# Vaccination against COVID-19 reduced the mortality risk of COVID-positive hip fracture patients to baseline levels

# **Vaccination against COVID-19 reduced the mortality risk of COVID-positive hip fracture patients to baseline levels:** The nationwide data-linked IMPACT Protect study

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**MINI ABSTRACT**

This nationwide study used data-linked records to assess the effect of COVID-19 vaccination in hip fracture patients. Vaccination was associated with a lower risk of contracting COVID-19 and, among COVID-positive patients, it reduced the mortality risk to that of COVID-negative patients. This provides essential data for future communicable disease outbreaks.

## ABSTRACT

*Purpose*

COVID-19 confers a three-fold increased mortality risk among hip fracture patients. The aims were to investigate whether vaccination was associated with: i) lower mortality risk, and ii) lower likelihood of contracting COVID-19 within 30 days of fracture.

*Methods*

This nationwide cohort study included all patients aged >50 years with a hip fracture between 01/03/20-31/12/21. Data from the Scottish Hip Fracture Audit were collected and included: demographics, injury and management variables, discharge destination, and 30-day mortality status. These variables were linked to population-level records of COVID-19 vaccination and testing.

*Results*

There were 13,345 patients with a median age of 82.0 years (IQR 74.0-88.0), and 9329/13345 (69.9%) were female. Of 3022/13345 (22.6%) patients diagnosed with COVID-19, 606/13345 (4.5%) were COVID-positive within 30 days of fracture. Multivariable logistic regression demonstrated that vaccinated patients were less likely to be COVID-positive (odds ratio (OR) 0.41, 95% confidence interval (CI) 0.34-0.48, $p<0.001$) than unvaccinated patients. 30-day mortality rate was higher for COVID-positive than COVID-negative patients (15.8% vs 7.9%, $p<0.001$). Controlling for confounders (age, sex, comorbidity, deprivation, pre-fracture residence), unvaccinated patients with COVID-19 had a greater mortality risk than COVID-negative patients (OR 2.77, CI 2.12-3.62, $p<0.001$), but vaccinated COVID19-positive patients were not at increased risk (OR 0.93, CI 0.53-1.60, $p=0.783$).

*Conclusion*

Vaccination was associated with lower COVID-19 infection risk. Vaccinated COVID-positive patients had a similar mortality risk to COVID-negative patients, suggesting a reduced severity of infection. This study demonstrates the efficacy of vaccination in this vulnerable patient group, and presents data that will be valid in the management of future outbreaks.



## KEYWORDS

Hip fracture, COVID-19, vaccination, mortality, frailty

## INTRODUCTION

Hip fracture patients are vulnerable to contracting and dying from COVID-19.[1–3] Unvaccinated patients that have COVID-19 around the time of an acute hip fracture admission have an approximate three-fold increased mortality risk compared to COVID-negative patients, are more likely to have longer hospital stays, higher post-discharge care needs, increased frailty, and more frequent readmissions to hospital.[4–6]

The prevalence of COVID-19 among hip fracture patients has fluctuated in line with background prevalence but this group of patients with high levels of frailty is likely to be at increased risk of transmission, particularly in inpatient or residential care settings.[7] A systematic review of COVID-19 in hip fracture patients conducted in the early stages of the pandemic reported a prevalence of 15% and demonstrated a 30-day mortality rate of 35% among COVID-positive hip fracture patients.[4] A longer term study found that half of all hip fracture patients affected by COVID-19 had died within a year of injury, with COVID-19 being a contributing factor in a quarter of all deaths.[8] COVID-19 in the context of an acute hip fracture has been shown to be associated with increased morbidity and a greater increase in frailty than those not affected by COVID-19.[6]

Strategies for mitigating the impact of COVID-19 on hip fracture patients and services have been described, and include pre-emptive testing, isolation of high-risk patients, operating separate circuits in periods of high disease prevalence, and ensuring adequate contact-tracing between inpatient and community-based residential care settings.[9–12] The COVID-19 pandemic prompted the development of a rapid population-wide vaccination programme and evidence suggests that this is effective in reducing transmission, morbidity, and mortality from COVID-19 in the general population, and protection against more severe infections may be particularly effective in frail or elderly groups.[13–16] In hip fracture patients specifically there is early evidence to suggest that vaccination against COVID-19 may be associated with improved outcomes, but no population-level studies have reported on the effects of vaccination against COVID-19 specifically in hip fracture patients.[17–19]

The aims of this study were to investigate whether vaccination against COVID-19 was associated with: (i) a lower risk of death within 30 days following hip fracture among COVID-positive patients, and ii) a lower likelihood of having COVID-19 within 30 days of a hip fracture.

## METHODS

*Study design*

This nationwide cohort study collected and collated data from the Scottish Hip Fracture Audit (SHFA) and from two COVID-specific nationwide healthcare databases.[20] It examined patients admitted with a hip fracture in Scotland over a 21-month period between 1st March 2020 and 31st December 2021. The study was conducted as part of the International Multicentre Project Auditing COVID-19 in Trauma & Orthopaedics (IMPACT), which is a collaborative research group established in 2020 and has delivered a portfolio of original research and audit studies into the effects of COVID-19 on hip fracture patients and the wider orthopaedic population.[21, 22]

*Study population*

The study included patients aged over 50 years that were admitted with an acute hip fracture between 01/03/20-31/12/21. A hip fracture was defined as a fracture of the intracapsular or extracapsular portion of the proximal femur up to the distal portion of the subtrochanteric region (defined as five centimetres distal to the lesser trochanter). Patients were identified from the live dataset of the SHFA, which is a national registry administered by Public Health Scotland (PHS).

*Data collection & linkage*

Patient-level data were collected prospectively as part of the routine SHFA activity by specialist audit coordinators at each of the 17 hospitals that manage acute hip fractures and submitted to PHS where they were collated into the central SHFA live dataset. Data pertaining to hip fracture patients admitted during the study period were extracted, and variables were: a universal identifier (community health index [CHI]); demographics (age, sex, pre-fracture residence level, postcode, American Society of Anesthesiologists (ASA) Physical Classification System Grade [a five-level classification of current physical status based on the existence and severity of systemic disease]); injury and treatment process factors (date of injury, date of surgery, length of stay in acute hospital (acute LOS), total length of stay as an inpatient (total LOS)), and outcome measures (discharge destination following the acute hospital stay, mortality status at 30 days post-fracture).[23] Postcode was used to assign a quintile on the Scottish Index of Multiple Deprivation (SIMD), with patients in quintile 1 being most deprived, and those in quintile 5 being least deprived.[24] To account for patients that suffered more than one hip fracture during the study period, SHFA episodes were categorised using a four-level 'fracture sequence' variable: single fracture (for patients experiencing only one hip fracture during the study period); first fracture (the first hip fracture in patients that had more than one in the study period); second fracture, and third fracture.

The unique community health index (CHI) number of each included patient was used to identify and extract relevant data from two national COVID-specific databases administered by PHS: the Electronic Communication of Surveillance in Scotland (ECOSS) system, a component of the national Infection Intelligence Platform (IIP) which collates all positive microbiology laboratory specimen results, and the Turas

Vaccination Management (TVM) tool, which is the web-based application used for point-of-care recording of COVID-19 vaccination information in Scotland.[25, 26] Variables extracted from ECOSS were: CHI, postcode, and date and time of all positive SARS-CoV-2 reverse transcription polymerase chain reaction (RT-PCR) swabs between (18/03/20-03/07/22). Variables extracted from TVM were: CHI and the date and product name of any vaccine doses administered (between 08/12/20-07/04/22). Patients were considered vaccinated if they had received a vaccine dose prior to the acute hip fracture episode.

The three datasets were collated into a single dataset using the Power Query function, utilising CHI as the common identifier to facilitate linkage of patient-level entries (Microsoft Excel, Microsoft Corporation, Redmond, WA, USA). The common dataset was cleaned to remove duplicate records, those with missing critical data, cases involving non-Scottish domiciled patients (where vaccination, microbiology, and follow-up data may not be complete), and to ensure appropriate homogeneity of coding.

*Statistical methods*

Statistical analysis for this study was performed using RStudio (Integrated Development for R. Rstudio, PBC, Boston, MA, USA) using the following packages: dplyr; tableone; mice, and finalfit.[27–30] Categorical variables were assessed using Chi-square tests and continuous variables were assessed for inter-group differences using independent samples t-tests for normally distributed data, and Mann-Whitney U tests for non-normally distributed data. Linear and logistic regression analyses were used when continuous or discrete outputs were required, respectively, and factors that demonstrated an association ($p<0.1$) on unadjusted analysis were included in multivariable regression models. A p-value of $<0.05$ was considered statistically significant. Missing data were assessed objectively for patterns of missingness.

*Missing data*

Missing data were analysed using the *finalfit* data science package, and multiple imputation by chained equations was carried out using the *mice* package.[31] Analysis of missing data demonstrated that ASA Grade was missing for 340/13345 (2.5%) and SIMD for 303/13345 (2.3%). ASA Grade is a core variable of the SHFA, however an assessment of availability conducted as part of a previous study revealed that it is systematically omitted from two participating centres and this accounted for 75% of missing values in this field. It was therefore considered likely that the majority of missing ASA Grade values are missing completely at random (MCAR), although some data may be missing due to patients not being assessed by an anaesthetist on account of being unfit for surgery, in which case these data would be missing not at random (MNAR). SIMD was unavailable for patients that did not have a complete postcode documented. Following analysis of the dataset it is likely that this is a result of random omission from the data collection process, and the missing SIMD values could be considered missing completely at random (MCAR). Missing data were modelled using multiple imputation by chained equation (MICE), and the output of logistic regression analyses performed using imputed data were presented alongside analyses performed with missing data.

*Ethical approval*

The study protocol was considered and approved by the SHFA Research Group on behalf of PHS, which is the owner and controller of SHFA data. Access to the SHFA, ECOSS, and TVM data were provided by an authorised PHS analyst to one author (AH) who is a PHS-affiliated research fellow. Data were handled in accordance with UK Caldicott principles.

## RESULTS

*Patient characteristics*

There were 13,345 patients that were admitted with an acute hip fracture in Scotland between 01/03/20-31/12/21. The median age was 82.0 years (IQR 74.0-88.0) and 9329/13345 (69.9%) were female. There were 6725/13345 (50.4%) patients that had been vaccinated before sustaining their hip fracture, and 6620/13345 (49.6%) patients were unvaccinated at the time of injury. Compared to the vaccinated group, the unvaccinated group was slightly younger (median age 81.0 years [IQR 73.0-87.0] versus 83.0 years [IQR 75.0-88.0], p<0.001.), had a lower level of co-morbidity (more likely to have a lower ASA Grade), and had a slightly lower level of socioeconomic deprivation (mean SIMD rank 3.27 (SD 1.39) versus 3.02 (SD 1.40), p<0.001.). (Table 1) Patient cohort characteristics are described according to 30-day mortality status in Table 2, and according to COVID-19 status and vaccination status in Table 3.

*Effect of vaccination on prevalence of COVID-19*

There were 3022/13345 (22.6%) patients diagnosed with COVID-19 at any time during the study period, and 606/13345 (4.5%) patients that were diagnosed with COVID-19 within 30 days of the fracture. The rate of COVID-19 among unvaccinated patients was higher than among vaccinated patients (420/6620 [6.3%] versus 186/6725 [2.8%]).

Unadjusted logistic regression analysis demonstrated associations between an increased likelihood of being COVID-positive and: older age (odds ratio (OR) 1.02, 1.01-1.03, p<0.001, for each increasing year); ASA Grade 3 or 4 (OR 1.61, 1.28-2.04, p<0.001, and OR 1.52, 1.14-2.04, p=0.005, respectively compared to the reference ASA Grade 2); pre-fracture residence in residential care (OR 1.29, 1.04-1.58, p=0.017), subacute hospital (OR 1.86, 1.16-2.83, p=0.006), or acute hospital (OR 1.96, 1.37-2.72, p<0.001), and being unvaccinated (OR 2.38, 2.00-2.85, p<0.001). (Table 4) When controlling for confounding factors (age, sex, ASA Grade, socioeconomic deprivation, pre-fracture residence, fracture sequence), multivariable logistic regression demonstrated that unvaccinated patients were more than twice as likely to be COVID-positive within 30 days of a hip fracture (OR 2.47, 95% confidence interval (CI) 2.06-2.95, p<0.001) than vaccinated patients. (Table 4)

*Effect of vaccination on mortality risk*

There were 1108/13345 (8.3%) that died within 30 days of fracture. The 30-day mortality rate for COVID-positive patients was twice as high as for COVID-negative patients (15.8% vs 7.9%, p<0.001), and when considering only unvaccinated COVID-positive the 30-day mortality rate was 19.3%, whereas for vaccinated COVID-positive patients it was 8.1% (p<0.001).

Unadjusted logistic regression analysis demonstrated associations between an increased 30-day mortality risk and: older age (OR 1.04, 1.04-1.05, p<0.001, for each increasing year); male sex (OR 1.74, 1.53-1.97, p<0.001); ASA Grade 3 (OR 2.57, 2.02-3.32, p<0.001), Grade 4 (OR 6.95, 5.39-9.08, p<0.001), or Grade 5 (OR 25.22, 17.72-36.05, p<0.001); pre-fracture residence in residential care (OR 2.65, 2.30-3.04, p<0.001),

subacute hospital (OR 2.19, 1.52-3.06, p<0.001), or acute hospital (OR 2.88, 2.22-3.68, p<0.001), and being unvaccinated (OR 2.38, 2.00-2.85, p<0.001) (Table 5). When controlling for confounding factors, unvaccinated COVID-positive patients had an almost three-fold greater mortality risk than COVID-negative patients (OR 2.77, CI 2.12-3.62, p<0.001), however the mortality risk of vaccinated COVID-positive patients was no higher than that of COVID-negative patients (OR 0.93, CI 0.53-1.60, p=0.783). (Table 5)

*Sub-group analysis including patients on a time-dependent basis*

To control for the potential effects of hip fracture service variation over the course of the pandemic, all analyses were repeated excluding patients admitted for a hip fracture within the first six months of the study period (01/03/20-31/08/20). The patient characteristics and rate of COVID-19 were comparable between this sub-group and the total study group (Supplementary Table 1). The main study findings were also replicated in this sub-group. When controlling for confounders, unvaccinated patients had a higher likelihood of being diagnosed with COVID-19 within 30 days of hip fracture than vaccinated patients (OR 3.68, CI 3.04-4.45, p<0.001; Supplementary Table 2), unvaccinated COVID-positive patients were more likely to die than vaccinated COVID-negative patients (OR 2.13, CI 1.52-2.98, p<0.001), and the mortality risk of vaccinated COVID-positive patients was no higher than that of COVID-negative patients (OR 0.94, CI 0.54-1.62, p=0.817; Supplementary Table 3).

## DISCUSSION

This nationwide population-level data-linked cohort study assessed the association between vaccination on COVID-19 prevalence and mortality risk among hip fracture patients. Patients that were vaccinated prior to sustaining a hip fracture had a lower risk of being diagnosed with COVID-19 within 30 days of the injury. Among patients that had COVID-19 within 30 days of fracture, unvaccinated patients had a three-fold increased 30-day mortality risk compared to COVID-negative patients, but COVID-19 affecting vaccinated patients was not associated with an increased mortality risk. These findings support the hypothesis that vaccination is effective at reducing the likelihood of both contracting and dying from COVID-19 among patients that sustain a hip fracture. This study provides essential data on the effectiveness of such a vaccination programme for future pandemics and highlights the importance of such programmes in this highly vulnerable patient group.

The study found an overall prevalence of COVID-19 of 22%, which is consistent with previous studies. The 5% rate of COVID-19 diagnosed within 30 days of fracture reported by the current study is lower than in the literature.[4] This could be due to this study considering only COVID-19 cases that were confirmed with SARS-CoV-2 RT-PCR testing, whereas other studies had broader inclusion criteria, particularly those conducted early in the pandemic (when background prevalence was highest), and included COVID-19 diagnoses based on radiological evidence or clinical suspicion.[12] Furthermore there is a recognised false-negative rate associated with SARS-CoV-2 RT-PCR testing that varies according to the timing of the test in relation to the course of the infection, the technique used to obtain the swab material, and other factors.[32, 33] The three-fold increased mortality risk associated with COVID-19 in unvaccinated patients is consistent with the magnitude of increase reported by studies conducted prior to the widespread availability of COVID-19 vaccines, and the reduction in mortality risk associated with vaccination reflects evidence of vaccination being effective in the non-hip fracture population.[2, 9, 13, 16, 17, 34]

Prior to the COVID-19 pandemic the 30-day mortality rate of hip fracture patients in Scotland was around 7.5%, with around 25% of patients dying within a year of the fracture.[35] The systematic review from before the widespread availability of a vaccine against COVID-19 demonstrated a 30-day mortality rate of 35% among COVID-positive hip fracture patients, and COVID-19 has been shown to be independently associated with a three-fold increased 30-day mortality risk when controlling for confounding factors.[4] This is consistent with the findings of the current study of an almost three-fold increased risk of death within 30 days for unvaccinated COVID-positive patients. The majority of COVID-related deaths in hip fracture patients occur within a month of diagnosis of COVID-19.[8] The current study found that vaccinated COVID-positive patients were no more likely to be deceased within 30 days of fracture than COVID-negative patients, which suggests that the lethal effects of COVID-19 in this frail group may be significantly diminished by vaccination, with mortality risk being reduced to near pre-pandemic levels.

Previous studies have demonstrated that vaccination against COVID-19 may be associated with lower rates of complications, admissions to intensive care, and overall mortality among hip fracture patients.[18, 19] The findings of this study are important as they are the first to assess the protective effects of vaccination against COVID-19 in hip fracture patients on a nationwide basis and appear to support the hypotheses that vaccination

against COVID-19 was effective at reducing the risk of this vulnerable patient group contracting COVID-19, as well as dying within a month of an acute hip fracture episode complicated by COVID-19. Although this study was not designed to assess for increased morbidity directly associated with vaccine administration, there is overwhelming evidence to support safety and widespread use in the general and frail population.

There are several strengths to this study. The use of population-level health records provided a large study sample that is generalisable to the whole hip fracture population. Furthermore, it is likely that these findings may be generalisable to hip fracture patients in similar healthcare systems, as well as to the wider frail population. This methodology is robust as data were collected prospectively at source, by trained clinical auditors (SHFA data), technicians (ECOSS data), and clinicians (TVM data) and underwent validation and collation by experience PHS analysts. Furthermore, the use of PHS-administered national health records ensured maximal data coverage and validity. The SHFA is known to report >99% of hip fracture admissions in Scotland.[35, 36] The ECOSS system is Scotland's nationwide infection surveillance system and draws directly from live health records relating to any positive laboratory microbiological finding, and the TVM was established as a bespoke system to record and monitor the administration of COVID-19 vaccinations in Scotland. This study focused on COVID-19 within 30 days of fracture because it is reported that, when adjusting for confounding factors, only a COVID-19 diagnosis made during the acute hip fracture period is associated with an increased mortality risk – the so-called 'double-hit' effect in which patients are more vulnerable to contracting and dying from COVID-19 during a period of acute illness and emergency surgery.[6] Mortality status at 30 days following fracture was the primary outcome measure because it is collected using robust methods by the SHFA local audit coordinators, and because the majority of deaths in COVID-positive patients occur within the first month. Finally, hip fracture services in Scotland are standardised and delivered according to the Scottish Standards of Care for Hip Fracture Patients (SSCHFP), which provides a consistent level of care quality against which to measure outcomes.[37, 38]

There are several limitations to this study. The frequency of COVID-19 fluctuated throughout the study period and public health data regarding disease prevalence relates to the general population, making it challenging to interpret findings relating to the direct effects of vaccination on COVID-19 in this group. Further, the vaccination programme prioritised the oldest and most vulnerable patients before being rolled out to younger and less vulnerable groups. The impact of both these limitations may have been mitigated by comparing disease prevalence between vaccinated and unvaccinated hip fracture patients, and by using multivariable logistic regression analysis to assess the independent effect of vaccination status on the risk of being COVID-positive within 30 days of injury. Secondly, the method of vaccination involved the use of different vaccine products and a multi-dose strategy, and each product has been shown to confer different levels of protection against contracting, transmitting, and dying from COVID-19. There were 12 distinct vaccine regimens administered to patients in the current study, based around three products (Oxford-AstraZenica, Pfizer BioNTech, Moderna), with patients receiving one, two or three doses. The study sample was insufficient to investigate the efficacy of different vaccine regimens and control for confounding factors. Thirdly, the ease and consistency of access to RT-PCR testing was limited in the early stages of the pandemic, and routine testing of all patients was not

introduced until around the height of the first wave of COVID-19 in the UK (and at different times according to local protocols). Fourthly, it is a limitation of population-level studies of this scale that patient-level data regarding specific comorbidities and medications are not routinely and/or robustly collected. In this study we included all patient characteristics available in the national datasets that could influence the study findings, including: age; sex; American Society of Anesthesiologists (ASA) grade (classifying pre-surgery medical comorbidities); pre-fracture residence (a surrogate marker for performance status), and socioeconomic deprivation (known to be associated with medical comorbidity and post-injury outcomes including mortality and healthcare needs).[15, 23, 24] We did not have direct measurements of frailty, dementia, or delirium status, which is a limitation common across national hip fracture registries, though controlling for ASA grade and pre-fracture place of residence to some extent indirectly adjusts for these variables.[6, 15, 39–41] It was beyond the scope of the study to collect and analyse patient-level data relating to pharmacological interventions for the management of active COVID-19. There is a lack of robust evidence demonstrating a clear clinical benefit of antiviral therapeutic regimens in the management of active COVID-19 in the geriatric orthopaedic population, and the use of these therapies would have been highly uncommon among hip fracture patients in Scotland, hence this was considered a minor limitation.[42]

A proportion of positive RT-PCR results will be false positives, representing a positive result despite the absence of SARS-CoV-2 infection.[43] However, although the operational rate of false positive SARS-CoV-2 RT-PCR tests is unknown, it is estimated to be <1% and is much smaller than the estimated false negative rate. This ranged from 100% to 67% over the first four days of infection (the pre-symptomatic phase), is around 20% for the next four days (the symptomatic phase), and then increases steadily to around 66% after three weeks of infection.[32, 33] These limitations in testing for SARS-CoV-2 infection means that the prevalence of COVID-19, as well as the mortality rate of COVID-positive patients, is potentially underestimated by the current study. It is therefore likely that the protective effects of vaccination against infection and mortality risk may be greater than observed. Further work will investigate the effects of vaccination on broader outcome measures in the hip fracture population including frailty, readmission to acute services, and post-discharge care needs.

## CONCLUSION

Vaccination against COVID-19 was independently associated with a lower risk of contracting COVID-19 within 30 days of a hip fracture. Among patients that had COVID-19 within 30 days of fracture, unvaccinated patients had a three-fold increased 30-day mortality risk compared to COVID-negative patients, but COVID-19 affecting vaccinated patients did not confer any increased mortality risk. The findings support the hypothesis that vaccination was effective in reducing the likelihood of both contracting and dying from COVID-19 among hip fracture patients, reducing the mortality risk back to near pre-pandemic levels. This provides a unique perspective on the management of COVID-19, and presents data that will be valid in the management of future outbreaks.

**Statements and Declarations:**

Andrew Hall, Nick Clement, Alasdair MacLullich, Tim White, and Andrew Duckworth declare that they have no conflict of interest.

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478 **TABLES**

479 **Table 1.** Patient characteristics according to vaccination status.

| | | Vaccination Status | | |
|---|---|---|---|---|
| | | ***Vaccinated*** | ***Unvaccinated*** | ***p-value**** |
| | | n= 6725 | n= 6620 | |
| **Age** [median (IQR)] | | 83.0 [75.0, 88.0] | 81.0 [73.0, 87.0] | **<0.001✝** |
| **Sex** (%) | | | | |
| | *Female* | 4750 (70.6) | 4579 (69.2) | 0.068 |
| | *Male* | 1975 (29.4) | 2041 (30.8) | |
| **ASA Grade** (%) | | | | |
| | *2* | 1352 (20.6) | 1469 (22.8) | **0.001** |
| | *1* | 94 (1.4) | 116 (1.8) | |
| | *3* | 3941 (60.1) | 3785 (58.7) | |
| | *4* | 1071 (16.3) | 957 (14.8) | |
| | *5* | 98 (1.5) | 122 (1.9) | |
| **SIMD Rank** [mean (SD)] | | 3.02 (1.40) | 3.27 (1.39) | **<0.001** |
| **Pre-fracture Residence** (%) | | | | |
| | *Home* | 5085 (75.6) | 5103 (77.1) | 0.086 |
| | *Residential Care* | 1223 (18.2) | 1097 (16.6) | |
| | *Subacute Hospital* | 159 (2.4) | 140 (2.1) | |
| | *Acute Hospital* | 242 (3.6) | 262 (4.0) | |
| | *Missing* | 16 (0.2) | 18 (0.3) | |
| **Acute LOS** [median (IQR)] | | 11.0 [8.0, 17.0] | 10.0 [7.0, 16.0] | **<0.001✝** |
| **Total LOS** [median (IQR)] | | 18.0 [9.0, 40.0] | 16.0 [9.0, 36.0] | **<0.001✝** |
| **Discharge Destination** (%) | | | | |
| | *Home* | 2505 (37.3) | 2698 (40.8) | **<0.001** |
| | *Residential Care* | 1045 (15.6) | 958 (14.5) | |
| | *Subacute Hospital* | 2514 (37.4) | 2295 (34.7) | |
| | *Acute Hospital* | 279 (4.2) | 293 (4.4) | |
| | *Deceased* | 370 (5.5) | 364 (5.5) | |
| **Fracture Sequence** (%) | | | | |
| | *Single fracture* | 6420 (95.5) | 6332 (95.6) | **<0.001** |
| | *First fracture* | 104 (1.5) | 192 (2.9) | |
| | *Second fracture* | 201 (3.0) | 95 (1.4) | |
| | *Third fracture* | 0 (0.0) | 1 (0.0) | |
| **COVID-19 Status** (%) | | | | |
| | *Negative* | 6539 (97.2) | 6200 (93.7) | **<0.001** |
| | *Positive within 30d* | 186 (2.8) | 420 (6.3) | |
| **Vaccination Doses** (%) | | | | |
| | *Unvaccinated* | 0 (0.0) | 6620 (100.0) | **<0.001** |
| | *First dose* | 1397 (20.8) | 0 (0.0) | |

| | | | | |
|---|---|---|---|---|
| | *Second dose* | 5328 (79.2) | 0 (0.0) | |
| **30-day Mortality Status (%)** | | | | |
| | *Alive* | 6183 (91.9) | 6054 (91.5) | 0.320 |
| | *Deceased* | 542 (8.1) | 566 (8.5) | |

480

481 IQR = interquartile range; ASA = American Society of Anesthesiologists; SIMD = Scottish Index of Multiple
482 Deprivation; SD = standard deviation; LOS = length of stay; d = days
483 *Chi-square test for categorical variables with a normal distribution, independent pairs t-test for continuous
484 variables, Mann-Whitney U test for continuous variables with a non-normal distribution (denoted with +)

485 **Table 2.** Patient characteristics according to mortality status at 30 days post-fracture.

| | | 30-day Mortality Status | | |
|---|---|---|---|---|
| | | ***Alive*** | ***Deceased*** | ***p-value**** |
| | | *n= 12237* | *n= 1108* | |
| **Age** [median (IQR)] | | 82.0 (74.0-87.0) | 85.0 (79.0-90.0) | **<0.001**[+] |
| **Sex** (%) | | | | |
| | *Female* | 8682 (70.9) | 647 (58.4) | **<0.001** |
| | *Male* | 3555 (29.1) | 461 (41.6) | |
| **ASA Grade** (%) | | | | |
| | *2* | 2747 (22.9) | 74 (7.5) | **<0.001** |
| | *1* | 204 (1.7) | 6 (0.6) | |
| | *3* | 7226 (60.1) | 500 (50.6) | |
| | *4* | 1708 (14.2) | 320 (32.4) | |
| | *5* | 131 (1.1) | 89 (9.0) | |
| **SIMD Rank** [mean (SD)] | | 3.1 (1.4) | 3.2 (1.4) | 0.531 |
| **Pre-fracture Residence** (%) | | | | |
| | *Home* | 9552 (78.1) | 636 (57.4) | **<0.001** |
| | *Residential care* | 1972 (16.1) | 348 (31.4) | |
| | *Subacute hospital* | 261 (2.1) | 38 (3.4) | |
| | *Acute hospital* | 423 (3.5) | 81 (7.3) | |
| | *Missing* | 29 (0.2) | 5 (0.5) | |
| **Acute LOS** [median (IQR)] | | 11.0 (8.0-17.0) | 8.0 (5.0-13.0) | **<0.001**[+] |
| **Total LOS** [median (IQR)] | | 18.0 (9.0-41.0) | 10.0 (6.0-18.0) | **<0.001**[+] |
| **Discharge Destination** (%) | | | | |
| | *Home* | 5184 (42.4) | 43 (3.9) | **<0.001** |
| | *Residential care* | 1825 (14.9) | 178 (16.1) | |
| | *Subacute hospital* | 4658 (38.1) | 151 (13.6) | |
| | *Acute hospital* | 490 (4.0) | 82 (7.4) | |
| | *Deceased* | 80 (0.7) | 654 (59.0) | |
| **Fracture Sequence** (%) | | | | |
| | *Single fracture* | 11668 (95.4) | 1084 (97.8) | **<0.001** |
| | *First fracture* | 293 (2.4) | 3 (0.3) | |
| | *Second fracture* | 275 (2.2) | 21 (1.9) | |
| | *Third fracture* | 1 (0.0) | 0 (0.0) | |

| | | | | |
|---|---|---|---|---|
| **COVID-19 Status** (%) | | | | |
| | *Negative* | 9381 (76.7) | 942 (85.0) | **<0.001** |
| | *Positive within 30d* | 510 (4.2) | 96 (8.7) | |
| | *Positive outwith 30d* | 2346 (19.2) | 70 (6.3) | |
| **Vaccination Status** (%) | | | | |
| | *Unvaccinated* | 6054 (49.5) | 566 (51.1) | 0.273 |
| | *Vaccinated* | 6183 (50.5) | 542 (48.9) | |

IQR = interquartile range; ASA = American Society of Anesthesiologists; SIMD = Scottish Index of Multiple Deprivation; SD = standard deviation; LOS = length of stay; d = days

*Chi-square test for categorical variables with a normal distribution, independent pairs t-test for continuous variables, Mann-Whitney U test for continuous variables with a non-normal distribution (denoted with +)

491 **Table 3.** Patient characteristics according to COVID-19 and vaccination status.

| | | COVID-19 Status (Vaccination Status) | | | |
|---|---|---|---|---|---|
| | | ***Negative*** | ***Positive (Vaccinated)*** | ***Positive (Unvaccinated)*** | ***p-value**** |
| | | *n= 12739* | *n= 186* | *n= 420* | |
| **Age** [median (IQR)] | | 82.0 [74.0, 88.0] | 85.00 [79.0, 89.0] | 83.0 [77.7, 88.0] | **<0.001+** |
| **Sex** (%) | | | | | |
| | *Female* | 8909 ( 69.9) | 135 ( 72.6) | 285 ( 67.9) | 0.478 |
| | *Male* | 3830 ( 30.1) | 51 ( 27.4) | 135 ( 32.1) | |
| **ASA Grade** (%) | | | | | |
| | *2* | 2730 ( 22.0) | 27 ( 14.8) | 64 ( 15.5) | **0.004** |
| | *1* | 206 ( 1.7) | 1 ( 0.5) | 3 ( 0.7) | |
| | *3* | 7332 ( 59.1) | 126 ( 69.2) | 268 ( 65.0) | |
| | *4* | 1930 ( 15.6) | 27 ( 14.8) | 71 ( 17.2) | |
| | *5* | 213 ( 1.7) | 1 ( 0.5) | 6 ( 1.5) | |
| **SIMD Rank** [mean (SD)] | | 3.14 (1.40) | 2.92 (1.47) | 3.33 (1.40) | **0.003** |
| **Pre-fracture Residence** (%) | | | | | |
| | *Home* | 9770 ( 76.7) | 113 ( 60.8) | 305 ( 72.6) | **<0.001** |
| | *Residential Care* | 2199 ( 17.3) | 45 ( 24.2) | 76 ( 18.1) | |
| | *Subacute Hospital* | 277 ( 2.2) | 12 ( 6.5) | 10 ( 2.4) | |
| | *Acute Hospital* | 465 ( 3.7) | 15 ( 8.1) | 24 ( 5.7) | |
| | *Missing* | 28 ( 0.2) | 1 ( 0.5) | 5 ( 1.2) | |
| **Acute LOS** [median (IQR)] | | 10.0 [7.0, 16.0] | 13.0 [9.0, 24.0] | 14.0 [8.0, 26.0] | **<0.001+** |
| **Total LOS** [median (IQR)] | | 16.0 [9.0, 37.0] | 27.5 [13.2, 56.2] | 30.0 [18.0, 53.0] | **<0.001+** |
| **Discharge Destination** (%) | | | | | |
| | *Home* | 5063 ( 39.8) | 38 ( 20.7) | 102 ( 24.3) | **<0.001** |
| | *Residential Care* | 1920 ( 15.1) | 36 ( 19.6) | 47 ( 11.2) | |
| | *Subacute Hospital* | 4592 ( 36.1) | 67 ( 36.4) | 150 ( 35.8) | |
| | *Acute Hospital* | 478 ( 3.8) | 29 ( 15.8) | 65 ( 15.5) | |

| | | | | | |
|---|---|---|---|---|---|
| | *Deceased* | 665 ( 5.2) | 14 ( 7.6) | 55 ( 13.1) | |
| **Fracture Sequence** (%) | | | | | |
| | *Single fracture* | 12183 ( 95.6) | 175 ( 94.1) | 394 ( 93.8) | 0.228 |
| | *First fracture* | 278 ( 2.2) | 3 ( 1.6) | 15 ( 3.6) | |
| | *Second fracture* | 277 ( 2.2) | 8 ( 4.3) | 11 ( 2.6) | |
| | *Third fracture* | 1 ( 0.0) | 0 ( 0.0) | 0 ( 0.0) | |
| **30-day Mortality Status (%)** | | | | | |
| | *Alive* | 11727 ( 92.1) | 171 ( 91.9) | 339 ( 80.7) | **<0.001** |
| | *Deceased* | 1012 ( 7.9) | 15 ( 8.1) | 81 ( 19.3) | |

502

503 IQR = interquartile range; ASA = American Society of Anesthesiologists; SIMD = Scottish Index of Multiple Deprivation; SD = standard deviation; LOS =
504 length of stay; d = days
505 *Chi-square test for categorical variables with a normal distribution, independent pairs t-test for continuous variables, Mann-Whitney U test for continuous
506 variables with a non-normal distribution (denoted with +)

507 **Table 4.** Logistic regression analysis of factors associated with an increased likelihood of having COVID-19 within 30 days of hip fracture.

508

| | | *OR (Unadjusted)* | *OR (Multivariable)* | *OR (Multiple Imputation)* |
|---|---|---|---|---|
| **Age** | | **1.02 (1.01-1.03, p<0.001)** | **1.02 (1.01-1.03, p<0.001)** | **1.02 (1.01-1.03, p<0.001)** |
| **Sex** | | | | |
| | *Female* | Reference | Reference | Reference |
| | *Male* | 1.03 (0.86-1.23, p=0.742) | 1.04 (0.87-1.25, p=0.641) | 1.04 (0.87-1.25, p=0.644) |
| **ASA Grade** | | | | |
| | *2* | Reference | Reference | Reference |
| | *1* | 0.58 (0.18-1.41, p=0.295) | 0.64 (0.19-1.55, p=0.382) | 0.63 (0.23-1.74, p=0.370) |
| | *3* | **1.61 (1.28-2.04, p<0.001)** | **1.44 (1.14-1.84, p=0.003)** | **1.44 (1.13-1.83, p=0.003)** |
| | *4* | **1.52 (1.14-2.04, p=0.005)** | 1.28 (0.94-1.73, p=0.118) | 1.27 (0.94-1.73, p=0.125) |
| | *5* | 0.99 (0.41-2.01, p=0.972) | 0.79 (0.33-1.63, p=0.565) | 0.79 (0.36-1.74, p=0.559) |
| **SIMD Rank** | | 1.03 (0.97-1.09, p=0.283) | - | 1.01 (0.95-1.08, p=0.676) |
| **Pre-fracture Residence** | | | | |
| | *Home* | Reference | Reference | Reference |
| | *Residential care* | **1.29 (1.04-1.58, p=0.017)** | 1.08 (0.86-1.34, p=0.502) | 1.10 (0.89-1.37, p=0.379) |
| | *Subacute hospital* | **1.86 (1.16-2.83, p=0.006)** | **1.76 (1.09-2.70, p=0.014)** | **1.64 (1.04-2.60, p=0.033)** |
| | *Acute hospital* | **1.96 (1.37-2.72, p<0.001)** | **1.83 (1.27-2.57, p=0.001)** | **1.82 (1.28-2.57, p=0.001)** |
| **Fracture Sequence** | | | | |
| | *Single fracture* | Reference | Reference | Reference |
| | *First fracture* | 1.39 (0.82-2.18, p=0.186) | - | 1.17 (0.72-1.91, p=0.527) |
| | *Second fracture* | 1.47 (0.89-2.29, p=0.111) | - | 1.49 (0.92-2.42, p=0.108) |
| | *Third fracture* | 0.00 (NA, p=0.966) | | 0.00 (NA, p=0.964) |

| | | | | |
|---|---|---|---|---|
| **Vaccination Status** | | | | |
| | *Vaccinated* | Reference | Reference | Reference |
| | *Unvaccinated* | **2.38 (2.00-2.85, p<0.001)** | **2.47 (2.07-2.96, p<0.001)** | **2.47 (2.06-2.95, p<0.001)** |

509

510 OR = odds ratio; ASA = American Society of Anesthesiologists; SIMD = Scottish Index of Multiple Deprivation

511 **Table 5.** Logistic regression analysis of factors associated with an increased likelihood of death within 30 days of fracture.

| | | *OR (Unadjusted)* | *OR (Multivariable)* | *OR (Multiple Imputation)* |
|---|---|---|---|---|
| **Age** | | **1.04 (1.04-1.05, p<0.001)** | **1.03 (1.02-1.04, p<0.001)** | **1.03 (1.02-1.04, p<0.001)** |
| **Sex** | | | | |
| | *Female* | Reference | Reference | Reference |
| | *Male* | **1.74 (1.53-1.97, p<0.001)** | **1.79 (1.55-2.06, p<0.001)** | **1.80 (1.58-2.06, p<0.001)** |
| **ASA Grade** | | | | |
| | *2* | Reference | Reference | Reference |
| | *1* | 1.09 (0.42-2.34, p=0.838) | 1.36 (0.52-2.92, p=0.482) | 1.42 (0.60-3.34, p=0.423) |
| | *3* | **2.57 (2.02-3.32, p<0.001)** | **1.87 (1.46-2.42, p<0.001)** | **1.87 (1.44-2.43, p<0.001)** |
| | *4* | **6.95 (5.39-9.08, p<0.001)** | **4.36 (3.35-5.76, p<0.001)** | **4.33 (3.29-5.70, p<0.001)** |
| | *5* | **25.22 (17.72-36.05, p<0.001)** | **17.43 (12.11-25.18, p<0.001)** | **17.61 (12.06-25.72, p<0.001)** |
| **SIMD Rank** | | 1.01 (0.97-1.06, p=0.531) | - | 1.03 (0.98-1.08, p=0.237) |
| **Pre-fracture Residence** | | | | |
| | *Home* | Reference | Reference | Reference |
| | *Residential care* | **2.65 (2.30-3.04, p<0.001)** | **2.06 (1.76-2.42, p<0.001)** | **1.90 (1.64-2.22, p<0.001)** |
| | *Subacute hospital* | **2.19 (1.52-3.06, p<0.001)** | **1.50 (0.99-2.20, p=0.045)** | **1.59 (1.10-2.31, p=0.014)** |
| | *Acute hospital* | **2.88 (2.22-3.68, p<0.001)** | **1.95 (1.46-2.57, p<0.001)** | **1.96 (1.50-2.56, p<0.001)** |
| **Fracture Sequence** | | | | |
| | *Single fracture* | Reference | Reference | Reference |
| | *First fracture* | **0.11 (0.03-0.29, p<0.001)** | **0.12 (0.03-0.31, p<0.001)** | **0.10 (0.03-0.32, p<0.001)** |
| | *Second fracture* | 0.82 (0.51-1.25, p=0.391) | 0.68 (0.41-1.06, p=0.106) | 0.65 (0.41-1.03, p=0.068) |
| | *Third fracture* | 0.00 (NA, p=0.963) | 0.00 (NA, p=0.964) | 0.00 (NA, p=0.963) |

| | | | | |
|---|---|---|---|---|
| **COVID-19 Status** (%) | | | | |
| | *Negative* | Reference | Reference | Reference |
| | *Positive [Vaccinated]* | 1.02 (0.57-1.67, p=0.952) | 0.98 (0.53-1.66, p=0.938) | 0.93 (0.53-1.60, p=0.783) |
| | *Positive [Unvaccinated]* | **2.77 (2.14-3.54, p<0.001)** | **3.10 (2.35-4.04, p<0.001)** | **2.77 (2.12-3.62, p<0.001)** |

OR = odds ratio; ASA = Association of Anesthesiologists; SIMD = Scottish Index of Multiple Deprivation

## SUPPLEMENTARY MATERIALS

**Supplementary Table 1.** Patient characteristics according to COVID-19 and vaccination status for the reduced study period September 2020 to December 2021 (i.e. excluding the first six months of total study period).

| | | COVID-19 Status (Vaccination Status) | | | |
|---|---|---|---|---|---|
| | | ***Negative*** | ***Positive (Vaccinated)*** | ***Positive (Unvaccinated)*** | ***p**** |
| | | *n= 9656* | *n= 186* | *n= 319* | |
| **Age** [median (IQR)] | | 82.00 [74.00, 88.00] | 85.00 [79.00, 89.00] | 83.00 [77.00, 88.00] | **<0.001✢** |
| **Sex** (%) | | | | | |
| | *Female* | 6731 ( 69.7) | 135 ( 72.6) | 221 ( 69.3) | 0.688 |
| | *Male* | 2925 ( 30.3) | 51 ( 27.4) | 98 ( 30.7) | |
| **ASA Grade** (%) | | | | | |
| | *2* | 2059 ( 21.9) | 27 ( 14.8) | 56 ( 17.8) | **0.050** |
| | *1* | 156 ( 1.7) | 1 ( 0.5) | 2 ( 0.6) | |
| | *3* | 5539 ( 58.9) | 126 ( 69.2) | 199 ( 63.4) | |
| | *4* | 1486 ( 15.8) | 27 ( 14.8) | 51 ( 16.2) | |
| | *5* | 171 ( 1.8) | 1 ( 0.5) | 6 ( 1.9) | |
| **SIMD Rank** [mean (SD)] | | 3.04 (1.40) | 2.92 (1.47) | 3.30 (1.41) | **0.003** |
| **Pre-fracture Residence** (%) | | | | | |
| | *Home* | 7441 ( 77.1) | 113 ( 60.8) | 251 ( 78.7) | **<0.001** |
| | *Residential Care* | 1613 ( 16.7) | 45 ( 24.2) | 36 ( 11.3) | |
| | *Subacute Hospital* | 217 ( 2.2) | 12 ( 6.5) | 8 ( 2.5) | |
| | *Acute Hospital* | 364 ( 3.8) | 15 ( 8.1) | 21 ( 6.6) | |
| | *Missing* | 21 ( 0.2) | 1 ( 0.5) | 3 ( 0.9) | |
| **Acute LOS** [median (IQR)] | | 27.00 [8.00, 58.00] | 23.00 [8.25, 56.50] | 27.00 [11.00, 47.50] | <0.610✢ |
| **Total LOS** [median (IQR)] | | 17.00 [9.00, 39.00] | 27.50 [13.25, 56.25] | 32.00 [19.00, 55.00] | **<0.001✢** |
| **Discharge Destination** (%) | | | | | |
| | *Home* | 3824 ( 39.7) | 38 ( 20.7) | 96 ( 30.2) | **<0.001** |
| | *Residential Care* | 1396 ( 14.5) | 36 ( 19.6) | 22 ( 6.9) | |

| | | | | | |
|---|---|---|---|---|---|
| | *Subacute Hospital* | 3522 ( 36.5) | 67 ( 36.4) | 100 ( 31.4) | |
| | *Acute Hospital* | 376 ( 3.9) | 29 ( 15.8) | 58 ( 18.2) | |
| | *Deceased* | 521 ( 5.4) | 14 ( 7.6) | 42 ( 13.2) | |
| **Fracture Sequence** (%) | | | | | |
| | *Single fracture* | 9231 ( 95.6) | 175 ( 94.1) | 296 ( 92.8) | 0.052 |
| | *First fracture* | 176 ( 1.8) | 3 ( 1.6) | 12 ( 3.8) | |
| | *Second fracture* | 249 ( 2.6) | 8 ( 4.3) | 11 ( 3.4) | |
| **30-day Mortality Status (%)** | | | | | |
| | *Alive* | 8888 ( 92.0) | 171 ( 91.9) | 272 ( 85.3) | **<0.001** |
| | *Deceased* | 768 ( 8.0) | 15 ( 8.1) | 47 ( 14.7) | |

IQR = interquartile range; ASA = American Society of Anesthesiologists; SIMD = Scottish Index of Multiple Deprivation; SD = standard deviation; LOS = length of stay; d = days

*Chi-square test for categorical variables with a normal distribution, independent pairs t-test for continuous variables, Mann-Whitney U test for continuous variables with a non-normal distribution (denoted with ⁺)

**Supplementary Table 2.** Logistic regression analysis of factors associated with an increased likelihood of having COVID-19 within 30 days of hip fracture for the reduced study period September 2020 to December 2021 (i.e. excluding the first six months of total study period).

| | | *OR (Unadjusted)* | *OR (Multivariable)* | *OR (Multiple Imputation)* |
|---|---|---|---|---|
| **Age** | | **1.02 (1.01-1.03, p<0.001)** | **1.02 (1.01-1.03, p<0.001)** | **1.02 (1.01-1.03, p<0.001)** |
| **Sex** | | | | |
| | *Female* | Reference | Reference | Reference |
| | *Male* | 1.03 (0.86-1.23, p=0.742) | 0.97 (0.79-1.19, p=0.769) | 0.97 (0.79-1.19, p=0.769) |
| **ASA Grade** | | | | |
| | *2* | Reference | Reference | Reference |
| | *1* | 0.58 (0.18-1.41, p=0.295) | 0.53 (0.13-1.45, p=0.289) | 0.53 (0.13-1.45, p=0.289) |
| | *3* | **1.61 (1.28-2.04, p<0.001)** | **1.33 (1.03-1.73, p=0.030)** | **1.33 (1.03-1.73, p=0.030)** |
| | *4* | **1.52 (1.14-2.04, p=0.005)** | 1.11 (0.79-1.55, p=0.548) | 1.11 (0.79-1.55, p=0.548) |
| | *5* | 0.99 (0.41-2.01, p=0.972) | 0.76 (0.31-1.58, p=0.495) | 0.76 (0.31-1.58, p=0.495) |
| **SIMD Rank** | | 1.03 (0.97-1.09, p=0.283) | 1.04 (0.98-1.12, p=0.201) | 1.04 (0.98-1.12, p=0.201) |
| **Pre-fracture Residence** | | | | |
| | *Home* | Reference | Reference | Reference |
| | *Residential care* | **1.29 (1.04-1.58, p=0.017)** | 0.90 (0.69-1.17, p=0.442) | 0.90 (0.69-1.17, p=0.442) |
| | *Subacute hospital* | **1.86 (1.16-2.83, p=0.006)** | **1.68 (1.00-2.69, p=0.038)** | **1.68 (1.00-2.69, p=0.038)** |
| | *Acute hospital* | **1.96 (1.37-2.72, p<0.001)** | **1.88 (1.28-2.69, p=0.001)** | **1.88 (1.28-2.69, p=0.001)** |
| **Fracture Sequence** | | | | |
| | *Single fracture* | Reference | Reference | Reference |
| | *First fracture* | 1.39 (0.82-2.18, p=0.186) | 1.27 (0.69-2.16, p=0.401) | 1.27 (0.69-2.16, p=0.401) |
| | *Second fracture* | 1.47 (0.89-2.29, p=0.111) | 1.48 (0.87-2.37, p=0.123) | 1.48 (0.87-2.37, p=0.123) |
| **Vaccination Status** | | | | |
| | *Vaccinated* | Reference | Reference | Reference |
| | *Unvaccinated* | **2.38 (2.00-2.85, p<0.001)** | **3.68 (3.04-4.45, p<0.001)** | **3.68 (3.04-4.45, p<0.001)** |

OR = odds ratio; ASA = Association of Anesthesiologists; SIMD = Scottish Index of Multiple Deprivation

**Supplementary Table 3.** Logistic regression analysis of factors associated with an increased likelihood of death within 30 days of hip fracture for the reduced study period September 2020 to December 2021 (i.e. excluding the first six months of total study period).

| | | *OR (Unadjusted)* | *OR (Multivariable)* | *OR (Multiple Imputation)* |
|---|---|---|---|---|
| **Age** | | **1.03 (1.02-1.04, p<0.001)** | **1.03 (1.02-1.04, p<0.001)** | **1.03 (1.02-1.04, p<0.001)** |
| **Sex** | | | | |
| | *Female* | Reference | Reference | Reference |
| | *Male* | **1.80 (1.54-2.09, p<0.001)** | **1.77 (1.50-2.09, p<0.001)** | **1.80 (1.54-2.09, p<0.001)** |
| **ASA Grade** | | | | |
| | *2* | Reference | Reference | Reference |
| | *1* | 1.64 (0.65-4.15, p=0.295) | 1.78 (0.61-4.15, p=0.231) | 1.64 (0.65-4.15, p=0.295) |
| | *3* | **1.98 (1.48-2.66, p<0.001)** | **2.05 (1.52-2.82, p<0.001)** | **1.98 (1.48-2.66, p<0.001)** |
| | *4* | **4.76 (3.48-6.50, p<0.001)** | **4.80 (3.48-6.73, p<0.001)** | **4.76 (3.48-6.50, p<0.001)** |
| | *5* | **19.08 (12.69-28.70, p<0.001)** | **19.09 (12.49-29.40, p<0.001)** | **19.08 (12.69-28.70, p<0.001)** |
| **SIMD Rank** | | 1.00 (0.95-1.06, p=0.881) | 0.99 (0.93-1.04, p=0.647) | 1.00 (0.95-1.06, p=0.881) |
| **Pre-fracture Residence** | | | | |
| | *Home* | Reference | Reference | Reference |
| | *Residential care* | **1.93 (1.61-2.31, p<0.001)** | **2.15 (1.78-2.59, p<0.001)** | **1.93 (1.61-2.31, p<0.001)** |
| | *Subacute hospital* | **1.59 (1.05-2.41, p=0.027)** | 1.46 (0.91-2.26, p=0.098) | 1.59 (1.05-2.41, p=0.027) |
| | *Acute hospital* | **2.09 (1.55-2.81, p<0.001)** | **1.98 (1.42-2.71, p<0.001)** | **2.09 (1.55-2.81, p<0.001)** |
| **Fracture Sequence** | | | | |
| | *Single fracture* | Reference | Reference | Reference |
| | *First fracture* | **0.17 (0.05-0.54, p=0.003)** | **0.19 (0.05-0.52, p=0.005)** | **0.17 (0.05-0.54, p=0.003)** |
| | *Second fracture* | 0.67 (0.41-1.10, p=0.113) | 0.66 (0.38-1.07, p=0.116) | 0.67 (0.41-1.10, p=0.113) |
| | *Third fracture* | 0.00 (NA, p=0.963) | 0.00 (NA, p=0.964) | 0.00 (NA, p=0.963) |
| **COVID-19 Status** (%) | | | | |
| | *Negative* | Reference | Reference | Reference |
| | *Positive [Vaccinated]* | 0.94 (0.54-1.62, p=0.817) | 0.99 (0.54-1.69, p=0.981) | 0.94 (0.54-1.62, p=0.817) |
| | *Positive [Unvaccinated]* | **2.13 (1.52-2.98, p<0.001)** | **2.46 (1.74-3.43, p<0.001)** | **2.13 (1.52-2.98, p<0.001)** |

OR = odds ratio; ASA = Association of Anesthesiologists; SIMD = Scottish Index of Multiple Deprivation

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