





Mode of anesthesia is not associated with outcomes following emergency hip fracture surgery: a population-level cohort study

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ABSTRACT

Background Hip fractures often occur in frail patients with several comorbidities. In those undergoing emergency surgery, determining the optimal anesthesia modality may be challenging, with equipoise concerning outcomes following either spinal or general anesthesia. In this study, we investigated the association between mode of anesthesia and postoperative morbidity and mortality with subgroup analyses.

Methods This is a retrospective study using all consecutive adult patients who underwent emergency hip fracture surgery in Örebro County, Sweden, between 2013 and 2017. Patients were extracted from the Swedish National Hip Fracture Registry, and their electronic medical records were reviewed. The association between the type of anesthesia and 30-day and 90-day postoperative mortality, as well as in-hospital severe complications (Clavien-Dindo classification $\geq 3a$), was analyzed using Poisson regression models with robust SEs, while the association with 1-year mortality was analyzed using Cox proportional hazards models. All analyses were adjusted for potential confounders.

Results A total of 2437 hip fracture cases were included in the study, of whom 60% received spinal anesthesia. There was no statistically significant difference in the risk of 30-day postoperative mortality (adjusted incident rate ratio (IRR) (95% CI): 0.99 (0.72 to 1.36), $p=0.952$), 90-day postoperative mortality (adjusted IRR (95% CI): 0.88 (0.70 to 1.11), $p=0.281$), 1-year postoperative mortality (adjusted HR (95% CI): 0.98 (0.83 to 1.15), $p=0.773$), or in-hospital severe complications (adjusted IRR (95% CI): 1.24 (0.85 to 1.82), $p=0.273$), when comparing general and spinal anesthesia.

Conclusions Mode of anesthesia during emergency hip fracture surgery was not associated with an increased risk of postoperative mortality or in-hospital severe complications in the study population or any of the investigated subgroups.

Level of evidence: Therapeutic/Care Management, level III

INTRODUCTION

While there is heterogeneity in the hip fracture population, hip fracture patients are on average older and have a higher comorbidity burden than the general population.^{1–6} These comorbidities

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ The choice of anesthetic technique can be challenging, with literature and practice patterns divided mainly between spinal or general anesthesia.
- ⇒ Despite decades of research attempting to determine which patients benefit the most from each of these methods, clinical practice varies significantly between institutions.

WHAT THIS STUDY ADDS

- ⇒ This study investigates if subgroups within the hip fracture population could benefit from either spinal or general anesthesia.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ Considering that we did not find any difference in outcomes depending on mode of anesthesia, this study supports that the anesthesiologist should choose their personally preferred method.

along with the acute physiological insult, present additional perioperative, including anesthetic, concerns.^{7–9} Unlike elective surgery, the opportunity for preoperative optimization is limited in patients undergoing emergency surgery for hip fractures. Additionally, increased vigilance is required when assessing medication use such as anticoagulants, the potential for postoperative delirium, and the impact of respiratory compromise.^{10 11}

The choice of anesthetic technique can be challenging, with literature and practice patterns divided mainly between spinal or general anesthesia.^{12–16} Spinal anesthesia is often preferred due to the avoidance of neurologically active drugs, a reduction in intraoperative hypotension, and a possible reduction in early postoperative delirium.^{10 12 14 16} From an institutional standpoint, spinal anesthesia can provide a less expensive alternative.¹⁷ However, general anesthesia can be hypothesized to provide improved patient satisfaction due to inhibition of memory of the procedure and also a more desirable anesthetic plane particularly in complex patients. Nonetheless, decisions regarding choice of anesthetic method are made on a case-by-case basis considering the patient's preference, the preference of the anesthesiologist, the operating surgeon,

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and institutional practice; norms are likely to play a central role.^{10–14} Despite decades of research attempting to determine which patients benefit the most from each of these methods, clinical practice varies significantly between institutions.^{12–14} Meta-analyses published on this topic have found that spinal and general anesthesia result in equivalent results in terms of adverse outcomes; however, there are also a limited number of studies which have been able to observe a difference.^{12–13} The latest randomized controlled trial (RCT), published in *New England Journal of Medicine*, demonstrated similar results between the modes of anesthesia used regarding recovered ambulation, delirium, and survival.¹⁶

A recent publication by Lin *et al* pinpointed the importance of frailty and the geriatric syndrome in regard to anesthesia and surgery.¹⁴ Some of the indices commonly used to assess the risk of postoperative events in these patients are the American Society of Anesthesiologists (ASA) classification, the Charlson Comorbidity Index (CCI) and the Revised Cardiac Risk Index (RCRI).^{5–14–18–19} Furthermore, several other risk factors have been associated with an increased risk of adverse postoperative outcomes.^{20–25} However, the latest meta-analyses have not conducted any subgroup analyses taking into account these different risk factors. Therefore, the aim of the current study was to evaluate the association between mode of anesthesia and postoperative morbidity as well as mortality within a general hip fracture population as well as within specific subgroups.

METHODS

Both the Strengthening the Reporting of Observational Studies in Epidemiology guidelines and Declaration of Helsinki were adhered to throughout the study.²⁶ During the 5-year period between January 1, 2013 and December 31, 2017, all consecutive adult patients (aged ≥ 18 years) who underwent primary emergency hip fracture surgery in Örebro County, Sweden, were included. Patients were excluded if they suffered a pathological hip fracture, were managed non-operatively, or if the type of anesthesia used was missing. Data were retrieved from the Swedish National Hip Fracture Registry, Rikshöft.²⁷ This dataset provided information regarding age, sex, date of hospital admission, ASA classification, type of fracture, surgical method, and date of hospital discharge. These data were complemented with a review of the patients' electronic medical records to retrieve comorbidity data and time of death, as well as to supplement data missing from the national hip fracture register. Comorbidity data were used to calculate both the CCI and the RCRI.^{28–29}

Calculating the Revised Cardiac Risk Index

The RCRI score was based on the presence of a history of ischemic heart disease, a history of congestive heart failure, a history of cerebrovascular disease, preoperative insulin therapy, a preoperative creatinine > 2 mg/dL, and high-risk surgery. Each variable increased the RCRI by 1 point if present. Hip fracture surgery is considered intermediate risk surgery according to the American College of Cardiology and the American Heart Association guidelines³⁰; accordingly, points for high-risk surgery were not awarded to any patient in this study. Patients that had end-organ damage resulting from diabetes mellitus but lacked preoperative insulin therapy were also awarded 1 point to reflect the severity of their diabetes.³¹

Statistical analysis

Patients were divided into two groups based on the type of anesthesia they received: spinal anesthesia or general anesthesia.

Continuous variables were summarized as a median and IQR, with differences being compared using the Mann-Whitney U test, as these variables were non-normally distributed. Categorical variables were instead presented as counts with percentages and compared using the χ^2 test or Fisher's exact test. The primary outcome of interest was 30-day postoperative mortality with 90-day postoperative mortality, 1-year postoperative mortality, and in-hospital severe complications as secondary outcomes of interest. A complication was classified as severe if it had a Clavien-Dindo classification $\geq 3a$, that is, complications requiring surgical, endoscopic, or radiological intervention.

The associations between the type of anesthesia and 30-day mortality, 90-day mortality, as well as in-hospital severe complications were analyzed using Poisson regression models with robust SEs. The association with 1-year mortality was instead

Table 1 Demographics and clinical features in patients undergoing hip fracture surgery with spinal or general anesthesia.

| | Spinal anesthesia (n=1463) | General anesthesia (n=974) | P value |
|---|-------------------------------|-------------------------------|---------|
| Age, median (IQR) | 84 (77–89) | 83 (75–89) | <0.001 |
| Sex, n (%) | | | 0.002 |
| Female | 949 (64.9) | 692 (71.0) | |
| Male | 514 (35.1) | 282 (29.0) | |
| Charlson Comorbidity Index, n (%) | | | 0.247 |
| ≤ 4 | 455 (31.1) | 327 (33.6) | |
| 5–6 | 571 (39.0) | 349 (35.8) | |
| ≥ 7 | 437 (29.9) | 298 (30.6) | |
| ASA classification, n (%) | | | 0.797 |
| 1 | 111 (7.6) | 73 (7.5) | |
| 2 | 611 (41.8) | 388 (39.8) | |
| 3 | 629 (43.0) | 431 (44.3) | |
| 4 | 107 (7.3) | 77 (7.9) | |
| Missing | 5 (0.3) | 5 (0.5) | |
| Type of fracture, n (%) | | | 0.013 |
| Non-displaced cervical (Garden 1–2) | 186 (12.7) | 135 (13.9) | |
| Displaced cervical (Garden 3–4) | 497 (34.0) | 372 (38.2) | |
| Basicervical | 57 (3.9) | 54 (5.5) | |
| Peritrochanteric (two fragments) | 381 (26.0) | 204 (20.9) | |
| Peritrochanteric (multiple fragments) | 237 (16.2) | 142 (14.6) | |
| Subtrochanteric | 105 (7.2) | 67 (6.9) | |
| Preoperative fascia iliaca compartment block, n (%) | 99 (6.8) | 139 (14.3) | <0.001 |
| Missing | 2 (0.1) | 1 (0.1) | |
| Type of surgery, n (%) | | | <0.001 |
| Pins or screws | 296 (20.2) | 193 (19.8) | |
| Pins or screws with sideplate | 548 (37.5) | 333 (34.2) | |
| Intramedullary nail | 248 (17.0) | 151 (15.5) | |
| Hemiarthroplasty | 254 (17.4) | 236 (24.2) | |
| Total hip replacement | 117 (8.0) | 61 (6.3) | |
| Revised Cardiac Risk Index, n (%) | | | 0.278 |
| <2 | 1184 (80.9) | 806 (82.8) | |
| ≥ 2 | 279 (19.1) | 168 (17.2) | |
| Duration of surgery, median (IQR) | 45 (26–72) | 46 (28–71) | 0.359 |
| Missing, n (%) | 87 (5.9) | 32 (3.3) | |
| Out-of-hours surgery, n (%) | 597 (40.8) | 359 (36.9) | 0.056 |

ASA, American Society of Anesthesiologists.

Table 2 Preoperative comorbidities in patients undergoing hip fracture surgery with spinal or general anesthesia.

| | Spinal anesthesia (n=1463) | General anesthesia (n=974) | P value |
|---|-------------------------------|-------------------------------|---------|
| Myocardial infarction, n (%) | 225 (15.4) | 155 (15.9) | 0.765 |
| Congestive heart failure, n (%) | 265 (18.1) | 160 (16.4) | 0.308 |
| Peripheral vascular disease, n (%) | 110 (7.5) | 69 (7.1) | 0.746 |
| Cerebrovascular disease, n (%) | 360 (24.6) | 233 (23.9) | 0.735 |
| Dementia, n (%) | 360 (24.6) | 211 (21.7) | 0.103 |
| COPD, n (%) | 139 (9.5) | 84 (8.6) | 0.507 |
| Connective tissue disease, n (%) | 29 (2.0) | 11 (1.1) | 0.144 |
| Peptic ulcer disease, n (%) | 128 (8.7) | 121 (12.4) | 0.004 |
| Liver disease, n (%) | 11 (0.8) | 20 (2.1) | 0.009 |
| Diabetes mellitus, n (%) | | | 0.851 |
| Uncomplicated | 98 (6.7) | 63 (6.5) | |
| End-organ damage | 123 (8.4) | 88 (9.0) | |
| Hemiplegia, n (%) | 40 (2.7) | 29 (3.0) | 0.818 |
| Chronic kidney disease, n (%) | 106 (7.2) | 71 (7.3) | 1.00 |
| Cancer, n (%) | | | 0.297 |
| Local tumor | 298 (20.4) | 185 (19.0) | |
| Metastatic | 37 (2.5) | 34 (3.5) | |
| Leukemia, n (%) | 10 (0.7) | 7 (0.7) | 1.00 |
| Lymphoma, n (%) | 8 (0.5) | 4 (0.4) | 0.772 |
| COPD, chronic obstructive pulmonary disease.; | | | |

determined using a Cox proportional hazards model. All analyses were adjusted for known factors that previously have been shown to be associated with outcome after hip fracture surgery, namely: age, sex, CCI, ASA classification, type of fracture, and type of surgery.

Subsequently, subgroup analyses were performed by repeating the regression analyses with specific subgroups of patients who were deemed to potentially be at a higher risk of suffering adverse events as a result of the choice of anesthesiological method used.

Table 3 Crude outcomes in patients undergoing hip fracture surgery with spinal or general anesthesia.

| | Spinal anesthesia (n=1463) | General anesthesia (n=974) | P value |
|--|-------------------------------|-------------------------------|---------|
| Length of stay, median (IQR) | 8.0 (5.0–11) | 8.0 (5.0–12) | 0.340 |
| 30-day mortality, n (%) | 127 (8.7) | 73 (7.5) | 0.332 |
| 90-day mortality, n (%) | 228 (15.6) | 125 (12.8) | 0.067 |
| 1-year mortality, n (%) | 382 (26.1) | 232 (23.8) | 0.219 |
| Severe complication, n (%) | 79 (5.4) | 59 (6.1) | 0.554 |
| Missing | 6 (0.4) | 3 (0.3) | |
| Anemia, n (%) | 28 (1.9) | 21 (2.2) | 0.787 |
| Delirium, n (%) | 1 (0.1) | 2 (0.2) | 0.568 |
| Infection, n (%) | 27 (1.8) | 16 (1.6) | 0.829 |
| Urinary tract infection, n (%) | 4 (0.3) | 3 (0.3) | 1.00 |
| Pneumonia, n (%) | 15 (1.0) | 6 (0.6) | 0.397 |
| Cardiovascular event, n (%) | 24 (1.6) | 20 (2.1) | 0.552 |
| Thromboembolic event, n (%) | 1 (0.1) | 0 (0.0) | 1.00 |
| Cerebrovascular event, n (%) | 5 (0.3) | 2 (0.2) | 0.709 |
| Gastrointestinal bleeding, n (%) | 5 (0.3) | 5 (0.5) | 0.533 |
| Acute kidney injury, n (%) | 11 (0.8) | 2 (0.2) | 0.126 |
| Sepsis, n (%) | 3 (0.2) | 3 (0.3) | 0.688 |
| Multiple organ failure, n (%) | 8 (0.5) | 4 (0.4) | 0.772 |
| Other complications, n (%) | 12 (0.8) | 17 (1.7) | 0.061 |
| Length of stay is measured in days. In-hospital severe complications are defined as those with a Clavien-Dindo classification ≥ 3 . | | | |

These subgroups were selected since prior studies have observed an association between them and postoperative outcomes; they consisted of patients who underwent internal fixation or arthroplasty, had an extended surgical duration (surgical duration >100 min), had a reduced surgical fitness (ASA classification ≥ 3), had an elevated RCRI (RCRI ≥ 2), had an increased comorbidity burden (CCI ≥ 7), had a diagnosis of dementia prior to surgery, underwent surgery out-of-hours (17:00–08:00), and geriatric patients (aged ≥ 65 years).^{5 18–22 24 25 31 32} An extended surgical duration was defined as any operation that lasted >100 min, as this was the 90th percentile for all operations in this dataset. Results are presented as incident rate ratios (IRRs) or HRs with 95% CIs.

Statistical significance was defined as a two-sided p value <0.05 . Multiple imputation by chained equations was applied using the mice package to manage missing values. 10 imputed datasets were generated for the whole study population as well as each subgroup (internal fixation, arthroplasty, etc). Imputed values were calculated using logistic regression models for binary variables, Bayesian polytomous regression for nominal variables, and proportional odds models for ordinal variables. Poisson regression models were fitted to each imputed dataset; this resulted in 10 models for each analysis (all patients, internal fixation, arthroplasty, etc). These 10 models were pooled by calculating the average value of the coefficients and associated SEs. The resulting coefficient and SE for the mode of anesthesia was used to calculate the IRR, CI, and p value. No patients were lost to follow-up. All analyses were performed using the statistical programming language R (R Foundation for Statistical Computing, Vienna, Austria).³³

RESULTS

A total of 2437 cases were included in the current study. Patients who received general anesthesia were more often female (71.0% vs 64.9%, $p=0.002$) and were more frequently operated on using arthroplasty (30.5% vs 25.4%, $p<0.001$). Accordingly, patients who underwent general anesthesia were more likely to have suffered an intracapsular hip fracture (57.6% vs 50.6%, $p=0.013$). While statistically significant, the 1-year difference in median age was not considered to be clinically significant. Furthermore, no statistically significant differences were observed in overall comorbidity burden based on their CCI, fitness for surgery based on their preoperative ASA classification, cardiac risk based on their RCRI, or surgical duration (table 1). There were no statistically significant differences in any comorbidities, except for peptic ulcer disease and liver disease, which were both more prevalent among patients who underwent general anesthesia (table 2).

There were also no statistically significant differences in length of stay, 30-day mortality, 90-day mortality, 1-year mortality, or in-hospital severe complications between the cohorts (table 3). This remained unchanged after adjusting for potential confounders in the Poisson regression analyses or Cox proportional hazards model. There were no statistically significant differences in the risk of 30-day postoperative mortality (adjusted IRR (95% CI): 0.99 (0.72 to 1.36), $p=0.952$), 90-day postoperative mortality (adjusted IRR (95% CI): 0.88 (0.70 to 1.11), $p=0.281$), 1-year postoperative mortality (adjusted HR (95% CI): 0.98 (0.83 to 1.15), $p=0.773$), or in-hospital severe complications (adjusted IRR (95% CI): 1.24 (0.85 to 1.82), $p=0.273$), when comparing general anesthesia with spinal anesthesia. These results remained unchanged in all subgroups analyzed (table 4).

Table 4 IRRs and HRs for 30-day, 90-day, and 1-year mortality as well as severe complications after hip fracture surgery, comparing patients having spinal with those having general anesthesia.

| Population | 30-day mortality IRR (95% CI) | P value | 90-day mortality IRR (95% CI) | P value | 1-year mortality HR (95% CI) | P value | Severe complication* IRR (95% CI) | P value |
|--|----------------------------------|---------|----------------------------------|---------|---------------------------------|---------|--------------------------------------|---------|
| All patients N=2437 | 0.99 (0.72 to 1.36) | 0.952 | 0.88 (0.70 to 1.11) | 0.281 | 0.98 (0.83 to 1.15) | 0.773 | 1.24 (0.85 to 1.82) | 0.273 |
| Patients who underwent internal fixation N=1769 | 1.03 (0.73 to 1.47) | 0.858 | 0.83 (0.64 to 1.08) | 0.160 | 0.96 (0.79 to 1.16) | 0.677 | 1.27 (0.79 to 2.05) | 0.322 |
| Patients who underwent an arthroplasty N=668 | 0.92 (0.45 to 1.91) | 0.839 | 1.15 (0.7 to 1.89) | 0.603 | 1.06 (0.75 to 1.5) | 0.735 | 1.16 (0.61 to 2.18) | 0.670 |
| Patients with an extended surgical duration† N=221 | 1.8 (0.54 to 5.97) | 0.344 | 1.15 (0.43 to 3.09) | 0.796 | 1.24 (0.57 to 2.68) | 0.573 | 0.77 (0.22 to 2.65) | 0.692 |
| Patients with reduced surgical fitness‡ N=1244 | 0.98 (0.68 to 1.4) | 0.908 | 0.88 (0.68 to 1.14) | 0.327 | 0.96 (0.79 to 1.17) | 0.712 | 1.33 (0.86 to 2.06) | 0.194 |
| Patients with an elevated RCRI§ N=447 | 0.71 (0.37 to 1.34) | 0.292 | 0.86 (0.56 to 1.32) | 0.500 | 0.94 (0.69 to 1.29) | 0.717 | 1.01 (0.50 to 2.06) | 0.972 |
| Patients with an elevated CCI¶ N=735 | 1.02 (0.68 to 1.53) | 0.937 | 1.01 (0.75 to 1.36) | 0.954 | 1.1 (0.88 to 1.38) | 0.414 | 1.3 (0.80 to 2.11) | 0.292 |
| Patients with dementia N=571 | 0.87 (0.53 to 1.41) | 0.582 | 0.91 (0.65 to 1.29) | 0.620 | 0.99 (0.76 to 1.3) | 0.957 | 0.86 (0.40 to 1.84) | 0.705 |
| Patients who underwent out-of-hours surgery** N=956 | 1.09 (0.66 to 1.8) | 0.750 | 0.8 (0.55 to 1.16) | 0.243 | 0.89 (0.68 to 1.17) | 0.390 | 0.68 (0.32 to 1.44) | 0.320 |
| Geriatric patients†† N=2295 | 0.99 (0.72 to 1.36) | 0.965 | 0.88 (0.70 to 1.11) | 0.286 | 0.97 (0.82 to 1.15) | 0.745 | 1.26 (0.85 to 1.85) | 0.249 |

The reference group in each analysis is patients who received spinal anesthesia. IRRs are calculated using Poisson regression models with robust SEs. HRs are calculated using Cox proportional hazards model. The analyses are adjusted for age, sex, CCI, ASA classification, type of fracture, and type of surgery. Multiple imputation by chained equations was used to manage missing values.

*A complication was classified as severe if it had a Clavien-Dindo classification $\geq 3a$.

†An extended surgical duration was defined as a surgery lasting >100 min, which constitute 90th percentile of the operative time in the current study cohort.

‡Patients were deemed to have a reduced fitness for surgery, if they had an ASA classification ≥ 3 .

§An elevated RCRI was defined as RCRI ≥ 2 .

¶An elevated CCI was defined as CCI ≥ 7 .

**Out-of-hours surgery was defined as surgery between 17:00 and 08:00 hours.

††Geriatric patients were defined as ≥ 65 years old.

ASA, American Society of Anesthesiologists; CI, Charlson Comorbidity Index; IRR, incident rate ratio; RCRI, Revised Cardiac Risk Index.

DISCUSSION

No significant associations between mode of anesthesia and in-hospital severe complications, or mortality up to 1 year postoperatively could be demonstrated in the current study. These results remained consistent within all subgroups that were analyzed.

The debate on what anesthesiological method to use in hip fracture patients, who are often elderly and frail, has been ongoing for decades.^{1-6 12-14 31 34-38} Despite this, there is a clinical equipoise regarding which patients should be provided spinal or general anesthesia, and great variation is seen in clinical practice.^{12-14 16} Zheng *et al* published the latest meta-analysis on this topic in 2020, including nine RCTs with low heterogeneity. They concluded that there were no significant differences between spinal or general anesthesia regarding the rate of delirium (OR (95% CI): 1.05 (0.27 to 4.00), $p=0.95$), myocardial infarction (OR (95% CI): 0.88 (0.17 to 4.65), $p=0.88$), pneumonia (OR (95% CI): 1.04 (0.23 to 4.61), $p=0.96$), deep vein thrombosis (OR (95% CI): 0.48 (0.09 to 2.72), $p=0.41$), or 30-day mortality (OR (95% CI): 1.34 (0.56 to 3.21), $p=0.51$).¹² Another meta-analysis by Van Waesberghe *et al* included 20 retrospective observational studies and 3 prospective RCTs. Like the current study, it only included patients who had undergone hip fracture surgery where the incidence of postoperative myocardial infarction, pneumonia, pulmonary embolism, respiratory failure, and mortality was investigated. They could not demonstrate any difference in the incidence of pneumonia (OR (95% CI): 0.74 (0.46 to 1.17), $p=0.20$), pulmonary embolism (OR (95% CI): 0.86 (0.64 to 1.17), $p=0.35$), or 30-day mortality (OR (95% CI): 0.99 (0.94 to 1.04), $p=0.60$).¹⁴ However, in contrast to Zheng *et al*, this meta-analysis found that the incidence of myocardial infarction was lower in the neuraxial anesthesia group (OR (95% CI): 0.90 (0.82 to 0.99), $p=0.03$).^{12 14} Furthermore, Van Waesberghe *et al* could also demonstrate a decreased incidence of respiratory failure (OR (95% CI): 0.50 (0.28 to 0.87), $p=0.02$) and in-hospital mortality (OR (95% CI): 0.85 (0.76 to 0.95), $p=0.004$) in the neuraxial anesthesia group. In their article, they also mentioned that the patients who received general anesthesia had an elevated risk of overall morbidity, especially in patients with pre-existing respiratory diseases.¹³

It has been demonstrated in several previous studies that patients sustaining a hip fracture are old and have a high comorbidity burden.^{1-6 31 34-38} These comorbidities, along with the acute injury, have a negative impact on the cardiovascular system as well as other organ systems, which may affect the postoperative risk of adverse events.^{7-9 14} Furthermore, studies have shown that several other factors could increase the risk of postoperative adverse events after hip fracture surgery, such as surgical duration, out-of-hours surgery, and dementia.^{5 19-22 24 25 31} However, these variables have not been taken into account in the previous studies on this topic.^{12 13}

Lin *et al* published a review article in 2018, pinpointing the importance of frailty in regard to anesthesia and surgery. They describe that depending on how frail a patient is, the consequences of the primary and secondary insult will differ. The least frail individual can recover from a minor insult, while a moderately frail patient can have a reduced functional outcome, and the frailest individual will have a severe decline in functional outcome. Furthermore, they suggest that if a frail patient suffers several insults, recovery could be impossible and might even result in death.¹⁴ Hip fracture patients are often frail and suffer several insults in a short period: the insult from the trauma causing the fracture, the insults from fasting and preparing for

surgery, the insult from anesthesia, as well as the insult from the hip fracture surgery.^{7-9 14} Recently, Neuman *et al* published a prospective randomised trial where 1600 patients were included in the *New England Journal of Medicine*. They investigated the effects of spinal anesthesia compared with general anesthesia on the functional outcome and demonstrated no differences in the relative risk (RR) of recovered ambulation (RR (95% CI): 1.06 (0.82 to 1.36)), delirium (RR (95% CI): 1.04 (0.84 to 1.30)), or survival (RR (95% CI): 0.97 (0.59 to 1.57)).¹⁶

Owing to the current study being an observational study, the analyses included patients that would have been ethically challenging for prospective RCTs to incorporate due to potential adverse outcomes or difficulties acquiring consent. Previous RCTs have otherwise avoided including patients with cognitive impairments or who have been considered to be high-risk patients.^{16 39} For example, Heidari *et al* excluded patients with dementia and those with an ASA classification >3 .³⁹ A substantial portion of hip fracture patients suffer from cognitive impairment. However, the current investigation comprises all adult patients with traumatic hip fractures that underwent surgery within the specified time frame. This difference likely also explains the higher crude mortality rates observed in the current study compared with previous RCTs, as it is well known that patients with dementia have a higher risk of mortality.^{21 24 32} This study suggests that, regarding both mortality and severe complications, even these high-risk patients are not affected by the mode of anesthesia.

The ASA classification, CCI, and RCRI are commonly used to assess the risk of postoperative events in patients who are frail or suffer from geriatric syndromes.^{14 19 23 40} However, these indices do not specifically measure frailty, but rather fitness for surgery, comorbidity burden, and cardiac risk. While frailty is related to these concepts, true frailty indices such as the traumatic frailty index, might be even more useful for directing resource allocation and patient care.^{14 41} Nevertheless, when performing subgroup analyses on these indices in the current study, no differences could be demonstrated when comparing the mode of anesthesia used. Previous studies investigating hip fracture patients with dementia have shown that this subgroup of patients suffer from a higher degree of pre-existing comorbidities and consequently also exhibit a higher risk of mortality postoperatively.^{21 24 32} Nevertheless, when performing a subgroup analysis on these patients, no association between mode of anesthesia and postoperative severe complications or mortality up to 1 year postoperatively.

Other factors that have been demonstrated to affect adverse outcomes after surgery is the surgical method used, where internal fixation has been associated with lower risks compared with arthroplasty when the surgery is performed out-of-hours, while patients with dementia and dislocated cervical hip fractures had better outcomes when they underwent hemiarthroplasty rather than internal fixation.^{22 25} However, no difference was seen in the outcomes measured in the current study when analyzing patients who underwent internal fixation, arthroplasty, had an extended surgical duration, or underwent surgery out-of-hours. One potential explanation for our findings could be the relatively short procedure time for hip fracture surgery; as most surgical techniques are relatively simple procedures the overall surgical trauma might result in less physiological strain compared to more complex surgeries with longer surgical durations.

The medical field has tried to reduce the high mortality rates after hip fracture surgery for decades.^{1-3 6 37 38 42} Despite several efforts including fast-track programs and multidisciplinary care, the mortality rates remain high.^{3 42} It has been suggested that

refining the surgical technique might not be the optimal strategy if the goal is to further decrease the mortality rates after hip fracture surgery; instead surgeons likely need to investigate other avenues that might affect postoperative outcomes.⁴³ Therefore, the main goal of the current study was to evaluate if mode of anesthesia had any effects on morbidity and mortality when considering different subgroups of hip fracture patients. The findings in the current study mirrors previous investigations on this topic in that the anesthetic method does not appear to affect adverse outcomes.^{12 13 16}

The environmental impact of the anesthetic choice should also play a role in the decision-making. Although spinal anesthesia would be anticipated to have a lower carbon footprint, the use of single-use instruments, packaging, and other equipment can increase the carbon dioxide emission rate to one similar to general anesthesia using inhalational agents. However, local variations in practices may impact this.^{44–46} Furthermore, from an institutional standpoint, spinal anesthesia is a more cost-effective choice in comparison to general anesthesia, which may impact the choice of departmental standard routine mode of anesthesia offered.^{17 47}

Strengths and limitations

There are strengths and limitations that need to be mentioned regarding the current study. In this study, we performed several analyses investigating specific subgroups in the hip fracture population that have not been previously studied. The subgroup analyses, along with the fact that all patients had surgery within the same orthopedic department, distributed across one university hospital and two affiliated hospitals, may have aided in reducing the heterogeneity that would otherwise arise as a result of institutional preferences and norms. Furthermore, the data collected for this study were based on reviews from the patients' electronic medical records, which could be considered more reliable than register data alone. Considering that this was a retrospective study with the limitations accompanying this type of studies, we cannot draw any conclusions about causal relationships. Finally, the observational nature of the current investigation allowed us to include patients that are otherwise ethically challenging to include due to potential adverse outcomes or difficulty acquiring consent, such as those with dementia or considered less fit for surgery (ASA ≥ 3). As a consequence, our results are likely even generalizable to these high-risk populations.

CONCLUSIONS

The mode of anesthesia used for emergency hip fracture surgery was not associated with an increased risk of either postoperative mortality or severe complications in the entire study population or in any of the included subgroups. Considering these results, in combination with previous studies, it may be suggested that pursuing other avenues of research might provide a greater benefit to hip fracture patients.

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REFERENCES

- 1 Cher EWL, Allen JC, Howe TS, Koh JSB. Comorbidity as the dominant predictor of mortality after hip fracture surgeries. *Osteoporos Int* 2019;30:2477–83.
- 2 Choi HG, Lee YB, Rhyu SH, Kwon BC, Lee JK. Mortality and cause of death postoperatively in patients with a hip fracture: a national cohort longitudinal follow-up study. *Bone Joint J* 2018;100-B:436–42.
- 3 Gundel O, Thygesen LC, Gögenur I, Ekeloef S. Postoperative mortality after a hip fracture over a 15-year period in Denmark: a national register study. *Acta Orthop* 2020;91:58–62.
- 4 Ahi R, Mohammad Ismail A, Borg T, Sjölin G, Forssten MP, Cao Y, Wretenberg P, Mohseni S. A nationwide observational cohort study of the relationship between beta-blockade and survival after hip fracture surgery. *Eur J Trauma Emerg Surg* 2022;48:743–751.
- 5 Forssten MP, Mohammad Ismail A, Borg T, Ahi R, Wretenberg P, Cao Y, Peden CJ, Mohseni S. Postoperative mortality in hip fracture patients stratified by the revised cardiac risk index: a Swedish nationwide retrospective cohort study. *Trauma Surg Acute Care Open* 2021;6:e000778.
- 6 Panula J, Pihlajamäki H, Mattila VM, Jaatinen P, Vahlberg T, Aarnio P, Kivela S-L. Mortality and cause of death in hip fracture patients aged 65 or older: a population-based study. *BMC Musculoskelet Disord* 2011;12:105.
- 7 Mohseni S, Joseph B, Peden CJ. Mitigating the stress response to improve outcomes for older patients undergoing emergency surgery with the addition of beta-adrenergic blockade. *Eur J Trauma Emerg Surg* 2022;48:799–810.
- 8 Moor D, Aggarwal G, Quiney N. Systemic response to surgery. *Surgery* 2017;35:220–3.
- 9 Desborough JP. The stress response to trauma and surgery. *Br J Anaesth* 2000;85:109–17.
- 10 Wenk M, Frey S. Elderly hip fracture patients: surgical timing and factors to consider. *Curr Opin Anaesthesiol* 2021;34:33–9.
- 11 Kanonidou Z, Karystianou G. Anesthesia for the elderly. *Hippokratia* 2007;11:175–7.
- 12 Zheng X, Tan Y, Gao Y, Liu Z. Comparative efficacy of neuraxial and general anesthesia for hip fracture surgery: a meta-analysis of randomized clinical trials. *BMC Anesthesiol* 2020;20:162.
- 13 Van Waesberghe J, Stevanovic A, Rossaint R, Coburn M. General vs. neuraxial anaesthesia in hip fracture patients: a systematic review and meta-analysis. *BMC Anesthesiol* 2017;17:87.

- 14 Lin H-S, McBride RL, Hubbard RE. Frailty and anesthesia - risks during and post-surgery. *Local Reg Anesth* 2018;11:61–73.
- 15 Morgan L, McKeever TM, Nightingale J, Deakin DE, Moppett IK. Spinal or general anaesthesia for surgical repair of hip fracture and subsequent risk of mortality and morbidity: a database analysis using propensity score-matching. *Anaesthesia* 2020;75:1173–9.
- 16 Neuman MD, Feng R, Carson JL, Gaskins LJ, Dillane D, Sessler DI, Sieber F, Magaziner J, Marcantonio ER, Mehta S, et al. Spinal anesthesia or general anesthesia for hip surgery in older adults. *N Engl J Med* 2021;385:2025–35.
- 17 Chakladar A, White SM. Cost estimates of spinal versus general anaesthesia for fractured neck of femur surgery. *Anaesthesia* 2010;65:810–4.
- 18 Fleisher LA, Fleischmann Kirsten E, Auerbach Andrew D, Barnason Susan A, Beckman Joshua A, Biykem B, Davila-Roman VG, Gerhard-Herman MD, Holly TA, Kane GC, et al. ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery. *Circulation* 2014;130:e278–333.
- 19 Forssten MP, Bass GA, Ismail AM, Mohseni S, Cao Y. Predicting 1-year mortality after hip fracture surgery: an evaluation of multiple machine learning approaches. *J Pers Med* 2021;11:727.
- 20 Tu D-P, Liu Z, Yu Y-K, Xu C, Shi X-L. Internal fixation versus Hemiarthroplasty in the treatment of unstable Intertrochanteric fractures in the elderly: a systematic review and meta-analysis. *Orthop Surg* 2020;12:1053–64.
- 21 Ioannidis I, Mohammad Ismail A, Forssten MP, Ahl R, Cao Y, Borg T, Mohseni S. The mortality burden in patients with hip fractures and dementia. *Eur J Trauma Emerg Surg* 2022;48:2919–2925.
- 22 Ioannidis I, Mohammad Ismail A, Forssten MP, Ahl R, Cao Y, Borg T, Mohseni S. Surgical management of displaced femoral neck fractures in patients with dementia: a comparison in mortality between hemiarthroplasty and pins/screws. *Eur J Trauma Emerg Surg* 2022;48:1151–1158.
- 23 Cao Y, Forssten MP, Mohammad Ismail A, Borg T, Ioannidis I, Montgomery S, Mohseni S. Predictive values of preoperative characteristics for 30-day mortality in traumatic hip fracture patients. *J Pers Med* 2021;11:353.
- 24 Bai J, Zhang P, Liang X, Wu Z, Wang J, Liang Y. Association between dementia and mortality in the elderly patients undergoing hip fracture surgery: a meta-analysis. *J Orthop Surg Res* 2018;13:298.
- 25 Forssten MP, Mohammad Ismail A, Borg T, Cao Y, Wretenberg P, Bass GA, Mohseni S. The consequences of out-of-hours hip fracture surgery: insights from a retrospective nationwide study. *Eur J Trauma Emerg Surg* 2022;48:709–719.
- 26 WMA - The World Medical Association-WMA Declaration of Helsinki. Ethical Principles for Medical Research Involving Human Subjects. <https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/> (21 Sep 2020).
- 27 RIKSHÖFT. Om Rikshöft. <https://www.xn--rikshft-e1a.se/om-oss> (20 Apr 2021).
- 28 Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987;40:373–83.
- 29 Lee TH, Marcantonio ER, Mangione CM, Thomas EJ, Polanczyk CA, Cook EF, Sugarbaker DJ, Donaldson MC, Poss R, Ho KK, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. *Circulation* 1999;100:1043–9.
- 30 Fleisher LA, Beckman JA, Brown KA, Calkins H, Chaikof E, Fleischmann KE, Freeman WK, Froehlich JB, Kasper EK, Kersten JR, et al. ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: a report of the American College of Cardiology/American heart association Task force on practice guidelines (writing Committee to revise the 2002 guidelines on perioperative cardiovascular evaluation for noncardiac surgery): developed in collaboration with the American Society of echocardiography, American Society of nuclear cardiology, heart rhythm Society, society of cardiovascular Anesthesiologists, Society for cardiovascular angiography and interventions, Society for vascular medicine and biology, and Society for vascular surgery. *Circulation* 2007;116:e418–99.
- 31 Forssten MP, Mohammad Ismail A, Sjölin G, Ahl R, Wretenberg P, Borg T, Mohseni S. The association between the revised cardiac risk index and short-term mortality after hip fracture surgery. *Eur J Trauma Emerg Surg* 2022;48:1885–1892.
- 32 Forssten MP, Ioannidis I, Mohammad Ismail A, Bass GA, Borg T, Cao Y, Mohseni S. Dementia is a surrogate for frailty in hip fracture mortality prediction. *Eur J Trauma Emerg Surg* 2022;45. [Epub ahead of print: 30 Mar 2022].
- 33 R Development Core Team. *R: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing, 2008. <http://www.R-project.org/>.
- 34 Mohammad Ismail A, Borg T, Sjölin G, Pourlofti A, Holm S, Cao Y, Wretenberg P, Ahl R, Mohseni S. β -adrenergic blockade is associated with a reduced risk of 90-day mortality after surgery for hip fractures. *Trauma Surg Acute Care Open* 2020;5:e000533.
- 35 Mohammad Ismail A, Ahl R, Forssten MP, Cao Y, Wretenberg P, Borg T, Mohseni S. The interaction between pre-admission β -blocker therapy, the revised cardiac risk index, and mortality in geriatric hip fracture patients. *J Trauma Acute Care Surg* 2022;92:49–56.
- 36 Mohammad Ismail A, Ahl R, Forssten MP, Cao Y, Wretenberg P, Borg T, Mohseni S. Beta-blocker therapy is associated with increased 1-year survival after hip fracture surgery: a retrospective cohort study. *Anesth Analg* 2021;133:1225–34.
- 37 Schnell S, Friedman SM, Mendelson DA, Bingham KW, Kates SL. The 1-year mortality of patients treated in a hip fracture program for elders. *Geriatr Orthop Surg Rehabil* 2010;1:6–14.
- 38 Kanis JA, Odén A, McCloskey EV, Johansson H, Wahl DA, Cooper C, . IOF Working Group on Epidemiology and Quality of Life. A systematic review of hip fracture incidence and probability of fracture worldwide. *Osteoporos Int* 2012;23:2239–56.
- 39 Heidari SM, Soltani H, Hashemi SJ, Talakoub R, Soleimani B. Comparative study of two anesthesia methods according to postoperative complications and one month mortality rate in the candidates of hip surgery. *J Res Med Sci* 2011;16:323–30.
- 40 Kim S, Brooks AK, Groban L. Preoperative assessment of the older surgical patient: honing in on geriatric syndromes. *Clin Interv Aging* 2015;10:13–27.
- 41 Joseph B, Pandit V, Zangbar B, Kulvatunyou N, Tang A, O'Keeffe T, Green DJ, Vercruysee G, Fain MJ, Fries RS, et al. Validating trauma-specific frailty index for geriatric trauma patients: a prospective analysis. *J Am Coll Surg* 2014;219:10–17.
- 42 Tureson E, Ivarsson K, Thorngren K-G, Hommel A. The impact of care process development and comorbidity on time to surgery, mortality rate and functional outcome for hip fracture patients: a retrospective analysis over 19 years with data from the Swedish National Registry for hip fracture patients, RIKSHÖFT. *BMC Musculoskelet Disord* 2019;20:616.
- 43 Rogmark C. Further refinement of surgery will not necessarily improve outcome after hip fracture. *Acta Orthop* 2020;91:123–4.
- 44 Varughese S, Ahmed R. Environmental and occupational considerations of anesthesia: a narrative review and update. *Anesthesia Analgesia* 2021;133:826–35.
- 45 McGain F, Sheridan N, Wickramarachchi K, Yates S, Chan B, McAlister S. Carbon footprint of general, regional, and combined anesthesia for total knee replacements. *Anesthesiology* 2021;135:976–91.
- 46 White SM, Shelton CL, Gelb AW, Lawson C, McGain F, Muret J, Sherman JD, McGain F, Muret J, Lawson C, . representing the World Federation of Societies of Anaesthesiologists Global Working Group on Environmental Sustainability in Anaesthesia. Principles of environmentally-sustainable anaesthesia: a global consensus statement from the world Federation of societies of Anaesthesiologists. *Anaesthesia* 2022;77:201–12.
- 47 Morris MT, Morris J, Wallace C, Cho W, Sharan A, Abouelrigal M, Joseph V. An analysis of the cost-effectiveness of spinal versus general anesthesia for lumbar spine surgery in various hospital settings. *Global Spine J* 2019;9:368–74.