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Clinical outcomes of non-COVID-19 orthopaedic patients admitted during the COVID-19 pandemic: a multi-centre interrupted time series analysis across hospitals in six different countries

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ABSTRACT

Objectives To assess across seven hospitals from six different countries the extent to which the COVID-19 pandemic affected the volumes of orthopaedic hospital admissions and patient outcomes for non-COVID-19 patients admitted for orthopaedic care.

Design A multi-centre interrupted time series (ITS) analysis.

Setting Seven hospitals from six countries who collaborated within the Global Health Data@Work collaborative.

Participants Non-COVID-19 patients admitted for orthopaedic care during the pre-pandemic (January/2018–February/2020) and COVID-19 pandemic (March/2020–June/2021) period. Admissions were categorised as: (1) acute admissions (lower limb fractures/neck of femur fractures/pathological fractures/joint dislocations/upper limb fractures); (2) subacute admissions (bone cancer); (3) elective admissions (osteoarthritis).

Outcome measures Monthly observed versus expected ratios (O/E) were calculated for in-hospital mortality, long (upper-decile) length-of-stay and hospital readmissions, with expected rates calculated based on case-mix. An ITS design was used to estimate the change in level and/or trend of the monthly O/E ratio by comparing the COVID-19 pandemic with the pre-pandemic period.

Results 69 221 (pre-pandemic) and 22 940 (COVID-19 pandemic) non-COVID-19 orthopaedic patient admissions were included. Admission volumes were reduced during the COVID-19 pandemic for all admission categories (range: 33%–45%), with more complex patients treated as shown by higher percentages of patients admitted with ≥1 comorbidity (53.8% versus 49.8%, p<0.001). The COVID-19 pandemic was not associated with significant changes in patient outcomes for most diagnostic groups. Only for patients diagnosed with pathological fractures (pre-pandemic n=1671 and pandemic n=749), the COVID-19 pandemic was significantly associated with an immediate mortality reduction (level change of −77.7%, 95% CI −127.9% to −25.7%) and for lower limb fracture patients (pre-pandemic n=9898 and pandemic n=3307) with a significantly reduced trend in readmissions (trend change of −6.3% per month, 95% CI −11.0% to −1.6%).

Conclusions Acute, subacute, as well as elective orthopaedic hospital admissions volumes were reduced in all global participating hospitals during the COVID-19 pandemic, while overall patient outcomes for most admitted non-COVID-19 patients remained the same despite the strain caused by the surge of COVID-19 patients.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This is the first multi-centre study assessing the impact of the COVID-19 pandemic on non-COVID-19 orthopaedic patients solely across different geographical regions.
- ⇒ All seven included hospitals were large academic centres, thereby providing a unique opportunity to evaluate the impact on orthopaedic care in similar institutions across geographical regions that differed in how they were affected by an influx of COVID-19 patients.
- ⇒ This study was conducted in academic centres which may limit the generalisability of the study results and different results may be found for smaller (non-academic) hospitals.
- ⇒ This study only assessed in-hospital mortality, long length-of-stay and hospital readmissions as indicators for the quality of care delivered, whereas other patient outcomes are also relevant to judge the quality of care and may provide a different perspective.

INTRODUCTION

COVID-19 caused by the SARS-CoV-2 virus had a tremendous effect on healthcare systems worldwide. Hospitals had to restructure to accommodate the influx of COVID-19 patients and prioritise acute care for non-COVID-19 patients, which disrupted orthopaedic care worldwide including reductions in elective and emergency surgical interventions,[1–13] reduced clinic capacity[3 4 6 10 12] and a decrease in orthopaedic trauma referrals and emergency admissions.[6 7 12 14 15] Even more, the COVID-19 pandemic have led to an estimated total health loss for elective orthopaedic arthroplasty patients of approximately 30 000 QALYs, with decades of back-log of surgical capacity for these patients if capacity is not increased.[13] Many studies have described the impact of the COVID-19 pandemic on the volume of orthopaedic admissions,[1–11 13] numbers of orthopaedic surgeries performed[1–11 13] and the outcomes for COVID-19 patients admitted for orthopaedic care.[16–20] However, the impact of the COVID-19 pandemic on the outcomes for non-COVID-19 orthopaedic patients and thereby the quality of orthopaedic care delivered during the COVID-19 pandemic at a global level, has not been well described.

As most hospitals had to ensure sufficient capacity for the surge of COVID-19 patients, patients admitted during the COVID-19 pandemic period are likely a selection of more urgent and complex patients for which care could not be postponed. This is supported by findings of two previous studies reporting higher mortality for orthopaedic patients admitted during the COVID-19 pandemic when compared with the pre-pandemic period.[14 21] Yet, other studies found similar mortality risks when examining the impact of the COVID-19 pandemic for hip fracture patients[22 23] and patients who underwent hip or knee arthroplasty surgery[24] compared with expected mortality risks based on pre-pandemic years. However, there has not been a more comprehensive evaluation of the quality of care delivered for non-COVID-19 orthopaedic patients during the COVID-19 pandemic, including a wider range of outcomes.

Patient outcomes such as in-hospital mortality, long length-of-stay (LOS) and hospital readmissions are commonly used indicators to assess the quality of care delivered, and used to drive quality improvement initiatives.[25–31] In the present study, we therefore aimed to assess the extent to which the COVID-19 pandemic affected these patient outcomes for non-COVID-19 orthopaedic patients across different geographical regions (Australia, Europe and the USA) for acute, subacute and elective orthopaedic admissions.

METHODS AND ANALYSIS

Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination plans of this study.

Study design and setting

An interrupted time series design (ITS) was used to evaluate the effect of the COVID-19 pandemic (March 2020 to June 2021) on in-hospital mortality, long LOS and hospital readmissions when compared with the pre-pandemic period (January 2018 until March 2020) for non-COVID-19 patients admitted for orthopaedic care. An ITS is a quasi-experimental design to evaluate the effects of an event or intervention which occurs or is introduced at a clearly defined point in time.[32 33] By comparing the trend before and after the start of the COVID-19 pandemic, the effect associated with the COVID-19 pandemic can be estimated by a change in absolute level (the immediate effect) and/or a change in trend[33] representing a gradual change in daily practice following an event.[34] We chose March 2020 as the month in which the COVID-19 pandemic started, as the World Health Organization (WHO) declared the COVID-19 outbreak a pandemic in that month.[35]

Patients and definitions

Anonymised patient data from the Global Heath Data@Work collaborative were used, in which seven academic medical centres from countries all over the world (Melbourne (Australia), Leuven (Belgium), Milan (Italy), Leiden (the Netherlands), Coventry (the UK), Los Angeles (the USA) and New Jersey (the USA) shared their routinely collected admission data with the aim to learn from best practices and thereby improve the quality of care.[36] Within the collaborative, patients were grouped into homogenous patient groups using the Clinical Classification Software (CCS) diagnosis groups from the Agency for Healthcare Research and Quality's to reconcile the different coding systems used, as done in previous studies.[37]

All non-COVID-19 orthopaedic patients admitted between January 2018 and June 2021 in the seven participating academic medical centres were included. Clinical admissions as well as day-care admissions were included. Orthopaedic non-COVID-19 patients were identified based on the primary diagnosis for their admission falling into the following CCS diagnostic groups: (1) cancer of bone and connective tissue; (2) lower limb fractures; (3) neck of femur fractures; (4) osteoarthritis; (5) pathological fractures; (6) trauma-related joint disorders and dislocations and (7) upper limb fractures. These groups were chosen as these patients would likely receive orthopaedic care while also having different nature of diagnosis to represent both acute, subacute and elective admissions as these may be affected by the COVID-19 pandemic differently. Included beta versions of the CCS for International Classification of Diseases (ICD) codes per diagnostic group are listed in online supplemental table 1. These diagnostic groups were a priori classified in three types of admissions based on the nature of the diagnostic groups, as we hypothesised that this may have modified the effect of the COVID-19 pandemic: (1) acute admissions (including lower limb fractures, neck of femur fractures, pathological fractures, trauma-related joint disorders and dislocations, and upper limb fractures); (2) subacute admissions (including cancer of bone and connective tissue) and (3) elective admissions (including osteoarthritis).

For each patient, we extracted: (1) patients' age on admission; (2) gender; (3) season of admission (winter/

Table 1 Patient and admission characteristics across diagnostic groups

	Lower limb fractures		Neck of femur fractures		Pathological fractures		Trauma-related joint disorders and dislocations	
	Pre-pandemic	Pandemic	Pre-pandemic	Pandemic	Pre-pandemic	Pandemic	Pre-pandemic	Pandemic
Admissions, n	9898	3307	6925	2671	1671	749	8687	2785
Mean age, years (SD)	51.4 (22.9)	51.4 (23.1)	78.8 (14.3)	79.4 (13.6)	70.9 (17.3)	70.5 (16.8)	42.6 (19.2)	41.8 (18.4)
Male, n (%)	4839 (48.9)	1534 (46.4)	2265 (32.7)	898 (33.6)	516 (30.9)	226 (30.2)	5290 (60.9)	1722 (61.8)
Comorbidities, n (%)								
≥1 comorbidity	4249 (42.9)	1655 (50.0)	5588 (80.6)	2276 (85.2)	1262 (75.5)	573 (76.5)	2538 (29.2)	863 (30.9)
Diabetes mellitus	572 (5.8)	201 (6.1)	667 (9.6)	266 (10.0)	149 (8.9)	59 (7.9)	374 (4.3)	103 (3.7)
Hypertension	1589 (16.1)	726 (22.0)	2424 (35.0)	1129 (42.3)	526 (31.5)	245 (32.7)	1093 (12.6)	413 (14.8)
Obesity	906 (9.2)	383 (11.6)	374 (5.4)	175 (6.6)	142 (8.5)	76 (10.1)	706 (8.1)	232 (8.3)
Pulmonary	723 (7.3)	315 (9.5)	1007 (14.5)	447 (16.7)	285 (17.1)	131 (17.5)	549 (6.3)	165 (5.9)
Season of admission, n (%)								
Winter	2833 (28.6)	690 (20.9)	2041 (29.5)	597 (22.4)	514 (30.8)	154 (20.6)	2546 (29.3)	670 (24.1)
Spring	2244 (22.7)	745 (22.5)	1536 (22.2)	671 (25.1)	398 (23.8)	201 (26.8)	2020 (23.3)	585 (21.0)
Summer	2582 (26.1)	865 (26.2)	1707 (24.6)	594 (22.2)	360 (21.5)	182 (24.3)	1914 (22.0)	730 (26.2)
Autumn	2239 (22.6)	1007 (30.5)	1641 (23.7)	809 (30.3)	399 (23.9)	212 (28.3)	2207 (25.4)	800 (28.7)
Emergency admission, n (%)	6204 (62.7)	2148 (65.0)	6189 (89.4)	2504 (93.7)	902 (54.0)	390 (52.1)	1236 (14.2)	334 (12.0)
Admission from another hospital, n (%)	968 (9.8)	387 (11.7)	1142 (16.5)	432 (16.2)	240 (14.4)	101 (13.5)	663 (7.6)	493 (17.7)
Patient outcomes, n (%)								
In-hospital mortality	36 (0.4)	16 (0.5)	204 (2.9)	63 (2.4)	18 (1.1)	9 (1.2)	4 (0.0)	2 (0.1)
Long length of hospital stay	697 (7.0)	153 (4.6)	687 (9.9)	129 (4.8)	123 (7.4)	31 (4.1)	277 (3.2)	69 (2.5)
28-day hospital readmissions	208 (2.1)	56 (1.7)	272 (3.9)	104 (3.9)	80 (4.8)	30 (4.0)	72 (0.8)	19 (0.7)

	Upper limb fractures		Cancer of bone and connective tissue		Osteoarthritis	
	Pre-pandemic	Pandemic	Pre-pandemic	Pandemic	Pre-pandemic	Pandemic
Admissions, n	12 927	3924	3022	1156	26 091	8348
Mean age, years (SD)	48.4 (25.4)	49.3 (25.1)	50.0 (20.3)	46.1 (21.4)	66.1 (11.5)	65.6 (11.1)
Male, n (%)	6561 (50.8)	1952 (49.7)	1709 (56.6)	664 (57.4)	10 763 (41.3)	3633 (43.5)
Comorbidities, n (%)						
≥1 comorbidity	4052 (31.3)	1483 (37.7)	1534 (50.7)	536 (46.3)	15 229 (58.3)	5247 (62.8)
Diabetes mellitus	596 (4.6)	176 (4.5)	131 (4.3)	32 (2.8)	2426 (9.3)	739 (8.9)
Hypertension	1536 (11.9)	632 (16.1)	369 (12.2)	139 (12.0)	9499 (36.4)	3392 (40.6)
Obesity	739 (5.7)	276 (7.0)	162 (5.4)	66 (5.7)	4593 (17.6)	1498 (17.9)
Pulmonary	657 (5.1)	273 (7.0)	166 (5.5)	41 (3.5)	2534 (9.7)	956 (11.5)

Continued

Table 1 Continued

	Upper limb fractures		Cancer of bone and connective tissue		Osteoarthritis	
	Pre-pandemic	Pandemic	Pre-pandemic	Pandemic	Pre-pandemic	Pandemic
Season of admission, n (%)						
Winter	3303 (25.6)	725 (18.5)	930 (30.8)	167 (14.4)	7893 (30.3)	2044 (24.5)
Spring	2996 (23.2)	873 (22.2)	704 (23.3)	414 (35.8)	5995 (23.0)	1362 (16.3)
Summer	3385 (26.2)	1012 (25.8)	685 (22.7)	332 (28.7)	5647 (21.6)	2323 (27.8)
Autumn	3243 (25.1)	1314 (33.5)	703 (23.3)	243 (21.0)	6556 (25.1)	2619 (31.4)
Emergency admission, n (%)	6925 (53.6)	2225 (56.7)	222 (7.3)	87 (7.5)	459 (1.8)	140 (1.7)
Admission from another hospital, n (%)	878 (6.8)	371 (9.5)	143 (4.7)	80 (6.9)	1120 (4.3)	693 (8.3)
Patient outcomes, n (%)						
In-hospital mortality	32 (0.2)	13 (0.3)	19 (0.6)	8 (0.7)	3 (0.0)	3 (0.0)
Long length of hospital stay	687 (5.3)	175 (4.5)	134 (4.4)	43 (3.7)	1913 (7.3)	297 (3.6)
28-day hospital readmissions	268 (2.1)	78 (2.0)	115 (3.8)	32 (2.8)	236 (0.9)	97 (1.2)

spring/summer/autumn); (4) admission from another hospital (yes/no); (5) emergency admission (yes/no) and (6) patients' comorbidity status using the Elixhauser comorbidity index,[38] comorbidity statuses were identified based on secondary CCS diagnosis groups for patients' admissions and (7) the patient outcomes in-hospital mortality, long LOS and hospital readmissions. In-hospital mortality was defined as any death during hospital admission. We defined a long LOS per diagnostic group as an LOS in the upper decile for that specific diagnostic group. Readmissions were defined as any unplanned (ie, emergency) inpatient hospital admission within 28 days after either a day-care or clinical admission.

For each month in the COVID-19 pandemic period, we calculated the hospital-level percentage of COVID-19 admissions, defined as admissions with a primary or secondary diagnosis ICD-10 codes B34.2, B97.2, J12.8, U07.1 and U07.2.

Statistical analysis

First, descriptive analyses were performed to assess the effect of the COVID-19 pandemic on volumes of orthopaedic admissions for non-COVID-19 patients for each hospital. For each hospital, we calculated the monthly COVID-19 admissions as a percentage of the total number of admissions. For each of the three admission types (acute, subacute and elective admissions), we calculated the average monthly volume of orthopaedic admissions in the pre-pandemic period. For each month in the COVID-19 pandemic period, we then expressed the reduction in volume as a percentage of the volume in the pre-pandemic period. Therafter, we assessed the extent to which orthopaedic non-COVID-19 patients admitted in the COVID-19 pandemic differed in case-mix (percentage of patients with comorbidities, age and emergency admissions) when compared with patients admitted in the pre-pandemic period. Independent t-tests were used for continuous variables and chi-square tests for categorical variables.

For each hospital and diagnostic group, we then calculated monthly observed (O) versus expected (E) numbers of mortality, readmission and long LOS to adjust for differences in case-mix. Expected numbers were calculated using a logistic regression analysis in which all non-COVID-19 patient admissions from all hospitals were included, using the respective patient outcome as the dependent variable and all previously mentioned patient and admission characteristics (including age, gender, season of admission, admission from another hospital, emergency admission and patients' comorbidity status) as independent variables as these are known to influence the risk on these outcomes. For each patient, the expected probability of each outcome was calculated based on their characteristics and summed for each hospital to arrive at the expected number. Subsequently, we calculated the monthly observed (O) versus expected (E) ratios for each patient outcome.

For each diagnostic group, a segmented linear regression analysis was then used to assess the changes in level

Table 2 In-hospital mortality

	Trend pre-pandemic	Level change	Trend change
Acute admissions			
Lower limb fractures	0.009 (–0.007 to 0.025)	2.205 (–2.736 to 7.147)	-0.198 (–0.622 to 0.225)
Neck of femur fractures	-0.020 (–0.062 to 0.021)	-0.069 (–0.538 to 0.400)	0.014 (–0.098 to 0.128)
Pathological fractures	0.045 (–0.009 to 0.100)	**-0.768 (–1.279 to –0.257)**	-0.001 (–0.150 to 0.146)
Trauma-related joint disorders and dislocations	-0.001 (–0.002 to 0.000)	0.042 (–0.090 to 0.174)	-0.003 (–0.023 to 0.016)
Upper limb fractures	-0.013 (–0.041 to 0.015)	-0.078 (–0.862 to 0.705)	0.083 (–0.020 to 0.187)
Subacute admissions			
Cancer of bone and connective tissue	-0.105 (–0.240 to 0.029)	0.296 (–1.429 to 2.023)	0.044 (–0.108 to 0.197)
Elective admissions			
Osteoarthritis	-0.023 (–0.073 to 0.027)	1.380 (–1.970 to 4.730)	-0.110 (–0.392 to 0.172)

and trend in the monthly O/E ratios for each of the patient outcomes (adjusted for case-mix), including a random intercept for hospital to take into account the clustering of patients within hospitals. We compared the pre-pandemic period (26 data points) with the COVID-19 pandemic period (15 data points). The following formula was used to estimate changes in level and trend between the pre-pandemic period and the COVID-19 pandemic period: $Y_t=\beta_0+\beta_1$*Time (months)+β_2*start COVID-19 pandemic+β_3*Time after start COVID-19 pandemic (months). Y_t represents the O/E ratio of the respective patient outcome, β_1 estimates the pre-pandemic trend, β_2 estimates the change in level directly following the event (level change) and β_3 represents the change in trend in the postevent period relative to the pre-pandemic period (trend change).[39]

The Dicky Fuller and the KPSS test were used to test stationarity which showed stationary trends.[40 41] The Durbin-Watson test was used to test first order autocorrelations and autocorrelation function plots were used to test higher order autocorrelations and seasonality.[42] No autocorrelations or seasonalities were found. Stata V.16.1 (StataCorp LP, College Station, Texas, USA) was used for analysis. Significance was set at p<0.05.

RESULTS

A total of 69 221 (pre-pandemic) and 22 940 (COVID-19 pandemic) non-COVID-19 orthopaedic patient admissions were included. Reduced volumes in non-COVID-19 orthopaedic admissions during the COVID-19 pandemic were observed for all three diagnostic groups: acute admissions decreased by an average of 42% per month, subacute admissions by 33% and elective admissions by 45% compared with the average volume in the pre-pandemic period (data not shown). Large between-hospital variation in both volumes of non-COVID-19 orthopaedic care admissions as well as the increase in percentage of COVID-19 admissions and associated decrease in volume of acute, subacute and elective non-COVID-19 orthopaedic care admissions was observed (online supplemental figures 1–3).

Table 3 Long length of hospital stay

	Trend pre-pandemic	Level change	Trend change
Acute admissions			
Lower limb fractures	-0.009 (–0.038 to 0.020)	0.766 (–0.639 to 2.171)	-0.127 (–0.266 to 0.012)
Neck of femur fractures	-0.006 (–0.032 to 0.020)	0.614 (–1.401 to 2.629)	-0.110 (–0.307 to 0.086)
Pathological fractures	-0.022 (–0.051 to 0.006)	1.015 (–0.860 to 2.892)	-0.115 (–0.323 to 0.092)
Trauma-related joint disorders and dislocations	0.010 (–0.010 to 0.031)	0.659 (–0.486 to 1.804)	-0.140 (–0.307 to 0.025)
Upper limb fractures	-0.007 (–0.023 to 0.007)	-0.222 (–0.470 to 0.025)	0.021 (–0.011 to 0.054)
Subacute admissions			
Cancer of bone and connective tissue	0.032 (–0.019 to 0.084)	-0.650 (–1.452 to 0.151)	-0.034 (–0.149 to 0.081)
Elective admissions			
Osteoarthritis	-0.031 (–0.067 to 0.005)	0.272 (–1.062 to 1.607)	-0.031 (–0.165 to 0.102)

Table 4 28-day hospital readmissions

	Trend pre-pandemic	Level change	Trend change
Acute admissions			
Lower limb fractures	0.021 (–0.016 to 0.059)	-0.326 (–1.008 to 0.354)	**-0.063 (–0.110 to –0.016)**
Neck of femur fractures	0.000 (–0.022 to 0.023)	0.084 (–0.409 to 0.578)	-0.048 (–0.115 to 0.018)
Pathological fractures	-0.009 (–0.031 to 0.013)	0.122 (–0.785 to 1.029)	0.008 (–0.085 to 0.102)
Joint disorders and dislocations (trauma related)	-0.021 (–0.083 to 0.040)	-1.057 (–4.723 to 2.607)	0.018 (–0.097 to 0.134)
Upper limb fractures	0.011 (–0.004 to 0.027)	-0.434 (–1.116 to 0.246)	0.010 (–0.042 to 0.062)
Subacute admissions			
Cancer of bone and connective tissue	-0.010 (–0.044 to 0.024)	0.279 (–0.197 to 0.756)	0.023 (–0.120 to 0.167)
Elective admissions			
Osteoarthritis	0.000 (–0.032 to 0.033)	-0.003 (–0.658 to 0.652)	-0.070 (–0.146 to 0.005)

Differences in case-mix

The percentage of non-COVID-19 orthopaedic patients admitted with at least one comorbidity was higher during the COVID-19 pandemic when compared with the pre-pandemic period: 53.8% versus 49.8% (p<0.001) (data not shown). The median age of non-COVID-19 admitted orthopaedic patients and the mean percentage of emergency admissions was not significantly different between the pre-pandemic and COVID-19 pandemic period, respectively: 58.5 years (interquartile range (IQR): 57.9–59.1) versus 58.2 years (IQR: 56.8–59.8) (p=0.21) and 32% versus 31% (p=0.75). Patient and admission characteristics of the population are shown in table 1.

Patient outcomes during the COVID-19 pandemic

For in-hospital mortality, there was no pre-pandemic trend for any of the diagnostic groups. For pathological fracture patients, the COVID-19 pandemic was associated with a significantly reduced level change in in-hospital mortality of 77% (–0.768, 95% CI –1.279 to –0.257) (table 2). There were no significant changes in either level or trend for any of the other diagnostic groups.

Regarding long LOS, there was no pre-pandemic trend and the COVID-19 pandemic was not associated with any significant changes in level or trend for any of the diagnostic groups (table 3).

For readmissions, there was no pre-pandemic trend for any of the diagnostic groups. For lower limb fracture patients, the COVID-19 pandemic was associated with a significantly reduced trend in readmissions of 6.3% per month (–0.063, 95% CI –0.110 to –0.016) (table 4).

DISCUSSION

The present study analysing seven hospitals in six countries showed that the volume of non-COVID-19 orthopaedic admissions was considerably reduced during the COVID-19 pandemic with more complex patients treated, consistent with previous reports. In addition to others, we showed that for most diagnostic groups the COVID-19 pandemic was not associated with a change in patient outcomes for non-COVID-19 orthopaedic patients, except for an immediate lower in-hospital mortality for pathological fracture patients and a more favourable (reduced) trend in readmissions lower limb fracture patients. In combination, this suggests good quality care being delivered to these non-COVID-19 orthopaedic patients despite the surge of COVID-19 patients in these hospitals.

Prior studies examining mortality rates for patients admitted for orthopaedic care during the COVID-19 pandemic report inconsistent findings, with some studies reporting higher mortality rates during the COVID-19 pandemic than in the pre-pandemic period,[14 21 43] whereas other studies reported no differences in mortality rates.[22–24 44 45] However, based on previous literature generally showing higher mortality rates for orthopaedic patients with a COVID-19 infection,[19 46–49] it is complex if not impossible to compare the findings of these studies with our results as these previous studies included all patients admitted for orthopaedic care (ie, also those with COVID-19 infections). We therefore focused on patient outcomes for non-COVID-19 orthopaedic patients solely to separate the impact of a COVID-19 infection on patient outcomes and thereby allow for a better comparison of the quality of orthopaedic care during the COVID-19 pandemic period to non-COVID-19 orthopaedic patients.

To the best of our knowledge, the only one previous study also focussing on non-COVID-19 orthopaedic patients solely, analysed outcomes for patients admitted following hip fractures. They found an increased 28-day mortality rate as well as an increased median length of hospital stay during the COVID-19 pandemic when compared with the pre-pandemic period.[50] However, 28-day hospital readmissions were comparable between the two periods, consistent with our findings for hip fracture (ie, neck of femur fractures) patients. A possible explanation for the different findings in mortality and length of stay in this Argentinian study is that patients admitted during the COVID-19 pandemic in the Argentinian study were significantly less active and more fragile than in the pre-pandemic period, the latter is known to increase both mortality and length of hospital stay.[51–56] Furthermore, the Argentinian study analysed 28-day mortality whereas we only had data on in-hospital mortality, and thus have missed any postdischarge deaths. On the other hand, 28-day mortality may include deaths from other causes rather than being associated with delivered hospital care, including risks due to be immunological compromised which is part of frailty and thus more probe for infections as well as COVID-19 infections.[57] Also, considering that these hip fracture patients are often discharged to elderly or nursing homes, known for their high COVID-19 prevalence during the pandemic[58–60] causes an extra mortality risk. In addition to this, one hospital included in our analysis was not allowed to admit any trauma-related patients, rather, only oncology and neurology patients. This may have resulted in a lower in-hospital mortality risk due to literature generally showing high risks of in-hospital mortality among trauma patients, such as hip fracture patients.[61 62] Yet, this hospital only included 15% of the analysed orthopaedic patients and only 4.8% of hip-fracture patients, so the potential effect of this might not have affected the overall results. Finally, a potential explanation could be that the different outcomes are inter-related, as previous studies have shown that long LOS is associated with higher odds of in-hospital mortality[63] so that a reduction in mortality could be due to these patients being discharged earlier. However, in the case of pathological fractures where we found a significant decrease in in-hospital mortality, long LOS stayed the same so that this does not seem to explain our results.

One of the strengths of our study is that it is the first multi-centre study assessing the impact of the COVID-19 pandemic on non-COVID-19 acute, subacute and elective orthopaedic patients across different countries around the world. The seven hospitals included were all large academic centres which provided a unique opportunity to evaluate the impact on orthopaedic care in similar institutions across geographical regions that differed in how they were affected by an influx of COVID-19 patients. However, some limitations remain. First, this study was conducted in academic centres which may limit the generalisability of our results and different results may be found for smaller (non-academic) hospitals. Second, COVID-19 incidence as well as implemented restrictions such as lockdowns, curfews, and closing country borders varied across countries, which may limit the external validity of the study to other countries.[64 65] However, since the hospitals in our study were from countries that varied considerably with respect to national COVID-19 pandemic measures as well as healthcare access systems (eg, including both Melbourne (Australia) with strict lockdowns but limited numbers of COVID-19 infected patients and also Milan (Italy) and New Jersey (the USA) where the COVID-19 pandemic hit hard) we likely have captured the extremes in the scale.[66] Third, we were only able to assess in-hospital mortality, long LOS and 28-day readmissions as indicators for the quality of care delivered, while other patient outcomes such as complications or patient reported outcome measures are also relevant to judge the quality of care. Fourth, we used routinely collected administrative data where there may be some misclassification of diagnoses and is influenced by different coding practices in hospitals. Fifth, the number of events was low for some outcomes (particularly mortality) in some diagnostic groups as shown in table 1. The small sample size per time point may have resulted in an underpowered analysis and thereby in finding no or only few statistically significant results for some patient outcomes.[67] In this context, it should be noted that looking at the point estimates in some cases did point to potential changes in patient outcomes that would be considered clinically meaningful, for instance the 200% increase in mortality (level change) directly following the start of the COVID-19 pandemic for lower limb fracture patients and a more than 100% direct decrease in readmissions for trauma-related joint disorders. Lastly, even though we adjusted for several important patient characteristics that determine the case-mix of patients treated both in the pre-pandemic and the COVID-19 pandemic period, there are other factors such as American Society of Anaesthesiologists scores and malnutrition that could not be taken into account and may have affected the patient outcomes.[68–70]

Interpretation and clinical implications

During the COVID-19 pandemic, healthcare systems were challenged to focus on reducing harm and managing risk for both COVID-19 and non-COVID-19 patients. To achieve this, the WHO provided guidance to maintain standards of care by the use of a 10-point plan for essential quality systems during COVID-19.[71] However, items listed in this WHO-guideline such as 'rapidly optimise health workforce capacity' are difficult to implement rapidly into daily clinical practice.[72] Nevertheless, our results show that patient outcomes for non-COVID-19 orthopaedic patients were mostly comparable (if not more favourable) during the COVID-19 pandemic as in the pre-pandemic period, suggesting maintenance of standard of healthcare. Although our study is, to our knowledge, the first multi-centre study examining the impact of the COVID-19 pandemic on patient outcomes for non-COVID-19 orthopaedic patients across different countries in the world, future studies may explore in more depth the changes in processes of orthopaedic care during the COVID-19 pandemic and increase our understanding how these have resulted in similar patient outcomes despite a worldwide health crisis. Such better understanding of changes may also result in identifying areas for further improvement after the COVID-19 pandemic and may support healthcare systems in preparing for future pandemics.

Conclusions

Even during a challenging period when the majority of healthcare is focused on treatment and prevention on COVID-19 infections and other care is de-prioritised, we found that the overall patient outcomes for non-COVID-19 patients who had to be admitted for orthopaedic care remained the same as during the pre-pandemic, thereby suggesting good quality care.

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Patient consent for publication Not applicable.

Ethics approval Given that all analyses were performed on available and anonymous data, the study was not considered by a Medical Ethics Committee as this was not required under Dutch law.

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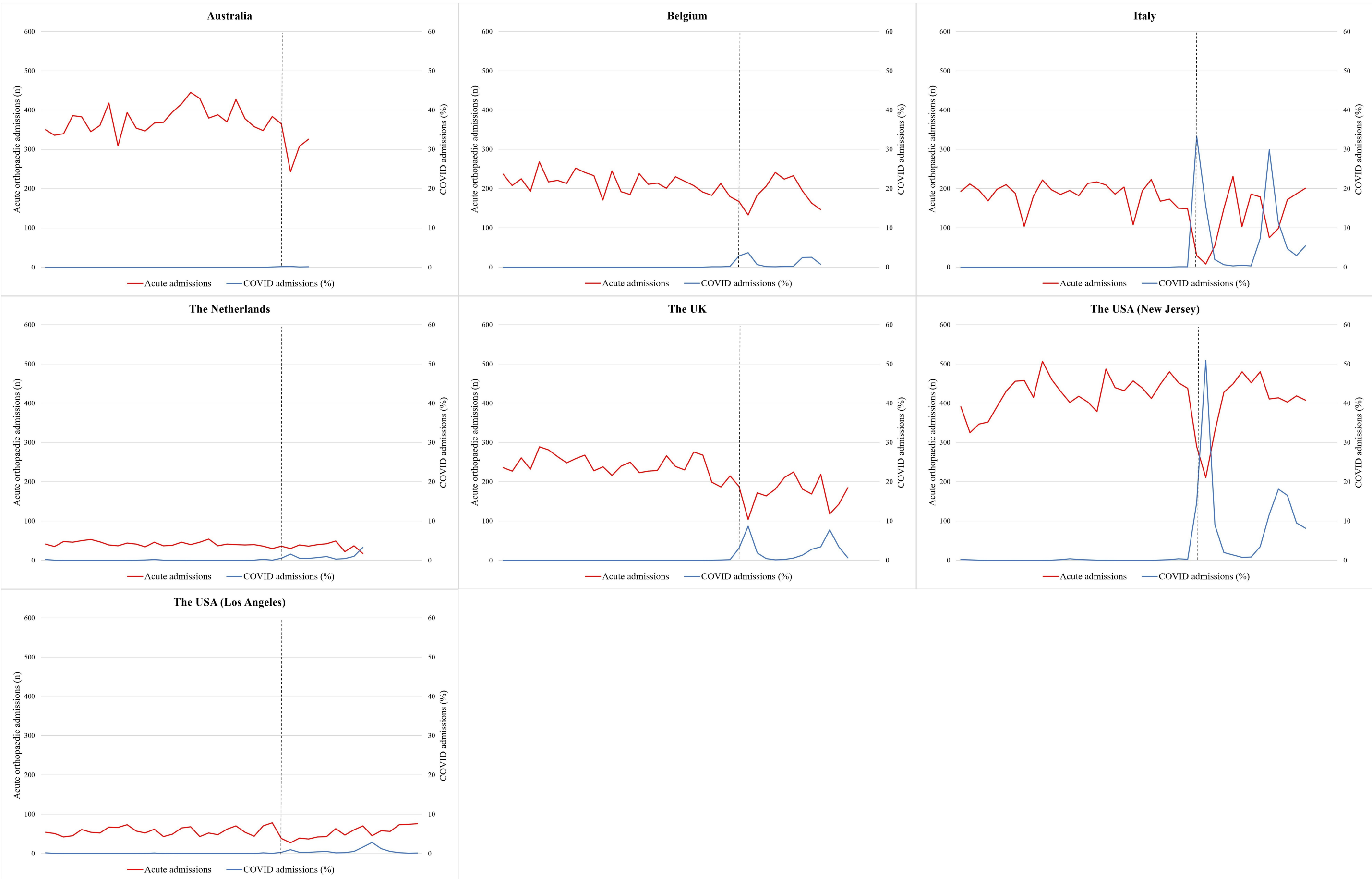
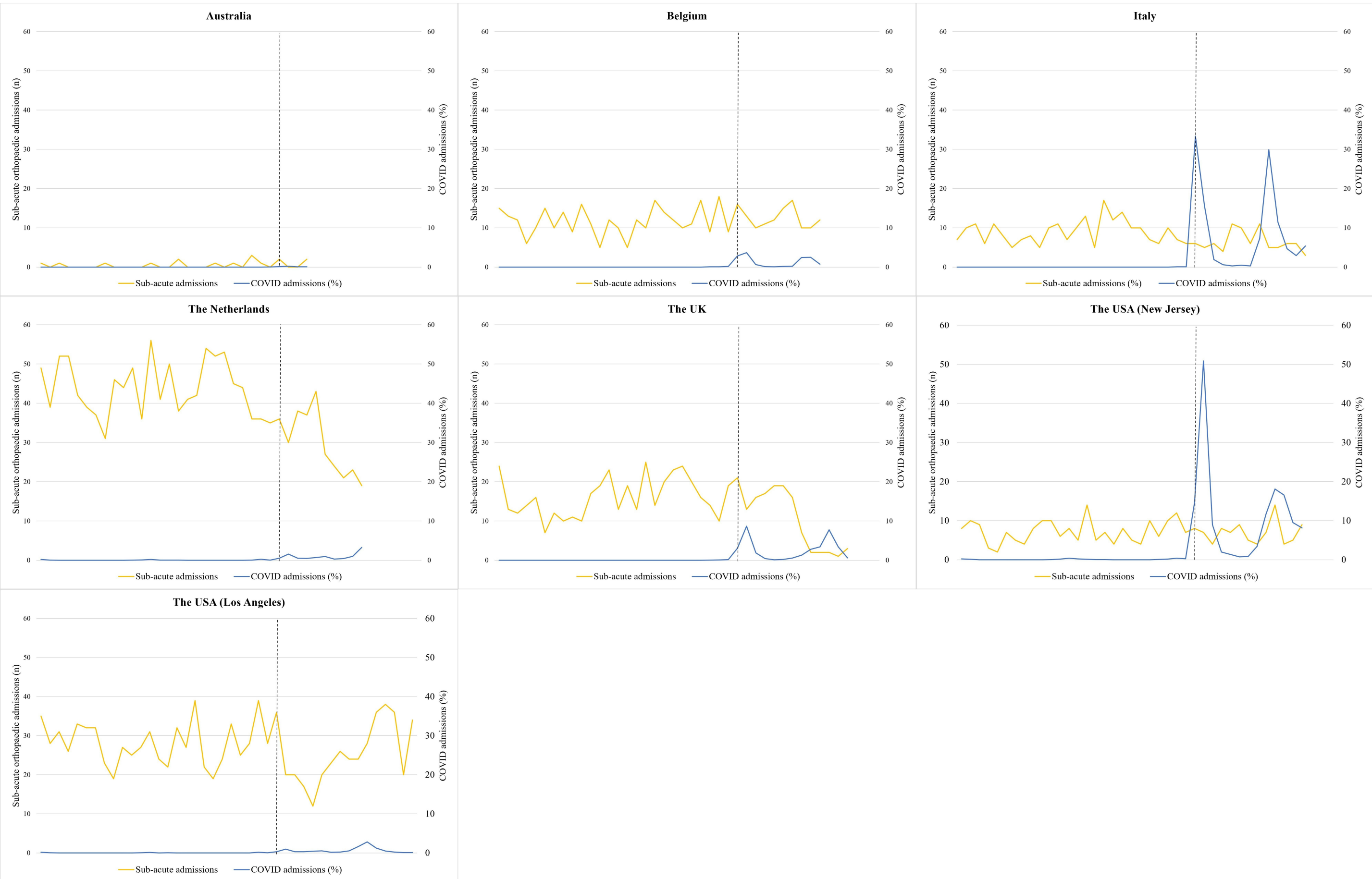
Supplemental table 1. Included Beta Versions of the CCS for ICD-10-CM per diagnostic group

Acute admissions					Sub-acute admissions	Elective admissions
Lower limb fractures	**Neck of femur fractures**	**Pathological fractures**	**Trauma-related joint disorders and dislocations**	**Upper limb fractures**	**Cancer of bone and connective tissue**	**Osteoarthritis**
M84.3	M84.3	M80.0	M12.5	M84.3	C40.0-40.3	M15.0-15.2
M84.7	S72.0-72.3	M80.2-80.5	M22.0-22.4	S42.0-42.4	C40.8-41.4	M15.4
S72.3-72.4	S72.7-72.9	M80.8-80.9	M22.8-23.6	S42.7-42.9	C41.8-41.9	M15.8-16.7
S72.8-72.9		M84.4-84.6	M23.8-23.9	S49.0-49.1	C49.0-49.6	M16.9-17.5
S79.0-79.1			M24.1	S49.7-49.9	C49.8-49.9	M17.9-18.3
S79.7-79.9			M24.4	S52.0-52.9		M18.5
S82.0-82.9			M43.5	S59.0-59.2		M18.9-19.2
S89.0-89.3			M99.1	S59.7-59.9		M19.8-19.9
S89.8-89.9			S03.0-03.2	S62.0-62.9		
S92.0-92.5			S03.4-03.5			
S92.7			S13.0-13.2			
S99.0			S13.4			
S99.2			S13.6			
S99.8-S99.9			S23.1-23.4			
			S33.0-S33.3			
			S43.0-43.5			
			S43.7			
			S53.0-53.1			
			S53.3			
			S63.0-S63.4			
			S63.7			
			S73.0			
			S83.0-83.3			
			S93.0-93.3			
			S93.5-93.6			


Australia
Belgium
Italy
The Netherlands
The UK
The USA (New Jersey)
The USA (Los Angeles)
Acute orthopaedic admissions (n)
COVID admissions (%)
0
100
200
300
400
500
600
0
10
20
30
40
50
60
Acute admissions
COVID admissions (%)


Australia
Sub-acute orthopaedic admissions (n)
COVID admissions (%)
Sub-acute admissions
COVID admissions (%)
Belgium
Sub-acute orthopaedic admissions (n)
COVID admissions (%)
Sub-acute admissions
COVID admissions (%)
Italy
Sub-acute orthopaedic admissions (n)
COVID admissions (%)
Sub-acute admissions (%)
COVID admissions (%)
The Netherlands
Sub-acute orthopaedic admissions (n)
COVID admissions (%)
Sub-acute admissions
COVID admissions (%)
The UK
Sub-acute orthopaedic admissions (n)
COVID admissions (%)
Sub-acute admissions
COVID admissions (%)
The USA (New Jersey)
Sub-acute orthopaedic admissions (n)
COVID admissions (%)
Sub-acute admissions
COVID admissions (%)
The USA (Los Angeles)
Sub-acute orthopaedic admissions (n)
COVID admissions (%)
Sub-acute admissions
COVID admissions (%)

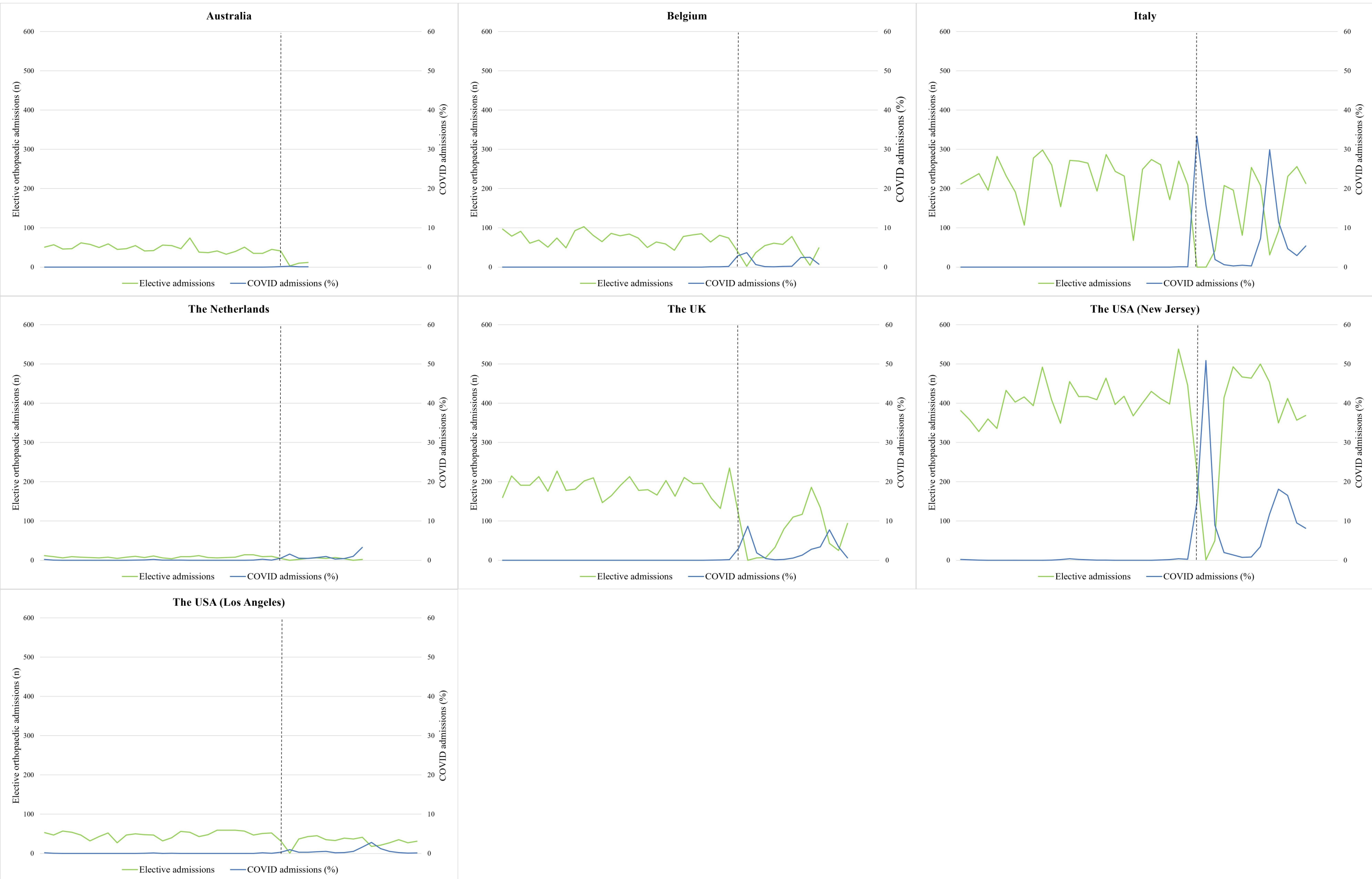

Australia
Belgium
Italy
The Netherlands
The UK
The USA (New Jersey)
The USA (Los Angeles)
Elective orthopaedic admissions (n)
COVID admissions (%)
COVID admisisons (%)
Elective admissions
COVID admissions (%)
0
100
200
300
400
500
600
10
20
30
40
50
60

Figure legends

Supplemental Figure 1 – title: Volumes of orthopaedic care admissions and percentages of COVID-19 admissions – acute orthopaedic care

Supplemetal Figure 1 – legend: Number of acute orthopaedic admissions (left y-axis) and percentage COVID-19 admissions in a hospital (right y-axis) per month (x-axis) with the red lines representing the number of acute orthopaedic admissions and the dashed vertical lines representing the start of the COVID-19 pandemic (March 2020)

Supplemental Figure 2 – title: Volumes of orthopaedic care admissions and percentages of COVID-19 admissions – sub-acute orthopaedic care

Supplemental Figure 2 – legend: Number of sub-acute orthopaedic admissions (left y-axis) and percentage COVID-19 admissions in a hospital (right y-axis) per month (x-axis) with the orange lines representing the number of sub-acute orthopaedic admissions and the dashed vertical lines representing the start of the COVID-19 pandemic (March 2020)

Supplemental Figure 3 – title: Volumes of orthopaedic care admissions and percentages of COVID-19 admissions – elective orthopaedic care

Supplemental Figure 3 – legend: Number of elective orthopaedic admissions (left y-axis) and percentage COVID-19 admissions in a hospital (right y-axis) per month (x-axis) with the green lines representing the number of eletive orthopaedic admissions and the dashed vertical lines representing the start of the COVID-19 pandemic (March 2020)