

Hospital resource use and in-hospital mortality before and during the COVID-19 pandemic: a nationwide cohort study

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Summary

INTRODUCTION: The COVID-19 pandemic has placed an enormous strain on the Swiss healthcare system. This study aims to assess the associations of the pandemic on Switzerland's hospital resource use and in-hospital mortality among both COVID-19 and non-COVID-19 patients.

METHODS: In this national cohort study, we analysed administrative claims data for medical inpatients from 1 January 2018 to 31 December 2021, using mixed-effects segmented regression models. Hospitalisations were divided into a control and an exposure group before (January 2018 to December 2019) and during (January 2020 to December 2021) the pandemic. Before the pandemic, the division into the groups was performed by random split. We investigated trends in in-hospital mortality, hospital length of stay, 30-day hospital readmission and facility discharge rates before and during the COVID-19 pandemic, to assess the pandemic's association with both COVID-19 (exposure) and non-COVID-19 (control) patients.

RESULTS: Among 1,510,836 included cases, 763,533 were hospitalised before and 747,303 during the COVID-19 pandemic including 61,151 with a diagnosis of COVID-19. Before the pandemic, there were no relevant changes in population-averaged in-hospital mortality in the control group and the randomly defined exposure group (−0.0263% and 0.0201% per month, respectively). During the pandemic, however, mortality showed an increase among COVID-19 patients by 0.3553% per month (95% confidence interval [CI]: 0.3546–0.3560; change in slope $p < 0.001$; difference in slopes $p < 0.001$), while there was no relevant change in the pandemic control group (slope: −0.0277% per month). Similarly, COVID-19 patients showed an increase in hospital length of stay and discharge to a post-acute care facility, while the trend for 30-day hospital readmission was decreased.

CONCLUSION: In this study, we observed an association between the COVID-19 pandemic and hospital resource use in COVID-19 patients only, resulting in higher in-hospital mortality, longer lengths of hospital stay and more

frequent facility discharges. No relevant differences were seen in the control group during both time periods.

Introduction

During the COVID-19 pandemic, significant uncertainty permeated daily hospital operations in Switzerland. While the first COVID-19 cases in Switzerland were registered in February 2020 [1], throughout the spring of 2020, Europe experienced a decline in hospitalisation rates due to a reduction in patient volume and the postponement of elective treatments [2–7]. Specifically, a notable decrease in admissions for myocardial infarction, cerebral stroke and cancer was observed, resulting in delays in diagnosis and initiation of therapy [2, 6, 8–10]. The clinical and demographic profile of non-COVID-19 patients admitted during the first wave of the pandemic was different to that of patients admitted in the years before. They were older and the severity of the patient status was increased [11].

The relatively calm period with the subsidy programme transitioned to a period of patient overload in autumn 2020 [3]. Hospital wards, especially intensive care units (ICU), were overwhelmed with COVID-19 patients requiring extensive inpatient care. Healthcare staff faced a lack of knowledge regarding the aetiopathogenesis and lethality of the new virus, in addition to rapidly evolving prevention and treatment strategies of uncertain efficacy. Moreover, the care of COVID-19 patients demanded more time. Since then, hospitals have appeared to operate at the limits of their capacity. Hospital beds had to be closed due to staff shortages, and this strain was evident in daily life. Multiple studies have demonstrated a correlation between COVID-19 surges and increased mortality among hospitalised patients with COVID-19 [12–15]. Between March and August 2020, in 558 US hospitals 23% of COVID-19

ABBREVIATIONS

COPD: chronic obstructive pulmonary disease
ICD-10 GM: International Classification of Diseases, version 10, German Modification

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deaths were linked to high hospital strain due to the COVID-19 caseload [12]. Non-COVID-19 patients seemed to be less affected by overburdening. A study in Alberta and Ontario reported similar results for 30-day mortality and hospital length of stay (LOS) before and during the pandemic in patients with a urinary tract infection, acute coronary syndrome and stroke without COVID-19 [15]. Furthermore, a survey conducted in Spain indicated a negative impact of the pandemic on healthcare quality for both COVID-19 and non-COVID-19 patients, but more pronounced in the former group [16]. Another study observed a negative effect in terms of encountered errors, with an increased risk of medication errors and sepsis (particularly central line-associated bloodstream infections) among hospitalised patients during the pandemic [17].

Still, Swiss data on hospital overload during the COVID-19 pandemic, particularly regarding outcomes for non-COVID-19 patients, is limited. The terminology and definition of capacity strain varied across published studies, complicating comparisons and leading to differing results [18]. Resource issues have been extensively studied in emergency departments and ICUs, where associations between delayed care due to overcrowding, staff shortages, decreased care efficiency and increased patient mortality have been identified [18–23]. However no such data among patients on medical acute care wards with and without COVID-19 has been reported in Switzerland. We therefore aimed to investigate whether and to what extent the COVID-19 pandemic was associated with additional hospital resource use in patients with COVID-19 and in those without.

Methods

Study design and data source

We conducted a population-based cohort study of adults using a nationwide administrative claims database between 1 January 2018 and 31 December 2021, provided by the Swiss Federal Statistical Office (Bundesamt für Statistik, Neuchâtel, Switzerland). The dataset included all Swiss inpatient discharge records from hospitals for acute somatic care. Individual-level data on patient demographics, healthcare utilisation, hospital typology, medical diagnoses, clinical procedures and in-hospital patient outcomes were provided. A multi-step anonymisation procedure ensured patient confidentiality, and a unique anonymised patient identifier was used to ascertain rehospitalisations. Medical diagnoses were coded using International Classification of Disease version 10, German Modification (ICD-10-GM) codes (<http://www.who.int/classifications/icd/en/>). The institutional review board of Northwestern and Central Switzerland (EKNZ) waived the need for an ethical authorisation due to the use of exclusively anonymised data (EKNZ Project-ID: Req-2021-01397).

In this interrupted time-series design, we compared outcomes between patients with and without a diagnosis of COVID-19. The overall 48-month study period was divided into a 24-month pre-pandemic phase, from January 2018 to December 2019, and a 24-month pandemic phase, from January 2020 to December 2021. Before the pandemic, we randomly split the study population into an “exposure” group (representing the pre-pandemic population

of the “exposure group” trajectory) and a “control” group (representing the pre-pandemic population of the “control group” trajectory); during the pandemic, patients with a diagnosis of COVID-19 were allocated to the exposure group and patients without a diagnosed COVID-19 infection to the control group.

Study population

For this analysis, we included all hospitalisations from January 2018 to December 2021 on the medical ward. Hospitalisations with a diagnosis of COVID-19 were identified using ICD-10-GM discharge codes U07.1 and U07.2. Validation studies have demonstrated high sensitivity and positive predictive value for these codes [24, 25]. Details on all ICD-10-GM codes used in the analysis are provided in tables S1–S2. Comorbidities were assessed using the Elixhauser Comorbidity Index [26], and frailty was quantified using the Hospital Frailty Score [27]. We excluded children (age <18 years) and patients with outlier hospitalisation stays longer than 100 days from the analysis. This study adheres to the “Strengthening The Reporting of Observational Studies in Epidemiology (STROBE)” statement [28].

Outcomes

The primary outcome was in-hospital mortality among the exposure and control groups during the pre-pandemic and pandemic periods. Secondary outcomes comprised trends in hospital length of stay, 30-day hospital readmission and facility discharge, both between the two groups and across the study phases. For facility discharge, we considered nursing homes, residential homes for the elderly and rehabilitation facilities based on claims data. The claims data also provided the number of days to the subsequent hospitalisation, which was used to calculate the 30-day hospital readmission rate. Rehospitalisations within 18 days after the initial hospitalisation for a related reason were not considered readmissions; instead they were included in the first hospitalisation. In accordance with the SwissDRG definition, every readmission to the same hospital after 18 days from discharge or any readmission into another hospital were defined as a new index hospitalisation [29]. Thus, a single patient may have more than one index admission during the study period. Length of stay that crossed from one study phase to another or that went past the study end date were attributed to the study phase applicable during hospital admission.

Statistical analysis

Descriptive statistics were calculated for patient demographics, including age, sex, nationality, patient comorbidity and level of frailty. All baseline characteristics are expressed as median (interquartile range [IQR]), standardised difference [Std. Diff.] or frequency (%). We performed segmented regression analyses of interrupted time-series data from 1 January 2018 to 31 December 2021, to analyse in-hospital mortality, hospital length of stay, 30-day hospital readmission and facility discharge. To model trends, we used a multivariable mixed-effects linear regression, including study time, modelled continuously as a linear spline with one knot location chosen at the start of the pan-

dem phase (January 2020). The model included random effects for patient-specific intercept and slope, allowing for individual trends for each patient, which improved models' fit over random intercept only models, based on log likelihood ratio tests, with statistical significance set at $p < 0.05$. At the patient level, the model was adjusted for age, sex, housing conditions, Elixhauser Comorbidity Index and the Hospital Frailty Risk Score. Time coefficients can be interpreted as monthly mean change in percentage of mortality, 30-day hospital readmission and facility discharge. For length of hospital stay, time coefficients are provided in days. We excluded patients who died during hospitalisation when assessing hospital readmission and facility discharge.

In a subgroup analysis, we stratified the results by the presence of the following diagnoses: cardiovascular disease (coronary artery disease, heart failure, hypertension), chronic obstructive pulmonary disease (COPD), diabetes mellitus, chronic kidney disease (CKD) and solid cancer. Moreover, we conducted an analysis based on the size of the hospital (small vs big hospital).

The assumptions of the linear models, including linearity, normality of residuals and homoscedasticity, were assessed using appropriate diagnostic plots and statistical tests. No violations were identified, confirming the validity of the model assumptions. There were no missing data for patient characteristics and study outcomes. Statistical significance was based on 95% confidence intervals (CIs) and all p -values were two-tailed. All statistical analyses were performed using STATA version 18.0 (STATA Corp., College Station, TX, USA).

Results

Characteristics of the cohort

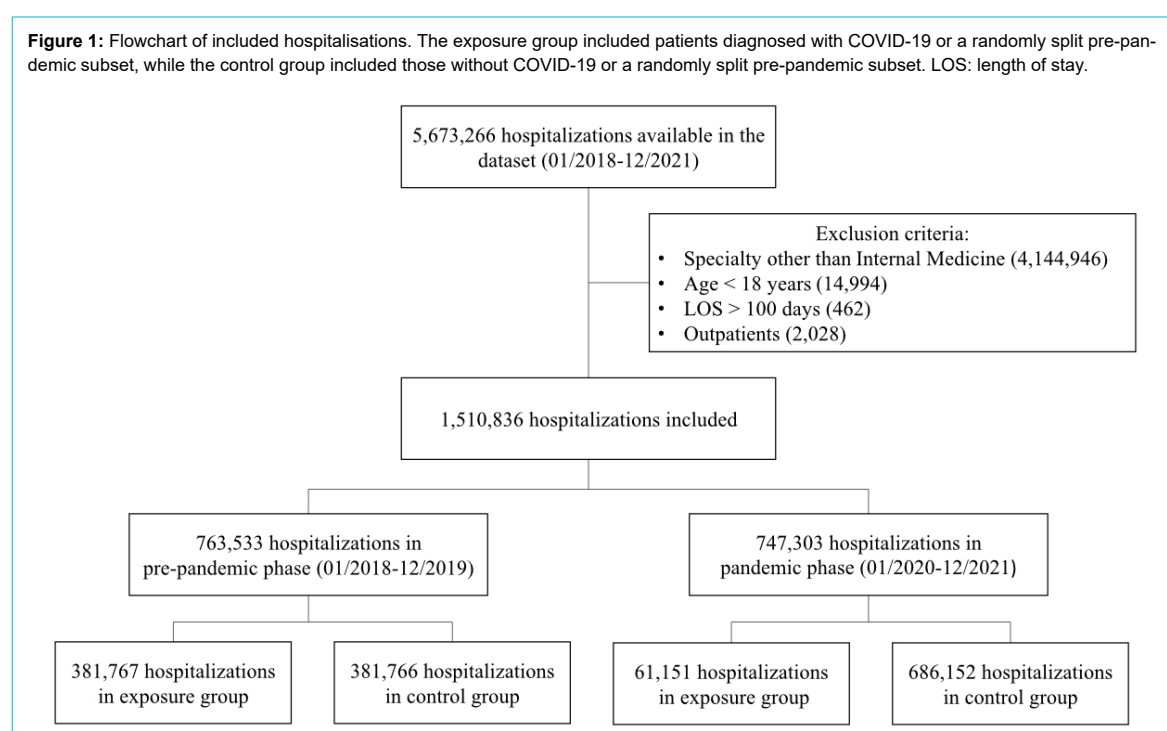
From 1 January 2018 to 31 December 2021, we identified a total of 1,510,836 hospitalisations, 763,533 (50.5%) be-

fore and 747,303 (49.5%) during the COVID-19 pandemic (figure 1). Table 1 shows baseline characteristics by study phase and exposure group. During the pre-pandemic phase, there were no differences between the randomly split groups. During the pandemic, exposure group hospitalisations ($n=61,151$) were significantly fewer compared to controls ($n = 686,152$). The exposure group during the pandemic had more male patients (57.6%) than before the pandemic (52.4%) and the control group during the pandemic (53.1%). Most hospitalisations were for patients aged over 69 years, but the exposure group had more patients aged 45–69 (41.4%) than the control group (34.8%) or pre-pandemic group (35.3%). Most patients were admitted from home, with fewer in the exposure group during the pandemic (83.3%). The exposure group during the pandemic had fewer comorbidities, with a lower median Elixhauser Comorbidity Index, fewer cardiovascular, cerebrovascular, chronic obstructive pulmonary and solid cancer diseases, but higher obesity rates. Despite fewer comorbidities, the exposure group during the pandemic had higher frailty scores.

Primary outcome before and during the COVID-19 pandemic

The primary outcome of in-hospital mortality occurred in 35,483 (4.7%) patients before the pandemic and in 38,991 (5.2%) patients during the pandemic, while more patients from the exposure group (10.96%) rather than controls (4.7%) were affected. The results for in-hospital mortality are summarised in table 2 and figure 2A. The increase in in-hospital mortality during the pandemic was higher in the exposure group (slope: 0.3553, 95% CI: 0.3546–0.3560) compared to both the pandemic control group (slope: -0.0277 , 95% CI: -0.0280 to -0.0273) and the pre-pandemic group (slope: 0.0201, 95% CI: 0.0199–0.0204) ($p < 0.001$ in both cases).

Figure 1: Flowchart of included hospitalisations. The exposure group included patients diagnosed with COVID-19 or a randomly split pre-pandemic subset, while the control group included those without COVID-19 or a randomly split pre-pandemic subset. LOS: length of stay.



Secondary outcomes before and during the COVID-19 pandemic

The mean hospital length of stay was 6.7 days before the pandemic and 6.6 days during the pandemic. However, the mean hospital length of stay for the exposure group was 9.6 days, higher than the control group, which had a mean hospital length of stay of 6.4 days during the pandemic. A longer hospital length of stay was observed in the exposure group compared to the control group during the pandemic ($p < 0.001$). The length of stay for hospitalisations of the exposure group increased by 0.1363 days per month (95% CI: 0.1313–0.1414) from January 2020 to December 2021. In contrast, there was a slight decrease in the hospital length of stay for controls over the same time period (slope: -0.0305 days per month, 95% CI: -0.0327 to -0.0283) (table 2, figure 2B).

The secondary outcome 30-day hospital readmission occurred in 84,202 (11.7%) patients before the pandemic and in 75,680 (10.8%) during the pandemic, whereas fewer patients from the exposure group than the control group (5.1% vs 11.3%) were readmitted within 30 days after the index hospitalisation. In the exposure group, we observed a decline in the slope for 30-day hospital readmission during the pandemic (slope: -0.4076 , 95% CI: -0.4085 to -0.4067). The control group also experienced a decrease

in the slope during the pandemic (slope: -0.0150 , 95% CI: -0.0155 to -0.0146), although this decline was less pronounced compared to the exposure group (difference in slopes, $p < 0.001$) (table 2, figure 2C).

Before the pandemic, 124,369 (16.3%) patients were discharged to an institution for further care, compared to 126,619 (16.9%) during the pandemic. More patients from the exposure group (20.4%) compared to the control group (16.6%) were discharged to a post-acute care facility. We observed a significant increase in the proportion of facility discharge for hospitalisations among the exposure group during the pandemic (slope: 0.2645, 95% CI: 0.2636–0.2654) and thus, a change to the prior slope during the pre-pandemic ($p < 0.001$). The control group also showed an increase in slope during the pandemic, although less pronounced (slope: 0.0020, 95% CI: 0.0016–0.0025; difference between slopes during the pandemic, $p < 0.001$) (table 2, figure 2D).

Subgroup analyses

Tables S3–S9 and figures S1–S7 present the findings of the subgroup analysis. For in-hospital mortality, hospital length of stay and facility discharge results remained mostly consistent; however, a steeper increase in the exposure group (pre-existing illness plus COVID-19) compared to

Table 1:

Baseline characteristics stratified by study phase and group. The exposure group included patients diagnosed with COVID-19 or a randomly split pre-pandemic subset, while the control group included those without COVID-19 or a randomly split pre-pandemic subset. Standardised difference is a measure of the size of the difference between two group means relative to the variability within the groups.

		Pre-pandemic phase		Pandemic phase		Standardised difference	Standardised difference
		Control	Exposure	Control	Exposure	Pre-pandemic vs pandemic exposure	Pandemic control vs pandemic exposure
Hospitalisations, n		381,766	381,767	686,152	61,151		
Demographics	Male sex, n (%)	200,402 (52.5%)	200,007 (52.4%)	364,039 (53.1%)	35,211 (57.6%)	0.104	0.091
	Age, n (%)					0.128	0.139
	...19–44	42,458 (11.1%)	42,396 (11.1%)	74,449 (10.9%)	6551 (10.7%)		
	...45–69	134,785 (35.3%)	134,593 (35.3%)	239,085 (34.8%)	25,303 (41.4%)		
	...>69	204,523 (53.6%)	204,778 (53.6%)	372,618 (54.3%)	29,297 (47.9%)		
	Swiss nationality, n (%)	312,434 (81.8%)	312,040 (81.7%)	564,262 (82.2%)	44,248 (72.4%)	0.224	0.237
Admission data	Admission from home, n (%)	332,717 (87.2%)	333,024 (87.2%)	594,260 (86.6%)	50,919 (83.3%)	0.112	0.093
	Tertiary care, n (%)					0.073	0.070
	...University hospital	68,618 (18.0%)	68,283 (17.9%)	127,089 (18.5%)	11,159 (18.2%)		
	...Non-university hospital	236,187 (61.9%)	236,276 (61.9%)	420,643 (61.3%)	35,915 (58.7%)		
	...Secondary care hospital	76,961 (20.2%)	77,208 (20.2%)	138,420 (20.2%)	14,077 (23.0%)		
Comorbidities, n (%)	Hypertension	184,509 (48.3%)	184,054 (48.2%)	338,015 (49.3%)	28,465 (46.5%)	0.033	0.054
	Coronary artery disease	91,617 (24.0%)	91,577 (24.0%)	170,216 (24.8%)	9079 (14.8%)	0.233	0.252
	Heart failure	52,575 (13.8%)	53,064 (13.9%)	102,959 (15.0%)	5658 (9.3%)	0.146	0.177
	Cerebrovascular disease	30,774 (8.1%)	30,341 (7.9%)	62,418 (9.1%)	2446 (4.0%)	0.167	0.207
	Obesity	7693 (2.0%)	7728 (2.0%)	17,751 (2.6%)	2520 (4.1%)	−0.122	−0.085
	Diabetes mellitus	70,759 (18.5%)	70,593 (18.5%)	130,281 (19.0%)	14,430 (23.6%)	−0.126	−0.113
	Chronic obstructive pulmonary disease	34,283 (9.0%)	34,209 (9.0%)	55,977 (8.2%)	4026 (6.6%)	0.089	0.060
	Chronic kidney disease	74,743 (19.6%)	75,154 (19.7%)	140,016 (20.4%)	10,456 (17.1%)	0.067	0.085
	Solid cancer	48,063 (12.6%)	47,627 (12.5%)	90,188 (13.1%)	2746 (4.5%)	0.290	0.309
	Liver disease	15,931 (4.2%)	15,907 (4.2%)	31,849 (4.6%)	2994 (4.9%)	−0.035	−0.012
	Elixhauser Comorbidity Index, median (IQR)	2 (1; 4)	2 (1; 4)	3 (1; 4)	2 (1; 4)	0.116	0.173
	Frailty category					0.123	0.084
	...<5 points	271,217 (71.0%)	271,061 (71.0%)	477,153 (69.5%)	40,143 (65.6%)		
	...5–15 points	99,267 (26.0%)	99,552 (26.1%)	183,958 (26.8%)	18,373 (30.0%)		
	...>15 points	11,282 (3.0%)	11,154 (2.9%)	25,041 (3.6%)	2635 (4.3%)		

the control group (pre-existing illness without COVID-19) was observed. The slope for 30-day hospital readmission showed a relevant decline in patients with an underlying health condition and COVID-19, while it was less pronounced in the control group.

The analysis based on hospital size showed similar findings as the primary outcome. Smaller hospitals showed a steeper increase in facility discharge during the pandemic, while larger hospitals showed a longer length of stay compared to smaller hospitals over the entire period (tables S8–S9, figures S6–S7).

Discussion

This study, focusing on in-hospital patient care in Switzerland before and during the COVID-19 pandemic, provides insights into the association between the pandemic and in-hospital resource use among individuals with and without a diagnosis of COVID-19. First, in-hospital mortality increased significantly during the pandemic, with the exposure group experiencing a notably higher mortality rate compared to controls. Second, while the hospital length of stay for the exposure group increased markedly during the

pandemic, there was a substantial decline in 30-day hospital readmission rates. Additionally, the proportion of facility discharges increased for the exposure group during the pandemic, indicating a shift in discharge patterns.

A significant number of hospitals reported shortages in COVID-19 testing supplies, the need to repurpose hospital spaces into intensive care units (ICUs) and staffing shortages. While these issues were prevalent around the world, there were regional differences due to the initial heterogeneous spread of the pandemic. For instance, the repurposing of hospital spaces to ICUs and higher staffing shortages in some regions of Switzerland may reflect increased COVID-19 caseloads among certain hospital areas, more limited space, fewer resources or lower staffing levels prior to the pandemic compared to other institutions. Therefore, data is needed to determine whether these operational strains may have contributed to higher rates of adverse outcomes for patients without COVID-19.

Overall, we observed an increase in in-hospital mortality, hospital length of stay and facility discharge among the exposure group during the COVID-19 pandemic. These findings highlight the additional use of hospital resources at

Table 2:

Multivariable random slope mixed-effects model of changes in in-hospital mortality, hospital length of stay, 30-day hospital readmission and facility discharge for exposure and control groups between January 2018 and December 2021. The exposure group included patients diagnosed with COVID-19 or a randomly split pre-pandemic subset, while the control group included those without COVID-19 or a randomly split pre-pandemic subset.

Outcome and study phase*		Coefficient (95% CI)**	Slope (95% CI)***	p-value		
				Slope differs from zero	Change in slope from prior slope	Difference in slopes (Control vs Exposure group)
In-hospital mortality						
Control group (reference)	Phase 1 (01/2018 to 12/2019)	−0.0263 (−0.0266; −0.0261)	−0.0263 (−0.0266; −0.0261)	<0.001	NA	NA
	Phase 2 (01/2020 to 12/2021)	−0.0013 (−0.0018; −0.0009)	−0.0277 (−0.0280; −0.0273)	<0.001	<0.001	NA
Exposure group	Exposure group by time interaction during phase 1 (01/2018 to 12/2019)	0.0465 (0.0461; 0.0468)	0.0201 (0.0199; 0.0204)	<0.001	NA	<0.001
	Exposure group by time interaction during phase 2 (01/2020 to 12/2021)	0.3365 (0.3356; 0.3374)	0.3553 (0.3546; 0.3560)	<0.001	<0.001	<0.001
Hospital length of stay****						
Control group (reference)	Phase 1 (01/2018 to 12/2019)	−0.0396 (−0.0424; −0.0367)	−0.0396 (−0.0424; −0.0367)	<0.001	NA	NA
	Phase 2 (01/2020 to 12/2021)	0.0091 (0.0054; 0.0127)	−0.0305 (−0.0327; −0.0283)	<0.001	<0.001	NA
Exposure group	Exposure group by time interaction during phase 1 (01/2018 to 12/2019)	0.0401 (0.0363; 0.0440)	0.0006 (−0.0023; 0.0034)	0.6950	NA	<0.001
	Exposure group by time interaction during phase 2 (01/2020 to 12/2021)	0.1267 (0.1190; 0.1344)	0.1363 (0.1313; 0.1414)	<0.001	<0.001	<0.001
30-day hospital readmission						
Control group (reference)	Phase 1 (01/2018 to 12/2019)	−0.0068 (−0.0072; −0.0065)	−0.0068 (−0.0072; −0.0065)	<0.001	NA	NA
	Phase 2 (01/2020 to 12/2021)	−0.0082 (−0.0088; −0.0076)	−0.0150 (−0.0155; −0.0146)	<0.001	<0.001	NA
Exposure group	Exposure group by time interaction during phase 1 (01/2018 to 12/2019)	−0.0287 (−0.0292; −0.0282)	−0.0355 (−0.0359; −0.0352)	<0.001	NA	<0.001
	Exposure group by time interaction during phase 2 (01/2020 to 12/2021)	−0.3639 (−0.3650; −0.3627)	−0.4076 (−0.4085; −0.4067)	<0.001	<0.001	<0.001
Facility discharge						
Control group (reference)	Phase 1 (01/2018 to 12/2019)	−0.0124 (−0.0127; −0.0121)	−0.0124 (−0.0127; −0.0121)	<0.001	NA	NA
	Phase 2 (01/2020 to 12/2021)	0.0144 (0.0139; 0.0150)	0.0020 (0.0016; 0.0025)	<0.001	<0.001	NA
Exposure group	Exposure group by time interaction during phase 1 (01/2018 to 12/2019)	0.0264 (0.0260; 0.0268)	0.0140 (0.0137; 0.0143)	<0.001	NA	<0.001
	Exposure group by time interaction during phase 2 (01/2020 to 12/2021)	0.2360 (0.2350; 0.2371)	0.2645 (0.2636; 0.2654)	<0.001	<0.001	<0.001

NA: not applicable.

* Time is treated continuously; coefficients and slopes are reported in monthly estimates (e.g. change per month).

** The model includes patient's age, sex, housing condition, Elixhauser comorbidity index and Hospital Frailty Risk Score.

*** The slope during the pandemic can be derived by summing coefficients from the pre-pandemic and pandemic phases.

**** Regression coefficients and slopes for hospital length of stay are in days.

that time among patients with COVID-19 and align with previous studies [12–15, 30]. University Hospital Basel reported a stable in-hospital mortality rate of around 9.5% to 10.2% during the first two waves, declining to 5.4% in the third wave due to factors such as vaccination, therapeutic advancements, and shifts in patient demographics and disease severity [31, 32]. This period also saw unchanged hospital length of stay [31]. In contrast, Cantonal Hospital Aarau recorded higher initial in-hospital mortality (19%) and longer hospital length of stay (8.9 days), with subsequent waves showing a reduction in hospital length of stay to 6.5 days without mortality change [33, 34]. Data from 20 Swiss hospitals during the second wave revealed an in-hospital mortality rate of 14.5% [35], while a broader study across 14 hospitals, including all five Swiss university hospitals, found an in-hospital mortality of 12.8% and an average hospital length of stay of 8 days between February and July 2020 [36].

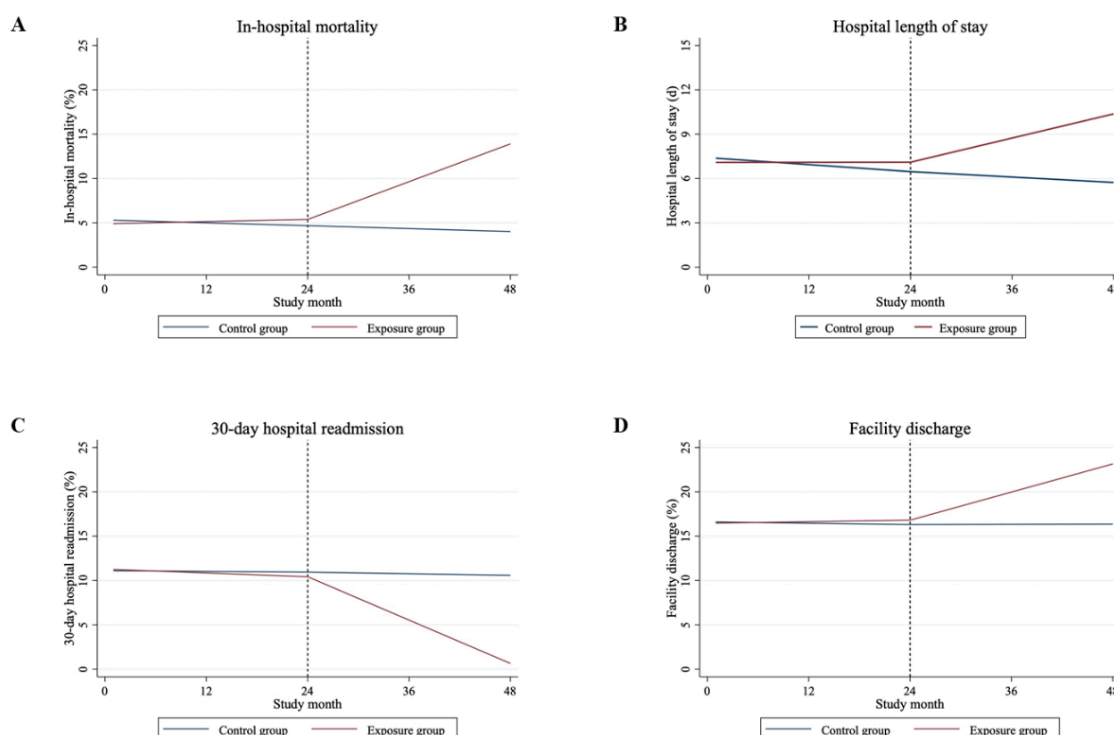
Global comparisons of in-hospital mortality and hospital length of stay are challenging due to variations in testing protocols, mortality ascertainment, societal age structures and healthcare systems [37]. During the first wave of the COVID-19 pandemic, in-hospital mortality was higher in Europe (22.9%) and America (22.2%) than in Asia (12.7%) [38]. In Italy, Germany and the USA, in-hospital mortality rates were roughly 20% [32, 39–42]. Data from the UK showed higher in-hospital mortality rates of about 30% [43, 44]. Conversely, Spain and China recorded lower first-wave in-hospital mortality at 17% and 14%, respectively [45–47]. Subsequent waves saw significantly reduced in-hospital mortality rates [32, 39, 46–50]. Second-

wave hospital length of stay data showed similar durations in Germany (8 days), Spain (9 days) and the USA (8.9 days) [51–53], with Italy reporting a median hospital length of stay of 6 days from February 2020 to March 2021 [54]. These findings are summarised in table S10.

However, it remains unclear whether COVID-19 patients themselves were directly affected by hospital overload and what specific factors contributed to the increased resource use and mortality. Similarly, our study design also does not allow for establishing causality. Nonetheless, it is likely that several factors may have contributed to these findings, including limited knowledge about the virus' aetiopathogenesis and treatment options, high frailty scores and frequent admissions from institutions.

Notably, the pandemic control group showed no association with additional hospital resource use, and there were no clinically meaningful changes compared to the pre-pandemic phase. While there is no data from Switzerland on any in-hospital resource use among patients without COVID-19 during the pandemic, in Canada patients with urinary tract infection, acute coronary syndrome or stroke without COVID-19 did not show increased 30-day mortality or hospital length of stay during COVID-19 surges. However, patients with heart failure, COPD and asthma without COVID-19 exhibited higher 30-day mortality rates. Whether this was based on the competition for scarce mechanical ventilation resources remains unclear [15]. Contrary to our findings, several studies have reported higher in-hospital mortality for non-COVID-19 patients during the beginning of the pandemic [55–58]. A survey of hospital administrators revealed poor quality of care and

Figure 2: Trends in in-hospital mortality (A), hospital length of stay (B), 30-day hospital readmission (C) and facility discharge (D) for exposure and control group before and during the COVID-19 pandemic. The exposure group included patients diagnosed with COVID-19 or a randomly split pre-pandemic subset, while the control group included those without COVID-19 or a randomly split pre-pandemic subset.



worse disease outcomes in inpatients without COVID-19 during pandemic hospital strain [59], even though this finding was mainly observed in hospitals serving high proportions of patients from racial or ethnic minority groups.

The decline in 30-day hospital readmission in the exposure group during the COVID-19 pandemic is consistent with the increase in facility discharges. Patients were often transferred to nursing homes or rehabilitation centres for further care, reducing the need for readmission within the first 30 days post-hospitalisation. Moreover, the COVID-19 population was younger with a lower burden of comorbidities, resulting in a faster and more complete recovery. Frequent discharges to institutions have also been previously described and represent an additional burden for nursing homes and rehabilitation clinics [60]; this also prolonged the hospital stay as due to overload patients had to wait for space.

In patients with pre-existing illnesses and COVID-19, in-hospital mortality, hospital length of stay and facility discharge increased to the same extent across all comorbidities during the pandemic. In contrast, the population without COVID-19 showed no clinically meaningful changes. These results in the exposure group align with previous findings [31, 61–63]. The mechanisms behind these outcomes remain unclear, with several possible explanations. For instance, diabetes mellitus can impair immune function, making it harder for patients to fight infections [64]. Many cancer treatments also weaken the immune system, which complicates recovery even more. In patients with underlying hypertension and other cardiovascular diseases, the risk of severe outcomes may be increased by several mechanisms, including therapeutic upregulation of angiotensin-converting enzyme 2, the host receptor for SARS-CoV-2 [65]. Obesity, which tends to impair lung function and dysregulate the immune system [66, 67], is another significant risk factor for a poorer prognosis [68, 69]. Although we did not include obesity in our subanalysis due to underreporting, our baseline characteristics indicated a higher percentage of obesity in the COVID-19 population compared to other groups. These findings suggest that patients with pre-existing conditions who contract COVID-19 are particularly vulnerable to severe outcomes, necessitating additional hospital resources and leading to higher rates of facility discharge. The increased burden on nursing homes and rehabilitation centres underscores the need for targeted strategies to manage these patients effectively during pandemics.

Limitations and strengths

These results must be interpreted in the context of the study design. First, given that COVID-19 hospitalisations were identified by ICD-10-GM codes used for billing purposes, misclassification and underreporting are possible, especially during the beginning of the COVID-19 pandemic when no specific ICD-10-GM codes were available. Second, confounding due to population differences during the pandemic is likely. However, we do not believe that the changes in trends among the groups are solely caused by different baseline characteristics or secular trends, given the presence of a comparison group. Third, because of the retrospective design of the study, no causal inference is possible. Nonetheless, there are several notable strengths.

This analysis was based on nationwide hospital care data with high external validity, strong statistical power and high generalisability across all regions in Switzerland. Furthermore, our results provide robust insights into the course of patients without COVID-19 during the pandemic, reassuring us of the high quality of care within the Swiss healthcare system, even during the challenging times of a pandemic.

Conclusion

In conclusion, our study assumes that the COVID-19 pandemic was associated with unfavourable in-hospital outcomes, particularly among patients hospitalised with or for COVID-19 and pre-existing conditions. However, we did not find evidence that patients without COVID-19 experienced similar unfavourable outcomes. Despite these challenges, the Swiss healthcare system maintained high-quality care for non-COVID-19 patients, highlighting its resilience and adaptability during a global health crisis.

Data sharing statement

Restrictions apply to the availability of data generated or analysed during this study, in order to preserve patient confidentiality or because they were used under licence. The corresponding author will on request detail the restrictions and any conditions under which access to some data may be provided.

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Potential competing interests

All authors have completed and submitted the International Committee of Medical Journal Editors form for disclosure of potential conflicts of interest. No potential conflict of interest related to the content of this manuscript was disclosed.

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Appendix

The appendix is available for download as a separate file at <https://doi.org/10.57187/s.4109>.