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

A LINKED MULTIREGISTRY STUDY

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

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

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

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

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

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

Table I. Patient descriptive characteristics.

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

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

in-hospital delay, hospital status, and in-hospital services).[1,2,4-7] Such information leads to the question of the relative value of individual risk factors associated with mortality. Interventions on patient factors or rectifying shortcomings in the health-care system must be based on measures of high feasibility and impact. Identifying the most important risk factors to address requires comprehensive analyses using multiple linkable data sources. This allows examination of many subsets of data in a single analysis.

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

Methods

This is a population-based national prospective study based on linked data from the Norwegian Hip Fracture Register (NHFR), the Norwegian Patient Registry (NPR), and socioeconomic data from Statistics Norway (SN). In all these databases, patients are identified with a unique 11-digit national identification number which enables data coupling. The term 'hip fracture' denotes patients with femoral neck fracture (FNF; International

Table II. Hospital and system descriptive characteristics.

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

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

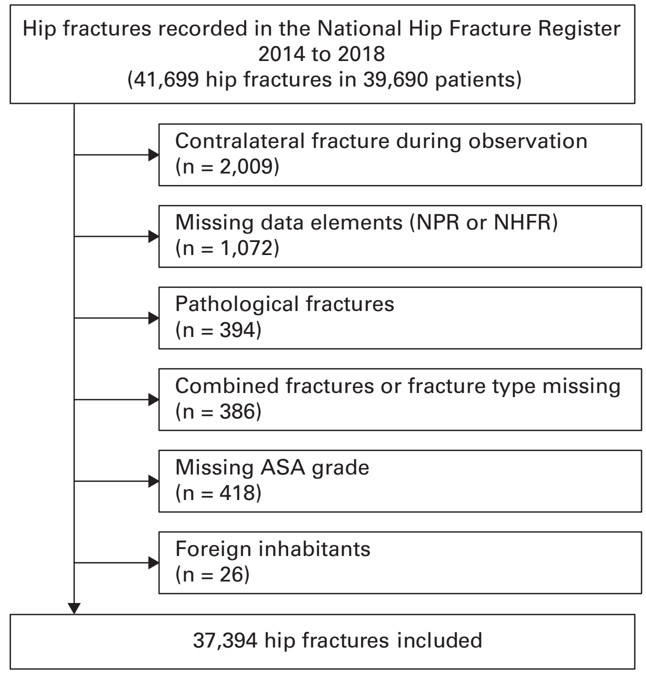


Fig. 1

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

Classification of Diseases (ICD)-10 code S72.0), trochanteric fracture (ICD-10 code S72.1), or subtrochanteric fracture (ICD-10 code S72.2).[8]

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

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

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

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

Characteristic	RC (SE)	p-value*
Sex†		
Male	Reference	
Female	0.67 (0.05)	< 0.001
Sex × Log(T)	-0.09 (0.009)	< 0.001
ASA grade†		
1	Reference	
2	1.68 (0.15)	< 0.001
3	2.86 (0.17)	< 0.001
4/5	4.01 (0.19)	< 0.001
ASA × Log(T)	-0.10 (0.008)	< 0.001
	HR (95% CI)	
Age	1.060 (1.058 to 1.062)	< 0.001
CCI		
0	Reference	
1	1.34 (1.29 to 1.39)	< 0.001
2	1.70 (1.60 to 1.80)	< 0.001
3	2.94 (2.73 to 3.16)	< 0.001
Socioeconomic factors		
Household income‡		
Q1	1.16 (1.07 to 1.26)	< 0.001
Q2	1.18 (1.09 to 1.27)	< 0.001
Q3	1.09 (1.04 to 1.15)	0.001
Q4	Reference	
Highest level of education		
Low	Reference	
Medium	0.93 (0.89 to 0.96)	< 0.001
High	0.86 (0.81 to 0.91)	< 0.001
Residential status		
Residing alone	Reference	
Cohabitant	1.04 (0.97 to 1.11)	0.260
Living in a healthcare facility	1.95 (1.86 to 2.04)	< 0.001
Municipality population		
Small	0.97 (0.92 to 1.03)	0.287
Medium	1.01 (0.97 to 1.05)	0.777
High	Reference	
Fracture type		
Displaced FNF (Garden 3 to 4)	Reference	
Undisplaced FNF (Garden 1 to 2)	1.02 (0.97 to 1.08)	0.498
Basocervical	1.18 (1.08 to 1.30)	0.001
Trochanteric AO/OTA[20] A1	1.15 (1.10 to 1.21)	< 0.001
Trochanteric AO/OTA A2	1.11 (1.05 to 1.16)	< 0.001
Subtrochanteric	0.98 (0.90 to 1.05)	0.510
Intertrochanteric AO/OTA A3	1.01 (0.91 to 1.12)	0.918
Hospital characteristics		
Regional Health Authority		
Northern	0.97 (0.91 to 1.03)	0.265
Central	0.85 (0.81 to 0.89)	< 0.001
Western	0.93 (0.89 to 0.97)	0.002
South-Eastern	Reference	
Hip fracture volume		
Low	0.96 (0.90 to 1.04)	0.331
Intermediate low	0.91 (0.86 to 0.95)	< 0.001
Intermediate high	0.95 (0.91 to 0.99)	0.013
High volume	Reference	
Dedicated orthopaedic ward		
No	Reference	
Yes	1.02 (0.96 to 1.08)	0.568
Dedicated hip fracture unit		
No	Reference	
Yes	0.99 (0.95 to 1.04)	0.770
Orthogeriatric services		
No	Reference	
Yes	0.95 (0.91 to 0.99)	0.008
Waiting time in hospital§		
Q1	Reference	
Q2	0.96 (0.92 to 1.01)	0.102
Q3	0.96 (0.91 to 1.00)	0.047
Q4	0.97 (0.92 to 1.03)	0.347
Expedited surgery		
Yes	Reference	
No	1.02 (0.96 to 1.09)	0.514
Best practice		
No	Reference	
Yes	1.00 (0.96 to 1.04)	0.973
Experienced surgeon		
No	Reference	
Yes	1.05 (1.00 to 1.10)	0.047

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

education), medium (upper secondary to short-cycle tertiary education), and high (bachelors level and beyond).

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

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

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

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

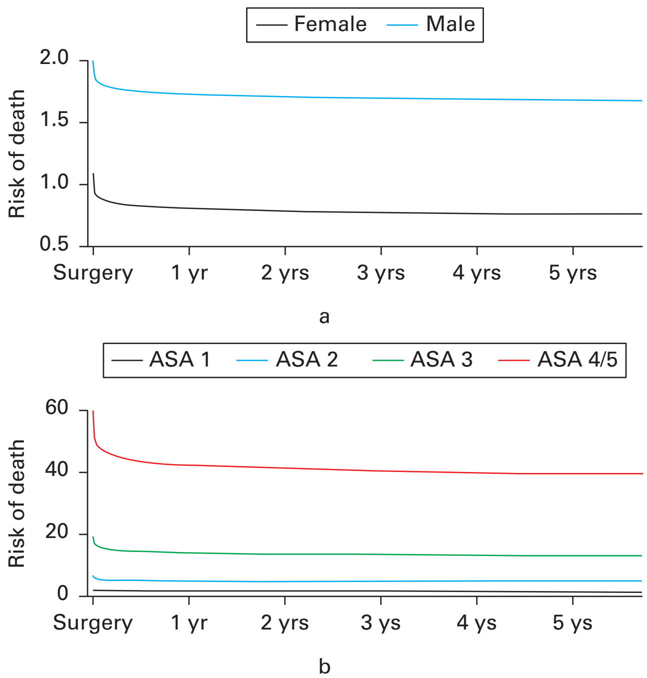


Fig. 2

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

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

The Wald chi-squared statistic,[18] assessing the strength of association between each covariate and mortality in the Cox regression model, was used in combination with degrees of freedom (df) to quantify the strength of association of covariates in the model (Wald χ^2 – df).

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

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

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

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

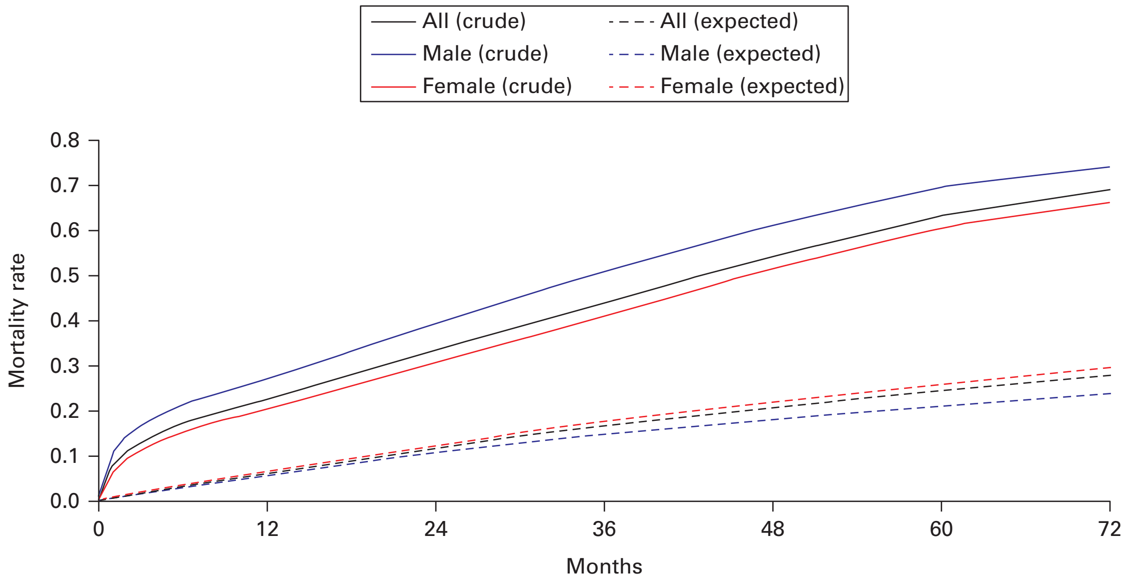
ASA, American Society of Anesthesiologists; CCI, Charlson Comorbidity Index.

Results

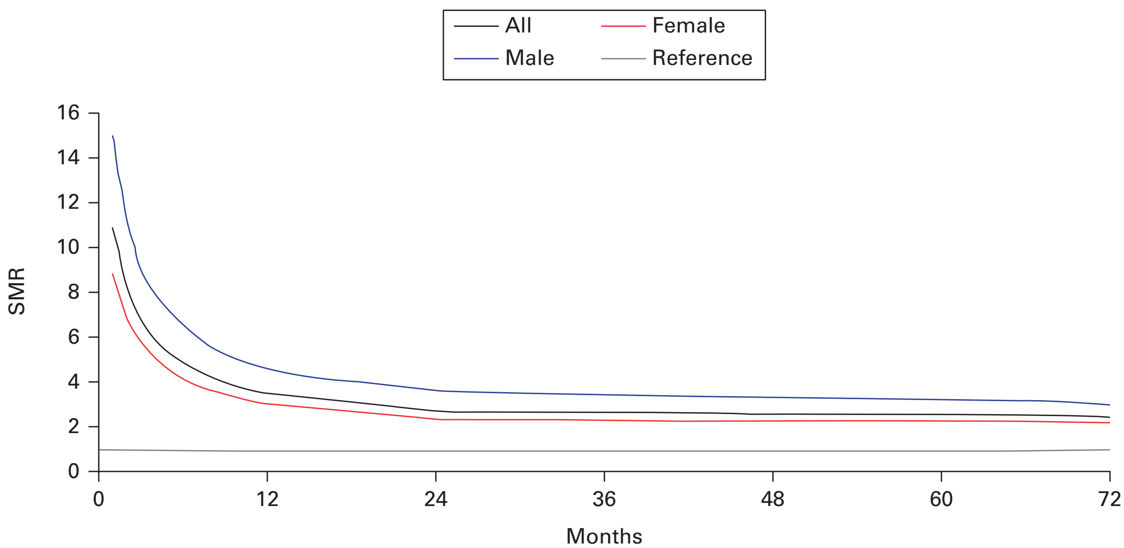
Characteristics. Mean age was 80.2 years (SD 11.4), 67.5% were female (n = 25,251) (Table I). Most patients were classified as ASA grades 3 to 5 (63.0%; n = 23,568), 31.2% had a CCI of 1 or above (n = 11,649). Median household income was NOK 261,610, 47.6% of patients lived alone (n = 17,791), and 86.5% had achieved a medium or high education level (n = 21,360). Most patients had a FNF (58.8%); 45.9% had a displaced (Garden type 3 to 4) fracture.[19]

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

Mortality risk. Table III presents results of the multivariate Cox regression analysis. The age effect on mortality was notable, with a HR of 1.06 (95% CI 1.058 to 1.062) for a one-year increment in patient age; a rate of 6% higher mortality per year. Sex was a time-dependent variable and females had a lower mortality than males in the immediate postoperative period, but this levelled off and stabilized after the first few weeks following surgery (Figure 2a). ASA grade was also a time-dependent risk factor. The risk of mortality was stable over time for ASA grade 1 and 2, but rapidly decreased the first two months after surgery for ASA grades 4 and 5 and less rapidly for ASA grade 3. The



a



b

Fig. 3

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

risk remained higher for ASA grades 2, 3, and 4 + 5 compared to ASA grade 1 (Figure 2b).

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

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

Table V. Median survival after hip fracture.

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

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

high-volume (HR 0.95 (95% CI 0.91 to 0.99)) hospitals had a statistically significant lower mortality. Expedited surgery was not associated with mortality, whereas mortality was relatively higher when the surgeon was experienced (HR 1.05 (95% CI 1.00 to 1.10)).

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

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

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

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

Discussion

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

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

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

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

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

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

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

Orthogeriatric assessment is recommended to improve functional outcomes,[14] and has been shown to reduce mortality in FNFs receiving arthroplasty by Roberts et al.[22] In this study, orthogeriatric services were associated with lower mortality, all fracture types included.

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

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

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

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

Take home message

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

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Supplementary material

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

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