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Changes in diagnostic patterns and resource utilisation in Swiss adult ICUs during the first two COVID-19 waves: an exploratory study

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Summary

BACKGROUND AND AIM: The coronavirus disease 2019 (COVID-19) outbreak deeply affected intensive care units (ICUs). We aimed to explore the main changes in the distribution and characteristics of Swiss ICU patients during the first two COVID-19 waves and to relate these figures with those of the preceding two years.

METHODS: Using the national ICU registry, we conducted an exploratory study to assess the number of ICU admissions in Switzerland and their changes over time, characteristics of the admissions, the length of stay (LOS) and its trend over time, ICU mortality and changes in therapeutic nursing workload and hospital resources in 2020 and compare them with the average figures in 2018 and 2019.

RESULTS: After analysing 242,935 patient records from all 84 certified Swiss ICUs, we found a significant decrease in admissions (–9.6%, corresponding to –8005 patients) in 2020 compared to 2018/2019, with an increase in the proportion of men admitted (61.3% vs 59.6%; p <0.001). This reduction occurred in all Swiss regions except Ticino. Planned admissions decreased from 25,020 to 22,021 in 2020 and mainly affected the neurological/neurosurgical (–14.9%), gastrointestinal (–13.9%) and cardiovascular (–9.3%) pathologies. Unplanned admissions due to respiratory diagnoses increased by 1971 (+25.2%), and those of patients with acute respiratory distress syndrome (ARDS) requiring isolation reached 9973 (+109.9%). The LOS increased by 20.8% from 2.55 ± 4.92 days (median 1.05) in 2018/2019 to 3.08 ± 5.87 days (median 1.11 days; p <0.001), resulting in an additional 19,753 inpatient days. The nine equivalents of nursing manpower use score (NEMS) of the first nursing shift (21.6 ± 9.0 vs 20.8 ± 9.4; p <0.001), the total NEMS per patient (251.0 ± 526.8 vs 198.9 ± 413.8; p <0.01) and mortality (5.7% vs 4.7%; p <0.001) increased in 2020. The number of ICU beds increased from 979 to 1012 (+3.4%), as did the number of beds equipped with mechanical ventilators (from 773 to 821; +6.2%).

CONCLUSIONS: Based on a comprehensive national data set, our report describes the profound changes triggered by COVID-19 over one year in Swiss ICUs. We observed an overall decrease in admissions and a shift in admission types, with fewer planned hospitalisations, suggesting the loss of approximately 3000 elective interventions. We found a substantial increase in unplanned admissions due to respiratory diagnoses, a doubling of ARDS cases requiring isolation, an increase in ICU LOS associated with substantial nationwide growth in ICU days, an augmented need for life-sustaining therapies and specific therapeutic resources and worse outcomes.

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Introduction

The coronavirus disease 2019 (COVID-19) pandemic has strained health services worldwide. In selected areas, the rapid increase of COVID-19 patients requiring hospitalisation overburdened acute healthcare systems, including intensive care units (ICUs), as seen in northern Italy, Madrid and New York [1–3]. Even in less affected jurisdictions, the anticipation of a potential surge in ICU admissions and the diversion of human resources forced government and healthcare administrators to transiently limit elective interventional and outpatient activity [4–6]. Interestingly, while some districts had to expand ICU capabilities to meet the need for ICU beds, the incidence of some acute conditions routinely managed in ICUs (e.g. acute coronary syndrome, intracranial haemorrhage, stroke and major trauma) declined drastically during the first wave of the pandemic [7–11], leading to an overflow of vacant ICU beds in other regions. Consequently, regional, national and sometimes international coordination bodies for intensive care had to be established [1, 12–14].

In a study conducted in Alberta, Canada, where the ICU bed base was 9.7 ICU beds per 100,000 population and

where there were 2335 COVID-19 cases per 100,000 population in 2020, the number of ICU admissions, the ICU length of stay (LOS) and mortality decreased during the lockdown compared to non-lockdown periods [15]. In Japan, where there were approximately five ICU beds per 100,000 population and 192 COVID-19 cases per 100,000 population in 2020, ICU admissions and organ support procedures declined substantially, while mortality and LOS remained stable compared to non-pandemic periods [16].

Switzerland reported its first coronavirus case on 20 February 2020. On 16 March 2020, given the rapid rise of COVID-19 cases, the Swiss government put the nation into a semi-lockdown until 11 May 2020 to prevent the collapse of the healthcare system [17, 18]. By the end of the year, the country had accumulated 452,296 laboratory-confirmed cases (5232/100,000 inhabitants), 18,630 hospitalisations (215.5/100,000 inhabitants) and 7082 deaths (81.9/100,000 inhabitants) associated with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection [19].

Given the different levels of pressure imposed on Switzerland by COVID-19, examining how the national critical care system responded to the pandemic will help future critical care planning. We hypothesised that ICU admissions, diagnostic patterns, human resource utilisation and outcomes changed during the first year of the COVID-19 pandemic, albeit with possible regional variation. Accordingly, we conducted a nationwide registry-based study to explore the characteristics of all patients admitted to certified ICUs in Switzerland in 2020 and compare them with a historical cohort from the previous two years (2018 and 2019).

Materials and methods

Design, setting and population

We performed a retrospective cohort study involving all patients aged ≥ 16 years admitted to any of the 84 certified Swiss ICUs. Given the type of study, no protocol was prepared. Switzerland (2021 population: ~8.7 million [20]) has an ICU bed base of approximately 11.4 per 100,000 inhabitants. ICUs operate with a “closed” model and are staffed with certified intensivists. Inter-hospital ICU transfers could occur in response to limited ICU capacity (e.g. no available beds) due to the need for specialised services (e.g. extracorporeal life support) or to centralise COVID-19 patients in designated ICUs (e.g. Ticino).

Data source

The Swiss ICU Registry (Minimal Dataset for ICUs, MDSi) systematically collects essential variables describing the structural characteristics of all certified Swiss ICUs (once a year) and a set of process data for every patient admitted, such as information on admission (e.g. time, whether planned or unplanned, etc.), the severity of illness, the diagnostic group, interventions, daily process variables and discharge details. Submitting this information to the MDSi is mandatory; consequently, the data reflect the situation at the national level [21]. The data quality of the MDSi has recently been assessed, and the results have been published [22]. The expansion of the pandemic did not allow timely mapping of COVID-19 in MDSi. Therefore, we used the combination of acute respiratory distress syndrome (ARDS) plus isolation during the ICU stay as a surrogate for severe COVID-19 pneumonia [23].

Objectives

Our study aimed to explore COVID-19-induced changes in Swiss ICUs over one year by comparing the data from 2020 with the average of figures from 2018 and 2019. We divided the objectives of our study into four groups: (a) to analyse the impact on admissions and patient characteristics, including the number of daily ICU admissions and its weekly moving average and the number of daily unplanned admissions with respiratory diagnoses and its weekly moving average; (b) to investigate whether patients had a different LOS in 2020 compared to the previous years; (c) to analyse whether mortality changed in 2020 and (d) to explore the impact of COVID-19 on the use of hospital resources, i.e. staffing and equipment.

We extracted the following data from the Swiss ICU Registry for the years 2018, 2019 and 2020 (1 January to 31 December):

- Number of admissions at the national level and in the seven major regions defined by the Swiss Federal Statistical Office [24].
- Patient characteristics: age, sex, diagnosis group according to the Swiss ICU Registry regulations (cardiovascular, gastrointestinal, metabolic, neurological, respiratory, trauma or other) [21], occurrence of ARDS and isolation (yes or no), early readmission status (within 48 hours), planned and unplanned admission status, treatment restrictions (present from admission to the ICU or decided during or at the end of the ICU stay), severity of acute illness (determined by the Simplified Acute Physiology Score II, SAPS II [25]) and destination on discharge from the ICU (general ward, step-down unit, inter-hospital ICU transfer, intra-hospital ICU-transfer, acute rehabilitation, home or other).
- LOS in days: overall, of the unplanned admissions with respiratory diagnoses and of the admissions with ARDS and isolation. LOS time-trend analysis: mean and median LOS by day of admission and its weekly moving average.
- ICU mortality: overall, of the unplanned admissions with respiratory diagnoses and of the admissions with ARDS and isolation.
- Use of hospital resources: nine equivalents of nursing manpower use score (NEMS [26]) of the first and the last nursing shifts, total NEMS per patient, total NEMS per patient from the unplanned respiratory diagnosis group, number of nursing shifts per NEMS item, number of full-time equivalents (FTEs) per professional category (specialised ICU nurses, other clinical nurses, nursing assistants, non-clinical nurses, specialised ICU physicians and non-specialised ICU physicians), number of ICU beds and number of ICU beds with mechanical ventilation.

Statistical analysis

Statistical analysis was performed in compliance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist [27]. The sample size was determined by the number of patients aged ≥ 16 years admitted during 2020 to the 84 certified Swiss ICUs. As a control group, we used a historical cohort of patients aged ≥16 years admitted to the certified Swiss ICUs in the previous two years (2018/2019). We used descriptive statistics to analyse demographic, structural and procedural characteristics. Results were given as number of observations (or percentages), mean ± standard deviation (SD), median and interquartile range (IQR) for continuous variables (age and LOS). Both daily and weekly moving averages were used for the time series (number of admissions and LOS by day of admission). Total NEMS per patient served to assess therapeutic nursing workload. Unless specified, all p-values refer to χ^2 tests associated with contingency tables, a Student's *t*-test for the comparison of two groups of continuous observations or a Wilcoxon rank test for highly asymmetric distributions such as that of LOS. No adjustment was made for multiple comparisons. All analyses were conducted using R version 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria).

Ethics approval and consent to participate

The Ethics Committee from Northwestern Switzerland – corresponding to the legal location of the Swiss Society for Intensive Care Medicine – approved the research project (EKNZ UBE-15/47). It was unnecessary to obtain the consent of the included patients due to the retrospective and registry-based study design.

Results

Admissions and patient characteristics

We analysed 242,935 patient records from all 84 certified Swiss ICUs. In 2020, there was a 9.6% reduction in admissions (84,266 in 2018, 83,027 in 2019 and 75,642 in 2020) affecting all major Swiss regions equally, except Ticino, where the number of patients admitted remained stable compared to the average of 2018 and 2019 (p <0.001). The usual net decrease in hospitalisations during the Christmas holidays was followed in 2020 by a substantial reduction during the two COVID-19 waves (figure 1). Low-risk admissions (i.e. SAPS II <20 points) decreased by 16%. In 2020, patients were slightly younger and had a higher acuity, and the proportion of male patients was slightly higher compared to in previous years (table 1). Planned admissions (e.g. following a scheduled inpatient procedure) decreased more than unplanned admissions (–12% vs –8.5%), from 25,020 to 22,021, and this mainly affected the neurological/neurosurgical (–14.9%), gastrointestinal (–13.9%) and cardiovascular (–9.3%) diagnosis groups. The overall reduction in admissions did not affect the respiratory group, whose admissions increased substantially. More patients required unplanned admission to intensive care due to respiratory diagnoses during the two COVID-19 waves of 2020, with two peaks (about 60 admissions per day) twice as prominent as in previous winter flu seasons (figure 2). In 2020, the subgroup of patients with ARDS requiring isolation reached 9973 and more than doubled compared to the 2018/2019 average.

Patient transfers between ICUs increased slightly in 2020, while the locations of the follow-up treatments of the patients after ICU stays remained unchanged. The 48-hour readmission rate was similar between the two periods.

Length of stay (ICU LOS)

The mean ICU LOS increased by 20.8%, generating an increase of 19,753 days of stay (+9.3%) in Swiss ICUs despite the reduction in admissions. This increase was mainly generated by patients with unplanned admissions and respiratory diagnoses (median LOS 3.2 days, IQR 1.2–8.9, vs 2.0 days, IQR 0.9–4.6; p <0.001), who showed a substantial but short-lived peak in ICU LOS during the first wave of COVID-19 and a milder but longer-lasting increase during the second wave (figure 3). The increase in LOS of all other admissions was not significant (median LOS 1.0 days, IQR 0.7–2.2, vs 1.0 days, IQR 0.7–2.1; p = 0.07).

Mortality in ICUs

The proportion of patients with treatment restrictions was slightly higher in 2020 compared to the average in 2018 and 2019 (16.3 vs 15.7%; p <0.001). However, mean mortality increased significantly from 4.7% in 2018/2019 to 5.7% in 2020. This increase was driven mainly by a considerable increase in deaths among patients with unplanned admissions and respiratory diagnoses (13.3% vs 8.1% in 2018/2019; p <0.001).

Therapeutic hospital resources and staffing

The NEMS (± SD) of the first shift increased from 20.8 ± 9.4 in 2018/2019 to 21.6 ± 9.0 in 2020 (p <0.001), while the NEMS of the last shift remained nearly stable (table 2). In contrast, the total NEMS per patient was significantly higher in 2020, mainly due to the vast contribution from unplanned admissions with respiratory diagnoses (238.5, IQR 92–747, vs 148, IQR 72–332; p <0.001).

Breaking down the therapeutic workload by NEMS items, we found a significant increase in shifts with mechanical ventilation, single vasoactive drugs and dialysis techniques in 2020. At the same time, Swiss ICUs employed more human resources from all professional categories except staff with administrative duties: specialised nurses went from 2393 to 2468 FTE (+3.1%), other clinical nurses from 988 to 1127 FTE (+14.1%), nursing assistants from 464 to 549 FTE (+18.4%), non-clinical nurses from 465 to 454 FTE (–2.3%), specialised ICU physicians from 364 to 405 FTE (+11.2%) and non-specialised physicians from 666 to 727 FTE (+9.2%). The number of ICU beds increased from 979 (2018/2019 average) to 1012, representing a 3.4% gain during the 2020 COVID-19 pandemic. The number of beds with mechanical ventilation increased from 773 (2018/2019 average) to 821 (+6.2%).

Discussion

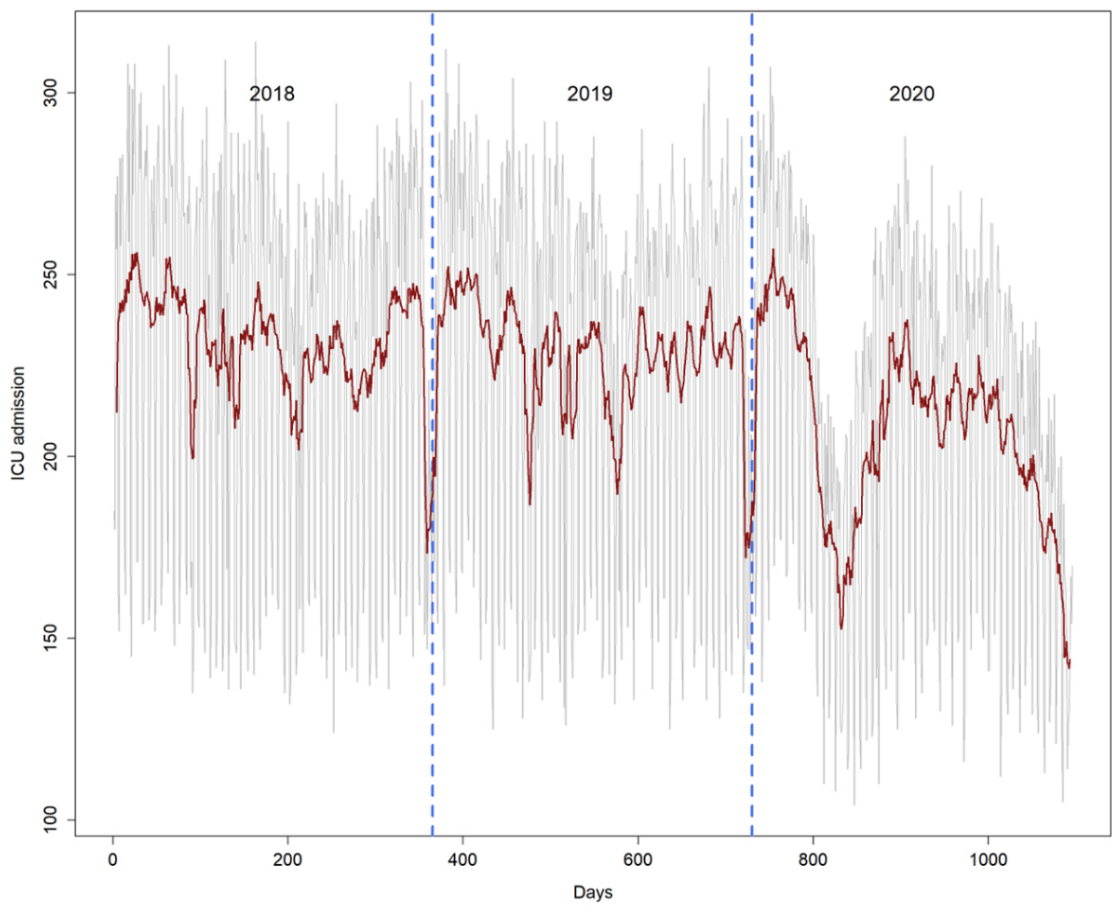
The present study describes the utilisation of ICUs in Switzerland at a national level before and during the first year of the COVID-19 pandemic and presents several key

findings: (a) an overall decrease in the number of admissions, including planned admissions; (b) fewer admissions of low-risk cases (SAPS II <20 points); (c) an increase in unplanned admissions due to respiratory diagnoses and related mortality rates; (d) a nationwide 9.3% increase in ICU bed-days; (e) an increased need for ICU-specific therapies (e.g. mechanical ventilation, vasopressor therapy and renal replacement therapy) and human resources and (f) a significantly higher total NEMS per patient, reflecting longer ICU stays and increased use of ICU-specific therapies.

The countries hardest hit by the pandemic faced a sudden and disproportionate number of hospitalisations. Due to its proximity to Lombardy, the first area outside of China to be overwhelmed by the SARS-CoV-2 epidemic [28], Tici-no was the Swiss region that suffered most during the first wave, while the regions north of the Alps saw a much less aggressive spread of cases. This delay allowed the social distancing measures imposed by the government to mit-igate the impact of the disease and thus avoid overbur-dening hospitals and ICUs in large parts of the country. In parallel, on government instructions, hospitals rapidly reduced and finally ceased elective surgical/interventional activities and created additional *ad hoc* ICU beds to pro-vide a buffer to absorb the increase in patients with COVID-19. Under these circumstances, we found an ab-solute 9.6% reduction in ICU admissions in 2020. There were 14.5% fewer patients in the cardiovascular diagnosis group. Reports from different countries during the first pandemic wave describe a substantial reduction in ICU admissions for acute coronary syndromes [29–35]. This reduction was partly related to patients' reluctance to present to the hospital for fear of contracting COVID-19 or violating social distancing regulations and misinterpretation of heart attack symptoms rather than being a beneficial effect of lifestyle changes during the pandemic lockdown [36]. In addition, a survey conducted by the European Association of Percutaneous Coronary Interventions showed that catheterisation laboratories reduced their activity due to the unavailability of staff and to decrease the risk of infection, thereby admitting fewer patients to ICU for post-procedural monitoring [37]. Cardiac surgical volumes displayed an even stronger decrease, with 30–90% reductions as a result of discontinuing all elective or deferrable surgeries [6, 38–40], and only a partial recovery after the surge [39–42]. In Switzerland, two major tertiary centres confirmed that the overall incidence of patients with acute coronary syndromes undergoing percutaneous coronary interventions was significantly lower, whereas the incidence of transmural myocardial infarction did not differ considerably from that of previous years [43, 44].

In this context, we observed 16% fewer low-risk ICU admissions in 2020, probably due to the reduction of ICU admissions for monitoring patients with acute coronary syn-

Figure 1: Number of daily intensive care unit (ICU) admissions (grey) and its weekly moving average (red) during the study period. The dashed vertical blue lines indicate the calendar year changes. The usual net decrease in hospitalisations during the Christmas holidays (also recognisable during the weeks after Easter and Whitsun) was followed in 2020 by a massive drop during the two COVID-19 waves.



drome or after elective surgery and, in addition, the need to allocate ICU beds to severely ill emergency patients. The reduction in planned ICU admissions from 25,020 (2018/2019) to 22,021 (2020), mainly to the neurological/neurosurgical, gastrointestinal and cardiovascular diagnosis groups, suggests a loss of about 3,000 elective interventions. As reported by several authors, there was a reduction in referrals for evaluation of brain tumours during the lockdown. Some patients with malignant brain tumours changed their initial treatment strategy and often received only simple diagnostic biopsy [45, 46]. In general, about 10% of patients with several solid cancer types did not receive their planned surgical treatment, and those awaiting surgery in a complete lockdown for more than six weeks had an increased likelihood of non-operation. The effect of these changes in therapeutic approach on outcomes has not been reported [5]. In situations with several treatment options (e.g. coronary artery disease), the least invasive option might have been selected to reduce hospital time and avoid intensive care. However, no statistically significant change in in-hospital mortality was demonstrated [40, 41].

Table 1:
Patient characteristics and outcomes.

			Mean 2018/2019	2020	Difference	p-value
n			83,647	75,642	–9.6%	
Age, years		Mean (SD)	65.2 (17.1)	65.0 (16.8)		0.005**
		Median (IQR)	69 (56–78)	68 (56–77)		
Male sex		%	59.6	61.3		<0.001#
Planned admissions		n	25,020	22,021	–12.0%	<0.001#
Unplanned admissions		n	58,627	53,621	–8.5%	
Unplanned admissions, respiratory		n	7807	9778	+25.2%	<0.001#
SAPS II		Mean (SD)	32.1 (17.3)	32.7 (16.9)		<0.001**
		Median (IQR)	29 (21–40)	30 (21–41)		
SAPS II <20 (low risk)		n (%)	17,780 (21.3%)	14,984 (19.8%)	–15.7%	<0.001#
Diagnosis group*						<0.001##
	Cardiovascular	n (%)	26,878 (32.1%)	22,969 (30.4%)	–14.5%	
	Gastrointestinal	n (%)	10,855 (13.0%)	9608 (12.7%)	–11.5%	
	Metabolic	n (%)	5350 (6.4%)	4594 (6.1%)	–14.1%	
	Neurological	n (%)	12,432 (14.9%)	10,860 (14.4%)	–12.6%	
	Respiratory	n (%)	10,501 (12.6%)	12,306 (16.3%)	+17.2%	
	Respiratory: ARDS requiring isolation	n (%)	4751 (5.7%)	9973 (13.2%)	+109.9%	<0.001#
	Trauma	n (%)	4969 (5.9%)	4484 (5.9%)	–9.8%	
	Other	n (%)	12,662 (15.1%)	10,821 (14.3%)	–14.5%	
Length of stay	Overall, days	Mean (SD)	2.5 (4.9)	3.1 (5.9)	+20.8%	<0.001***
		Median (IQR)	1.0 (0.7–2.4)	1.1 (0.8–2.8)		
	Unplanned admissions, respiratory	Mean (SD)	4.1 (6.5)	7.2 (10.0)	+76.4%	<0.001***
		Median (IQR)	2.0 (0.9–4.6)	3.2 (1.2–8.9)		
	ARDS requiring isolation	Mean (SD)	6.6 (11.2)	6.0 (9.3)	–9.6%	<0.001***
		Median (IQR)	2.8 (1.2–6.9)	2.6 (1.1–6.7)		
	Cumulative ICU days	n	213,238	232,991	+19,753 (+9.3%)	
Discharge route						<0.001###
	General ward	n (%)	61,625 (73.7%)	54,554 (72.1%)	–11.5%	
	Step-down unit	n (%)	6052 (7.2%)	5522 (7.3%)	–8.8%	
	Inter-hospital ICU transfer	n (%)	2676 (3.2%)	2901 (3.8%)	+8.4%	
	Intra-hospital ICU transfer	n (%)	233 (0.3%)	300 (0.4%)	+28.8%	
	Inter-hospital transfer	n (%)	3256 (3.9%)	2831 (3.7%)	–13.1%	
	Acute rehabilitation	n (%)	115 (0.1%)	184 (0.2%)	+60%	
	Home	n (%)	3634 (4.3%)	3216 (4.3%)	–11.5%	
	Other	n (%)	2097 (2.5%)	1778 (2.4%)	–15.2%	
Readmission rate		n (%)	1965 (2.3%)	1702 (2.3%)	–13.4%	0.13#
ICU mortality	Overall	n (%)	3961 (4.7%)	4315 (5.7%)	+8.9%	<0.001#
	Women	n (%)	1540 (4.6%)	1532 (5.2%)	–0.5%	
	Men	n (%)	2421 (4.9%)	2783 (6.0%)	+15.0%	
	Unplanned admissions, respiratory	n (%)	634 (8.1%)	1301 (13.3%)	+105.2%	<0.001#
	ARDS requiring isolation	n (%)	471 (9.9%)	1053 (10.6%)	+123.6%	0.14#
Treatment restrictions		n (%)	13,100 (15.7%)	12,336 (16.3%)	–5.8%	<0.001#

*:The grouping of diagnoses is described in the MDSi regulations [21].

**: Student's *t*-test comparing the mean 2020 data with the 2018/2019 data.

***: Wilcoxon rank sum test comparing 2020 data with the 2018/2019 data.

#: χ^2 test of equality of proportion of the admissions with the labelled characteristics among all admissions comparing the 2020 data with the 2018/2019 data.

##: χ^2 test of equality of distribution of the diagnostic categories comparing the 2020 data with the 2018/2019 data.

###: χ^2 test of equality of distribution of the discharge routes comparing the 2020 data with the 2018/2019 data.

ARDS, acute respiratory distress syndrome; ICU, intensive care unit; SAPS II, Simplified Acute Physiology Score II.

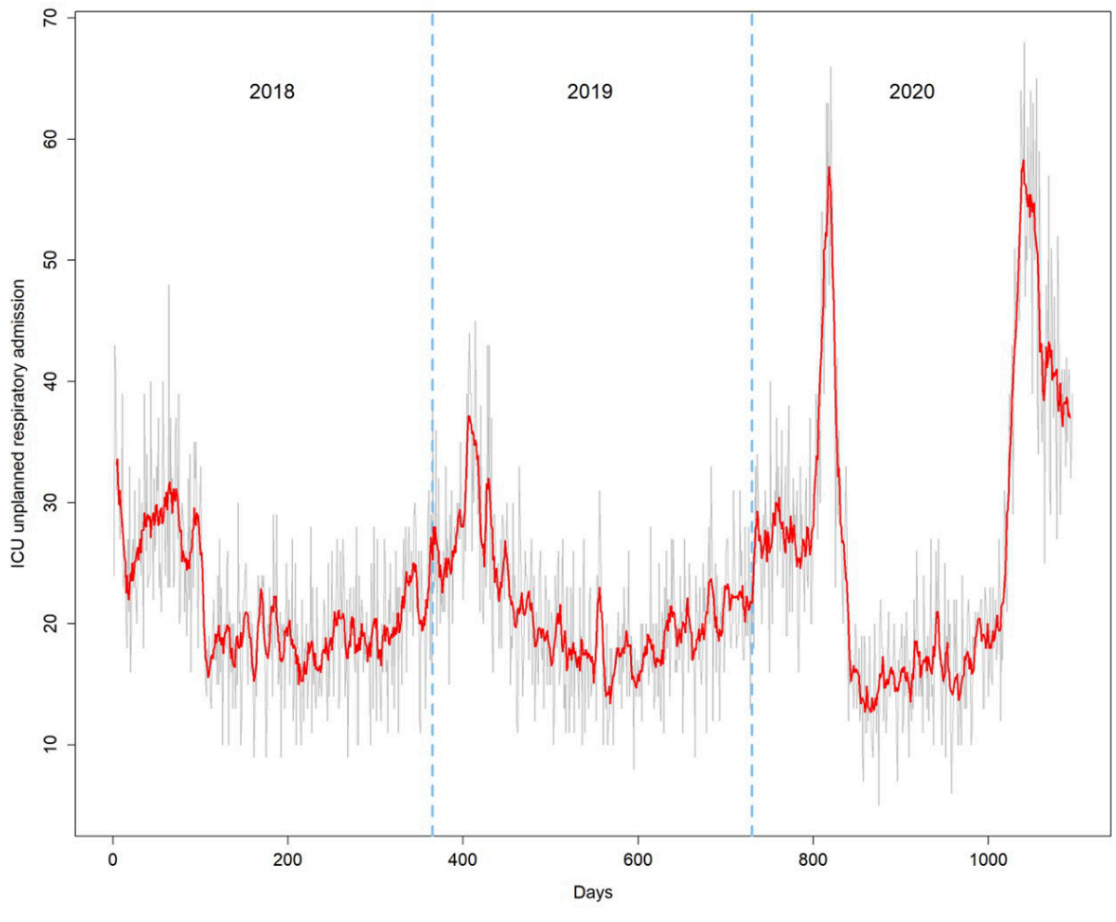
In contrast, we observed a 17% increase in respiratory diagnoses and a doubling of ARDS cases requiring isolation. Although data from our registry do not allow tracing the exact aetiology, it is likely that many of these admissions were due to COVID-19, which explains the higher mortality over the year and the significantly worse outcomes among patients with unplanned admissions and respiratory diagnoses compared to the 2018/2019 control group.

The previous studies in Japan and Alberta, Canada, where the critical care surge of COVID-19 did not exceed the ICU bed capacity, showed a substantial decline in ICU admissions during the first COVID-19 pandemic year and the COVID-19 lockdown, respectively [15, 16]. Despite fewer admissions in 2020, Swiss ICUs recorded about 20,000 more inpatient days due to a significant increase in ICU LOS, mainly driven by unplanned respiratory admissions. On average, such patients remained in the ICU for seven days, almost twice as long as in 2018/2019, while their median LOS increased from 2.0 to 3.2 days. In contrast, the median LOS of patients with ARDS requiring isolation decreased from 2.8 to 2.6 days in 2020, which is significantly shorter than the 9.0 days described in a meta-analysis of studies involving critically ill COVID-19 patients [47]. This difference can have several explanations. First, our cohort might, to some extent, include patients with different characteristics (i.e. aetiology and severity), which the constraints of the Swiss ICU Registry mentioned above do not allow us to identify precisely. Second, management of COVID-19 patients different from that published may result in earlier transfer to a step-down unit or general ward. Finally, the lower LOS could be due to higher early mortality. However, this hypothesis is unlikely to explain the difference, given that patients with unplanned respiratory admissions and those with ARDS requiring isolation in our cohort had a substantially lower ICU mortality (13% and 10.6%, respectively, vs 32%) than those of the meta-analysis of COVID-19 cases [47].

During the pandemic, in 2020, patients were found to require more supportive care and invasive ICU-specific therapies over a longer period of time, as evidenced by an increase in ICU LOS. They required more mechanical ventilation (+55%), more renal replacement therapies (+35%) and more vasopressors (+46%) than in 2018/2019. In addition to indicating greater patient severity, this translated into a 26% increase in the total NEMS.

During the pandemic, Swiss ICUs employed more human resources from all professional categories except staff with administrative duties. However, as they were able to recruit only 3% more intensive care nurses, critical care departments had to mitigate staff shortages by reallocating non-specialised nurses and nursing assistants from other departments. Furthermore, due to reduced elective activity and the closure of operating theatres for scheduled and deferrable operations, it was possible to redeploy medical

Figure 2: Figure 2: Daily unplanned ICU admissions with a respiratory diagnosis (grey) and its weekly moving average (red) during the study period. The dashed vertical blue lines indicate the calendar year changes.



personnel (i.e. anaesthetists and other specialists with some ICU expertise) and thus substantially increase staffing levels. This experience will help in future emergency planning. For example, it has demonstrated the value of preserving the expertise of physicians with specialities other than critical care but with experience in this area and of promoting regular ICU rotations. Furthermore, it has encouraged the establishment of critical care training courses for anaesthesia, emergency room and intermediate care nurses to facilitate flexible work assignments in a crisis such as a pandemic. Finally, given the increase in ICU bed-days, the reduction in elective admissions and the uneven distribution of patients across Swiss regions, the pandemic experience has shown that central coordination is essential to ensure optimal use of resources and equal accessibility to all categories of patients while respecting distributive justice.

The main strengths of our study are its nationwide design, its large sample size within the setting of a homogeneous healthcare system and the good data quality of the Swiss ICU Registry. Nevertheless, there are some limitations. First, this was a retrospective study of registry-based data with possible variation in coding among people and institutions. Second, as the rapid expansion of the pandemic did not allow for a timely mapping of COVID-19 patients in the MDSi, we had to use a combination of two variables (ARDS and isolation) to define this patient group. However, even with this limitation, we were able to illustrate substantial changes in Swiss ICUs that occurred during the COVID-19 pandemic. Third, there might have been some missing data (e.g. additional beds ± mechanical ventilators or inaccurate scoring). Accordingly, structural and procedural data might have been under- or overestimated. Furthermore, the structural data represent the average over the year and do not reflect the fluctuations in beds and staff during waves of the pandemic. Fourth, the Swiss ICU Registry provides only ICU mortality data. Due to different ICU admission and discharge practices in various hospitals, the mortality data need to be interpreted accordingly. Nonetheless, excess mortality in Switzerland during the pandemic year 2020 was in line with that of other European countries [48]. Fifth, unimportant differences might become statistically significant in large-scale registry-based studies. Consequently, we focused on results with clinical and public health relevance. Sixth, our results may not be generalised to other countries because of different approaches and strategies for managing the crisis. Finally, this study was mainly exploratory and used an extensive database to generate hypotheses for further research.

Conclusions

Our report describes the nationwide changes in ICU needs and resource use triggered by the COVID-19 pandemic in 2020: an overall decrease in the number of admissions and

Figure 3: Mean (black) and median (dark green) length of stay (LOS) by day of admission and its weekly moving average (bold lines). The dashed vertical blue lines indicate the calendar year changes.

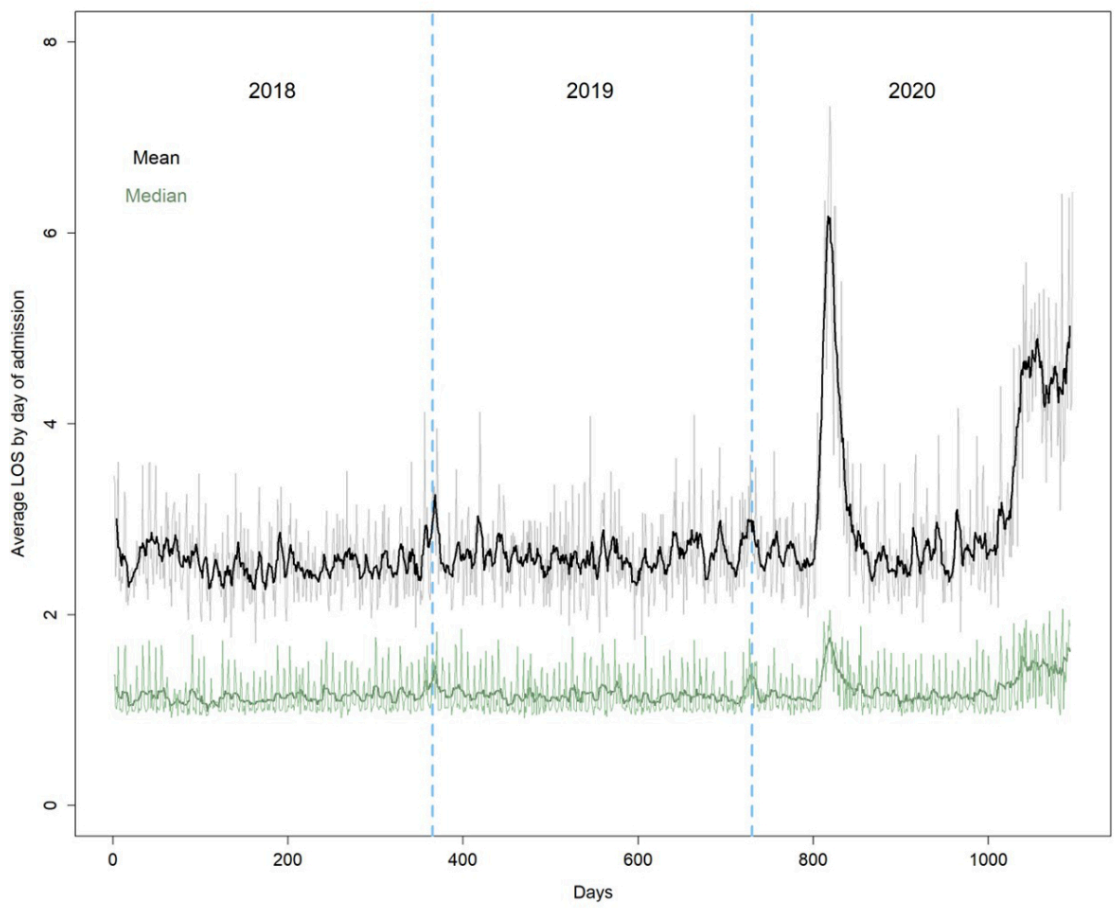


Table 2:
Therapeutic workload and employment of human resources in Swiss ICUs.

Values represent mean (± SD) and median (IQR) in nursing shifts and percent change during the 2020 COVID-19 pandemic compared to the previous period.

P-values were obtained using a Wilcoxon rank sum test comparing 2020 data and 2018/2019 data.

		Average 2018/2019	2020	Difference	p-value
NEMS					
First shift	Mean (SD)	20.8 (9.4)	21.6 (9.0)	+3.8%	
	Median (IQR)	18 (15–25)	18 (15–27)		<0.001
Last shift	Mean (SD)	17.4 (6.0)	17.3 (6.7)	–0.6%	
	Median (IQR)	18 (15–18)	18 (15–18)		<0.001
Total, all	Mean (SD)	198.9 (413.8)	251.0 (526.8)	+26.2%	
	Median (IQR)	84 (54–172)	88 (54–198)		<0.001
Total, unplanned admissions, respiratory	Mean (SD)	324.4 (551.7)	617.7 (918.4)	+90.4%	
	Median (IQR)	148 (72–332)	239 (92–747)		<0.001
Total, all except unplanned admissions, respiratory	Mean (SD)	186.0 (394.7)	196.6 (413.0)	+5.7%	
	Median (IQR)	79 (54–159)	81 (54–162)		0.014
Resource use according to NEMS					
Basic monitoring	Mean (SD)	8.6 (14.7)	10.2 (17.5)	+18.4%	
	Median (IQR)	4 (3–8)	4 (3–9)		<0.001
	Total shifts	*719,947*	*771,145*	*+7.1%*	
Intravenous medication	Mean (SD)	7.7 (13.7)	9.3 (16.8)	+20.1%	
	Median (IQR)	4 (3–7)	4 (3–9)		<0.001
	Total shifts	*648,118*	*704,101*	*+8.6%*	
Mechanical ventilation	Mean (SD)	2.7 (10.2)	4.2 (13.9)	+55.1%	
	Median (IQR)	0 (0–1)	0 (0–2)		<0.001
	Total shifts	*228,531*	*320,441*	*+40.2%*	
Supplementary ventilatory care	Mean (SD)	4.2 (6.8)	4.4 (7.0)	+4.2%	
	Median (IQR)	3 (1–5)	3 (1–5)		0.01
	Total shifts	*351,224*	*331,017*	*–5.8%*	
Single vasoactive drug	Mean (SD)	2.2 (6.5)	3.3 (9.0)	+46.4%	
	Median (IQR)	0 (0–2)	0 (0–3)		<0.001
	Total shifts	*185,814*	*246,076*	*+32.4%*	
Multiple vasoactive drugs	Mean (SD)	0.6 (2.9)	0.6 (3.0)	+3.8%	
	Median (IQR)	0 (0–0)	0 (0–0)		0.48
	Total shifts	*46,104*	*43,265*	*–6.2%*	
Dialysis techniques	Mean (SD)	0.5 (4.8)	0.7 (5.4)	+35.3%	
	Median (IQR)	0 (0–0)	0 (0–0)		<0.001
	Total shifts	*40,350*	*49,401*	*+22.4%*	
Specific intervention in the ICU	Mean (SD)	0.6 (2.4)	0.7 (2.8)	+18.8%	
	Median (IQR)	0 (0–0)	0 (0–0)		<0.001
	Total shifts	*50,410*	*54,079*	*+7.3%*	
Specific intervention outside the ICU	Mean (SD)	0.4 (1.1)	0.4 (1.2)	+5.0%	
	Median (IQR)	0 (0–0)	0 (0–0)		0.40
	Total shifts	*32,628*	*30,991*	*–5.0%*	

CU: intensive care unit; NEMS: nine equivalents of nursing manpower use score.

a shift in admission types, with fewer planned admissions, suggesting the loss of about 3,000 elective interventions; fewer admissions of low-risk cases; an increase in patients with unplanned admissions due to respiratory diagnoses and related mortality rates; a nationwide 9.3% increase in ICU bed-days and a significantly higher total NEMS per patient, reflecting the increased ICU LOS and the increased use of ICU-specific therapies. In future emergencies, a national body should allocate patients requiring intensive care in a coordinated manner to optimise resource use while respecting distributive justice. In the meantime, the expertise of doctors with past ICU experience should be preserved, and training courses for "multi-specialised" nurses in the "resuscitation" area should be developed to obtain a reserve of sufficiently qualified personnel. Furthermore, it is necessary to invest in infrastructure, which must be maintained, to be prepared for future emergencies.

Availability of data and materials

The datasets analysed during the current study are available from the corresponding author upon reasonable request.

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Authors' contributions: AP, MP and BC conceived the study, edited the data and developed the methodology. BC performed the formal analysis. MP and AP drafted, edited and reviewed the original manuscript (equal contributions). AC, MK, HP and RL helped to develop the methodology and participated in drafting the manuscript. All authors approved the final version.

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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

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