 dags dødelighed og genindlæggelse, men at det ikke umiddelbart kan forklares af forskelle i opfyldelse af procesindikatorerne, ventetid på operation eller indlæggelsestid.

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11. APPENDIX

11.1 Details on search strategy

Search terms, medical subject headings indicated by [] otherwise keywords

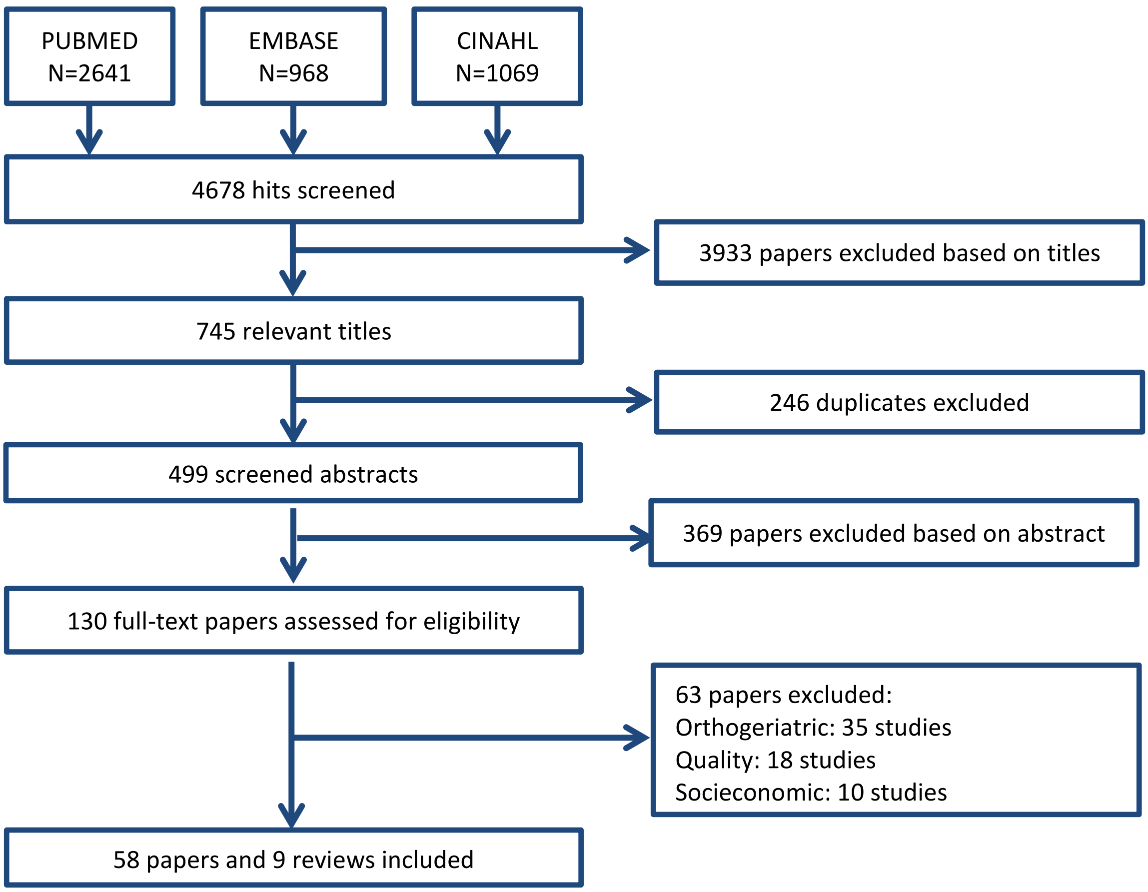
	AND								
	Hip fracture	**Quality of care**	**Ortogeriatric[1]**	**Socioeconomic**	**Time to surgery[2]**	**Length of stay**	**Mortality**	**Readmission**	**Hospital costs[3]**
OR	**[Hip Fractures]**	**[Quality of Health Care]**	**[Patient Care Management]**	**[Socioeconomic Factors]**	**[Time-to-Treatment]**	**[Length of Stay]**	**[Mortality]**	**[Patient Readmission]**	**[Costs]**
	"Femoral neck fracture*"	"quality indicator*"	**[Geriatric Assessment]**	"wives*"	"Time-to-Treatment"	"bed day savings”	"short term mortality"	readmission*	**[Cost Analysis]**
	"Subtrochanteric hip fracture*"	"basic mobility"	**[Geriatrics/standards]**	"wife"	"Surgical delay"	"length of stay"	"30-day mortality"	rehospitalisation*	"economic"
	"Intracapsular hip fracture*"	"prevention osteoporosis"	**[Geriatrics/organization and administration]**	"husband"	"time to surgery"	"hospital stay*"	mortality		Costs
	"Intertrochanteric hip fracture*"	"anti osteoporosis"	**[Health Services for the Aged]**	"immigrants"		"stay length"			Cost
	"Femoral head fracture*"	"fall prevention"		"ethnicity"					
	"hip fracture*"	"rehabilitation program"	“Orthogeriatric*”	"marital status"					
		"functional assessment"		"marriage"					
		"early mobilisation"		"spouse*"					
		“pain assessment”		"cohabitant"					
		"Quality of hospital care"		"social class"					
		"Quality of care"		"poverty"					
		"Quality of health care"		"education"					
		"Quality improvement*"		"income"					
		"Quality assessment"		"inequalities"					
		"Process of care"		"inequality"					
		"process assessment"		"living standard*"					
		"Health care Performance"		"standard of living"					
		"Process performance measures"		"Socioeconomic*"					
		"quality criteria"							
		"Improved quality"							
		"Improved care"							

[1] In CINAHL: [Geriatric Assessment+], [Geriatrics], [Health Services for the Aged], [Aged+] (Major term), [Gerontologic Care[- ([Patient Care Management] + keywords
[2] In CINAHL: No medical subject headings, but all medical subject headings was searched as keywords in the full period.
[3] In CINAHL: [Cost and Costs Analysis+] + keywords

Search combinations

		Hits		
		PubMed	EMBASE	CINAHL
	Search	**13.12.16**	**12.01.17**	**01.02.17**
Paper 1:	Hip fracture and Quality of care and Mortality		240	135
	Hip fracture and Quality of care and Readmission	1333	25	37
	Hip fracture and Quality of care and Length of stay		88	186
Paper 2:	Hip fracture and Quality of care and Hospital Costs	416	34	128
Paper 3:	Hip fracture and Orthogeriatric and Mortality		282	63
	Hip fracture and Orthogeriatric and Quality of care	1321	166	181
	Hip fracture and Orthogeriatric and Time to surgery		16	78
	Hip fracture and Orthogeriatric and Length of stay		85	70
Paper 4:	Hip fracture and Socioeconomic and Mortality		17	27
	Hip fracture and Socioeconomic and Quality of care		9	109
	Hip fracture and Socioeconomic and Time to surgery	233	1	4
	Hip fracture and Socioeconomic and Length of stay		4	43
	Hip fracture and Socioeconomic and Readmission		1	8
		3303	968	1069
	Duplicates	662		
	Hits included for screening	2641	968	1069

Figure : Flowchart describing study selection



PAPERS

Are process performance measures associated with clinical outcomes among patients with hip fractures?
– A population-based cohort study.

Paper I

Is high quality of care associated with higher costs?
– A nationwide cohort study among hip fracture patients.

Paper II

Can improved quality of care explain the success of the orthogeriatric units?
– A population-based study.

Paper III

Socioeconomic inequality in clinical outcome among hip fracture patients:
– A nationwide cohort study.

Paper IV

Paper I

Are process performance measures associated with clinical outcomes among patients with hip fractures?
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International Journal for Quality in Health Care Advance Access published September 2, 2016

International Journal for Quality in Health Care, 2016, 1–10
doi: 10.1093/intqhc/mzw093
Research Article

Research Article

Are process performance measures associated with clinical outcomes among patients with hip fractures? A population-based cohort study

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Accepted 19 July 2016

Abstract

Objectives: To examine the association between process performance measures and clinical outcome among patients with hip fracture.
Design: Nationwide, population-based follow-up study.
Setting: Public Danish hospitals.
Participants: A total of 25 354 patients 65 years or older who were admitted with a hip fracture in Denmark between 2010 and 2013.
Intervention: The process performance measures, including systematic pain assessment, early mobilization, basic mobility assessment at arrival and at discharge, post-discharge rehabilitation program, anti-osteoporotic medication and prevention of future fall accidents measures, were analysed individually as well as an opportunity-based score defined as the proportion of all relevant performance measures fulfilled for the individual patient (0–50%, 50–75% and 75–100%).
Main Outcome Measures: Thirty-day mortality, 30-day readmission after discharge and length of stay (LOS).
Results: Fulfilling 75–100% of the relevant process performance measures was associated with lower 30-day mortality (22.6% vs. 8.5%, adjusted odds ratio (OR) 0.31 (95% CI: 0.28–0.35)) and lower odds for readmission (21.7% vs. 17.4%, adjusted OR 0.78 (95% CI: 0.70–0.87)). The overall opportunity score for quality of care was not associated with LOS (adjusted OR 1.00 (95% CI: 0.98–1.04)). Mobilization within 24 h postoperatively was the process with the strongest association with lower 30-day mortality, readmission risk and shorter LOS.
Conclusions: Higher quality of in-hospital care and in particular early mobilization was associated with a better clinical outcome, including lower 30-day mortality, among patients with hip fracture.

Introduction

The prognosis after hip fracture remains serious and significantly worse than for comparable patients undergoing hip replacement [1]. The majority of patients with hip fractures are treated surgically and hospitalized for several days [2]. Quality of in-hospital care is therefore a particular concern in this patient group. However, currently the strength of the available evidence for the association between specific care processes to hip fracture patient and patient outcome is almost entirely drawn from uncontrolled before and after studies with inconsistent results [3]. To the best of our knowledge, only two previous studies have examined the association between meeting specific process performance measures and clinical outcomes among patients with hip fracture, but the results were inconsistent [4, 5]. There is consequently a need for further studies as we lack knowledge about the clinical effectiveness of the recommended processes of care in routine clinical settings. Hence, it is not documented whether the hospitals can in fact significantly influence outcomes among patients with hip fracture by complying with clinical guidelines recommendations. We therefore examined the association between process performance measures and 30-day mortality, readmission within 30 days after discharge and length of stay (LOS) in a routine setting among unselected patients.

Methods

This study was based on nationwide data from medical registries in Denmark, a country with 5.6 million inhabitants with free access to medical care. The study was approved by the Danish Data Protection Agency (journal number 2012-41-1274).

Data sources

The Danish Multidisciplinary Hip Fracture Registry (DMHFR) was used to identify hip fracture patients (including medial, pertrochanteric or subtrochanteric femoral fractures) at 65 years or older. DMHFR is a clinical quality registry, established in 2003 to document and improve in-hospital quality of care. The registry includes patient-level data on quality of care reflected by receiving seven process performance measures. The process performance measures reflect recommendations from the national clinical guidelines on hip fracture care in Denmark. A multidisciplinary expert panel consisting of experienced clinicians (physicians, nurses, physiotherapists and occupational therapists) identified the process performance measures covering in-hospital care based on a systematic literature search. The ability of the process performance measures to reflect the multidisciplinary efforts involved in modern hip fracture care and the feasibility of the collection of the required data in routine setting were also considered.

Data are prospectively collected for each patient from the time of hospital admission, and project participation is mandatory for all Danish hospital departments treating hip fracture, which allowed complete follow-up on the process performance measures [6, 7]. A structured audit process is carried out every year to critically assess the quality and completeness of the data. From the Danish National Registry of Patients (DNRP), we furthermore obtained Charlson comorbidity index data using the unique personal identification number assigned to each Danish citizen [8, 9]. The DNRP serves as a basis for reimbursement in the Danish health care system and includes administrative data for all hospitalizations and diagnoses coded according to the *International Classification of Diseases version 10* (ICD-10) from 1977 [10]. The Danish Civil Registration System maintained electronic records of changes in vital status and migration for the entire Danish population on a daily basis since 1968, which allowed complete follow-up on mortality in the study [8, 11]. Furthermore, data on socio demographic characteristics on the patients were obtained from Statistics Denmark [12].

Study population

We identified all hip fracture patients registered in the DMHFR with a discharge date between 1 March 2010 and 31 November 2013 (N = 26 271). Patients with a second hip fracture during this study period were only included once; therefore, 821 hip fracture procedures were excluded (n = 821). Furthermore, patients, who had immigrated within the last 5 years, were excluded because of insufficient information in the Danish registries (n = 80) along with patients with no registered address (n = 16). Our study cohort therefore included 25 354 patients.

Process performance measures

The quality of in-hospital care was assessed using the following performance measures: (i) daily systematic pain assessment using a visual analog scale or a numeric rating scale at rest and during mobilization [13], (ii) being mobilized within 24 h postoperatively, defined as assisting the patient from bed rest to walking or rest in a chair, (iii and iv) basic mobility assessment using a validated test such as Cumulated Ambulation Score, Barthel 20, Functional Recovery score or New Mobility score [14–16] prior to admission measured at admission and at discharge measured prior to discharge, (v) post-discharge rehabilitation program including assessment of activities of daily living with a validated test before fracture and again before discharge, (vi) initiation of treatment to prevent future fall accidents, including a fall risk assessment to account for coexisting medical conditions, medication, functional disability, symptoms from the central nervous system, musculoskeletal system and cardiopulmonary status and (vii) initiation of treatment with anti-osteoporotic medications. Patients were classified as eligible or ineligible for each individual process performance measure depending on whether the hospital staff identified contraindications (e.g. dementia that disabled the patients from reporting their level of pain during mobilization). The number of patients assessed in the analysis of the individual process performance measures therefore varied.

Clinical outcomes

Thirty-day mortality

Follow-up started on the day of hospital admission and ended after 30 days.

Readmission within 30 days

Readmission was defined as an acute all-cause readmission to any Danish hospital within 30 days after discharge.

Length of stay

Defined as time span from hospital admission to hospital discharge. The discharge date was defined as the date of discharge to home, a nursing home or death. If the patients were transferred between hospital units, the days spent in all units were included.

Covariates

A prior-defined covariates included: age, sex, Charlson comorbidity index, body mass index (BMI), housing, type of fracture and fracture displacement type of surgery and time to surgery that was classified as <24, 24–48, >48 h [17]. Furthermore, we adjusted for socioeconomic variables including civil status (cohabitants/living alone) and family mean income. To account for yearly variation in income, we calculated the average income in the 5 years before admission for the patient and cohabiting partner. All patients were divided into quartiles of increasing income. At unit level we adjusted for hospital setting (orthopedic unit or orthogeriatric unit) and hip fracture patient volume per year (<152, 152–350 >350) [18, 19].

Statistical analysis

Data were analyzed using Stata 14.0 (StataCorp LP, College Station, TX, USA) and multilevel regression modeling (xtmelogit and xtmixed procedure), taking into account the hierarchical data structure with patients nested in units. We first examined the association between each individual performance measure and the clinical outcomes. Second, the quality of care was summarized using an opportunity-based measure. For each patient, the total number of relevant performance measures was defined as the denominator and the number of performance measures actually complied with was defined as the numerator, and the proportion of relevant performance measures the single patient met was computed. The opportunity-based score was divided into categories of fulfillment (0–50%, 50–75% 75–100%), and we examined the association between the opportunity score and 30-day mortality, readmission within 30 days of discharge and LOS, respectively. The multilevel regression analyses included three models; Model 0 adjusted for the hierarchical data structure, Model I adjusted for potential covariates mentioned above and Model II included the covariates in Model I and all the process performance measures. The Model II therefore mutually adjusted for correlation between the process performance measures. The association between performance measures and 30-day mortality or readmission within 30 days of discharge was analyzed using multilevel logistic regression model. The association between the performance measures and LOS was analyzed using multilevel linear regression modeling. We used a natural log transformation to correct for the right skewness in LOS, and the results were reported as ratios between geometric means. The association was adjusted for the above-mentioned covariates.

To evaluate the robustness of our findings, the mortality analyses were also done excluding patients who died during hospitalization. To handle missing data on the covariates such as BMI, housing, fracture displacement and time to surgery, we used multiple imputations procedure using all available information from patients presented in Table 1, including also outcome data [20]. Categorical variables were imputed using the ologit method. We used 25 imputed data sets to reduce sampling variability from the imputation process. All analyses were also performed as compete-case analysis.

Results

Our study cohort included 25 354 hip fracture patients from all 26 units treating patients with hip fracture in Denmark. Table 1 summarizes the patient characteristics. Patients receiving 0–50% of the relevant process performance measures tended to have a more adverse prognostic profile. However, the differences were small. For the patients for whom it was relevant, 81.8% received systematic pain assessment, 77.6% were mobilized within 24 h after surgery, 74.6% received basic mobility assessment, 95.0% received a post-discharge rehabilitation program, 89.3% anti-osteoporotic medication and 89.3% prevention of future fall accidents. Overall, the 30-day mortality in the cohort was 11.2%. Table 2 shows crude and adjusted odds ratios (ORs) for death within 30 days according to the individual process performance measures met. All seven performance measures were associated with lower 30-day mortality. The adjusted mortality ORs ranged from 0.40 (95% CI: 0.35–0.45) for systematic pain assessment to 0.78 (95% CI: 0.67–0.91) for basic mobility assessment at discharge. When we mutually adjusted for all process performance measures, mobilization within 24 h postoperatively and receiving a post-discharge rehabilitation program, respectively, remained independently associated with lower 30-day mortality. Analyses with exclusion of patients who died during hospitalization (n = 1713, 6.8%) showed weakened associations, but patients with fulfilled process performance measures still had lower adjusted ORs and the associations remained statistically significant for five out of seven process performance measures (Appendix 1). For patients who fulfilled 0–50%, 50–75% and 75–100% of the process performance measures, the 30-day mortality was 22.6%, 17.4% and 8.5%, respectively (Table 3). We found a dose–response relationship between the proportion of the relevant process performance measures met and the 30-day mortality. Using patients receiving 0–50% of the process performance measures as a reference, the adjusted ORs for 30-day mortality were 0.71 (95% CI: 0.61–0.81) and 0.32 (95% CI: 0.29–0.36) for receiving 50–75% and 75–100% of the relevant process performance measures, respectively (Table 3).

Table 4 shows crude and adjusted ORs for readmission within 30 days after discharge according to the process performance measures met. Among patients who were mobilized within 24 h postoperatively, 16.9% were readmitted compared to 20.7% for patients mobilized after 24 h (adjusted OR 0.84, 95% CI: 0.78–0.92). Readmission was also lower for patients who received systematic pain assessment (21.1% vs. 16.9%, adjusted OR 0.80 (95% CI: 0.72–0.89)) and anti-osteoporotic medication (21.4% vs. 17.5%, adjusted OR 0.79, 95% CI: 0.70–0.88). In the mutual adjustment, all three performance measures were independently associated with lower odds for readmission. For the opportunity-based score, patients receiving 0–50%, 50–75% and 75–100% process performance measures 21.7%, 17.7% and 17.4% were readmitted to the hospital, within 30 days of discharge, respectively (see Table 3). Receiving 75–100% of the relevant process performance measures was associated with a decreased adjusted OR for readmission within 30 days of 0.78 (95% CI: 0.70–0.87) compared to receiving 0–50% of the relevant process performance measures.

Patients who were mobilized within 24 h postoperatively had a median LOS of 8.1 days compared to 9.8 days for patients mobilized after 24 h (adjusted relative LOS = 0.88 (95% CI: 0.86–0.89)). For the remaining six performance measures, the differences in LOS were <1 day (Table 5). No association was seen between the opportunity-based score and LOS, see Table 3.

Complete case analyses provided results comparable to the imputation analyses.

Discussion

In this nationwide population-based study of hip fracture patients, we found that mobilization within 24 h postoperatively and discharging patients with a rehabilitation program was associated with a lower 30-day mortality risk. Receiving mobilization within 24 h postoperatively was also associated with lower risk for early readmission and shorter LOS. Furthermore, receiving systematic pain assessment and anti-osteoporotic medication was associated with lower risk of readmission. Moreover, the overall opportunity-based score was associated with lower 30-day mortality and 30-day readmission.

Table 1 Characteristics of patients with hip fracture according to quality of in-hospital care reflected by proportion of fulfilled process performance measures

	Total	0–50%		50–75%		75–100%	
	N = 25354	*n* = 2908		*n* = 3071		*n* = 19375	
Age group (years)							
65–74	4938	19.9	(580)	18.6	(571)	19.6	(3787)
75–84	9376	34.4	(1000)	35.6	(1092)	37.6	(7284)
>85	11040	45.7	(1328)	45.9	(1408)	42.9	(8304)
Gender							
Women	18066	69.1	(2009)	70.3	(2158)	71.7	(13899)
Men	7288	30.9	(899)	29.7	(913)	28.3	(5476)
Housing							
Own home	16665	26.9	(781)	63.0	(1934)	72.0	(13950)
Own home affiliated to an institution	1556	2.4	(69)	6.6	(201)	6.6	(1286)
Institution	4536	10.3	(298)	22.6	(695)	18.3	(3543)
Missing	2597	60.5	(1760)	7.9	(241)	3.1	(596)
BMI (kg/m^2)							
<19: Underweight	3289	5.2	(150)	13.2	(404)	14.1	(2735)
20–25: Normal	11878	16.2	(472)	44.2	(1358)	51.9	(10048)
>26: Overweight	5096	6.6	(191)	17.5	(536)	22.6	(4369)
Missing	5091	72.0	(2095)	25.2	(773)	11.5	(2223)
CCI[a]							
0: no comorbidity	9717	34.5	(1003)	35.0	(1074)	39.4	(7640)
1: low comorbidity	6015	23.4	(680)	24.2	(744)	23.7	(4591)
2: moderate comorbidity	4437	18.6	(540)	18.2	(558)	17.2	(3339)
+3: high comorbidity	5185	23.6	(685)	22.6	(695)	19.6	(3805)
Fracture displacement							
Displaced	18420	47.1	(1369)	76.1	(2336)	76.0	(14715)
Undisplaced	2935	6.8	(199)	11.7	(360)	12.3	(2376)
Unspecified	3999	46.1	(1340)	12.2	(375)	11.8	(2284)
Type of fracture							
Femoral neck	13405	51.1	(1485)	51.9	(1593)	53.3	(10327)
Pertrochanteric	10080	39.3	(1144)	40.2	(1234)	39.8	(7702)
Subtrochanteric	1869	9.6	(279)	8.0	(244)	7.0	(1346)
Type of surgery							
Osteosynthesis	16885	68.7	(1999)	66.9	(2055)	66.2	(12.831)
Hemi arthroplasty	6931	26.9	(781)	28.8	(883)	27.2	(5267)
Total hip arthroplasty	1538	4.4	(128)	4.3	(133)	6.6	(1277)
Unit setting							
Orthopedic unit	19608	82.3	(2393)	74.7	(2301)	77.0	(14914)
Orthogeriatric unit	5746	17.7	(515)	25.0	(770)	23.0	(4461)
Time to surgery (hours)							
<24	15058	51.8	(1507)	56.8	(1744)	60.9	(11807)
24–48	7341	31.2	(908)	29.9	(919)	28.5	(5514)
>48	2945	16.9	(492)	13.2	(406)	10.6	(2047)
Missing	10	0.03	(1)	0.07	(2)	0.04	(7)
Civil status							
Married or cohabitant	7785	69.9	(874)	68.7	(961)	69.3	(5950)
Lives alone	17569	30.1	(2034)	31.3	(2110)	30.7	(13425)
Family mean income							
Low	6338	25.9	(752)	26.6	(817)	24.6	(4769)
Medium	6339	24.2	(703)	25.4	(779)	25.1	(4857)
High	6338	25.2	(733)	23.7	(72.7)	25.2	(4878)
Very high	6339	24.8	(720)	24.4	(748)	25.1	(4871)

BMI, Body mass index.
[a]CCI, Charlson comorbidity index.

The process performance measures in our study are proxy measures believed to influence the prognosis and mortality among hip fracture patients. Systematic pain assessment and basic mobility assessment may not *per se* reduce 30-day mortality; however, assessment may promote adequate mobilization and prevent bed rest complication such pulmonary embolism and infections and myocardial infarction. This is supported by our analysis with the mutually adjustment for the process performance measures where only mobilization and receiving a post-discharge rehabilitation program remained independently associated with 30-day mortality.

An observational study by Siu *et al.* with 554 patients has previously found that early mobilization initiated on first postoperative

Table 2 Association between individual process performance measures and 30-day mortality among patients with hip fracture

Process performance measures	Died % (*N*)	Basis OR		Adjusted OR		Adjusted OR	
		(95% CI) Model 0[a]		(95% CI) Model 1[b]		(95% CI) Model 2[c]	
Systematic pain assessment							
No (ref)	16.1% (574/3556)						
Yes Complete case	6.8% (1087/16024)	0.33	(0.29–0.37)	0.37	(0.29–0.47)	0.89	(0.63–1.27)
Imputed				**0.40**	**(0.35–0.45)**	**0.91**	**(0.71–1.16)**
Random effect							
Unit-level variance							
Complete case		0.10	(0.05–0.19)	0.13	(0.05–0.31)		
Imputed				**0.06**	**(0.03–0.12)**		
Mobilized <24 h postoperatively							
No (ref)	15.4% (825/5354)						
Yes Complete case	7.8% (1436/18526)	0.45	(0.41–0.50)	0.60	(0.52–0.69)	0.70	(0.58–0.85)
Imputed				**0.53**	**(0.48–0.59)**	**0.81**	**(0.69–0.94)**
Random effect							
Unit-level variance							
Complete case		0.02	(0.01–0.05)	0.01	(0.00–0.07)		
Imputed				**0.01**	**(0.00–0.04)**		
Basic mobility assessment at admission							
No (ref)	18.2% (130/715)						
Yes Complete case	8.9% (249/2807)	0.36	(0.27–0.48)	0.57	(0.39–0.84)	0.94	(0.75–1.19)
Imputed				**0.48**	**(0.36–0.64)**	**0.73**	**(0.50–1.05)**
Random effect							
Unit-level variance							
Complete case		0.07	(0.02–0.23)	0.03	(0.00–0.42)		
Imputed				**0.02**	**(0.00–0.27)**		
Basic mobility assessment at discharge							
No (ref)	6.2% (370/5986)						
Yes Complete case	4.8% (850/17655)	0.74	(0.64–0.85)	0.85	(0.69–1.06)	0.94	(0.75–1.19)
Imputed				**0.78**	**(0.67–0.91)**	**0.88**	**(0.75–1.04)**
Random effect							
Unit-level variance							
Complete case		0.03	(0.01–0.07)	0.02	(0.00–0.11)		
Imputed				**0.02**	**(0.01–0.07)**		
Post-discharge rehabilitation program							
No (ref)	11.1% (121/1094)						
Yes Complete case	4.3% (927/21438)	0.34	(0.28–0.42)	0.45	(0.32–0.63)	0.51	(0.36–0.72)
Imputed				**0.41**	**(0.32–0.51)**	0.45	(0.36–0.57)
Random effect							
Unit-level variance							
Complete case		0.04	(0.02–0.11)	0.05	(0.01–0.16)		
Imputed				**0.03**	**(0.01–0.09)**		
Anti-osteoporotic medication							
No (ref)	19.5% (527/2702)						
Yes Complete case	10.2% (2308/22652)	0.47	(0.42–0.52)	0.46	(0.36–0.58)	1.06	(0.70–1.62)
Imputed				**0.47**	**(0.42–0.53)**	**0.93**	**(0.72–1.21)**
Random effect							
Unit-evel variance							
Complete case		0.01	(0.00–0.03)	0.01	(0.00–0.06)		
Imputed				**<0.01**	**(0.00–0.04)**		
Prevention of future fall accidents							
No (ref)	15.8% (753/4763)						
Yes Complete case	10.1% (2082/20591)	0.58	(0.53–0.64)	0.68	(0.57–0.81)	0.99	(0.75–1.31)
Imputed				**0.61**	**(0.55–0.68)**	**1.04**	**(0.85–1.27)**
Random effect							
Unit-level variance							
Complete case		0.02	(0.01–0.04)	0.02	(0.01–0.08)		
Imputed				**0.01**	**(0.00–0.04)**		

Table continued

Table 2 Continued

Process performance measures	Died % (*N*)	Basis OR (95% CI) Model 0[a]		Adjusted OR (95% CI) Model 1[b]		Adjusted OR (95% CI) Model 2[c]	
Random effect							
Unit-level variance							
Complete case						0.05	(0.02–0.14)
Imputed						**0.04**	**(0.02–0.10)**

The bold values in the table refer to the imputed analysis.
[a]Model 0: Adjusted for the hierarchical data structure.
[b]Model 1: Adjusted for gender, age, housing, BMI, CCI, type of fracture, fracture displacement, type of surgery, time to surgery, civil status, family mean income, hip fracture patient volume and unit setting.
[c]Model 2: Adjusted for covariates as in Model 1 and all process performance measures for their mutual adjustment.

Table 3 Proportion of fulfillment of all relevant process performance measures and clinical outcomes

	Patients, *n*	Events, *n* (%)/Median (IQR)[a]		Basis ratio[b] (95% CI) Model 0[c]		Adjusted ratio[d] (95%CI) Model 1	
30-day mortality							
0–50% fulfillment (ref)	2908	22.6	(657)				
50–75% fulfillment complete case	3071	17.4	(533)	0.73	(0.64–0.83)	0.52	(0.41–0.65)
50–75% fulfillment imputed						**0.71**	**(0.61–0.82)**
75–100% fulfillment complete case	19375	8.5	(1645)	0.30	(0.27–0.33)	0.21	(0.17–0.26)
75–100% fulfillment imputed						**0.32**	**(0.29–0.36)**
Random effect							
Unit-level variance							
Complete case				0.03	(0.01–0.07)	0.07	(0.03–0.17)
Imputed						**0.03**	**(0.01–0.07)**
Length of hospital stay in days among patients discharge alive							
0–50% fulfillment (ref)	2388	8.8	(5.6–14.8)				
50–75% fulfillment complete case	2734	8.0	(5.7–12.2)	1.01	(0.98–1.05)	1.00	(0.95–1.05)
50–75% fulfillment imputed						**1.03**	**(0.99–1.06)**
75–100% fulfillment complete case	18519	8.5	(5.8–12.3)	0.98	(0.96–1.01)	0.94	(0.90–0.98)
75–100% fulfillment imputed						**0.97**	**(0.94–1.00)**
Random effect							
Individual-level variance							
Complete case				0.39	(0.38–0.39)	0.26	(0.25–0.26)
Imputed							
Unit-level variance							
Complete case				0.05	(0.50–0.51)	0.04	(0.02–0.07)
Imputed						**0.04**	**(0.02–0.06)**
Readmission within 30 days after admission among patients discharge alive							
0–50% fulfillment (ref)	2388	519	(21.7)				
50–75% fulfillment complete case	2734	483	(17.7)	0.8	(0.69–0.91)	0.83	(0.64–1.08)
50–75% fulfillment imputed						**0.79**	**(0.69–0.91)**
75–100% fulfillment complete case	18519	3219	(17.4)	0.76	(0.68–0.85)	0.83	(0.66–1.04)
75–100% fulfillment imputed						**0.78**	**(0.70–0.87)**
Random effect							
Unit-level variance							
Complete case				0.02	(0.01–0.05)	0.02	(0.01–0.05)
Imputed						**0.01**	**(0.00–0.03)**

The bold values in the table refer to the imputed analysis.
[a]IQR = interquartile range.
[b]OR, if 30-day mortality or readmission and ratio between geometric means if LOS.
[c]Model 0: Adjusted for the hierarchical data structure.
[d]Model 1: Adjusted for gender, age, housing, BMI, CCI, type of fracture, fracture displacement, type of surgery, time to surgery, civil status, family mean income, hip fracture patient volume and unit setting.

day was associated with improved function, survival and readmission [5]. However, the association did not remain statistical significant in the adjusted analyses. This may be explained by the relative small study size in this study, which may have affected the statistical power in the adjusted analysis, as the point estimates still indicated an association after adjustment.

LOS was also lower for patients receiving mobilization within 24 hours postoperatively in our study. This has previously been

Table 4 Association between process performance measure and readmission within 30 days after discharge among patients discharged alive

Process performance measures	Events % (*N*)	Basis OR		Adjusted OR		Adjusted OR	
		(95% CI) Model 0[a]		(95% CI) Model 1[b]		(95% CI) Model 2[c]	
Systematic pain assessment							
No (ref)	21.1% (656/3112)						
Yes Complete case	16.9% (2599/15343)	0.76	(0.68–0.84)	0.92	(0.77–1.10)	0.92	(0.77–1.10)
Imputed				**0.80**	**(0.72–0.89)**	**0.86**	**(0.76–0.98)**
Random effect							
Unit-level variance							
Complete case		0.03	(0.01–0.06)	0.01	(0.00–0.05)		
Imputed				**0.01**	**(0.00–0.03)**		
Mobilized <24 h postoperatively							
No (ref)	20.7% (994/4807)						
Yes Complete case	16.9% (3008/17780)	0.80	(0.74–0.87)	0.88	(0.78–0.98)	0.88	(0.78–0.98)
Imputed				**0.84**	**(0.78–0.92)**	**0.90**	**(0.82–0.99)**
Random effect							
Unit-level variance							
Complete case		0.02	(0.01–0.05)	0.02	(0.01–0.04)		
Imputed				**0.01**	**(0.00–0.03)**		
Basic mobility assessment at admission							
No (ref)	16.1% (102/634)						
Yes Complete case	17.9% (477/2673)	1.03	(0.79–1.34)	1.28	(0.90–1.84)	1.28	(0.91–1.78)
Imputed				**1.17**	**(0.90–1.52)**	**1.23**	**(0.97–1.57)**
Random effect							
Unit-level variance:							
Complete case		0.06	(0.02–0.17)	0.02	(0.00–0.27)		
Imputed				**0.03**	**(0.01–0.15)**		
Basic mobility assessment at discharge							
No (ref)	18.1% (1081/5986)						
Yes Complete case	17.8% (3140/17655)	0.88	(0.80–0.97)	1.02	(0.89–1.17)	1.04	(0.90–1.19)
Imputed				**0.91**	**(0.83–1.00)**	**0.97**	**(0.88–1.07)**
Random effect							
Unit-level variance							
Complete case		0.03	(0.01–0.06)	0.02	(0.01–0.05)		
Imputed				**0.01**	**(0.01–0.04)**		
Post-discharge rehabilitation program							
No (ref)	20.5% (224/1094)						
Yes Complete case	17.7% (3804/21438)	0.87	(0.75–1.01)	0.83	(0.67–1.03)	0.83	(0.67–1.04)
Imputed				**0.89**	**(0.76–1.04)**	**0.96**	**(0.82–1.12)**
Random effect							
Unit-level variance:							
Complete case		0.03	(0.01–0.05)	0.02	(0.01–0.05)		
Imputed				**0.01**	**(0.01–0.04)**		
Anti-osteoporotic medication							
No (ref)	21.4% (488/2284)						
Yes Complete case	17.5% (3733/21357)	0.79	(0.71–0.88)	0.95	(0.75–1.20)	0.92	(0.72–1.17)
Imputed				**0.79**	**(0.71–0.88)**	**0.85**	**(0.73–0.99)**
Random effect							
Unit-level variance							
Complete case		0.02	(0.01–0.05)	0.02	(0.01–0.05)		
Imputed				**0.01**	**(0.00–0.03)**		
Prevention of future fall accidents							
No (ref)	19.3% (813/4210)						
Yes Complete case	17.5% (3408.19431)	0.90	(0.82–0.99)	1.10	(0.94–1.27)	1.14	(0.97–1.34)
Imputed				**0.92**	**(0.84–1.01)**	**1.10**	**(0.98–1.23)**
Random effect							
Unit-level variance							
Complete case		0.02	(0.01–0.05)	0.02	(0.01–0.05)		
Imputed				**0.01**	**(0.00–0.03)**		

Table continued

Table 4 Continued

Process performance measures	Events % (N)	Basis OR (95% CI) Model 0[a]		Adjusted OR (95% CI) Model 1[b]		Adjusted OR (95% CI) Model 2[c]	
Random effect							
Unit level variance							
Complete case						0.02	(0.01–0.05)
Imputed						**0.01**	**(0.00–0.03)**

The bold values in the table refer to the imputed analysis.
[a]Model 0: Adjusted for the hierarchical data structure.
[b]Model 1: Adjusted for gender, age, housing, BMI, CCI, type of fracture, fracture displacement, type of surgery, time to surgery, civil status, family mean income, hip fracture patient volume and unit setting.
[c]Model 2: Adjusted for covariates as in Model 1 and all process performance measures for their mutual adjustment.

Table 5 Association between process performance measure and LOS when excluding patients who died during hospitalization

Process performance measures	Median LOS in days (IQR)	Basis OR (95% CI) Model 0[a]		Adjusted OR (95% CI) Model 1[b]		Adjusted OR (95% CI) Model 2[c]	
Systematic pain assessment							
No (ref)	8.7 (5.9–13.9)						
Yes Complete case	8.8 (6.3–12.7)	1.03	(1.01–1.05)	1.01	(0.97–1.04)	1.02	(0.98–1.05)
Imputed				**1.01**	**(0.99–1.03)**	**1.05**	**(1.02–1.08)**
Random effect							
Individual-level variance							
Complete case		0.34	(0.33–0.34)	0.26	(0.25–0.26)		
Imputed				**0.26**	**(0.25–0.26)**		
Unit-level variance							
Complete case		0.05	(0.03–0.09)	0.04	(0.02–0.07)		
Imputed				**0.04**	**(0.02–0.07)**		
Mobilized <24 h postoperatively							
No (ref)	9.8 (6.1–15.3)						
Yes Complete case	8.1 (5.8–11.8)	0.89	(0.87–0.90)	0.84	(0.82–0.88)	0.84	(0.83–0.86)
Imputed				**0.87**	**(0.86–0.89)**	**0.85**	**(0.84–0.87)**
Random effect							
Individual-level variance							
Complete case		0.37	(0.36–0.38)	0.24	(0.24–0.25)		
Imputed				**0.26**	**(0.26–0.27)**		
Unit-level variance							
Complete case		0.05	(0.03–0.09)	0.04	(0.02–0.06)		
Imputed				**0.04**	**(0.02–0.07)**		
Basic mobility assessment at admission							
No (ref)	7.1 (4.9–11.0)						
Yes Complete case	7.7 (5.5–11.0)	1.10	(1.03]–1.17)	1.00	(0.93–1.07)	1.03	(0.97–1.10)
Imputed				**1.03**	**(0.98–1.09)**	**1.04**	**(0.99–1.09)**
Random effect							
Individual-level variance							
Complete case		0.34	(0.32–0.35)	0.23	(0.22–0.24)		
Imputed				**0.24**	**(0.23–0.26)**		
Unit-level variance							
Complete case		0.06	(0.03–0.11)	0.04	(0.02–0.07)		
Imputed				**0.03**	**(0.02–0.06)**		
Basic mobility assessment at discharge							
No (ref)	8.1 (5.8–12.5)						
Yes Complete case	8.6 (5.8–12.6)	0.92	(0.90–0.94)	0.90	(0.87–0.92)	0.91	(0.88–0.93)
Imputed				**0.92**	**(0.90–0.94)**	**0.92**	**(0.90–0.94)**
Random effect							
Individual-level variance							
Complete case		0.39	(0.38–0.39)	0.25	(0.25–0.26)		
Imputed				**0.27**	**(0.27–0.28)**		
Unit-level variance							
Complete case				0.06	(0.03–0.10)	0.04	(0.03–0.08)
Imputed				**0.04**	**(0.03–0.08)**		

Table continued

Table 5 Continued

Process performance measures	Median LOS in days (IQR)	Basis OR (95% CI) Model 0[a]		Adjusted OR (95% CI) Model 1[b]		Adjusted OR (95% CI) Model 2[c]	
Post-discharge rehabilitation program							
No (ref)	8.0 (4.6–14.1)						
Yes Complete case	8.5 (5.9–12.3)	1.13	(1.08–1.17)	1.04	(0.99–1.08)	1.06	(1.01–1.11)
Imputed				**1.06**	**(1.03–1.10)**	**1.09**	**(1.05–1.12)**
Random effect							
Individual-level variance							
Complete case		0.37	(0.36–0.37)	0.24	(0.24–0.25)		
Imputed				**0.26**	**(0.26–0.27)**		
Unit-level variance							
Complete case		0.05	(0.03–0.09)	0.04	(0.02–0.08)		
Imputed				**0.04**	**(0.03–0.08)**		
Anti-osteoporotic medication							
No (ref)	8.8 (5.7–14.8)						
Yes Complete case	8.5 (5.8–12.4)	0.98	(0.95–1.01)	1.02	(0.98–1.07)	1.02	(0.98–1.07)
Imputed				**0.99**	**(0.97–1.02)**	**1.03**	**(1.00–1.06)**
Random effect							
Individual-level variance							
Complete case		0.39	(0.38–0.39)	0.26	(0.25–0.26)		
Imputed				**0.27**	**(0.26–0.28)**		
Unit-level variance							
Complete case		0.05	(0.03–0.09)	0.04	(0.02–0.07)		
Imputed				**0.04**	**(0.02–0.07)**		
Prevention of future fall accidents							
No (ref)	8.3 (5.7–13.1)						
Yes Complete case	8.5 (5.8–12.5)	1.00	(0.98–1.03)	1.05	(1.02–1.08)	1.06	(1.03–1.10)
Imputed				**1.01**	**(0.99–1.03)**	**1.05**	**(1.03–1.08)**
Random effect							
Individual-level variance							
Complete case		0.39	(0.38–0.39)	0.26	(0.25–0.26)		
Imputed				**0.27**	**(0.27–0.28)**		
Unit-level variance							
Complete case		0.05	(0.03–0.09)	0.04	(0.02–0.07)		
Imputed				**0.04**	**(0.02–0.07)**		
Random effect							
Individual-level variance							
Complete case						0.25	(0.24–0.26)
Imputed						**0.27**	**(0.26–0.27)**
Unit-level variance							
Complete case						0.05	(0.03–0.08)
Imputed						**0.05**	**(0.03–0.08)**

The bold values in the table refer to the imputed analysis.

[a]Model 0: Adjusted for the hierarchical data structure.

[b]Model 1: Adjusted for gender, age, housing, BMI, CCI, type of fracture, fracture displacement, type of surgery, time to surgery, civil status, family mean income, hip fracture patient volume and unit setting.

[c]Model 2: Adjusted for covariates as in Model 1 and all process performance measures for their mutual adjustment.

reported from a randomized controlled trial from Australia with 60 patients [21]. Here early mobilization accelerated functional recovery and contributed to a 2.1 days shorter LOS. This is comparable to our finding of a difference in LOS of 1.7 days.

We are unaware of any studies that have investigated the association between receiving a post-discharge rehabilitation program and mortality among hip fracture patients. It can be hypothesized that receiving the rehabilitation program before discharge is a proxy measure for a good transition to the health service in the municipalities, which accelerates recovery and contributes to lower mortality.

Our finding of an overall association between the opportunity-based score of process performance and 30-day mortality is in accordance with previous findings from another Danish study based on a somewhat different set of process performance measures, which found an adjusted OR for 30-day mortality of 0.28 (95% CI: 0.18–0.44) for receiving 81–100% of relevant processes performance measures [4]. To the best of our knowledge, no prior studies have examined the association between the specific performance measures used in our study and readmission within 30 days. Siu *et al.* also assessed the association between nine quality measures and readmission within 2 months [5]. They found an adjusted hazard ratio of readmission within 2 months of 0.95 (95% CI: 0.91–0.98) for meeting the whole scale of processes of care. The stronger association revealed in our study may be explained by that our study examines performance measures and not patient predictors such as abnormal clinical findings before surgery and number of days of severe pain. No performance measures were independently associated with lower readmission rates. In our study, we found that performance measures such as systematic pain assessment, mobilization within 24 h postoperative and initiation of anti-osteoporotic medication were independently associated with lower odds for all-cause readmission within 30 days after discharge.

This study has potential limitations. Data were collected by a large number of clinicians during routine clinical work, which may reduce the reliability of data. However, major efforts including dissemination of detailed written instructions for reporting of data to the DMHFR and regular clinical audits have been carried out to ensure validity of the data. The process performance measures can only describe whether the patient has been assessed but does not provide information concerning whether patients actually were treated appropriately according to results of the assessments [7]. However, such miscoding and misclassification are highly unlikely to be differential and would therefore tend to underestimate rather than overestimate the true association. Furthermore, our results may have been influenced by confounding by contraindication. The staff may have been less likely to offer early and appropriate care for frail patients near end-of-life. However, the staff had the possibility to consider the patients ineligible for the process performance measures, e.g. if the patient was found too weak to participate in mobilization and therefore excluded from the analysis. Furthermore, we conducted a sensitivity analysis excluding all patients who died during hospitalization and found the same associations. Still, we cannot exclude the possibility that our findings remain influenced by unmeasured and residual confounding (e.g. lack of information on preoperative functional level or preexisting dementia) [22, 23].

The strengths of our study include the population-based design with prospective data collection and complete follow-up, which minimized the risk of selection and information bias. Furthermore, we were able to adjust for a range of potential confounders. Unfortunately, no nationwide data quality audit of DNRP-reported diagnosis and operation codes for emergency patients with proximal femoral fracture exist. However, a regional pilot test indicates high predictive value for the presence of true operated hip fracture for the combination of the code for diagnosis of hip fracture and hip surgery code.

The total variation at the unit level was low, which indicates that the patients in the units were not much correlated. However, we used the hierarchical structure to include explanatory variables such as unit volume and unit setting at unit level.

Conclusions

In conclusion, individual and opportunity-based process performance measures of in-hospital care were associated with patient outcomes including 30-day mortality, early readmission and LOS among patients with hip fracture. Looking at the process performance individually, mobilization within 24 h postoperatively was particularly strongly associated with a better all-patient outcomes, while systematic pain assessment and anti-osteoporotic medication were linked with lower odds of readmission. These findings link hospitals' performance with better survival and lower readmission risk, which may have substantial implications for hip fracture patients and health care as it represents a feasible avenue for improving quality of care for hip fracture patients.

Acknowledgements

We thank the staff of the hospital departments caring for patients with hip fracture for their continuous effort and contribution to acquisition of the data in the Danish Multidisciplinary Hip Fracture Registry.

Funding

This work was supported by the Health Research Fund of Central Denmark Region, the Family Hede Nielsens Fund and Gurli and Friis Engell Fund. The financial sponsors did not play a role in the design, execution, analysis, interpretation of data or writing of the study.

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Appendix 1. Table that illustrates the association between process performance measure and 30-day mortality when excluding patients who died during hospitalization

Proces performance measures	Died % (*N*)	Basis OR (95 % CI), Model 0[a]		Adjusted OR (95% CI), Model 1[b]		Adjusted OR (95% CI), Model 2[c]	
Systematic pain assessment							
No (ref)	5.4 % (168/3112)						
Yes Complete case	2.9 % (450/15343)	0.49	(0.41–0.60)	0.63	(0.43–0.92)	0.79	(0.55–1.15)
Imputed				0.65	(0.53–0.80)	0.88	(0.68–1.14)
Random effect							
Unit-level variance							
Complete case		0.11	(0.04–0.26)	0.05	(0.01–0.26)		
Imputed				0.03	(0.01–0.14)		
Mobilized < 24h postoperatively							
No (ref)	6.7 % (321/4807)						
Yes Complete case	4.1 % (734/17780)	0.58	(0.50–0.66)	0.63	(0.52–0.76)	0.69	(0.56–0.83)
Imputed				0.71	(0.62–0.83)	0.79	(0.68–0.93)
Random effect							
Unit-level variance							
Complete case		0.04	(0.02–0.09)	0.03	(0.01–0.12)		
Imputed				0.03	(0.01–0.08)		
Basic mobility assessment at admission							
No (ref)	7.9 % (50/634)						
Yes Complete case	4.6 % (122/2673)	0.56	(0.40–0.79)	0.96	(0.53–1.72)	1.06	(0.60–1.86)
Imputed				0.74	(0.50–1.09)	0.78	(0.53–1.14)
Random effect							
Unit-level variance							
Complete case		<0.01	(0.00–0.23)	<0.01	(0.00–0.01)		
Imputed				<0.01	(0.00–0.01)		
Basic mobility assessment at discharge							
No(ref)	6.2 % (370/5986)						
Yes Complete case	4.8 % (850/17655)	0.74	(0.64–0.85)	0.85	(0.69–1.05)	0.96	(0.76–1.22)
Imputed				0.78	(0.67–0.91)	0.93	(0.79–1.10)
Random effect							
Unit-level variance							
Complete case		0.03	(0.01–0.07)	0.02	(0.00–0.11)		
Imputed				0.02	(0.01–0.06)		
Postdischarge rehabilitation program							
No (ref)	11.1 % (121/1094)						
Yes Complete case	4.3 % (927/21438)	0.34	(0.28–0.42)	0.45	(0.32–0.64)	0.52	(0.37–0.74)
Imputed				0.41	(0.33–0.51)	0.46	(0.37–0.58)
Random effect							
Unit-level variance							
Complete case		0.04	(0.02–0.11)	0.04	(0.01–0.14)		
Imputed				0.03	(0.01–0.09)		
Antiosteoporotic medication							
No (ref)	6.4 % (147/2284)						
Yes Complete case	5.0 % (1073/21357)	0.76	(0.63–0.91)	0.78	(0.52–1.17)	0.90	(0.58–1.39)
Imputed				0.77	(0.63–0.94)	0.81	(0.62–1.07)
Random effect							
Unit-level variance							
Complete case		0.03	(0.01–0.07)	0.02	(0.00–0.10)		
Imputed				0.02	(0.01–0.07)		
Prevention of future fall accidents							
No (ref)	5.8 % (243/4210)	1		1		1	
Yes Complete case	5.0 % (977/19431)	0.87	(0.74–1.00)	0.99	(0.76–1.30)	1.06	(0.79–1.42)
Imputed				0.92	(0.78–1.08)	1.06	(0.86–1.30)
Random effect							
Unit-level variance							
Complete case		0.02	(0.01–0.07)	0.02	(0.00–0.10)		
Imputed				0.02	(0.01–0.06)		
Random effect							
Unit-level variance							
Complete case						0.05	(0.02–0.15)
Imputed						0.04	(0.02–0.10)

[a]Model 0 Adjusted for the hierarchical data structure.
[b]Model 1: Adjusted for gender, age, CCI, type of fracture, type of surgery, time to surgery, civil status, family mean income, patientvolume and unit setting.
[c]Model 2: Adjusted for covariates as in model 1 and all process performance measures for their mutual adjustment.

Paper II

Is high quality of care associated with higher costs?
– A nationwide cohort study among hip fracture patients.

Is high quality of care associated with higher costs? - a nationwide cohort study among hip fracture patients

ABSTRACT:

Background It is unknown whether improvements in quality of care will require increased spending or lead to a reduction in costs.

Objective To examine whether fulfilment of process performance measures are associated with in-hospital costs among hip fracture patients.

Design A nationwide cohort study with 20,458 hip fracture patients ≥65 years based on prospectively collected data from the Danish Multidisciplinary Hip Fracture Registry including fulfilment of seven process performance measures from the national multidisciplinary guideline for in-hospital hip fracture care: systematic pain assessment, early mobilization, basic mobility assessment before admission and discharge, post discharge rehabilitation program, anti-osteoporotic medication and prevention of future fall accidents. Total costs were defined as the sum of costs used for treating the individual patient according to the Danish Reference Cost Database.

Results Fulfilment of nearly all process performance measures were all associated with lower total costs within the index admission. The adjusted ratio ranged from 0.91 (95% Confidence Interval (CI): 0.91-0.92) to 0.99 (95% CI: 0.98-0.99), corresponding to adjusted mean differences between EUR304 to EUR3538. Receiving between 50% to 75% or more than 75% of the performance measures were also associated with lower total costs. The association were weakened when taking into account all costs related to hospitalisations within the first year.

Conclusions Improvement in quality of care will not imply increased spending and may even lead to lower hospital costs for the index admission and within the first year.

INTRODUCTION

Healthcare systems in highly developed countries face similar challenges with a need to improve not only productivity but also quality of care and patient safety. The challenge has in recent years been addressed in different ways, including by the introduction of the highly profiled concept of "Triple Aim" by Institute of Healthcare Improvement[1]. This framework aims for simultaneous improvement in patient experience of care (including quality and satisfaction), the health of populations and a reduction in the per capita cost of health care[1]. Although the idea of Triple Aim is highly appealing, our current understanding of the association between quality of care and costs is limited and the available data are sparse. It is consequently unknown whether improvements in quality of care will require increased health care spending or whether improvements in quality of care will lead to a reduction in adverse patient outcomes, including fewer complications and readmissions, and less inappropriate use of health care and hereby to lower costs[1-4]. Studies have shown considerable geographical variation in healthcare expenditures and a weak or even negative overall association between costs and quality of care at regional level[3, 5-10]. Other studies using hospital level data have shown conflicting conclusions[9, 11-14]. The inconsistency may be caused by different levels of analysis (e.g. area-level versus provider level analysis) and different measures of quality of care (e.g. structure, process and outcome) as a structure related quality measure such as specialisation may have different cost implications than provider process performance[2]. A better understanding of the complex relationship between quality and costs is therefore required. Hip fracture is a well-suited case for examining the association between quality and costs as it is a common and costly injury among the frail and elderly involving many aspects of in-hospital care and is often used as a tracer for the overall quality at the hospital level[15-17]. However, so far only a few studies have examined the association between quality related processes and costs. Furthermore, the studies have been limited by small sample sizes and the fact that they only focused on aggregated quality of care data at hospital level, and access only to information on reimbursement costs rather than information on actual costs[18-21]. It therefore remains unknown whether quality of care as defined by process performance measures reflecting multidisciplinary clinical guideline recommendations are associated with in-hospital costs among patients with hip fracture.

The availability of nationwide, population-based registries with detailed individual-level information on quality of in-hospital care, patients characteristics and costs of care makes Denmark a relevant setting for further exploring the association between quality of care and hospital costs in routine clinical settings. The topic is of particular importance as it has recently been demonstrated at patient-level that high process performance is associated with lower 30-day mortality and lower risk for acute readmission after discharge among Danish hip fracture patients[22]. Hence, it is urgent to clarify whether it is possible to achieve the good clinical outcome through high process performance without increasing hospital costs.

MATERIALS AND METHODS

Design and setting:

We conducted a population-based cohort study using prospectively collected data available from medical registries covering the entire population in Denmark (5.7 million inhabitants)[23]. All medical emergencies in Denmark, including hip fracture, are exclusively treated at public hospitals. We used the Danish Multidisciplinary Hip Fracture Registry (DMHFR) to identify a cohort of hip fracture patients admitted to all Danish hospitals between 2010 and 2013[24]. We linked these data to other national population-based registries, including the Danish National Registry of Patients, the Danish Civil Registration System, the Danish Reference Cost Database and the population, education and income registries from Statistics Denmark[25, 26]. Accurate and unambiguous linkage of all registries was made possible by using the unique Central Personal Registration (CPR) number assigned to all Danish citizens at birth and to residents upon immigration[27]. The study was approved by the Danish Data Protection Agency (journal number 2012-41-1274).

Data sources:

The Danish Multidisciplinary Hip Fracture Registry (DMHFR) was established in 2003 to document and improve in-hospital quality of care among patients with hip fracture. The registry includes patient-level data on whether patients received recommended processes related to the early management of hip fracture and data on the patients' sociodemographic and clinical characteristics. Data are prospectively collected for each patient from the time of hospital admission, and reporting is mandatory for all Danish hospital departments treating patients with hip fracture[24].

The Danish National Registry of Patients (DNRP) provides information on all non-psychiatric hospital inpatient admissions since 1977 and on all outpatient clinic and emergency room visits since 1995[28]. Each hospital discharge or outpatient visit is recorded with one primary diagnosis and up to 19 secondary diagnoses classified according to a Danish classification (1977 through 1995) and a Danish version of the Nordic Medico-Statistical Committee (NOMESCO) Classification of Surgical Procedures (from 1996 on)[28].

The Danish Civil Registration System (CRS), established in 1968, contains information on sex, residence, and date of death and emigration, with daily updates[27].

The Danish Reference Cost Database was established in 2005 to support the development and validation of national tariffs for case-mix groups of the Diagnosis-Related Grouping-based remuneration model. The registry contains information on resource use and costs at the individual patient level. Information about costs is linked to activities, procedures and bed days / visits using patient administrative data and performance data respectively. Overall, patient costs are therefore calculated from bed costs from the primary department and activity costs from transversal departments. Hospitals report to the database once a year based on accounting figures.

Statistics Denmark is a collection of registry data with detailed information on each citizen [29, 30]. The education register contains information on type of education. The income registry contains data on income composition at the individual level and household level. The population register contains data on emigration status and residence area on each citizen. We used the three registers to obtain data on highest obtained education, family income and ethnicity. These registers are updated yearly.

Study population:

We identified hospitalisations for patients with hip fracture (The International Classification of Diseases 10th revision (ICD-10) codes S720 to S722) registered in the DMHFR with a discharge date between 1 March 2010 and 31 November 2013 (N=26,271). We only included the first admission in the study period for patients with more than one hip fracture during the study period. Patients who had immigrated within the last 5 years were excluded because of insufficient information in the Danish registries (n=80). Patients without a registered address (n=16) were also excluded. Furthermore, we excluded patients who had been treated at a hospital that had not reported to the Danish Reference Cost Database for the year in question due to lack of financial employees to calculate the yearly cost report for the hospital (n=2,617). One patient who was registered as hospitalised for more than one year and 2,278 patients with erroneously recorded data with no radiology, surgery and bed day cost were also excluded, which left a total of 20,458 (81 %) patients available for analyses.

Quality of in-hospital care:

Quality of in-hospital care was assessed as fulfilment of seven process performance measures reported to the DMHR reflecting whether the patients received care according to the national clinical guidelines for hip fracture care. The process performance measures are defined in Table 1.

Table 1: Definition of the process performance measures and fulfilment

Process performance measures	Proportion of fulfilment %	(N)	Definition
Systematic pain assessment.			
No	19.5	(3,111)	Measured daily by a visual analog scale or a numeric rating scale at rest and during mobilization.
Yes	80.5	(12,845)	
Lack of indication		(4,506)	

Mobilization within 24 hours postoperatively.			
No	22.7	(4,380)	Defined as assisting the patient from bed-rest to walking or rest in a chair.
Yes	77.3	(14,901)	
Lack of indication		(1,177)	
Basic mobility assessment prior to admission.			
No	22.2	(666)	Measured at admission by a validated test such as Cumulated Ambulation Score, Barthel 20, Functional Recovery score or New Mobility score.
Yes	77.8	(2,339)	
Lack of indication		(17,453)	
Basic mobility assessment at discharge			
No	26.6	(5,063)	By a validated test such as Cumulated Ambulation Score, Barthel 20, Functional Recovery score or New Mobility score.
Yes	73.4	(13,982)	
Lack of indication		(1,413)	
Post discharge rehabilitation program.			
No	5.1	(931)	Including assessment of activities of daily living (ADL) with a validated test before the fracture and again before discharge
Yes	94.9	(17,202)	
Lack of indication		(2,325)	
Anti-osteoporotic medications.			
No	10.9	(2,221)	Initiation of treatment with anti-osteoporotic medications.
Yes	89.1	(18,237)	
Prevention of future fall accidents.			
No	20.0	(4,090)	Including a fall risk assessment to account for co-existing medical conditions, medication, functional disability, symptoms from the central nervous system, musculoskeletal system and cardiopulmonary status.
Yes	80.0	(16,368)	

Lack of indication : Patients were classified as eligible or ineligible for each individual process depending on whether the hospital staff identified contraindications
(e.g. dementia that disabled the patients from reporting their level of pain during mobilisation).

Patients were classified as eligible or ineligible for each individual processes of care depending on whether the hospital staff identified contraindications (e.g. dementia that disabled the patients from reporting their level of pain during mobilisation). We examined the measures individually and as a composite score; overall proportion of fulfilled relevant measures for each patient. The score was calculated by dividing the total number of fulfilled measures for each patient with the total number of measures for which the patient was deemed eligible. The composite score was categories according to whether 0-50%, 50-75% and 75-100% of all relevant process performance measures had been met for the individual patient. The categorisation was chosen pragmatically in order to ensure a reasonable number of patients in each group.

Outcome:

Hospitals costs were measured as the sum of costs used by the individual patient for both orthopaedic and non-orthopaedic diseases based on information the Danish Reference Cost Database. The costs were calculated as the total costs and the costs for different cost categories including radiology services, surgery and anaesthesia services, further diagnostic services, further treatment services, therapy services and bed days. The day of admission was the start time window for both endpoints (index admission and one year). Indirect costs were not included because of the high mean age of the patients (mean age 84 years). All costs were inflated to the common price year of 2014 using the general consumer price index and converted into EUR by a fixed exchange rate (7.45 DKK = 1 EUR).

Patient and hospital characteristics:

A priori identified potential patient-level confounders included sex, age, highest obtained education, 5-year family income, cohabiting status, ethnicity, housing, body mass index (BMI), Charlson Comorbidity index score (CCI), fracture type, fracture displacement, type of surgery and time to surgery[31-33]. At the hospital unit level, we adjusted for yearly hip fracture patient volume and orthogeriatric specialisation[34, 35] (Supplemental Appendix 1).

Statistical analysis:

First, we examined patient and hospital characteristics, stratified by the composite score categories (i.e., 0-50%, 50-75%, 75-100% of all relevant process performance measures fulfilled). Secondly, we calculated the mean, and 10% and 90 % percentiles for the total cost according to each process. The association between the individual process performance measures, as well as the overall proportion of process performance measures fulfilled and the total hospital cost was analysed using a multilevel linear regression model (xtmixed commando in STATA) in order to estimate the cost after adjustment for the aforementioned covariates and taking into account the hierarchical data structure with patients nested in hospitals. A natural log-transformation was used to correct for the right-skewness in cost data, and the cost differences were reported as ratios between arithmetic means. The adjusted mean costs were estimated by the equation: mean=exp(mean(log)+0.5 x total variance). Furthermore, we calculated the mean, 10% and 90% percentiles for the costs according to each cost category and total cost within the index admission and within the first year. To handle missing data on covariates including housing, BMI, fracture displacement, education and time to surgery multivariate imputation by chained equations (MICE procedure in Stata) were performed based on the missing at random assumption. The distribution of the observed data (see Supplemental Appendix 1) was used to estimate multiple values of e.g. missing baseline BMI that reflect the uncertainty around the true value[36]. We generated 25 complete data sets with imputed data using all available information from patients presented in Supplemental Appendix 1, including also outcome data. All analyses were also performed only for patients for whom complete data were available (n=11754). Furthermore, we tested a number of alternative specifications for total costs including different categorisations and a quadric polynomial model. None of these were found to alter the conclusion of the base case analysis.

RESULTS

Patient characteristics of the 20,458 included patients with hip fracture are summarized in Supplemental Appendix 1. Patients receiving care meeting 0-50% of the relevant process performance measures on average had a more adverse prognostic profile. Higher 30-day mortality was observed among the patients that received lowest quality of care compared to patients receiving care in accordance with clinical guidelines recommendations (21.9 % versus 8.4 %).

Index admission:

The individual process performance measures were all associated with lower mean total costs within the index admission, however, the differences were small for some of the process performance measures (Table 2).

Table 2: Fulfilment of individual process performance measures and total hospital costs in euro within index admission and within the first year.

	Mean total cost in euro	(P10-p90)[1]	Adjusted mean total cost in euro	Crude ratio[2] (95 %CI)		Adjusted ratio[3] (95 % CI)	
Index admission:							
Systematic pain assessment							
No (Reference)	13,783	(6,101-22,972)	15,365				
Yes	12,289	(6,471-19,234)	13,670	0.99	(0.97-1.01)	0.98	(0.97-0.98)
Mobilisation < 24 hours after surgery							
No (Reference)	14,474	(6,369-24,477)	16,038				
Yes	11,739	(6,248-18,172)	13,008	0.91	(0.89-0.92)	0.91	(0.91-0.92)
Basic mobility assessment at admission							
No (Reference)	12,198	(5,601-19,406)	13,558				
Yes	11,445	(5,878-17,463)	12,721	1.02	(0.98-1.07)	0.95	(0.94-0.95)
Basic mobility assessment at discharge							
No (Reference)	12,734	(6,399-20,346)	14,024				
Yes	11,874	(6,180-19,035)	13,077	0.93	(0.92-0.95)	0.99	(0.97-1.00)
Rehabilitation program							
No (Reference)	12,237	(5,398-23,292)	13,451				
Yes	11,960	(6,341-18,838)	13,147	1.05	(1.02-1.08)	1.01	(0.97-1.05)
Antiosteoporotic medication							
No (Reference)	15,270	(6,045-25,966)	17,007				
Yes	12,094	(6,215-19,038)	13,469	0.93	(0.91-0.95)	0.94	(0.94-0.95)
Initiation of treatment to prevent future fall accidents.							
No (Reference)	13,292	(5,871-23,528)	14,822				
Yes	12,226	(6,280-19,123)	13,633	0.99	(0.98-1.01)	0.99	(0.98-0.99)
Within the first year:							
Systematic pain assessment							
No (Reference)	20,427	(7,015-38,573)	24,462				
Yes	19,125	(7,735-34,763)	22,903	1.01	(0.98-1.03)	0.99	(0.98-1.00)
Mobilisation < 24 hours after surgery							
No (Reference)	20,799	(7,262-38,825)	24,643				
Yes	18,130	(7,303-33,083)	21,480	1.07	(1.00-1.14)	0.95	(0.94-0.95)
Basic mobility assessment at admission							
No (Reference)	17,770	(6,745-30,526)	21,597				
Yes	18,031	(6,929-33,647)	21,914	1.06	(1.02-1.10)	1.02	(1.00-1.04)
Basic mobility assessment at discharge							
No (Reference)	19,530	(7,512-35,445)	23,038				
Yes	18,579	(7,274-34,312)	21,917	0.95	(0.92-0.98)	0.96	(0.96-0.97)
Rehabilitation program							
No (Reference)	18,979	(6,350-34,797)	22,373				
Yes	18,733	(7,444-34,370)	22,083	1.06	(1.02-1.10)	1.05	(1.04-1.06)
Antiosteoporotic medication							
No (Reference)	21,417	(6,942-38,800)	25,476				
Yes	18,374	(7,199-33,687)	21,857	0.96	(0.93-0.99)	0.96	(0.96-0.97)

Initiation of treatment to prevent future fall accidents.							
No (Reference)	22,638	(6,844-36,981)	26,946				
Yes	18,457	(7,261-33,687)	21,969	1.00	(0.97-1.02)	0.99	(0.98-0.99)

1) P10-P90, range of data from 10 % percentile to 90 % percentile.
2) Crude ratio but taking the hierarchical data structure into account
3) Adjusted for gender, age, Charlson Comorbidity Index, Body Mass Index, type of fracture, fracture displacement, type of surgery, time to surgery, civil status, five year family mean income, highest obtained education, ethnicity, yearly unit hip fracture patient volume and orthogeriatric care.

The unadjusted mean differences ranged from EUR270 to EUR2735. The largest difference in mean total costs was seen for mobilisation within 24 hours after surgery and for receiving osteoporotic medication. The associations remained in the adjusted analysis except for receiving postoperative rehabilitation program. The adjusted ratio ranged from 0.91 (95% CI: 0.91-0.92) to 0.99 (95% CI: 0.98-0.99), corresponding to adjusted mean differences between EUR304 to EUR3538 (Table 2). Figure 1 shows a scatterplot of total costs according to the proportion of the relevant process performance measures fulfilled. Higher overall quality of in-hospital care appear not to be associated with higher total costs. Table 3 addresses the question of a potential dose-response relationship between the composite score categories and total costs.

Table 3: Fulfilment of process performance measures (composite) and total cost in euro within the index admission and within the first year

	Patient, n	Mean total cost in euro	(p10-p90)[1]	Adjusted Mean total cost in euro	Crude ratio[2] (95 % CI)		Adjusted ratio[3] (95%CI)	
Index admission:								
0-50 % fulfilment (ref.)	2,440	15,141	(5,878-25,926)	16,865				
50-75 % fulfilment	2,609	12,766	(6,017-20,641)	14,220	0.96	(0.94-0.99)	0.98	(0.97-0.98)
75-100 % fulfilment	15,409	11,956	(6,277-18,834)	13,317	0.94	(0.92-0.96)	0.94	(0.94-0.95)
Within the first year:								
0-50 % fulfillment (ref.)	2,440	21,188	(6,650-39,696)	25,212				
50-75 % fulfilment	2,609	18,840	(7,000-33,890)	22,418	0.98	(0.95-1.02)	0.98	(0.97-0.99)
75-100 % fulfilment	15,409	18,288	(7,274-33,550)	21,762	0.98	(0.95-1.01)	0.97	(0.97-0.98)

4) P10-P90, range of data from 10 % percentile to 90 % percentile.
5) Crude ratio but taking the hierarchical data structure into account
6) Adjusted for gender, age, Charlson Comorbidity Index, Body Mass Index, type of fracture, fracture displacement, type of surgery, time to surgery, civil status, five year family mean income, highest obtained education, ethnicity, yearly unit hip fracture patient volume and orthogeriatric care.

Fulfilling 50% to 75% or more than 75% of the process performance measures were also associated with lower total costs. The unadjusted mean differences were EUR2375 and EUR3185, respectively. The association remained in the adjusted analysis, corresponding to adjusted mean differences of EUR2645 and EUR3548, respectively (Table 3). The range between the upper and lower percentiles was wider for the lowest quality of care group compared to the highest quality of care group. Table 4 presents the distribution of costs according to the composite process performance measure.

Table 4: Costs in euro from admission to discharge and from admission and within one year according to the fulfilment of composite process performance measure.

	0-50% N= 2440		50-75 % N= 2609		75-100 % N= 15409	
RESOURCE USE	**Mean cost in euro**	**(p10-p90)**	**Mean cost in euro**	**(p10-p90)**	**Mean cost in euro**	**(p10-p90)**
Index admission:						
Radiology	303	(112-563)	264	(115-466)	240	(717-3,023)
Surgery & anaesthesia	4,137	(2,004-6,973)	4,059	(1,921-6,817)	4041	(1,749-6,962)
Further diagnostic	381	(0-711)	310	(2-631)	252	(17-513)
Further treatment	2,126	(0-1,246)	1,157	(0-827)	403	(0-707)
Therapy	777	(60-1,683)	625	(462-9,576)	698	(150-1,373)
Bedday	7,337	(2,120-15,610)	6,312	(62-11,746)	6287	(2,452-11,296)
Outpatient services	79	(0-89)	40	(0-0)	36	(0-0)
Total costs	15,141	(5,878-25,926)	12,766	(6,017-20,641)	11956	(6,277-18,834)
First year:						
Radiology	473	(137-957)	458	(145-901)	438	(133-875)
Surgery & anaesthesia	4937	(2,036-9,020)	4,977	(2,006-9,192)	4,965	(1,876-9,124)
Further diagnostic	607	(31-1,254)	566	(44-1,213)	522	(42-1,172)
Further treatment	2612	(0-2,367)	1,735	(0-1,633)	952	(0-1,283)
Therapy	955	(66-2,121)	809	(81-1,698)	885	(170-1,822)
Bedday	10895	(2,414-23,568)	9,782	(2,671-20,438)	9,954	(2,947-20,305)
Outpatient services	708	(0-1,304)	513	(0-1,240)	570	(0-1,307)
Total costs	21188	(6,650-39,696)	18,840	(7,000-33,890)	18,288	(7,274-33,550)

The cost categories contributing the most to the differences in total costs between the composite score categories in the index admission were further diagnostic services and bed days.

Within the first year

The differences in total costs between patients with and without fulfilment of the individual process performance measures during the index admission dropped, when taking into account all costs related to hospitalisations within the first year after hip fracture (Table 2). However, mobilization within 24 hours post operatively, receiving basic mobility assessment at admission, anti-osteoporotic medication and initiation of treatment to prevent future fall accidents remained associated with lower total costs in the adjusted analysis when focusing on treatment costs during first year of follow-up (Table 2). Still patients receiving more than 50 % of the relevant process performance measures had lower total cost within the first year. However, but the adjusted ratio was weakened for patients receiving more than 75% of the process performance measures compared to the index admission (Table 3). Costs due to further diagnostic treatment and bed days were also the dominant cost categories driving the difference in total costs between the composite score categories during the one year follow-up period (Table 4).

Results from complete case analysis are provided in Supplemental Appendix 2.

DISCUSSION

Overall, we found support for the hypothesis that improvement in quality of in-hospital care will not imply increased hospital spending and may even lead to lower total hospital costs for the index admission as well as for total hospitalisations costs within the first year.

The inference that high quality of in-hospital care is associated with lower total cost should however, be made with caution. First, observational studies may be influenced by confounding including confounding by contraindication. The staff may have been less likely to offer early and appropriate care for frail patients near end-of-life. However, this is unlikely to be a major problem in this analysis, for two reasons. First the staff had the possibility to consider the patients ineligible for the process performance measures, e.g. if the patient was too weak to participate in early mobilisation. These patients were consequently excluded from the analyses on the association between fulfilment of the mobilisation performance measure and the treatment costs. Secondly, we adjusted for a range of well-established prognostic factors without this having any strong impact on the relative risk measures. Still, we cannot exclude the possibility that our findings remain influenced by unmeasured and residual confounding (e.g., lack of information on pre-existing dementia)[32, 37]. Another concern could be collection of data in a routine setting, which may have affected the accuracy of the data, but major efforts were made to ensure the validity of our data.

These steps included disseminating detailed written instructions for reporting data to the DMHFR and carrying out regular clinical audits. Any inaccuracy of data is furthermore, highly unlikely to be differential in this analysis and would therefore most likely tend to underestimate the true associations. Finally, the categorisation of quality of care could have influenced the associations, however, the overall findings were confirmed also when looking at the individual process performance measures and the scatterplot did not indicated higher overall costs to be associated with higher total costs.

Wide variability in hospital costs for hip fracture has previously been reported, due to different inclusion criteria, ranging from £5083 to £16,452 for the index admission and between £6176 and £20470 for 1-year costs[38-41]. A recent population-based study including 33,172 hip fractures in United Kingdom estimated the costs for index admission to be similar with our estimate of 12398EUR (£9832) and 18704EUR (£14833) for the 1-year costs, which supports the external validity of the present findings to have potential generalizability to other European health care systems[38].

Information in the existing scientific literature is very sparse on association between quality of care identified by process performance measures and treatment costs among hip fracture patients[18-21]. To our knowledge no previous studies have examined fulfillment of process performance measures and hospital costs at the individual level. Three previously studies from United Kingdom have examined the association between hospital quality identified by the hospitals overall fulfillment of the process performance measures and reimbursement cost in two different time periods[19-21]. However, the studies were unable to demonstrate that higher quality of care was associated with lower cost as the studies only assessed reimbursement in a pay for performance healthcare system. In contrast, Laudicella and colleagues in a discussion paper from the Imperial College London Business School investigated the link between hospital costs and quality of care, identified by the hospitals's overall fulfilment of process performance measures. They found no clear relationship between total costs among patients with hip fracture and hospital quality based on a clinical audit of minimum 20 consecutive cases per hospital. However, they did in accordance with our findings observe higher mortality and readmissions rates among patients admitted to high spending hospitals[18]. Our results are also in partial agreement with previous Danish findings among stroke patients, where substantially lower total costs were found for patients receiving guideline-recommended care[42].

The finding that mobilisation within 24 hours postoperative was associated with lower hospital costs in the index admission may mainly be explained by the fact that mobilization within 24 hours is associated with a shorter length of stay, which is a major contribution to the cost within index admission[22]. The largest costs saving within the first year appeared to be intervention to prevent future falls and receiving anti-osteoporotic medication. A possible explanation for these associations may be successful prevention of further fall accidents including a second hip fracture[38, 43, 44].

Previous research shows that receiving the process performance measures is linked with lower 30-day mortality risk and lower risk for acute readmission within 30 day after discharge[22]. The higher proportion of dead patients among the group of patients receiving care of lower quality may have influenced the total costs, because of the reduced time to consume health care services compared to the group of patients, whom received high quality of care and thus had a higher survival and longer time to consume health care services[16, 38]. Hospitals that are high performer on delivering the evidence-based treatment are therefore, likely to be penalized in term of higher costs, as they have a larger share of vulnerable patients surviving the first admission with an un-observably higher need for ensuing health care as compared to hospitals with low performance and higher mortality[16].

Several implications for future research and for policy makers may arise from our results. First, it highlights the importance of ensuring a high hospital performance on care processes as it improves the survival and convalescence of hip fracture patients without increasing the total cost. It should be noted that the Danish process performance measures are nearly identical to the measures used in the UK Hip fracture program under the Health Foundation [19, 21]. Secondly, the roughly EUR3000 higher average total mean costs for the 2440 patients in our study population who had below 50% of the process performance measures fulfilled could theoretically finance a quality improvement strategy over three years of 7 million EURO without increasing costs. Thirdly, the higher hospital performance on these processes does not require a special hospital setup, but are implementable in standard clinical settings and therefore, represents a feasible avenue for improving quality of care for hip fracture patients across most developed health care systems.

In conclusion, our study underlines the importance of fulfilling clinical guidelines recommendations among patients with hip fracture as the quality improvements for patients with hip fracture entail a lower 30-day mortality and lower risk for readmission, which may be achieved without increasing the total costs of in-hospital care.

Financial support: The study received financial support from the Health Research Fund of Central Denmark Region, Familiy Hede Nielsens Fund and Gurli and Hans Friis Fund.

Potential conflicts of interest: None

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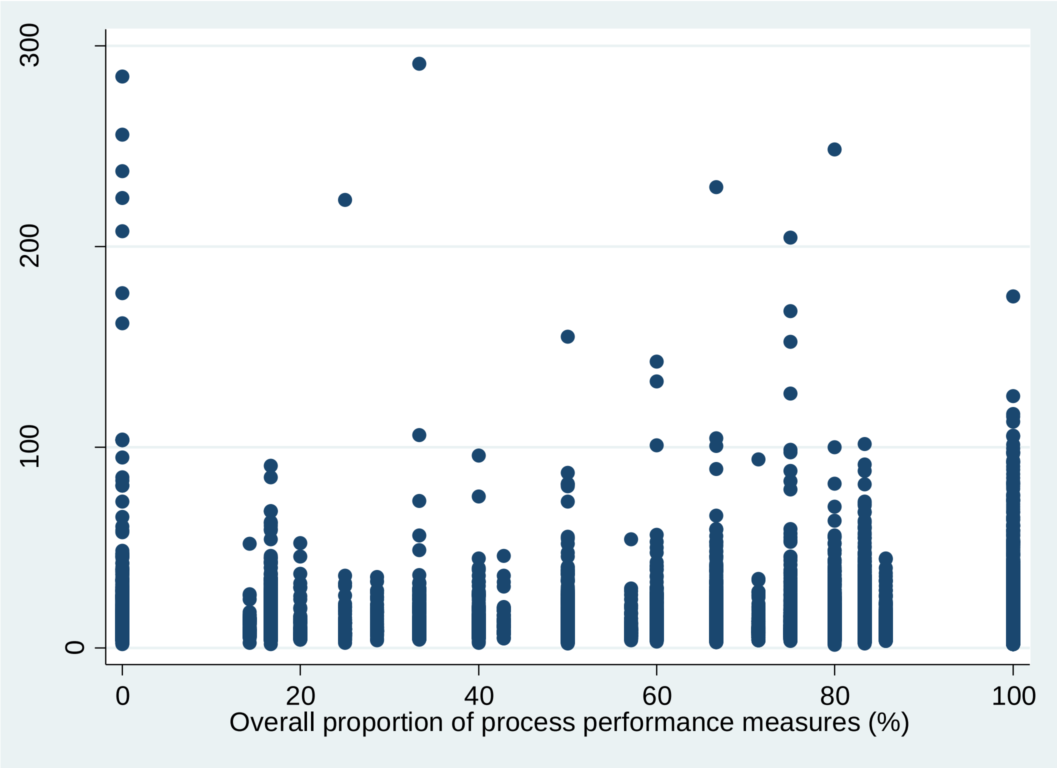
Figure 1: Scatterplot of total costs according to the proportion of the relevant process performance measures fulfilled.



Supplemental Appendix 1: Descriptive characteristics of patients with hip fracture in different quality of care categories:

	0-50% n= 2440		**50-75 %** n= 2609		**75-100 %** n=15409	
Age group (year)						
65-74	19.5 %	(475)	18.8 %	(491)	19.6 %	(3023)
75-84	34.4 %	(839)	35.4 %	(923)	37.8 %	(5822)
> 85	46.2 %	(1126)	45.8 %	(1195)	42.6 %	(6564)
Gender						
Women	69. 9 %	(1706)	70.3 %	(1835)	71.5 %	(11018)
Men	30.1 %	(734)	29.7 %	(774)	28.5 %	(4391)
Housing						
Own home	27.1 %	(661)	63.5 %	(1657)	72.0 %	(11098)
Own home affiliated to an institution	2.5 %	(60)	6.3 %	(163)	6.5 %	(994)
Institution	10.8 %	(263)	22.1 %	(576)	18.1 %	(2790)
Missing	59.7 %	(1456)	8.2 %	(213)	3.4 %	(527)
BMI[1] (kg/m^2)						
< 19: Underweight	5.2 %	(127)	13.3 %	(347)	14.3 %	(2208)
20-25: Normal	16.4 %	(401)	44.3 %	(1156)	51.7 %	(7973)
>26: Overweight	6.6 %	(162)	18.1 %	(471)	21.8 %	(3355)
Missing	71.2 %	(1750)	24.3 %	(635)	12.2 %	(1873)
CCI[2]						
0 point: no comorbidity	34.9 %	(852)	34.5 %	(900)	38.8 %	(5983)
1: low comorbidity	23.1 %	(563)	24.7 %	(645)	23.6 %	(3640)
2 point moderate comorbidity	18.9 %	(461)	17.8 %	(465)	17.6 %	(2711)
+3 point: high comorbidity	23.1 %	(564)	23.0 %	(599)	20.0 %	(3075)
Fracture displacement						
Displaced	47.5 %	(1160)	75.7 %	(1975)	76.8 %	(11827)
Undisplaced	6.8 %	(166)	11.4 %	(298)	11.8 %	(1818)
Unspecified	45.7 %	(1114)	12.9 %	(336)	11.5 %	(1764)
Type of fracture						
Femoral neck	51.2 %	(1248)	52.6 %	(1371)	54.0 %	(8314)
Pertrochanteric	39.2 %	(956)	39.3 %	(1025)	39.1 %	(6029)
Subtrochanteric	9.7 %	(236)	8.2 %	(213)	6.9 %	(1066)
Type of surgery						
Osteosynthesis	68.4 %	(1669)	65.7 %	(1714)	65.0 %	(10015)
Hemi arthroplasty	27.7 %	(675)	30.4 %	(794)	27.5 %	(4239)
Total hip arthroplasty	3.9 %	(96)	3.9 %	(101)	7.5 %	(1155)
Unit setting						
Orthopaedic unit	82.3 %	(2008)	73.1 %	(1907)	80.5 %	(12401)
Orthogeriatric treatment	17.7 %	(432)	26.9 %	(702)	19.5 %	(3008)
Time to surgery (hours)						
<24	51.9 %	(1267)	55.7 %	(1453)	59.4 %	(9148)
24-48	32.0 %	(780)	30.9 %	(807)	29.4 %	(4530)
> 48	16.1 %	(392)	13.3 %	(348)	11.2 %	(1726)
Missing	0.04 %	(1)	0.04 %	(1)	0.03%	(5)
Civil status						
Married or cohabitant	70.5 %	(1721)	68.7 %	(1792)	69.2 %	(10667)
Lives alone	29.5 %	(719)	31.3 %	(817)	30.8 %	(4742)

Family mean income						
Low	25.9 %	(632)	25.9 %	(676)	24.0 %	(3697)
Medium	24.0 %	(585)	25.0 %	(651)	24.8 %	(3818)
High	25.0 %	(609)	24.0 %	(625)	25.6 %	(3948)
Very high	25.2 %	(614)	25.2 %	(657)	25.6 %	(3946)
Education						
Low (ground school)	48.2 %	(1176)	48.5 %	(1264)	50.4 %	(7770)
Medium	20.8 %	(507)	21.3 %	(555)	23.1 %	(3559)
High (university completed)	11.5 %	(280)	11.4 %	(296)	11.6 %	(1787)
Missing	19.6 %	(477)	18.9 %	(494)	14.9 %	(2293)
Ethnicity						
Immigrants	96.9 %	(2364)	96.6 %	(2521)	96.7 %	(14898)
Non-immigrants	3.1 %	(76)	3.4 %	(88)	3.3 %	(511)
30-day mortality						
Alive	78.1 %	(1905)	83.0 %	(2166)	91.6 %	(14119)
Dead	21.9 %	(535)	17.0 %	(443)	8.4 %	(1290)

[1] BMI= Body Mass Index

[2] CCI= Charlson Comorbidity Index

Supplemental Appendix 2 complete case analysis

Table 2a: Each process performance measure association with total cost within index admission and within the first year. Complete case analyses

	INDEX ADMISSION							FIRST YEAR						
	Mean	(P10-p90)	Adjusted mean	Crude ratio	95 %CI	Adjusted ratio	95 % CI	Mean	(P10-p90)	Adjusted mean	Crude ratio	95 %CI	Adjusted ratio	95 %CI
Systematic pain assessment														
No (Reference)	13,783	(6,101-22,972)	15,079					20,427	(7,015-38,573)	24,286				
Yes	12,289	(6,471-19,234)	13,444	0.99	(0.97-1.01)	1.04	(1.01-1.07)	19,125	(7,735-34,763)	22,738	1.01	(0.98-1.03)	1.03	(0.99-1.08)
Mobilisation < 24 hours postoperatively														
No (Reference)	14,474	(6,369-24,477)	15,834					20,799	(7,262-38,825)	24,645				
Yes	11,739	(6,248-18,172)	12,842	0.91	(0.89-0.92)	0.90	(0.88-0.92)	18,130	(7,303-33,083)	21,483	1.07	(1.00-1.14)	0.93	(0.91-0.96)
Basic mobility assessment at admission														
No (Reference)	12,198	(5,601-19,406)	13,577					17,770	(6,745-30,526)	21,359				
Yes	11,445	(5,878-17,463)	12,739	1.02	(0.98-1.07)	1.00	(0.94-1.06)	18,031	(6,929-33,647)	21,673	1.06	(1.02-1.10)	1.06	(0.97-1.15)
Basic mobility assessment at discharge														
No (Reference)	12,734	(6,399-20,346)	15,441					19,530	(7,512-35,445)	23,110				
Yes	11,874	(6,180-19,035)	14,398	0.93	(0.92-0.95)	0.92	(0.89-0.95)	18,579	(7,274-34,312)	21,985	0.95	(0.92-0.98)	0.92	(0.88-0.96)
Rehabilitation program														
No (Reference)	12,237	(5,398-23,292)	13,316					18,979	(6,350-34,797)	22,421				
Yes	11,960	(6,341-18,838)	13,015	1.05	(1.02-1.08)	1.01	(0.97-1.05)	18,733	(7,444-34,370)	22,131	1.06	(1.02-1.10)	0.98	(0.93-1.04)
Antiosteoporotic medication														
No (Reference)	15,270	(6,045-25,966)	16,798					21,417	(6,942-38,800)	25,490				
Yes	12,094	(6,215-19,038)	13,304	0.93	(0.91-0.95)	0.91	(0.87-0.95)	18,374	(7,199-33,687)	21,868	0.96	(0.93-0.99)	0.94	(0.89-1.00)
Initiation of treatment to prevent future fall accidents.														
No (Reference)	13,292	(5,871-23,528)	14,627					22,638	(6,844-36,981)	26,949				
Yes	12,226	(6,280-19,123)	13,454	0.99	(0.98-1.01)	1.01	(0.99-1.04)	18,457	(7,261-33,687)	21,972	1.00	(0.97-1.02)	1.00	(0.97-1.99)

Table 3a: Proportion of fulfilment of all relevant process performance measures and total cost within the index admission and within the first year complete case analyses

	Patients, n	Mean cost	(p10-p90)[1]	Adjusted mean	Crude ratio[2]	(95 % CI)	Adjusted ratio[3]	(95%CI)
Total cost within the index admission								
0-50 % fulfillment (reference)	2,440	15,141	(5,878-25,926)	17,095				
50-75 % fulfilment	2,609	12,766	(6,017-20,641)	14,413	0.96	(0.94-0.99)	0.94	(0.90-0.98)
75-100 % fulfilment	15,409	11,956	(6,277-18,834)	13,499	0.94	(0.92-0.96)	0.90	(0.87-0.94)
Total cost within the first year								
0-50 % fulfillment (reference)	2,440	21,188	(6,650-39,696)	25,218				
50-75 % fulfilment	2,609	18,840	(7,000-33,890)	22,424	0.98	(0.95-1.02)	0.99	(0.93-1.05)
75-100 % fulfilment	15,409	18,288	(7,274-33,550)	21,767	0.98	(0.95-1.01)	0.96	(0.96-1.02)

1) P10-P90, range of data from 10 % percentile to 90 % percentile.

2) Crude ratio but taking the hierarchical data structure into account

3) Adjusted for gender, age, Charlson Comorbidity Index, Body Mass Index, type of fracture, fracture displacement, type of surgery, time to surgery, civil status, five year family mean income, highest obtained education, ethnicity, yearly unit hip fracture patient volume and orthogeriatric care.

Paper III

Can improved quality of care explain the success of the orthogeriatric units?
– A population-based study.

Age and Ageing Advance Access published November 17, 2015

Age and Ageing 2015; **0:** 1–6
doi: 10.1093/ageing/afv155

Can improved quality of care explain the success of orthogeriatric units? A population-based cohort study

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Abstract

Background: admission to orthogeriatric units improves clinical outcomes for patients with hip fracture; however, little is known about the underlying mechanisms.
Objective: to compare quality of in-hospital care, 30-day mortality, time to surgery (TTS) and length of hospital stay (LOS) among patients with hip fracture admitted to orthogeriatric and ordinary orthopaedic units, respectively.
Design: population-based cohort study.
Measures: using prospectively collected data from the Danish Multidisciplinary Hip Fracture Registry, we identified 11,461 patients aged ≥65 years admitted with a hip fracture between 1 March 2010 and 30 November 2011. The patients were divided into two groups: (i) those treated at an orthogeriatric unit, where the geriatrician is an integrated part of the multidisciplinary team, and (ii) those treated at an ordinary orthopaedic unit, where geriatric or medical consultant service are available on request. Outcome measures were the quality of care as reflected by six process performance measures, 30-day mortality, the TTS and the LOS. Data were analysed using log-binomial, linear and logistic regression controlling for potential confounders.
Results: admittance to orthogeriatric units was associated with a higher chance for fulfilling five out of six process performance measures. Patients who were admitted to an orthogeriatric unit experienced a lower 30-day mortality (adjusted odds ratio (aOR) 0.69; 95% CI 0.54–0.88), whereas the LOS (adjusted relative time (aRT) of 1.18; 95% CI 0.92–1.52) and the TTS (aRT 1.06; 95% CI 0.89–1.26) were similar.
Conclusions: admittance to an orthogeriatric unit was associated with improved quality of care and lower 30-day mortality among patients with hip fracture.

Keywords: *hip fracture, orthogeriatric, quality of care, 30-day mortality, length of stay, older people*

Introduction

Hip fracture is a major clinical and public health problem associated with increased mortality, disability and substantial healthcare costs [1, 2]. Patients with hip fractures are often frail and have multiple comorbidities [2]. To deal better with the special needs of these patients, various models for collaborative orthogeriatric care of patients with hip fracture have been developed [3–5]. Systematic reviews of clinical trials have reported that hip fracture patients, who receive multidisciplinary inpatient rehabilitation, tend to achieve better outcomes, including a statistical non-significant lower mortality [4–9]. A recent observational study from Australia found statistical significantly lower 30-day mortality rates and longer length of stay in hospitals with an orthogeriatric service [10]. Yet, the underlying mechanisms explaining the apparently better outcomes of hip fracture patients receiving orthogeriatric care remain poorly understood. In Denmark, all hip fracture patients are reported to a nationwide hip fracture-specific clinical registry with detailed data on the quality of care, which makes it possible, for the first time, to directly compare the quality of care offered at orthopaedic units with and without collaborative orthogeriatric care.

Aims

We examined the association between unit setting and quality of care, 30-day mortality, time to surgery (TTS) and length of hospital stay (LOS).

Methods

This study draws on individual-level record linkage of data from nationwide medical registries using the unique civil registration number assigned to all citizens, which permits unambiguous record linkage between registries [11]. The healthcare system provides free access to hospital care for all residents [12]. Treatment of hip fracture in Denmark is performed at the nearest public hospital (i.e. patients are not triaged according to health status, fracture severity or other characteristics). The study was approved by the Danish Data Protection Agency (journal number 2012-41-1274).

Data sources

The primary data source was the Danish Multidisciplinary Hip Fracture Registry (DMHFR). These data were supplemented by Charlson comorbidity index (CCI) data from the Danish National Registry of Patients (DNRP) and vital status from the Danish Civil Registration System [13, 14].

The DMHFR was established in 2003 to document and improve the quality of care and the registry includes data on all patients ≥65 years admitted with a hip fracture (including medial, pertrochanteric or subtrochanteric femoral fractures). Reporting is mandatory for all hospital units treating hip fracture patients. Data on care quality using specific process performance measures and on patient characteristics are collected upon hospital admission by the care staff [14].

DNRP contains records of all patients admitted to Danish non-psychiatric hospitals since 1977, including data from all hospitalisations and diagnoses coded according to the International Classification of Diseases version 10 (ICD-10) [12]. The CCI is a well-established measure of comorbidity, which covers 19 diseases [15]. We calculated CCI by identifying the ICD-10 diagnoses for each patient during the past 10 years before admission with hip fracture [13].

The Danish Civil Registration System has maintained electronic records of changes in vital status and migration for the entire Danish population since 1968 [11].

Study population

We identified all hip fracture patients registered in the DMHFR with a discharge date between 1 March 2010 and 31 November 2011 ($N = 12{,}516$). Patients with multiple hip fractures during this study period were excluded ($n = 406$) along with patients whose admission date was erroneously recorded to be later than the hip fracture operation or the discharge date ($n = 45$). Furthermore, patients were excluded if they were transferred to a geriatric unit after 1–2 days at the orthopaedic unit following surgery ($n = 604$). Our study cohort therefore included 11,461 patients.

Hip fracture unit setting

In the traditional, orthopaedic care model, the orthopaedic surgeon assumes principal care responsibility, while medical queries and complications are handled by medical service on the surgeon's demand. The orthogeriatric unit is established on a co-management basis with a geriatrician and an orthopaedic surgeon sharing responsibility and leadership from admission to discharge. The units were categorised according to a report from the Danish Geriatric Society [16].

Outcomes

Quality of care

The quality of care was assessed using six process performance measures: (i) daily systematic pain assessment using a visual analogue scale or a numeric rating scale at rest and during mobilisation [17], (ii) being mobilised within 24 h postoperatively, defined as assisting the patient from bed-rest to walking or rest in a chair, (iii) basic mobility assessment using a validated test such as Cumulated Ambulation Score, Barthel 20, Functional Recovery score or New Mobility score [18–20], (iv) post discharge rehabilitation programme, including assessment of activities of daily living (ADL) with a validated test before the fracture and again before discharge, (v) initiation of treatment to prevent future fall accidents, including a fall risk assessment to account for co-existing medical conditions, medication, functional disability, symptoms from the central nervous system, musculoskeletal system and cardiopulmonary status and (vi) initiation of treatment with anti-osteoporotic medications. The patients were classified as eligible or ineligible for each individual process performance measure depending on whether the hospital staff identified contraindications (e.g. dementia that disabled the patients from reporting their level of pain during mobilisation).

30-Day mortality

Follow-up started on the day of hospital admission and ended after 30 days.

Time to surgery

The TTS was defined as the time in hours from hospital admission to operation.

Length of hospital stay

The LOS was defined as the time span from hospital admission to hospital discharge or from hip fracture occurrence if the patient was already hospitalised. The discharge date was defined as the date of discharge to home, a nursing home or death. If the patients were transferred between hospital units, the days spent in all units were included in the LOS.

Covariates

A priori identified potential confounders included age (65–74, 75–84, ≥85), gender, housing (own home, own home affiliated to an institution, institution, unspecified), body mass index (BMI) (≤19, 20–25, 26–30, >30 kg/m^2, unspecified), CCI (none (0), low (1–2), ≥3 (high)), type of fracture (medial, pertrochanteric, subtrochanteric), fracture displacement (displaced, undisplaced, unspecified), type of surgery (osteosynthesis, hemi arthroplasty, total hip arthroplasty) [21, 22].

Statistical analysis

The associations between unit setting and the six process performance measures were examined separately using binomial regression because the rare disease assumption was not fulfilled. Patient characteristics were not included as covariates in these analyses as only patients who were found eligible for the individual process performance measures were included. The association between unit setting and 30-day mortality was examined using multivariable logistic regression, adjusted for the covariates mentioned above. Furthermore, we repeated the mortality analysis with additional adjustment for process performance measures to examine whether they were intermediates between unit setting and mortality. Furthermore, we also repeated the analyses on mortality after stratifying the patients according to their predicted risk for 30-day mortality at the time of admission. The predicted mortality risk for each patient was estimated using multiple logistic regression conditional on all covariates observed at the time of admission. These analyses were done in order to explore whether the association between the type of unit and 30-day mortality differed according to the prognostic profile of the patients.

In all adjusted analyses, random effects models were used to account for potential clustering by units, because other measured and unmeasured characteristics at the healthcare provider level may be associated with orthogeriatric units. To evaluate the possible impact of missing data, the analyses were also repeated using multiple imputation, which is expected to yield unbiased and more precise estimates if data are missing at random conditional on measured variables [23]. We generated 20 complete datasets with imputed data based on measurements for age, gender, housing, BMI, CCI, type of fracture, fracture displacement, type of surgery, TTS, LOS and 30 day-mortality.

We used a natural log transformation to correct for the right skewness in TTS and LOS, and the results were reported as ratios between geometric means. Estimates of associations between unit setting and TTS and LOS were analyses with linear regression with adjustment for age, gender, housing, BMI, CCI, type of fracture, fracture displacement type of surgery and patient volume. Estimates of the association between unit setting and LOS were stratified by TTS (<24 h, 24–48 h, >48 h) and only patients alive at discharged were included. Data were analysed using Stata 12.0 (StataCorp LP, College Station, TX, USA).

Results

Patients in orthogeriatric units were often older, underweight, living at an institution and had more comorbidities compared with patients in ordinary orthopaedic units. In the ordinary orthopaedic units, however, there were more men, who are known to have an adverse risk profile at admission. (See the Supplementary data Table S1, available in *Age and Ageing* online, which summarises patient characteristics and missing data according to patient characteristics.)

As shown in Table 1, admission to an orthogeriatric unit was associated with 1.13 times (95% CI 1.10–1.16) the chance of receiving systematic pain assessment and 1.04 times (95% CI 1.02–1.06) the chance of receiving basic mobility assessment, compared with ordinary orthopaedic units. Comparing orthogeriatric with ordinary orthopaedic units, the risk ratios (RR) for admission to post-discharge rehabilitation, anti-osteoporotic medication and prevention of future fall accidents were 1.07 (95% CI 1.05–1.09), 1.04 (95% CI 1.02–1.06) and 1.15 (95% CI 1.12–1.18), respectively. The chance of being mobilised before 24 h postoperatively was similar in the two unit types.

Table 1. The quality of care according to unit settings

Process of care	Eligible patients, *n*	Process received, (%)	Unadjusted RR (95% CI)
Systematic pain assessment			
Orthopaedic unit	7,542	5,529 (73.3%)	1 (reference)
Orthogeriatric unit	1,416	1,171 (82.7%)	1.13 (1.10–1.16)
Mobilised <24 h postoperatively			
Orthopaedic unit	9,024	6,411 (71.0%)	1 (reference)
Orthogeriatric unit	1,955	1,396 (71.4%)	1.01 (0.97–1.04)
Basic mobility assessment			
Orthopaedic unit	9,454	7,743 (81.9%)	1 (reference)
Orthogeriatric unit	2,007	1,705 (85.0%)	1.04 (1.02–1.06)
Post discharge rehabilitation programme			
Orthopaedic unit	8,828	7,615 (86.3%)	1 (reference)
Orthogeriatric unit	1,882	1,738 (92.4%)	1.07 (1.05–1.09)
Anti-osteoporotic medication			
Orthopaedic unit	9,454	7,953 (84.1%)	1 (reference)
Orthogeriatric unit	2,007	1,750 (87.2%)	1.04 (1.02–1.06)
Prevention future fall accidents			
Orthopaedic unit	9,454	6,717 (71.1%)	1 (reference)
Orthogeriatric unit	2,007	1,635 (81.5%)	1.15 (1.12–1.18)

Table 2. 30-Day mortality according to unit settings

	Patients, *n*	Dead, *n* (%)	Unadjusted OR (95% CI)	Adjusted OR[a] (95% CI)	Adjusted OR[b] (95% CI)
Orthopaedic units	9454	1137 (12.0)	1 (reference)	1 (reference)	1 (reference)
Orthogeriatric units	2007	188 (9.4)	0.76 (0.64–0.89)	0.69 (0.54–0.88)	0.77 (0.62–0.96)
				0.69[c] (0.57–0.84)	**0.80 (0.64–0.99)**

[a]Adjusted for age, gender, housing, BMI, Charlson Comorbidity Score, fracture displacement, type of fracture, type of surgery and surgical delay.
[b]Adjusted for age, gender, housing, BMI, Charlson Comorbidity Score, fracture displacement, type of fracture, type of surgery, surgical delay and process performance measures.
[c]Bold values indicate adjusted analysis in imputed dataset.

Table 3. 30-Day mortality by risk stratification according to unit setting

	Patients, *n*	Dead (%)	OR (95% CI)
0–20% baseline outcome risk			
Orthopaedic unit	7,971	694 (8.71)	1 (reference)
Orthogeriatric unit	1,671	112 (6.70)	0.75 (0.61–0.93)
21–40% baseline outcome risk			
Orthopaedic unit	1,311	358 (27.31)	1 (reference)
Orthogeriatric unit	291	62 (21.31)	0.72 (0.53–0.98)
>40% baseline outcome risk			
Orthopaedic unit	172	85 (49.42)	1 (reference)
Orthogeriatric unit	45	14 (31.11)	0.46 (0.23–0.93)

Risk of 30-day mortality was 12.0% for patients admitted to an orthopaedic unit and 9.4% for patients admitted to an orthogeriatric unit, which corresponded to an adjusted odds ratio (OR) for 30-day mortality for patients admitted to an orthogeriatric unit of 0.69 (95% CI 0.54–0.88). After further adjusting for differences in process performance measures, the OR for 30-day mortality shifted upward to 0.77 (95% CI 0.62–0.96) (Table 2). The multivariable logistic regression analysis based on the imputed dataset provided results that were comparable with the primary analysis. When we stratified according to the patients predicted risk for 30-day mortality at the time of admission, the association between hip fracture unit setting and 30-day mortality was consistent (Table 3).

The TTS was 22.0 and 23.4 h patients admitted to orthopaedic units and orthogeriatric units, respectively. No differences were found in TTS (adjusted relative time of 1.06; 95% CI 0.89–1.26).

The LOS was 8.5 days for patients admitted to orthopaedic units, and 10.5 days for patients admitted to orthogeriatric units. However, the difference did not reach statistical significance in the adjusted analysis (adjusted relative LOS of 1.18; 95% CI 0.92–1.52). When restricted to patients with a TTS longer than 48 h, the results were similar. (See Supplementary data S2, available in *Age and Ageing* online, which shows the association between unit setting and LOS stratified by TTS.)

Discussion

In this nationwide study of hip fracture patients, we found that patients admitted to orthogeriatric units received a higher quality of care and had lower mortality rates. The quality of care was demonstrated to be a likely mediator of the lower 30-day mortality in patients admitted to orthogeriatric units. No differences in TTS were observed; however, a non-significantly longer LOS was observed among patients from ortogeriatric units.

Our study's strengths include the population-based design with prospective data collection and complete follow-up, which minimised the risk of selection and information bias. Furthermore, we aimed to minimise the risk of confounding by adjusting for a range of well-established prognostic factors. However, we cannot exclude the possibility that our findings remain influenced by unmeasured and residual confounding (e.g. lack of information on preoperative functional level, pre-existing dementia or socioeconomic factors) [21, 22]. There appear to be differences in the distribution of patient characteristics according to the categorisation of the units. However, those differences were in general in favour of the orthopaedic unit, indicating that the favourable results observed among patients admitted to orthogeriatric units would likely not be explained by unmeasured confounding.

A limitation of this study is the reliability of the data, as it was collected by a large number of clinicians during routine clinical work. Major efforts including dissemination of detailed written instructions for reporting of data to the DMHFR and regular clinical audits have been carried out to ensure validity of the data. Regardless, misclassification would most likely be unrelated to categorisation of units because registration is mandatory, updated on a daily basis, and all units have substantial experience with data collection.

Process performance measures reported to the DMHFR are proxy measures for processes believed to influence the prognosis and mortality among patients with hip fracture. Process performance measures can only describe whether the patient has been assessed but does not provide information concerning whether patients actually were treated appropriately according to results of the assessments [14]. This is consistent with a previous Danish study which showed an inverse dose–response between five process performance measures: systematic pain scoring, nutritional screening, assessment of Activities of Daily Living before hip fracture and again before discharge, anti-osteoporotic medications and 30-day mortality [24].

A meta-analysis showed an OR for in-hospital mortality for patients admitted to orthogeriatric units of 0.66 (95% CI 0.42–1.04), which is comparable with our OR of 0.69 (95% CI 0.54–0.88) [6]. The non-significant result in the meta-analysis may be due to the inclusion of randomised controlled trials that included patients with low mortality risk. In-hospital mortality in one randomised controlled trial was 1.4 versus 0% compared with our study which have a 30-day mortality of 12 versus 9.7% [25]. The lower mortality in the trial may be due to exclusion of nursing home residents, patients with dementia and patients with specific other comorbidities, which are associated with higher mortality. Our results are in accordance with a recent observational study from Australia including 9,601 patients, which showed an adjusted 30-day mortality of 8.4 and 6.2% for hospitals without and with orthogeriatric service. The higher 30-day mortality rate in our study may partly be explained by a higher incidence of comorbidities in our population.

Orthogeriatric intervention is often reported to reduce waiting time for surgery and LOS [26–28]. In our study, however, TTS was similar across unit settings and there was a statistical non-significant longer LOS at orthogeriatric units. A likely explanation is that the geriatrician assessed all relevant disorders and disabilities and not only those precipitating the hospital admission which probably is more time-consuming. This is supported by Zeltzer *et al.*, which median LOS was longer at hospitals with orthogeriatric service compared with hospitals that did not have an orthogeriatric service [10].

In conclusion, patients admitted to an orthogeriatric unit had lower mortality rates and received higher quality of care, as reflected by the process performance measures. Lower mortality rates among patients in orthogeriatric units were consistent in all subgroups independent of patient risk profiles. Waiting time for surgery and LOS were similar by unit type. Differences in assessed process performance measures appeared to explain, in part, the lower 30-day mortality in orthogeriatric units. Continued efforts are warranted to clarify the mechanisms leading to better outcomes for hip fracture patients treated in orthogeriatric setting.

Key points

- Admission to an orthogeriatric unit was associated with lower 30-day mortality.
- Admittance to orthogeriatric units was associated with a higher quality of care.
- TTS was similar by unit type.
- Lower mortality rates among patients in orthogeriatric units were consistent in all subgroups independent of patient risk profile.
- Differences in assessed in quality of care appeared to explain, in part, the lower 30-day mortality in orthogeriatric units.

Acknowledgements

We thank the staff of the hospital departments caring for patients with hip fracture for their continuous effort and contribution to acquisition of the data in the Danish Multidisciplinary Hip Fracture Registry.

Conflicts of interest

None declared.

Funding

This work was supported by Health Research Fund of Central Denmark Region, Family Hede Nielsens Fund and Gurli and Hans Friis Fund. The financials sponsors did not play a role in the design, execution, analysis, interpretation of data or writing of the manuscript.

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Received 3 December 2014; accepted in revised form 7 August 2015

Paper IV

Socioeconomic inequality in clinical outcome among hip fracture patients:
– A nationwide cohort study.

Osteoporos Int
DOI 10.1007/s00198-016-3853-7

ORIGINAL ARTICLE

Socioeconomic inequality in clinical outcome among hip fracture patients: a nationwide cohort study

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Received: 11 August 2016 / Accepted: 22 November 2016

Abstract

Summary The evidence is limited regarding the association between socioeconomic status and the clinical outcome among patients with hip fracture. In this nationwide, population-based cohort study, higher education and higher family income were associated with a substantially lower 30-day mortality and risk of unplanned readmission after hip fracture.

Introduction We examined the association between socioeconomic status and 30-day mortality, acute readmission, quality of in-hospital care, time to surgery and length of hospital stay among patients with hip fracture.

Methods This is a nationwide, population-based cohort study using prospectively collected data from the Danish Multidisciplinary Hip Fracture Registry. We identified 25,354 patients ≥65 years admitted with a hip fracture between 2010 and 2013 at Danish hospitals. Individual-level socioeconomic status included highest obtained education, family mean income, cohabiting status and migrant status. We performed multilevel regression analysis, controlling for potential confounders.

Results Hip fracture patients with higher education had a lower 30-day mortality risk compared to patients with low education (7.3 vs 10.0% adjusted odds ratio (OR) = 0.74 (95% confidence interval (CI) (0.63–0.88)). The highest level of family income was also associated with lower 30-day mortality (11.9 vs 13.0% adjusted OR = 0.77, 95% CI 0.69–0.85). Cohabiting status and migrant status were not associated with 30-day mortality in the adjusted analysis. Furthermore, patients with both high education and high income had a lower risk of acute readmission (14.5 vs 16.9% adjusted OR = 0.94, 95% CI 0.91–0.97). Socioeconomic status was, however, not associated with quality of in-hospital care, time to surgery and length of hospital stay.

Conclusions Higher education and higher family income were associated with substantially lower 30-day mortality and risk of readmission after hip fracture.

Keywords 30-day mortality · Hip fracture · Length of stay · Patient readmission · Quality of health care · Social class

Electronic supplementary material The online version of this article (doi:10.1007/s00198-016-3853-7) contains supplementary material, which is available to authorized users.

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Introduction

A higher incidence of hip fracture has been reported in areas with low socioeconomic status [1–9]. This pattern has been ascribed to an unhealthy lifestyle, including poor diet (such as low calcium intake), cigarette smoking, physical inactivity, poor housing, heavy alcohol use and lower access to health services, being more common in social disadvantaged areas. All these factors may translate into underlying differences in bone strength and risk of falls [1, 10]. The evidence is more limited and conflicting regarding the extent to which low socioeconomic status may also have a negative impact on the clinical outcome after hip fracture [8, 11–15]. The conflicting results in the literature could be related to different measures used to define socioeconomic status, the lack of individual-level data and potential confounders. Furthermore, very little is known about the role of possible intermediate factors, e.g. potential socioeconomic-related differences in hip fracture care. Studies have indicated that hip fracture patients with low socioeconomic status may be less likely to undergo early surgery (i.e. within 48 h after arrival to the hospital) [15, 16].

Hip fracture care according to clinical guideline recommendations has previously been linked with lower mortality [17]. It is therefore of major importance to investigate whether differences in care may contribute to a potentially increased mortality among hip fracture patients with a low socioeconomic status.

Denmark is an interesting setting for further examining the role of socioeconomic status and clinical outcomes among patients with hip fracture. The entire population is served by universal tax-financed health care, including free hospital care and the availability of a nationwide hip fracture registry with detailed clinical data regarding in-hospital care as well as nationwide population registries with individual-level data on education, household income, cohabiting status and migrant status. It is therefore possible for the first time to investigate the association between different individual-level socioeconomic markers and patient outcomes among hip fracture patients. Moreover, the Danish Multidisciplinary Hip Fracture Registry contains individual data on quality of in-hospital hip fracture care, which makes it possible to examine the association between socioeconomic status and the delivered care in a large-scale study. We therefore examined whether socioeconomic status is associated with 30-day mortality, acute readmission, quality of in-hospital care, time to surgery (TTS) and length of stay (LOS) in Denmark.

Methods

We conducted a population-based cohort study based on prospective collected data available from medical registries in Denmark (5.6 million inhabitants) [18]. All medical emergencies, including hip fracture, are exclusively treated at public hospitals. All citizens have been assigned a unique civil registration number, which is used in all databases and permits unambiguous record linkage between the registries [19].

Data sources

We used the Danish Multidisciplinary Hip Fracture Registry (DMHFR) to identify a cohort of hip fracture patients [20]. These data were linked with data obtained from the Danish National Patient Registry (DNPR); the Danish Civil Registration System (DCRS); and the population, education and income registry from Statistic Denmark [19, 21].

The DMHFR was established in 2003 to document and improve quality of in-hospital care among hip fracture patients. The DMHFR monitors quality of care performance measures, which reflect recommendations from the national clinical guideline on hip fracture care. Reporting is mandatory for all hospital units treating hip fracture patients. Data are collected upon hospital admission by the care staff according to detailed data specifications [20].

DNPR has registered data on all non-psychiatric hospital admissions since 1977 and on all outpatient and emergency visits since 1995, recorded according to the International Classification of Diseases (eight revision, ICD-9) until the end of 1993 and tenth revision (ICD-10) thereafter [19]. The DNPR serves as a basis for reimbursement in the Danish Health Care System and includes administrative data including dates and times of any hospital contact (e.g. admission and discharge or start and end of an outpatient contact), procedures performed and secondary and primary diagnosis. We used the DNPR to identify all in-patient admissions and outpatient visits during the last 10 years. Using the hospitalization history for each patient, we computed the Charlson Comorbidity Index (CCI), which is a scoring system that assigns between one and six points to 19 groups of chronic diseases according to their ability to predict mortality [22]. Furthermore, we used the DNPR to identify TTS, LOS and whether the patient had an acute readmission to any Danish hospital within 30 days after discharge.

The DCRS has maintained electronic records of changes in vital status and migration for the entire Danish population since 1968 and includes daily updated information on vital status [19]. Through the DCRS, we obtained data on date and destination of registered emigration (if any), cohabiting status and mortality. Statistics Denmark is a collection of registry data which contains detailed information on each citizen and the Danish society [23, 24]. The income registry contains data on income composition at the individual level and household level. The population register contains data on migrant status and residence area on each citizen. The education register contains information on type of education. We used the three registers to obtain data on highest obtained education, family income and migrant status. The registers are updated yearly.

Study population

We identified hospitalizations for hip fracture patients registered in the DMHFR with a discharge date between 1 March 2010 and 31 November 2013 (N = 26,271). For patients with more than one hip fracture during the study period, we only include the first admission in the study cohort. Patients who had immigrated within the last 5 years were excluded because of insufficient information in the Danish registries (n = 80) along with patients without a registered address (n = 16). Our study cohort therefore included 25,354 patients.

Socioeconomic status

Socioeconomic status was measured using the highest obtained education, 5-year family mean income, cohabiting status and migrant status the year before the hip fracture occurred.

Highest obtained education was classified into three categories to ensure comparison with other studies: low level (none or less than elementary school completed), medium level (more than elementary school but less than university completed) and high level (university degree completed). We obtained information on family mean income for the 5 years before the hip fracture. To account for yearly variations in income, we calculated the average yearly total income in the 5 years before admission for the patient and cohabiting partner. The 5-year family mean income was categorized into quartiles of increasing income. Cohabiting status was categorized as living with a partner or living alone the year before hip fracture, irrespective of marital status. Migrant status was categorized into non-immigrants and immigrants, including their descendants.

Outcomes

Thirty-day mortality was defined as death occurring between the day of hospital admission and 30 days after. Readmission was defined as an acute all-cause readmission to any Danish hospital within 30 days after discharge.

The quality of in-hospital care was assessed using seven process performance measures: (1) daily systematic pain assessment using a visual analogue scale or a numeric rating scale at rest and during mobilization [25]; (2) mobilization within 24 h postoperatively, defined as assisting the patient from bed rest to walking or rest in a chair; (3) and (4) basic mobility assessment using a validated test such as the Cumulated Ambulation Score, Barthel 20, Functional Recovery Score or New Mobility Score measured prior to admission, measured at admission and at discharge and measured prior to discharge [26–28]; (5) initiation of a postdischarge rehabilitation program including assessment of activities of daily living (ADL) with a validated test before the fracture and again before discharge; (6) initiation of treatment to prevent future fall accidents, including a fall risk assessment to account for coexisting medical conditions; medication; functional disability; and symptoms from the central nervous system, musculoskeletal system and cardiopulmonary status; and (7) initiation of treatment with anti-osteoporotic medications. The patients were classified as eligible or ineligible for each individual process performance measure depending on whether the hospital staff identified contraindications (e.g. dementia that disabled the patients from reporting their level of pain during mobilization) or the patient died before the process was relevant (e.g. initiation of a discharge rehabilitation program). The quality of in-hospital care was further summarized using an all-or-none composite measure.

TTS was defined as time in hours from hospital admission to surgery. LOS was defined as the time span from hospital admission to hospital discharge or from hip fracture occurrence if the patient was already hospitalized. The discharge date was defined as the date of discharge to home, a nursing home or death. If the patients were transferred between hospital units, the days spent in all units were included in the LOS.

Potential confounders

A priori identified potential patient-level confounders included gender, age, housing, body mass index (BMI), CCI score, fracture type, fracture displacement, type of surgery and TTS [29, 30]. At the hospital unit level, we adjusted for yearly hip fracture patient volume and orthogeriatric specialization [31, 32] (Table 1).

Statistical analysis

We examined the prevalence proportion of different patient characteristics according to the four socioeconomic markers: education, income, cohabiting status and migrant status. We then calculated, for each stratum of education, income, cohabiting status and migrant status, the proportion of patients who died or were readmitted. We used hierarchical logistic regression to estimate the relationship between the four socioeconomic markers and mortality and readmission. We computed crude and adjusted odds ratios (ORs) with a 95% confidence interval (95% CI). To investigate the relationship among the four different markers of socioeconomic status, we finally conducted mutual adjustment for the socioeconomic markers. To investigate the combination of the socioeconomic markers, we constructed a three-level socioeconomic position variable

Table 1 Patient characteristics according to each stratum of education, income, cohabiting status and ethnicity

	Education[a]								Income						Cohabiting status				Migration status			
	Low *N* = 12,848		Middle *N* = 5566		High *N* = 2849		Missing *N* = 4091		Low *N* = 8451		Middle *N* = 8451		High *N* = 8452		Alone *N* = 17,569		Cohabitant *N* = 7785		Non-immigrants *N* = 24,570		Immigrants *N* = 784	
Sex	%	(*n*)	%	(*n*)	%	(*n*)	%	(*n*)	%	(*n*)	%	(*n*)	%	(*n*)	%	(*n*)	%	(*n*)	%	(*n*)	%	(*n*)
Men	23.5	(3020)	45.3	(2521)	32.4	(922)	20.2	(825)	18.6	(1575)	28.1	(2376)	39.5	(3337)	20.7	(3643)	46.8	(3645)	29.0	(7115)	22.1	(173)
Age																						
65–75 years	18.3	(2353)	29.6	(1649)	29.7	(847)	2.2	(89)	9.6	(808)	16.2	(1367)	32.7	(2763)	14.2	(2494)	31.4	(2444)	19.5	(4779)	20.3	(159)
75–85 years	43.7	(5620)	43.1	(2399)	41.9	(1194)	4.0	(163)	33.4	(2824)	39.6	(3342)	38.0	(3210)	33.8	(5929)	44.3	(3447)	37.0	(9093)	36.1	(283)
>85 years	37.9	(4875)	27.3	(1518)	28.4	(808)	93.8	(3839)	57.0	(4819)	44.4	(3742)	29.3	(2479)	52.1	(9146)	24.3	(1894)	43.5	(10698)	43.6	(342)
CCI																						
No comorbidity	37.6	(4831)	34.9	(1943)	40.2	(1145)	44.0	(1798)	41.0	(3464)	35.8	(3024)	38.2	(3229)	39.3	(6906)	36.1	(2811)	38.3	(9421)	37.8	(296)
Low comorbidity	24.2	(3109)	22.7	(1263)	22.8	(649)	24.3	(994)	23.7	(2004)	25.1	(2119)	22.4	(1892)	24.4	(4289)	22.2	(1726)	23.8	(5849)	21.2	(166)
Moderate	17.2	(2210)	18.7	(1040)	17.6	(500)	16.8	(687)	17.1	(1445)	17.9	(1514)	17.5	(1478)	17.4	(3055)	17.8	(1382)	17.4	(4277)	20.4	(160)
Comorbidity																						
High comorbidity	21.0	(2698)	23.7	(1320)	19.5	(555)	15.0	(612)	18.2	(1538)	21.2	(1794)	21.9	(1853)	18.9	(3319)	24.0	(1866)	20.4	(5023)	20.7	(162)
Housing																						
Own home	66.4	(8532)	72.2	(4020)	72.6	(2069)	50.0	(2044)	60.0	(5071)	62.3	(5268)	74.9	(6326)	60.8	(10686)	76.8	(5979)	65.8	(16159)	64.5	(506)
Own home	6.5	(839)	4.2	(231)	4.4	(125)	8.8	(361)	7.2	(608)	7.6	(639)	3.7	(309)	7.5	(1316)	3.1	(240)	6.2	(1514)	5.4	(42)
Affiliated to an institution																						
Institution	17.2	(2205)	13.7	(763)	12.3	(349)	29.8	(1219)	22.4	(1892)	19.8	(1671)	11.5	(973)	21.5	(3778)	9.7	(758)	17.9	(4389)	18.8	(147)
Missing	9.90	(1272)	9.9	(552)	10.7	(306)	11.4	(467)	10.4	(880)	10.3	(873)	10.0	(844)	10.2	(1789)	10.4	(808)	10.2	(2508)	11.4	(89)
Type of fracture																						
Medial	53.7	(6900)	52.6	(2929)	57.1	(1628)	47.6	(1948)	50.9	(4300)	52.8	(4464)	54.9	(4641)	51.7	(9090)	55.4	(4315)	52.8	(12980)	54.2	(425)
Pertrochanteric	38.6	(4960)	40.6	(2261)	36.0	(1026)	44.8	(1833)	41.8	(3533)	39.8	(3366)	37.6	(3181)	41.0	(7196)	37.1	(2884)	39.8	(9770)	39.5	(310)
Subtrochanteric	7.7	(988)	6.8	(376)	6.8	(195)	7.6	(310)	7.3	(618)	7.4	(621)	7.5	(630)	7.3	(1283)	7.3	(586)	7.4	(1820)	6.3	(49)
Fracture displacement																						
Displaced	72.9	(9369)	72.5	(4033)	71.4	(2035)	72.9	(2983)	72.9	(6162)	73.6	(6219)	71.5	(6039)	72.7	(12775)	72.5	(5645)	72.7	(17864)	70.9	(556)
Undisplaced	11.4	(1470)	12.4	(689)	12.5	(356)	10.3	(420)	10.8	(911)	11.1	(941)	12.8	(1083)	11.4	(1995)	12.1	(940)	11.6	(2843)	11.7	(92)
Missing	15.6	(2009)	15.2	(844)	16.1	(458)	16.8	(688)	16.3	(1378)	15.3	(1291)	15.7	(1330)	15.9	(2799)	15.4	(1200)	15.7	(3863)	17.4	(136)
Type of surgery																						
Osteosynthesis	65.6	(8433)	66.9	(3726)	66.0	(1881)	69.5	(2845)	66.8	(5649)	66.2	(5594)	66.8	(5642)	66.6	(11705)	66.5	(5180)	66.6	(16374)	65.2	(511)
Hemiarthroplasty	27.9	(3580)	26.3	(1462)	27.5	(784)	27.0	(1105)	27.9	(2360)	27.9	(2356)	26.2	(2215)	27.9	(4907)	26.0	(2024)	27.2	(6688)	31.0	(243)
Total hip	6.5	(835)	6.8	(378)	6.5	(184)	3.5	(141)	5.2	(442)	5.9	(501)	7.0	(595)	5.5	(957)	7.5	(581)	6.1	(1508)	3.8	(30)
Arthroplasty BMI																						
<19: underweight	12.5	(1606)	12.7	(709)	12.4	(352)	15.2	(622)	14.2	(1201)	12.8	(1084)	11.9	(1004)	14.0	(2451)	10.8	(838)	13.0	(3182)	13.7	(107)
20–25: normal	45.9	(5897)	47.5	(2643)	48.5	(1383)	47.8	(1955)	47.3	(3994)	46.7	(3944)	46.6	(3940)	47.0	(8258)	46.5	(3620)	46.9	(11516)	46.2	(362)

Table 1 (continued)

	Education[a]				Income			Cohabiting status		Migration status	
>25: overweight	22.4 (2875)	20.4 (1133)	18.4 (524)	13.8 (564)	18.4 (1555)	20.9 (1762)	21.1 (1779)	18.7 (3278)	23.4 (1818)	20.2 (4952)	18.4 (144)
Missing	19.2 (2470)	19.4 (1081)	20.7 (590)	23.2 (950)	20.1 (1701)	19.7 (1661)	20.5 (1729)	20.4 (3582)	19.4 (1509)	20.0 (4920)	21.8 (171)
Unit setting											
Orthopaedic unit	77.6 (9972)	77.6 (4320)	76.1 (2169)	76.9 (3147)	79.0 (6678)	76.2 (6441)	76.8 (6489)	77.7 (13642)	76.6 (5966)	77.2 (18970)	81.4 (638)
Orthogeriatric unit	22.4 (2876)	22.4 (1246)	23.9 (680)	23.1 (944)	21.0 (1773)	23.8 (2010)	23.2 (1963)	22.4 (3927)	23.4 (1819)	22.8 (5600)	18.6 (146)
Unit volume of hip fracture											
–151	8.4 (1077)	5.0 (279)	6.0 (171)	7.1 (289)	8.0 (678)	7.4 (629)	6.0 (509)	7.0 (1237)	7.4 (579)	7.3 (1784)	4.1 (32)
152–350	60.6 (7790)	54.1 (3013)	50.8 (1447)	55.2 (2256)	60.0 (5066)	58.6 (4956)	53.1 (4484)	56.3 (9887)	59.3 (4619)	57.6 (14142)	46.4 (364)
>350	31.0 (3981)	40.9 (2274)	43.2 (1231)	37.8 (1546)	32.0 (2707)	33.9 (2866)	40.9 (3459)	36.7 (6445)	33.2 (2587)	35.2 (8644)	49.5 (388)

CCI Charlson Comorbidity Index, *BMI* body mass index

[a] Low education: none or less than elementary school completed, middle education: more than elementary school but less than university and higher education: university degree completed

called class in which education and income were high, medium and low. We categorized patients with low education and low income into low class, patients with middle education and medium income as middle class and patients with higher education and higher income as high class. Patients with a discordant level of education and income (e.g. low income and high education) were excluded from these analyses. Secondly, we calculated, for each stratum of the socioeconomic markers, the proportion of patients, who received care which fulfilled all relevant process performance measures. Furthermore, we assessed whether the four socioeconomic markers were associated with receiving the individual process performance measures. We computed the relative risk for fulfilling the process performance measures using the binomial regression because the rare disease assumption was not fulfilled. Patient characteristics were not included as covariates in these analyses, as only patients who were found eligible for the individual process performance measures were included in the analysis.

We calculated median TTS and median LOS. The association between the four socioeconomic markers and TTS and LOS were analyzed using multilevel linear regression modelling. We used a natural log transformation to correct for the right skewness in TTS and LOS, and the results are reported as ratios between geometric means with and without adjustment. These analyses were also performed with mutual adjustment for the four socioeconomic markers and with the combination of education and income.

To handle missing data on covariates such as housing, BMI and fracture displacement (see Table 1), multiple imputations were performed based on the missing at random assumption in order to achieve unbiased and valid estimates of association from incomplete data that we would achieve if data were fully complete [33]. We generated 25 complete data sets with imputed data using all available information from patients with complete information presented in Table 1, including outcome data. All analyses were also performed only for patients for whom complete data were available (Supplement Appendix 1 shows complete case analysis). Data were analyzed using Stata 14.0 (StataCorp LP, College Station, TX, USA).

Results

Patient characteristics

Compared to patients with high education or patients with high income, patients with low education or low income were often women above age 85 years, were overweight and lived at an institution. Living alone was associated with higher age, being underweight and having less comorbidity. Immigrants were more often women and were more likely to be treated in a traditional orthopaedic department with high volume (Table 1).

30-day mortality

The overall 30-day mortality risk was 10.0, 9.4 and 7.3% for patients with low education, middle education and higher education, respectively. The association between higher education and lower mortality remained in all strata in the adjusted analysis (Table 2). The adjusted OR for 30-day mortality among patients with high education was 0.74 (95% CI 0.63–0.88) compared to patients with low education.

Increasing family income was also associated with lower 30-day mortality. The 30-day mortality varied from 13.0% among those with low income to 11.9% for those with middle income and 8.6% for the patients with high income. These differences corresponded to an adjusted OR for 30-day mortality of 0.77 (95% CI 0.69–0.85) for patients with high income and 0.93 (95% CI 0.84–1.02) for patients with middle income. The associations remained for both education level and high income in the mutually adjusted analysis. The same pattern was also seen when we combined education and income. The 30-day mortality was 11.9% for patients living alone compared to 9.6% for patients living with a partner and 11.2 and 10.6% for non-immigrants and immigrants, respectively. However, either cohabiting status or migrant status was associated with decreased 30-day mortality in the adjusted analysis.

Readmission within 30 days after discharge

The overall acute readmission rate of patients discharged alive (93%) was 23.6%. Of the patients with low education, 17.6% were admitted acute within 30 days at least once compared to 19.8% of the patients with middle education. Adjustment for confounding weakened this association from 1.13 (95% CI 1.04–1.22) to 1.06 (95% CI 0.98–1.16). For the combined variable of education and income, the 30-day readmission rate was 16.9, 21.7 and 14.5% for the low class, the middle class and the high class, respectively, corresponding to an adjusted OR for readmission for the higher class of 0.94 (95% CI 0.91–0.97) compared to the lower class. The differences between middle class and low class did not reach statistical significance in the adjusted analysis (OR = 0.97 95% CI 0.94–1.01) (see Table 3).

Quality of in-hospital care

Table 4 illustrates the proportions of patients that received all relevant process performance measures sum up in an all-or-none composite measure according to each stratum of education, income, cohabiting status and migrant status. There were no differences in quality of in-hospital care between patients with high or low socioeconomic status. There was no

Table 2 Crude and adjusted OR for 30-day mortality according to socioeconomic status

	Died % (*n*)		Unadjusted OR (95% CI)		Adjusted OR[b] (95% CI)		Mutually adjusted[c] OR (95% CI)	
Education[a]								
Low education	10.0	(1287/12,848)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Middle education	9.4	(521/5566)	0.91	(0.82–1.02)	0.85	(0.76–0.95)	0.88	(0.78–0.99)
Higher education	7.3	(208/2849)	0.70	(0.60–0.81)	0.74	(0.63–0.88)	0.81	(0.68–0.96)
Income								
Low	13.0	(1099/8451)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Middle	11.9	(1007/8451)	0.90	(0.82–0.99)	0.93	(0.84–1.02)	0.94	(0.84–1.04)
High	8.6	(729/8452)	0.62	(0.56–0.68)	0.77	(0.69–0.85)	0.80	(0.71–0.91)
Cohabiting status								
Single	11.9	(2091/17,569)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Cohabiting	9.6	(744/7785)	0.78	(0.72–0.85)	0.93	(0.84–1.03)	1.02	(0.91–1.14)
Migrant status								
Non-immigrants	11.2	(2752/24,570)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Immigrants	10.6	(83/784)	0.92	(0.73–1.17)	0.95	(0.75–1.22)	0.98	(0.77–1.26)
Class[d]								
Low	10.8	(519/4811)	1.00	(Reference)	1	(Reference)		
Middle	9.6	(116/1213)	0.92	(0.77–1.10)	0.80	(0.66–0.97)		
High	7.3	(69/940)	0.65	(0.53–0.79)	0.71	(0.58–0.88)		

[a] Low education: none or less than elementary school completed, middle education: more than elementary school but less than university and higher education: university degree completed

[b] Odds ratio adjusted for gender, housing, fracture type, fracture displacement, type of surgery, body mass index, age, Charlson Comorbidity Index, time to surgery and at the unit level: number of hip fracture patients and ortogeriatric specialization

[c] Adjusted for the previously mentioned covariates plus education, income, cohabiting status and migrant status

[d] Low class: low education and low income, middle class: middle education and middle income and high class: higher education and high income

Table 3 Crude and adjusted OR for at least one acute readmission within 30 days after discharge according to socioeconomic status

	Event % (*n*)		Unadjusted OR (95% CI)		Adjusted[b] OR (95% CI)		Mutually adjusted[c] OR (95% CI)	
Education[a]								
Low education	17.6	(2121/12,064)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Middle education	19.8	(1034/5217)	1.13	(1.04–1.22)	1.06	(0.98–1.16)	1.06	(0.98–1.16)
Higher education	16.9	(455/2699)	0.93	(0.83–1.04)	0.95	(0.84–1.06)	0.95	(0.84–1.07)
Income								
Low	17.2	(1349/7839)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Middle	18.5	(1447/7839)	1.08	(0.99–1.17)	1.05	(0.96–1.14)	1.07	(0.98–1.17)
High	17.9	(1425/7963)	1.02	(0.94–1.11)	1.00	(0.91–1.09)	1.04	(0.94–1.16)
Cohabiting status								
Single	17.9	(2927/16,353)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Cohabiting	17.8	(1294/7288)	1.00	(0.93–1.07)	0.94	(0.86–1.01)	0.92	(0.84–1.00)
Migrant status								
Non-immigrants	17.9	(4092/22,898)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Immigrants	17.4	(129/743)	0.93	(0.77–1.13)	0.93	(0.76–1.13)	0.93	(0.77–1.13)
Class[d]								
Low	16.9	(761/4514)	1.00	(Reference)	1.00	(Reference)		
Middle	21.7	(247/1141)	1.28	(1.11–1.48)	0.97	(0.94–1.01)		
High	14.5	(129/890)	0.98	(0.84–1.13)	0.94	(0.91–0.97)		

[a] Low education: none or less than elementary school completed, middle education: more than elementary school but less than university and higher education: university degree completed

[b] Odds ratio adjusted for gender, housing, fracture type, fracture displacement, type of surgery, body mass index, age, Charlson Comorbidity Index, time to surgery and at the unit level: number of hip fracture patients and ortogeriatric specialization

[c] Adjusted for the previously mentioned covariates plus education, income, cohabiting status and migrant status

[d] Low class: low education and low income, middle class: middle education and middle income and high class: higher education and high income

difference when we examined the association between the socioeconomic markers and the individual process performance measures or when combining education and income (Supplement Appendix 2).

Time to surgery

Table 5 displays the median TTS, according to each stratum of education, income, cohabiting status and migrant status.

Table 4 Proportion of patients who received all relevant process performance measures according to each stratum of education, income, cohabiting status and migrant status

Low education[a] (Reference)		RR	Middle education		RR	(95% CI)	Higher education		RR	(95% CI)
49.7%	(6334/12,749)	1.00	49.8%	(2750/5519)	1.00	(0.94–1.07)	49.5%	(1400/2827)	1.00	(0.92–1.09)
Low income	(Reference)	RR	Middle income		RR	(95% CI)	High income		RR	(95% CI)
47.4%	(3974/8380)	1.00	49.3%	(4114/8354)	1.04	(0.99–1.09)	50.2%	(4214/8392)	1.06	(0.98–1.14)
Single	(Reference)	RR	Cohabiting		RR	(95% CI)				
49.0%	(8535/17,412)	1.00	48.8%	(3767/7714)	1.00	(0.97–1.03)				
Non-immigrants	(Reference)	RR	Immigrants		RR	(95% CI)				
49.0%	(11,936/24,347)	1.00	47.0%	(366/779)	0.96	(0.86–1.07)				
Low class[b]	(Reference)	RR	Middle class		RR	(95% CI)	High class		RR	(95% CI)
47.9%	(2288/4777)	1.00	51.3%	(615/1200)	1.03	(0.94–1.13)	50.9%	(475/933)	1.04	(0.92–1.18)

RR relative risk

[a] Low education: none or less than elementary school completed, middle education: more than elementary school but less than university and higher education: university degree completed

[b] Low class: low education and low income, middle class: middle education and middle income and high class: higher education and high income

Table 5 Crude and adjusted relative time to surgery according to socioeconomic status

	Median TTS in hours (IQR)		Unadjusted relative TTS (95% CI)		Adjusted relative TTS[b] (95% CI)		Mutually adjusted[c] relative TTS (95% CI)	
Education[a]								
Low education	21.5	(14.9–33.0)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Middle education	21.7	(15.2–34.0)	1.01	(0.98–1.04)	0.99	(0.96–1.01)	0.99	(0.97–1.02)
Higher education	21.8	(14.9–34.4)	0.96	(0.92–0.99)	0.96	(0.92–0.99)	0.97	(0.93–1.00)
Income								
Low	21.8	(15.1–33.2)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Middle	21.3	(14.6–32.4)	0.97	(0.95–1.00)	0.96	(0.93–0.98)	0.97	(0.94–0.99)
High	21.6	(14.8–33.5)	0.97	(0.95–1.00)	0.94	(0.92–0.97)	0.96	(0.93–0.99)
Cohabiting status								
Single	21.5	(14.9–32.5)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Cohabiting	21.7	(14.8–34.2)	1.00	(0.98–1.02)	0.96	(0.94–0.99)	0.98	(0.95–1.00)
Migrant status								
Non-immigrants	21.5	(14.8–32.9)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Immigrants	22.6	(15.7–35.4)	1.04	(0.98–1.10)	1.04	(1.02–1.10)	1.04	(0.98–1.11)
Class[d]								
Low	21.9	(15.4–33.9)	1.00	(Reference)	1.00	(Reference)		
Middle	21.4	(15.0–32.4)	0.97	(0.92–1.01)	0.97	(0.94–1.01)		
High	21.4	(14.5–31.7)	0.91	(0.87–0.96)	0.94	(0.91–0.97)		

TTS time to surgery

[a] Low education: none or less than elementary school completed, middle education: more than elementary school but less than university and higher education: university degree completed

[b] Relative time to surgery adjusted for gender, housing, Charlson Comorbidity Index, fracture type, fracture displacement, type of surgery, body mass index, age and at the unit level: number of hip fracture patients and ortogeriatric specialization

[c] Relative time to surgery adjusted for the previously mentioned covariates plus education, income, cohabiting status and migrant status

[d] Low class: low education and low income, middle class: middle education and middle income and high class: higher education and high income

Overall, the median TTS was 21.7 h with an interquartile range between 14.9 to 34.4 h. There were only minor differences in TTS between patients with low and high socioeconomic status. The largest difference was seen for non-immigrants compared to immigrants (21.5 compared to 22.6 h); however, the difference did not remain in the adjusted analysis.

Length of stays

Of the patients discharged alive (93%), the overall median LOS was 8.6 days. According to each stratum of education, income, cohabiting status and migrant status, only differences less than 1 day were found (Table 6). Patient with both middle education and middle income had a LOS of 9.0 days compared to 8.4 days for patients with both low education and low income; however, the differences did not remain in the adjusted analysis.

Discussion

In this nationwide study of 25,354 elderly hip fracture patients, we found that higher education and higher family income were associated with substantially lower 30-day mortality after hip fracture. The higher mortality among low socioeconomic disadvantaged patients seems not to be explained by differences in quality of care as we found no differences in TTS, quality of in-hospital care or LOS for low versus high socioeconomic groups. Compared to patients with low education and low income, the combination of high income and high education was also associated with a lower risk of acute readmission.

Methodological considerations

The strengths of the present study include a population-based design with prospective data collection and complete follow-up, which minimized the risk of selection and information bias. Furthermore, the use of the data

Table 6 Crude and adjusted relative length of stay according to socioeconomic status

	Median LOS in days (IQR)		Unadjusted relative LOS (95% CI)		Adjusted relative LOS[b] (95% CI)		Mutually adjusted[c] relative LOS (95% CI)	
Education[a]								
Low education	8.4	(5.8–12.3)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Middle education	8.8	(6.0–13.0)	1.00	(0.98–1.02)	1.00	(0.98–1.03)	0.99	(0.98–1.01)
Higher education	8.5	(5.8–11.9)	0.95	(0.93–0.98)	0.98	(0.96–1.01)	0.97	(0.94–0.99)
Income								
Low	8.5	(5.7–12.7)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Middle	8.5	(5.8–12.6)	0.99	(0.97–1.01)	0.99	(0.97–1.01)	1.00	(0.98–1.02)
High	8.5	(5.8–12.5)	0.98	(0.96–1.00)	0.99	(0.97–1.01)	0.97	(0.95–0.99)
Cohabiting status								
Single	8.6	(5.8–12.7)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Cohabiting	8.2	(5.8–12.1)	1.01	(0.99–1.02)	1.00	(0.98–1.02)	0.94	(0.92–0.96)
Migrant status								
Non-immigrants	8.5	(5.8–12.6)	1.00	(Reference)	1.00	(Reference)	1.00	(Reference)
Immigrants	8.7	(5.9–12.8)	0.98	(0.94–1.03)	0.98	(0.94–1.02)	0.98	(0.94–1.02)
Class[d]								
Low	8.4	(5.8–12.4)	1.00	(Reference)	1.00	(Reference)		
Middle	9.0	(6.1–13.6)	0.99	(0.96–1.03)	0.99	(0.94–1.00)		
High	8.5	(5.9–11.7)	0.93	(0.90–0.96)	0.89	(0.87–0.92)		

LOS length of stay

[a] Low education: none or less than elementary school completed, middle education: more than elementary school but less than university and higher education: university degree completed

[b] Relative length of stay adjusted for gender, housing, fracture type, fracture displacement, type of surgery, body mass index, age, Charlson Comorbidity Index, time to surgery and at the unit level: number of hip fracture patients and ortogeriatric specialization

[c] Relative length of stay adjusted for the previously mentioned covariates plus education, income, cohabiting status and migrant status

[d] Low class: low education and low income, middle class: middle education and middle income and high class: higher education and high income

collected with an individual person number enables linkage to national registries. We had the opportunity to reduce the potential influence of a reverse causation phenomenon in our study by including four markers of socioeconomic status and adjust our estimates for co-morbid conditions, state of nutrition, fracture severity and housing as a proxy for functional level. Nevertheless, it is important also to take the limitations into account. First, unmeasured data on lifestyle habits including smoking and alcohol intake, which are expected to differ according to socioeconomic status, could have influenced the association. However, the crude and adjusted analyses yielded nearly identical results and the differences in patient characteristics were not systematically in favour of patients with a high socioeconomic status. These analyses are therefore not a strong indication of substantial residual or unaccounted confounding in our study.

Secondly, collection of data at multiple sites during routine clinical practice can potentially affect the accuracy of the collected data. However, major efforts including dissemination of detailed written instructions for reporting of data to the DMHFR and regular clinical audits have been carried out to ensure validity of the data. Regardless, misclassification of process performance measures would most likely be unrelated to socioeconomic status because we found no difference in the registration of the covariates, housing, fracture displacement and BMI between the socioeconomic strata reported to the DMHFR.

Comparison with previous literature

Our findings of lower 30-day mortality among higher socio-economic groups corroborate with three previous studies also reporting higher socioeconomic status to be associated with a lower mortality among hip fracture patients. It is noted that the point estimates in the previous studies appear to have been somewhat more extreme, which may reflect unaccounted or residual confounding due to a limited possibility to adjust for comorbidity among the patients [12, 14, 15]. In contrast, other studies have not found consistent pattern of lower 30-day mortality among high socioeconomic groups [8, 11, 14]. There are a number of possible explanations for these diverging results. First, socioeconomic status has been assessed using different measures such as marital status, income, education and consequently not usually understood as a multidimensional concept. Second, these differences may reflect that the studies mostly used area-based rather than individual-level measures of socioeconomic status, leading to a substantial risk of misclassification. Moreover, the studies did not include an unselected population and selection may have been related to the socioeconomic status of the patients.

The lower readmission risk among patients with high education and high income probably reflects a lower vulnerability in the patients with a higher socioeconomic status, because the associations get stronger after adjustment for patient characteristics. Moreover, well-educated patients with a high income may have the resources to remain more compliant with the treatment, rehabilitation recommendations and prescribed secondary prevention. Further studies are therefore needed to investigate whether there is inequality in the treatment of complications after discharge.

We did not find any socioeconomic-related differences in quality of care and TTS. Few studies on socioeconomic status have examined these outcomes among hip fracture patients. An Italian study among 5051 hip fracture patients did find that higher socioeconomic status was associated with shorter TTS [15]. Also, a study from the USA found that patients on Medicaid and/or uninsured were less likely to receive institutional care and home health care afterwards [34]. Even though our results are not directly comparable to other studies, we did find consistency of measures of the delivered care. Moreover, our results may be the result of more than 12 years of work with implementation of clinical guidelines for hip fracture care, which may have had an effect on especially the receiving of care of patients with low socioeconomic class. This is supported by an Italian study, which was able to show that public reporting of quality indicators seemed to reduce social inequality [16].

Furthermore, we did not found differences in LOS. The results may seem surprising given that LOS after a hip fracture should be adopted to the patient's general condition, and therefore, one may expect longer LOS among patients with lower socioeconomic status, as they have more comorbidity. A Swedish study has recently shown that LOS below 10 days increased the risk for 30-day mortality after hip fracture [35]. The study did not investigate the underlying causes of the higher mortality among patients being discharged within 10 days, but the authors make the hypothesis that early discharge lowers the possibility for regaining mobility and therefore increases the risk of complications and ultimately death. It could therefore be hypothesized that even though the LOS was comparable across social classes, the consequence of a short LOS (e.g. below 10 days) may be different according to socioeconomic status.

In conclusion, we found that higher education and higher family income were associated with substantially lower 30-day mortality after hip fracture. Furthermore, patients with both higher education and higher income had lower risk for readmission within 30 days. The socioeconomic differences were not related to differences in TTS, quality of in-hospital care or LOS. Future studies are warranted to further clarify the mechanisms leading to worse outcomes for hip fracture patients with low social class. In particular, the transition to the community setting and support from home care and nursing homes are of interest.

Acknowledgements We thank the staff of the hospital departments caring for patients with hip fracture for their continuous effort and contribution to acquisition of the data in the Danish Multidisciplinary Hip Fracture Registry.

Compliance with ethical standards The study was approved by the Danish Data Protection Agency (record no. 2012-41-1274).

Declaration of sources of funding This work was supported by the Health Research Fund of Central Denmark Region, the Family Hede Nielsens Fund and the Gurli and Hans Friis Fund. The financial sponsors did not play a role in the design, execution, analysis, interpretation of data or writing of the study.

Conflicts of interest None.

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