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RESEARCH PAPER

Individual and combined effects of somatic and mental disorders on reoperation risk after hip fracture surgery: a nationwide danish cohort study of 110,625 patients

Simon Storgaard Jensen[1,2] · Per Hviid Gundtoft[3] · Jan-Erik Gjertsen[4,5] · Alma Becic Pedersen[1,2]

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Key summary points

Aim To examine the risk of reoperation concerning individual comorbidity groups, their combinations, and overall comorbidity burden, after hip fracture surgery.

Findings The highest reoperation risk was observed in patients with mental, hepatic/gastrointestinal, neurological/alcohol, and mmusculoskeletal disorders. The risk increased with comorbidity burden, but the association was more pronounced for high-risk combinations.

Message Comorbidity profiles may offer greater prognostic value than composite scores alone for hip fracture patients.

Abstract

Purpose Surgical complications after hip fracture surgery are common, particularly among patients with comorbidities. We examined the risk of reoperation concerning individual comorbidity groups, their combinations, and overall comorbidity burden.

Methods Using nationwide Danish registry data, we identified all patients undergoing hip fracture surgery between 2004 and 2021. Comorbidities were analysed as: (1) 10 major comorbidity groups, (2) all pairwise combinations of the 10 groups, and (3) overall comorbidity burden based on the 10 groups. Reoperation risk was estimated with 95% confidence intervals (CI), treating death as a competing event.

Results We included 110,625 patients, with a mean age of 82.4 years (70% female). The most prevalent comorbidity groups were cardiovascular (54%), renal/haematological (24%), and metabolic (20%) disorders. The highest 30-day reoperation risks were observed in patients with mental disorders 4.8% (CI 4.3–5.3) and musculoskeletal disorders 4.7% (CI 4.2–5.3). Compared with patients without comorbidities, adjusted hazard ratios (aHRs) for reoperation were 1.53 (CI 1.27–1.83) for neurological/alcohol disorders and 1.40 (CI 1.15–1.70) for mental disorders. Several combinations were associated with a significantly increased reoperation risk, highest for mental and hepatic/gastrointestinal disorders, with an aHR of 2.27 (CI 1.20–4.32). The reoperation risk increased with comorbidity burden, reaching an aHR of 1.33 (CI 1.11–1.59) for patients with ≥ 5 comorbidities. Similar patterns were seen at 365 days.

Conclusion Specific comorbidities, particularly mental, hepatic/gastrointestinal, neurological/alcohol, and musculoskeletal disorders, were associated with increased reoperation risk after hip fracture surgery. Risk was highest for certain comorbidity combinations, highlighting the prognostic value of comorbidity profiles beyond overall burden and supporting their use in stratified care.

Keywords Hip Fracture · Interdisciplinary treatment · Reoperation · Comorbidity · Multimorbidity

✉ Simon Storgaard Jensen
ssj@clin.au.dk

[1] Department of Clinical Epidemiology, Aarhus University Hospital, Aarhus, Denmark

[2] Department of Clinical Medicine, Aarhus University, Aarhus, Denmark

[3] Department of Orthopaedic Surgery, Traumatology, Aarhus University Hospital, Aarhus, Denmark

[4] Department of Orthopaedic Surgery, Haukeland University Hospital, Bergen, Norway

[5] Department of Clinical Medicine, University of Bergen, Bergen, Norway

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Introduction

Hip fractures represent a significant global health burden, which is expected to grow substantially due to the ageing population [1]. The mortality rate within the first year after a hip fracture is approximately 30%, and nearly 30% of patients experience postoperative complications [2, 3]. Reoperation rates are around 10% within the first year, rising to 15% within 5 years [4–6].

Pre-existing chronic comorbidities are common in hip fracture patients [7]. However, there are no established guidelines for capturing comorbidity burden and its impact on postoperative outcomes [8]. Widely used indices, such as the Charlson Comorbidity Index (CCI), provide a summarised score but exclude several relevant conditions in this population [9, 10]. Although a higher CCI score (e.g. ≥ 3) has been linked to an increased risk of reoperation due to surgical site infection [11], few studies have explored the influence of comorbidities on other types of reoperations. Furthermore, composite indices like the CCI may obscure the distinct effects of specific comorbidities, limiting their usefulness in risk stratification and clinical decision-making.

Major somatic conditions, such as cardiovascular disease and diabetes, are known to elevate the risk of postoperative complications and mortality [12]. Recent studies also suggest that mental disorders may contribute to higher risks of both reoperation and mortality [6]. However, the combined impact of somatic and mental disorders on reoperation risk remains poorly understood. Although various methods exist to capture comorbidity, ranging from individual diagnoses to grouped categories or counts, no large-scale study has comprehensively examined their association with reoperation risk after hip fracture surgery.

This population-based cohort study aimed to assess the association between pre-existing comorbidities and reoperation risk following hip fracture surgery. We applied multiple approaches to capture comorbidity history, including individual comorbidity groups, combinations of comorbidities, and overall burden, and compared their associations with reoperation risk.

Methods

Data sources

In Denmark (population ~ 5.9 million in 2023), both primary hip fracture surgeries and subsequent reoperations are exclusively performed in public hospitals within a universal, tax-funded healthcare system [13].

The Danish Civil Registration System (DCRS) assigns a unique personal identifier to all residents, enabling individual-level linkage across medical registries and facilitating follow-up on vital status, emigration, and immigration [14]. Using this identifier, data from the Danish Multidisciplinary Hip Fracture Registry (DMHFR) were linked to other national registries [14].

Hip fracture patients were identified via the DMHFR [7], which has required mandatory reporting from all Danish hospitals since 2004 [15]. The registry includes patients aged ≥ 65 undergoing surgery for their first hip fracture and captures details of the acute hospital stay [7, 15].

The Danish National Patient Registry (DNPR) contains data on all hospitalisations since 1977, including discharge dates, diagnosis codes, and surgical procedures [16]. Since 1995, it has also included records from outpatient clinics and emergency departments [16].

The Danish Psychiatric Central Research Register (DPCRR) includes data on all psychiatric hospital admissions nationwide since 1969, with outpatient contacts recorded from 1995 onwards [17].

Statistics Denmark contains the National Population Education Register, which holds routinely collected data on the highest completed education for all Danish citizens dating back to the 1970s [18].

Study cohort

Using the DMHFR, we identified a cohort of 110,625 patients aged ≥ 65 with first-time unilateral osteoporosis-related hip fracture treated surgically with osteosynthesis or arthroplasty between January 2004 and November 2021.

Exposure

Comorbidities were selected based on previous research that systematically identified 27 chronic disorders among hip fracture patients [10, 12]. This selection was initially based on established comorbidity indices, including the CCI [9], the Elixhauser Comorbidity Index [19], and the Nordic Multimorbidity Index [20] to ensure comparability and consistency with existing literature. To ensure clinical relevance, only comorbidities with a prevalence greater than 1% were included, a criterion met by all 27 comorbidities considered [10, 12].

Comorbidities were grouped in line with existing literature to provide a clear, clinically interpretable overview, while ensuring adequate sample size for sub-analyses. Organic mental disorders (dementia) were analysed separately from other mental disorders, due to their distinct clinical profile and high mortality, which could otherwise obscure associations with reoperation [6].

Information on comorbid conditions was obtained for each patient and based on ICD-10 diagnosis codes recorded in the DNPR and the DPCRR during the 10 years prior to hip fracture surgery (Supplementary Tables S1 and S2). The

lookback period was chosen to align with clinical practice by capturing both recent and long-standing diagnoses. Both primary and secondary diagnoses from in-hospital and outpatient visits were used. Diagnosis codes from emergency department visits were excluded due to potential low validity [21].

Comorbidity was defined as the main exposure in three distinct ways:

- Individual comorbidity groups: The comorbidities were grouped into 10 categories: Cardiovascular, dementia, hepatic/gastrointestinal, malignant, mental disorders, metabolic, musculoskeletal, neurological/alcohol, pulmonary, and renal/haematological and analysed separately (Supplementary Tables 1 and 2).
- Comorbidity combinations: We examined all two-way combinations of the predefined somatic and mental disorder groups to explore potential interaction effects.
- Comorbidity burden: The number of individual comorbidity groups was summarised as a measure of overall comorbidity burden (0, 1–2, 3–4 or ≥ 5 comorbidity groups).

Outcome

The primary outcome was any reoperation, defined as any secondary hip-related surgical intervention occurring within 30 days after the initial hip fracture surgery. As a secondary outcome, we also examined reoperations within 365 days postoperatively. Reoperations were based on the Danish Clinical Quality Program—National Clinical Registries, designed to benchmark hospital performance and support quality improvement initiatives. Reoperations were identified using NOMESCO [22] surgical procedure codes from the DNPR (Supplementary Table S3).

Covariates

Length of stay was extracted from the DNPR, and we included the following variables measured at the date of admission for hip fracture:

- Patient sex and age (in categories 65–74 years, 75–84 years, 85–94 years, and ≥ 95 years) from DCRS.
- Information on surgery year (in categories 2004–2008, 2009–2013, 2014–2018, and 2019–2021), surgery delay (in hours), body mass index (BMI, in kg/m^2) (in categories underweight (< 19), normal weight (19–24.9), overweight (25–29.9), obese (≥ 30), outliers (BMI < 10 or > 50), or missing data), fracture type (S72.0 Femoral neck, S72.1 Pertrochanteric, and S72.2 Subtrochanteric), and surgery type (NFJ Fracture surgery of femur and NFB Primary prosthetic replacement of hip joint) were collected from DMHFR.
- The highest achieved education was retrieved from Statistics Denmark and categorised as low (primary and lower secondary education), medium (upper secondary education and academy progression program education), high (professional or non-academic bachelor's degree and university degree), or none/missing (Supplementary Table S1).
- Living situation (including marital status) was obtained by combining marital and cohabitation status from the Danish Civil Registration System with data on housing conditions from the DMHFR. Information on housing conditions was available from 2010 onwards (Supplementary Table S1).

Statistical analysis

The prevalence of comorbidities at the time of hip fracture was reported for the total study cohort. To estimate the probability of reoperation over time, we computed the cumulative incidence of reoperation, treating death as a competing event. Cumulative incidence was estimated using the Aalen-Johansen method, with stratification by comorbidity. All patients were followed from the date of hip fracture surgery up to one year after the index surgery or until reoperation, death, migration, or 31 December 2022, whichever occurred first. We used cause-specific Cox proportional hazards regression to estimate crude and adjusted hazard ratios (aHRs) with 95% confidence intervals (CIs) for the association between comorbidities and the risk of reoperation. HRs were adjusted for age, sex, education, and living situation, identified as potential confounders using directed acyclic graphs (DAGs). Patients who died during follow-up were censored at the time of death and contributed risk time only while event-free and alive. We selected the cause-specific Cox model rather than the Fine-Grey competing event regression [23], as we aimed to estimate the instantaneous risk of reoperation among those still at risk. The proportional hazards assumption was assessed using log(-log) plots and found to be fulfilled.

We conducted statistical analyses comparing patients with comorbidities to those without, based on individual comorbidity groups, combinations of comorbidity groups, and overall comorbidity burden. First, we assessed each of the 10 comorbidity groups. Second, we examined specific pairs of comorbidities (e.g. musculoskeletal and mental disorders), further adjusting for the presence of the remaining eight groups in a multivariate model. Finally, we evaluated the comorbidity burden by comparing patients with different numbers of comorbidity groups.

Additional analysis

To address potential differences in reoperation mechanisms, reoperations were categorised by primary indication (e.g., prosthetic replacement, infection, dislocation). We summarised the prevalence and distribution of reoperation types for both osteosyntheses and arthroplasties across comorbidity groups, providing insight into variations in reoperation profiles.

Ethical approval

The study was reported to the Danish Data Protection Agency through Aarhus University (Record number AU-2016–051-000001, sequential number 880). Registry-based studies in Denmark do not require specific consent or approval by the ethics committee. Analysis was performed using R software (V. 4.3.2 2023–10-31). This paper follows the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for cohort studies [24].

Results

Patient characteristics

We identified 110,625 patients who underwent hip fracture surgery. The mean age was 82.4 years, 70% of patients were female, and the average length of hospital stay was 10 days. A total of 25,923 individuals (23%) had no record of comorbidity preceding surgery. The most prevalent comorbidity groups were cardiovascular (54%), renal/haematological (24%), and metabolic (20%) disorders. The remaining comorbidity groups had a prevalence ranging from 5 to 13% (Table 1).

30-day reoperation risk

In patients without comorbidity, the cumulative incidence of reoperation within the first 30 days post-surgery was 3.6% (CI 3.4–3.9).

The comorbidity groups with the highest cumulative incidences were mental disorders (4.8%, CI 4.3–5.3), neurological/alcohol-related disorders (4.7%, CI 4.3–5.2), and musculoskeletal disorders (4.7%, CI 4.2–5.3) (Fig. 1A). All three groups, neurological/alcohol-related disorders (aHR 1.53, CI 1.27–1.83), musculoskeletal disorders (aHR 1.34, CI 1.07–1.69), and mental disorders (aHR 1.40, CI 1.15–1.70), had significantly higher 30-day adjusted hazard ratios for reoperation compared with patients without comorbidity (Fig. 2).

Several comorbidity combinations demonstrated significantly increased cumulative incidences and aHRs for

Table 1 Characteristics of the total cohort

Variable	N (%)
Total cohort	110,625 (100%)
Gender	
Female	77,533 (70.1%)
Male	33,092 (29.9%)
Age	
65–74 years	22,486 (20.3%)
75–84 years	42,805 (38.7%)
85–94 years	40,145 (36.3%)
≥ 95 years	5,189 (4.7%)
Mean, years (CI)	82.4 (82.4–82.5)
Surgery year	
2004–2008	31,668 (28.6%)
2009–2013	31,237 (28.3%)
2014–2018	30,100 (27.2%)
2019–2021	17,620 (15.9%)
Fracture type	
Femoral neck	60,757 (54.9%)
Pertrochanteric	42,276 (38.2%)
Subtrochanteric	7,592 (6.9%)
Surgery type	
Osteosynthesis	74,675 (67.5%)
Arthroplasty	35,950 (32.5%)
Surgery delay	
Median hours (IQR)	26.6 (26.0; 27.2)
Hospital stay	
Median days (IQR)	10.3 (10.2; 10.4)
BMI category	
< 19	6,096 (5.5%)
19–24,9	31,512 (28.5%)
25–29,9	16,042 (14.5%)
≥ 30	5,054 (4.6%)
< 10 or ≥ 50	150 (0.1%)
Missing[a]	51,771 (46.8%)
Comorbidity groups	
No comorbidity	25,923 (23.4%)
Cardiovascular	59,216 (53.5%)
Dementia	9,757 (8.8%)
Hepatic/gastrointestinal	7,175 (6.5%)
Malignant	18,741 (16.9%)
Mental disorders	7,181 (6.5%)
Metabolic	22,555 (20.4%)
Musculoskeletal	5,605 (5.1%)
Neurological/alcohol	10,189 (9.2%)
Pulmonary	15,813 (14.3%)
Renal/hematological	26,029 (23.5%)

CI, Confidence interval. *IQR*, Interquartile range. BMI, Body mass index

Values are *n (%)* unless otherwise specified

Variables are collected at baseline

Comorbidities are measured by prevalence within 10 years before hip fracture surgery

[a]BMI data has been mandatory in registries since 2016

reoperation within 30 days. The highest cumulative incidence was observed for mental disorders combined with neurological/alcohol disorders at 5.7% (CI 4.6–6.9), whereas the highest aHR was seen for the combination of hepatic/gastrointestinal disorders and mental disorders (aHR = 2.27, CI 1.20–4.32), when compared to patients without comorbidity. Combinations involving hepatic/gastrointestinal disorders, mental disorders, musculoskeletal disorders, and neurological/alcohol disorders were particularly associated with high reoperation rates and risks (Fig. 2).

Increasing comorbidity burden was associated with a higher cumulative incidence of reoperation. Among patients with five or more comorbidity groups, the 30-day cumulative incidence reached 4.2% (CI 3.5–4.9), corresponding to an aHR of 1.33 (CI 1.11–1.59) compared to patients without comorbidity. Patients with 3–4 comorbidity groups also had a significantly higher risk of reoperation (aHR = 1.20, CI 1.09–1.31) (Table 2).

365-day reoperation risk

In patients without comorbidity, the cumulative incidence of reoperation within the first 365 days post-surgery was 11.0% (CI 10.6–11.4). The three comorbidity groups with the highest cumulative incidences were mental disorders (12.2%, CI 11.5–13.0), musculoskeletal disorders (12.2%, CI 11.3–13.0), and hepatic/gastrointestinal disorders (11.6%, CI 10.9–12.2) (Fig. 1B). Four groups demonstrated

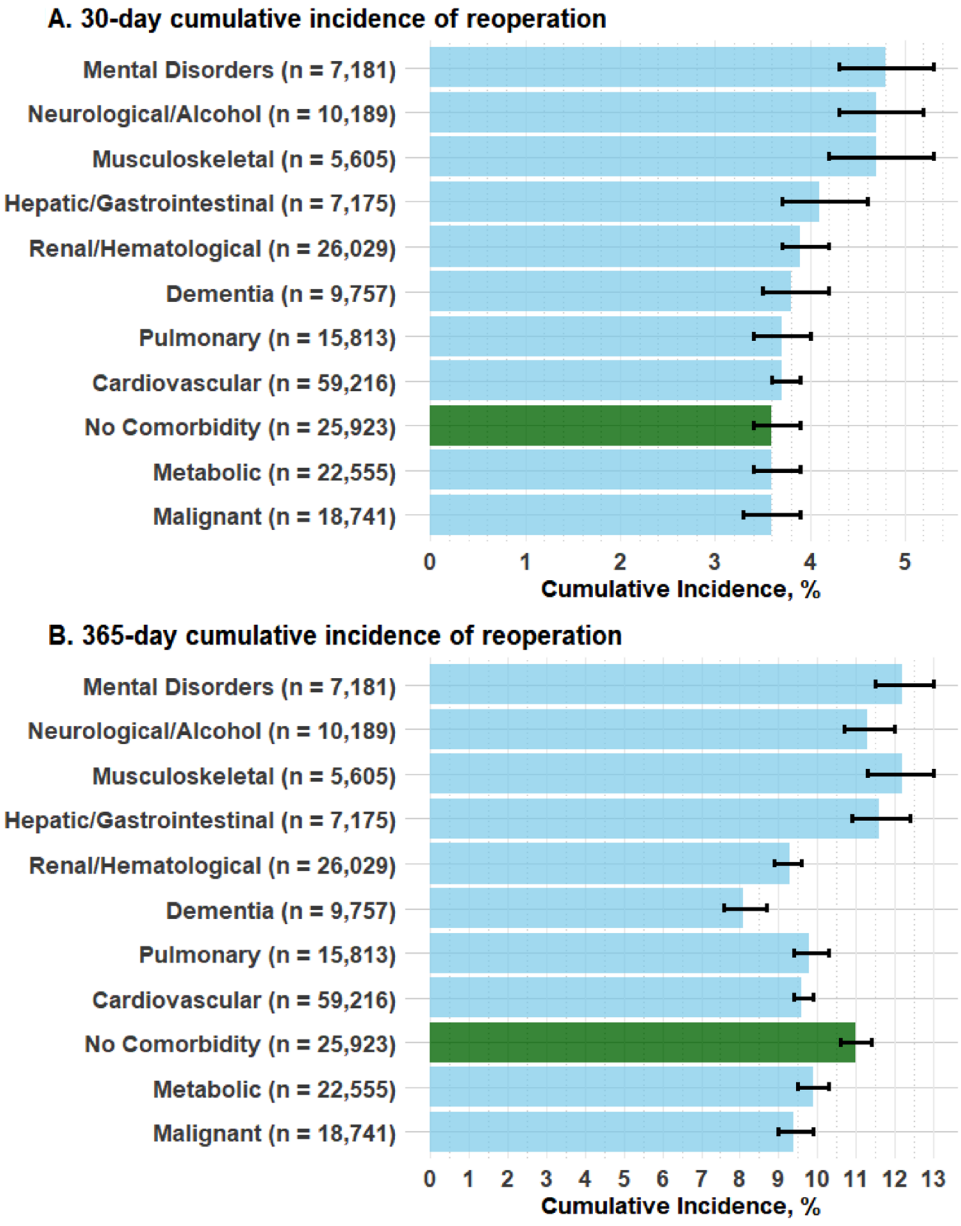

Fig. 1 Cumulative incidence of reoperation stratified by comorbidity groups. Cumulative incidence of any reoperation, accounting for death as a competing event. Number (n) of patients at risk on day 0 is shown. Estimates and confidence intervals of cumulative incidence and mortality are provided in Supplementary Table 4

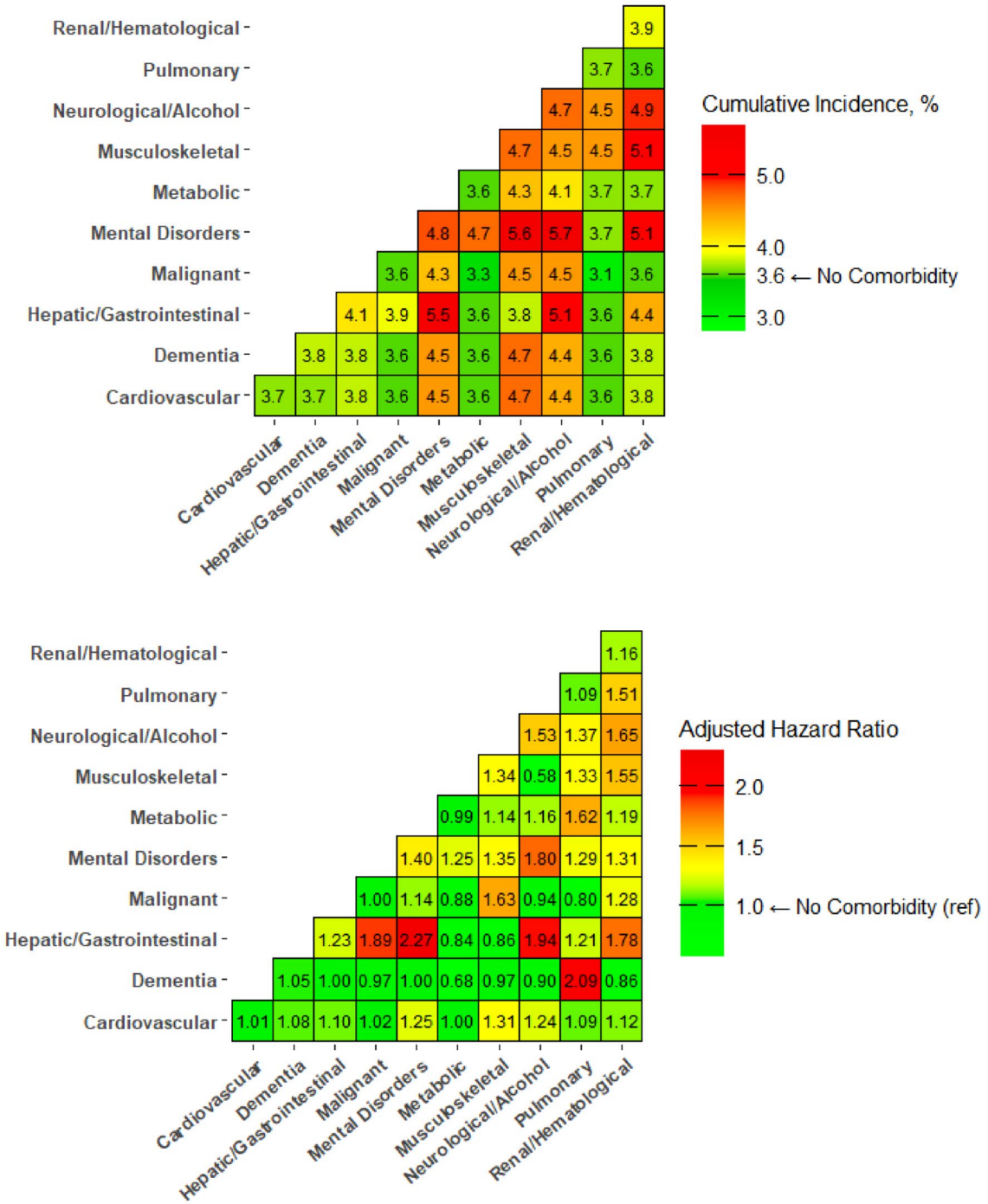

Fig. 2 Cumulative Incidence and Adjusted Hazard Ratios for 30-Day Reoperation by Comorbidity Group Combinations. Cumulative incidence of any reoperation, accounting for death as a competing event. Hazard ratios were adjusted for age, sex, the remaining eight comorbidity groups, education, and living situation (including marital status). Estimates, confidence intervals, and crude hazard ratios are provided in Supplementary Tables 5 and 6. *ref* reference

Table 2 Reoperation risk based on comorbidity burden

	Number at risk	Cumulative incidence of reoperation[a], %	Reoperation, crude HR[b]	Reoperation, adjusted HR[b]
30-day follow-up				
0 Comorbidities	25,923	3.6 (3.4–3.9)	ref	ref
1–2 Comorbidity groups	56,883	3.7 (3.6–3.9)	1.06 (0.98–1.17)	1.08 (1.00–1.17)
3–4 Comorbidity groups	24,552	3.9 (3.7–4.2)	1.15 (1.05–1.26)	1.20 (1.09–1.31)
≥5 Comorbidity groups	3,267	4.2 (3.5–4.9)	1.25 (1.04–1.49)	1.33 (1.11–1.59)
365-day follow-up				
0 Comorbidities	25,923	11.0 (10.6–11.4)	ref	ref
1–2 Comorbidity groups	56,883	10.1 (9.8–10.3)	0.99 (0.95–1.03)	1.03 (0.98–1.08)
3–4 Comorbidity groups	24,552	9.8 (9.4–10.1)	1.03 (0.98–1.09)	1.10 (1.04–1.16)
≥5 Comorbidity groups	3,267	10.1 (9.1–11.2)	1.12 (1.00–1.25)	1.17 (1.05–1.31)

HR, Hazard ratio. CI, Confidence interval. Ref, reference

Values are estimates with 95% confidence intervals (CI), unless otherwise specified

[a]Cumulative incidence for any reoperation treating death as a competing event

[b]Hazard ratios were adjusted for age, sex, education, and living situation (including marital status)

a significantly increased 365-day aHRs for reoperation compared with patients without comorbidity: mental disorders (aHR = 1.20, CI 1.06–1.35), hepatic/gastrointestinal disorders (aHR = 1.19, CI 1.03–1.37), musculoskeletal disorders (aHR = 1.16, CI 1.01–1.33), and pulmonary disorders (aHR = 1.13, CI 1.01–1.25) (Fig. 3).

Several comorbidity combinations demonstrated significantly increased cumulative incidences and aHRs for reoperation within 365 days. The highest cumulative incidence was observed for mental disorders combined with musculoskeletal disorders at 16.9% (CI 13.1–21.1), corresponding to an aHR of 1.87 (CI 1.11–3.15), when compared to patients without comorbidity. Several comorbidity combinations were associated with a significantly increased risk of reoperation. Combinations involving hepatic/gastrointestinal disorders, mental disorders, musculoskeletal disorders, and neurological/alcohol disorders were particularly related to elevated reoperation rates and risks (Fig. 3).

Increasing comorbidity burden was associated with a higher risk of reoperation. Among patients with five or more comorbidity groups, the 365-day cumulative incidence was 10.1% (CI 9.1–11.2), corresponding to an aHR of 1.17 (CI 1.05–1.31) compared to patients without comorbidity. Patients with 3–4 comorbidity groups also had a significantly higher risk of reoperation (aHR = 1.10, CI 1.04–1.16) (Table 2).

Additional analysis

Overall, the distribution of reoperation types after osteosyntheses was broadly similar across groups, with only modest variations reflecting clinical profiles. Prosthetic replacement (NFB) was generally evenly distributed, except in patients with dementia and hepatic/gastrointestinal disorders. Notably, patients with dementia had higher rates of resections (Girdlestone procedure (NFG)). For arthroplasty, patterns were generally similar across comorbidities. However, prosthesis dislocations (NFH) were more pronounced in patients with dementia and musculoskeletal disorders, whereas patients with pulmonary, renal/haematological and neurological/alcohol disorders had more infections (NFS) (Fig. 4).

Discussion

To our knowledge, this is the first study to apply a comprehensive framework to assess the impact of comorbidities on the risk of reoperation after hip fracture surgery. By examining individual comorbidity groups, common combinations of comorbidities, and overall comorbidity burden, we provide a distinct and comprehensive understanding of how multimorbidity influences reoperation risk.

Several individual comorbidity groups, like musculoskeletal, hepatic/gastrointestinal, metabolic, and mental disorders, were associated with a significantly increased risk of reoperation compared to patients without comorbidity. Notably, certain combinations of these conditions conferred an even higher risk, suggesting potential interaction effects. While an increasing comorbidity burden was associated with a higher risk of reoperation, the gradient was modest compared to the risk observed for specific combinations of comorbidities. These findings suggest that a composite comorbidity measure may not accurately capture the complexity of multimorbidity patterns and may underestimate the risk of reoperation.

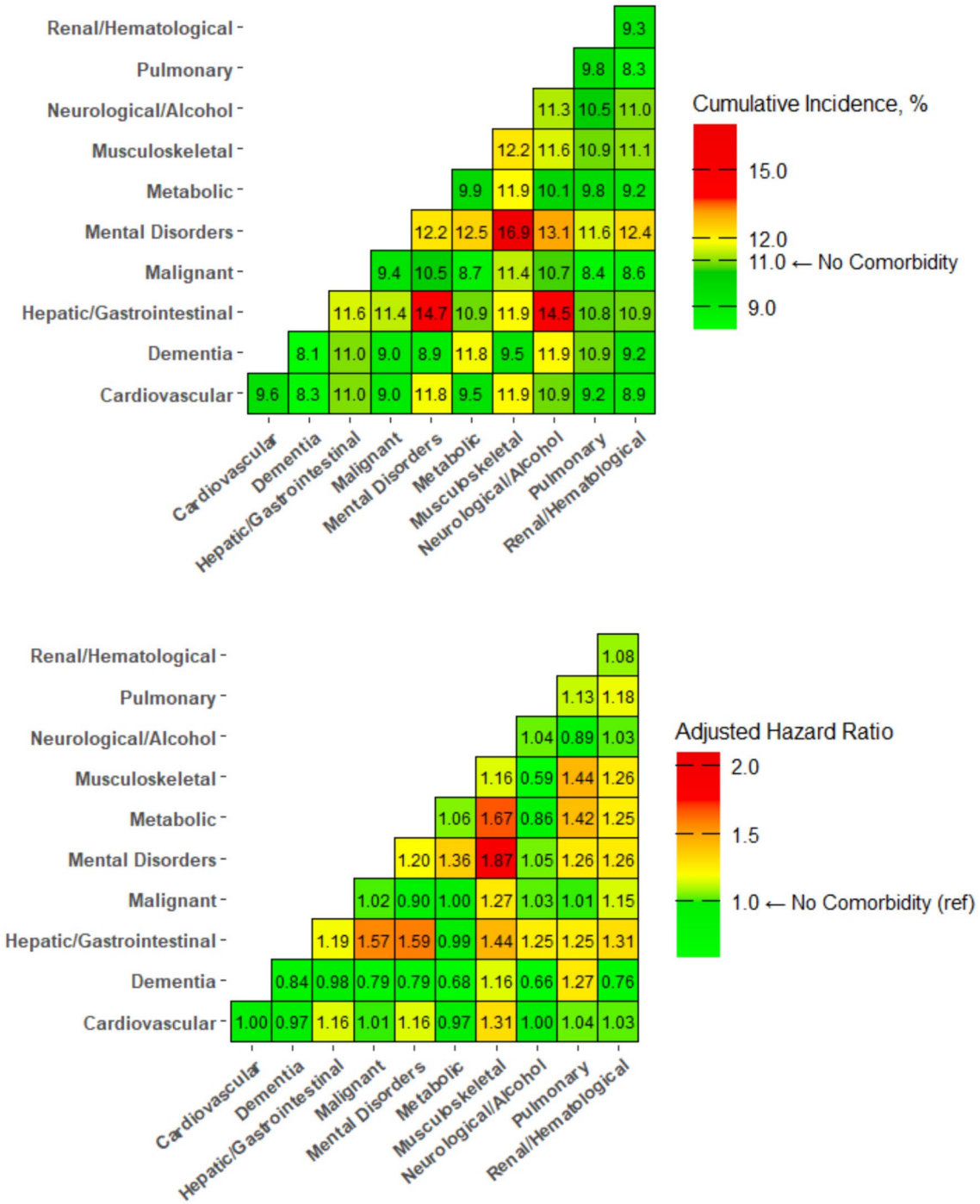

Fig. 3 Cumulative Incidence and Adjusted Hazard Ratios for 365-Day Reoperation by Comorbidity Group Combinations. Cumulative incidence of any reoperation, accounting for death as a competing event. Hazard ratios were adjusted for age, sex, the remaining eight comorbidity groups, education, and living situation (including marital status). Estimates, confidence intervals, and crude hazard ratios are provided in Supplementary Tables 5 and 6. *ref* reference

Although several studies have investigated the association between preoperative comorbidity and mortality in hip fracture patients, only a few have examined the impact of comorbidity on reoperation risk and primarily focus on specific treatment types (e.g., arthroplasty or internal fixation) and selected reoperations [4, 11, 25].

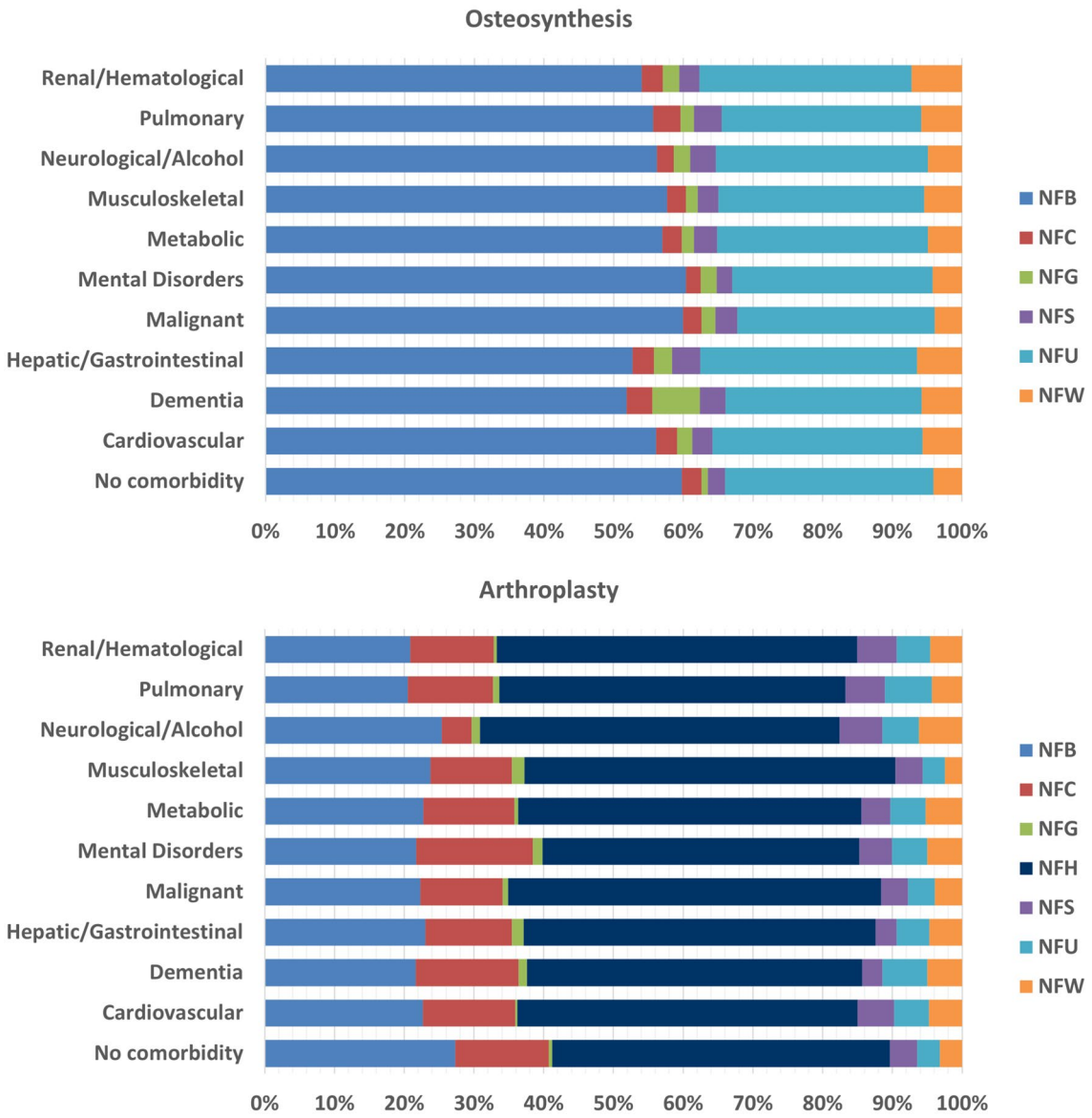

Fig. 4 Distribution and prevalence of reoperations by comorbidity groups. *NFB* Primary prosthetic replacement of hip joint, *NFC* Secondary prosthetic replacement of hip joint, *NFG* Excision, reconstruction and fusion of hip joint, *NFH*, Miscellaneous operations on hip joint (including closed/open reduction of a dislocated hip prosthesis), *NFS* Operations for infection of tendons, joints and bone of hip and thigh, *NFU* Removal of implants and external fixation devices from hip and femur, *NFW*, Reoperations on hip or thigh

Two Danish studies have investigated the risk of reoperation due to surgical site infection following hip fracture surgery [11, 25]. Gadgaard et al. reported an increased risk at 30 days among patients with a CCI score ≥ 3, with an aHR of 1.4 (CI 1.1–1.9) [22]. At 365 days, both studies found a similarly elevated risk for patients with high comorbidity burden, with an aHR of 1.3–1.4 [11, 22].

Gazgalis et al. [26]. investigated the risk of readmission, reoperation, and complications among patients with femoral neck fractures treated with arthroplasty, using the total number of comorbidities per patient as a measure of comorbidity burden. They reported a modest increase in reoperation risk at 90-day follow-up, with an odds ratio of 1.03 (CI 0.8–1.3) per additional comorbidity.

Our findings support the association between comorbidity burden and increased risk of reoperation and extend this evidence by demonstrating that the risk applies to reoperations from all causes, not solely surgical site infections. In contrast to Gadgaard et al. [25] and Kristensen et al. [11], who focused primarily on infections, our study examined all-cause reoperations and incorporated a broader set of comorbidities beyond those included in the CCI.

Compared to Gazgalis et al. [26], whose study was limited to femoral neck fractures treated with arthroplasty, we included all hip fracture types and surgical modalities. Moreover, their limited sample size ($n = 378$) and few reoperation events ($n = 14$) likely reduced the precision of their estimates.

This study highlights the clinical relevance of evaluating specific and combined comorbidities, rather than relying solely on composite indices. Conditions such as musculoskeletal, hepatic/gastrointestinal, and mental disorders were associated with elevated reoperation risk, particularly when co-occurring. These combinations may reflect shared pathophysiological pathways, care challenges, or broader vulnerability profiles [27]. They may also serve as markers of frailty or clinical complexity not fully captured by standard indices or registry data [28–30].

To contextualise these findings, several biological and clinical mechanisms may help explain why certain comorbidities are more strongly associated with reoperation. Musculoskeletal disorders could impair post-fracture mobility and are often treated with medications, which may further compromise bone healing and tissue repair [31]. Hepatic/gastrointestinal disorders may contribute to malnutrition and coagulopathy, potentially increasing bleeding and delaying recovery [32]. Mental disorders could increase postoperative vulnerability through reduced adherence to rehabilitation and the use of psychotropic medications [33]. These conditions frequently co-occur and are often accompanied by frailty and polypharmacy, including exposure to fall risk-increasing drugs, which together may raise the likelihood of reoperation beyond the contribution of any single comorbidity [34].

Beyond disease-specific mechanisms, patient-level factors may further influence postoperative outcomes. Patients with multiple comorbidities often have lower health literacy, potentially impairing their ability to follow postoperative instructions or recognise early complications [35]. This may contribute to preventable outcomes such as infections or delayed wound healing. In contrast, the number of patients who could benefit from reoperation may be underestimated, as subtle or atypical symptoms can be missed, delaying recognition and management.

These broader considerations also intersect with how comorbidity profiles inform surgical decision-making. In individuals with extensive multimorbidity and limited life expectancy, clinicians may avoid reoperation unless the indication is clear-cut (e.g. infection or periprosthetic fracture), due to concerns about surgical risk and the limited potential benefit. Previous studies have shown lower rates of elective procedures, such as total hip arthroplasty, in patients with high comorbidity burden [36]. In the context of reoperations, observed rates may reflect both the underlying clinical need and cautious decision-making in patients with extensive comorbidity. We did not observe a lower overall likelihood of reoperation, but found that reoperation risk was strongly influenced by the comorbidity profile. Moreover, in many European countries, routine postoperative follow-up after hip fracture surgery has gradually been discontinued, likely due to advances in treatment or resource constraints. However, this change may disproportionately impact patients with multimorbidity, who face a higher risk of being under-recognised and receiving insufficient support when complications occur [37, 38].

These findings support the integration of comorbidity-specific considerations into preoperative planning, perioperative management, and postoperative care. Although hip fracture is an acute event, targeted strategies such as rapid geriatric assessment, early medical optimisation (e.g. for heart failure, renal dysfunction, anaemia), and prioritisation of surgical timing may reduce complications. Postoperatively, patients with high-risk comorbidity profiles may benefit from stratified follow-up, enhanced rehabilitation, and coordinated care across sectors. Such approaches may improve outcomes and reduce preventable reoperations [39].

This large, population-based cohort study uses routinely collected healthcare data from high-quality national registries, ensuring a high capture rate and minimising selection bias. The study cohort was derived from the DMHFR [7], which has mandatory and partially automated reporting. Procedure codes for hip fracture surgeries in the DMHFR have a reported positive predictive value (PPV) of 100% [15]. Hospitals are financially incentivised to report diagnoses to the DNPR, and the validity of most comorbidities included in this study has been established, with PPVs ranging from 80 to 100% [16, 40]. Reoperations are generally well recorded, although completeness may be lower than for primary hip fractures, as seen in other Scandinavian countries [41, 42]. Similar patterns likely apply to Danish data. Importantly, there is no indication that reoperation reporting differs systematically by comorbidity status. The prevalence of comorbidities in our study aligns with previous reports [12, 43].

Several comorbidities were associated with an increased risk of reoperation, particularly early postoperatively. This risk declined at 365 days for some conditions, likely due to mortality as a competing event [44–46] (Supplementary Table S4). Therefore, we used cumulative incidence functions accounting for death as a competing event, rather than the Kaplan–Meier method, which may overestimate cumulative risks [47]. Patients with dementia were analysed separately from other mental disorders, as previous research has shown that they present a distinct clinical profile characterised by low reoperation rates and high mortality [6]. This could mask associations of mental disorders with

reoperation in the interaction analysis. However, as some comorbidities are recorded before the onset of dementia, we included these patients to evaluate this potential effect. Overall, dementia remained associated with a lower risk of reoperation, except when coexisting with comorbidities that markedly increase reoperation risk.

The study has limitations. Only comorbidities requiring hospital contact were captured, meaning milder conditions treated solely in primary care may have been missed. Thus, we likely captured fewer but more severe comorbidities [16]. Residual confounding remains a concern and cannot be fully ruled out in our study. To improve confounding control, we adjusted for education and living situation (including marital status) as proxies for health literacy and social support. However, key lifestyle factors such as smoking, physical activity, and diet are not captured in the nationwide registries and are generally inconsistently documented in other data sources. Although these factors may induce residual confounding, they could also act as mediators, and adjusting for them could inadvertently remove important effects on the causal pathway [48].

Although nearly all hip fracture patients in Denmark receive surgical treatment, selection bias may still influence estimates of reoperation rates. Patients with severe comorbidities or poor overall health may be deemed unfit for further surgery. Consequently, our findings may reflect both the clinical need for reoperation and decisions influenced by patient frailty or inoperability, rather than complication rates alone [49].

Conclusion

We found that specific comorbidities were associated with an increased risk of reoperation following hip fracture surgery. This was particularly evident for mental, hepatic/gastrointestinal, neurological/alcohol-related, and musculoskeletal disorders. Combinations of these comorbidities were associated with even higher risks. While the risk of reoperation also increased with a greater comorbidity burden, the association was more pronounced for certain high-risk comorbidity combinations. These findings underscore the prognostic value of specific comorbidity profiles beyond composite burden scores, supporting their use in stratifying care pathways.

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Data availability The data analysed in this study were made available to us in an anonymised form on Statistics Denmark's servers. To protect the privacy of patients, individual-level data are not publicly disclosed. Access may be granted by the relevant authorities in Denmark.

Declarations

Conflict of interests Simon Storgaard Jensen, Per Hviid Gundtoft, Jan-Erik Gjertsen, and Alma B. Pedersen declare that they have no personal conflict of interest.

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