

Relationship between intensive care patients and the number of elective surgeries at Charité-Universitätsmedizin Berlin during the COVID-19 pandemic 2020 to 2022

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Summary

Purpose

Coronavirus disease 2019 (COVID-19) led to supply shortages in critical care units worldwide. This study aimed to investigate the effects of pandemic-related bottlenecks on the number of elective surgeries performed at Charité-Universitätsmedizin Berlin. The aim of this study was to determine the extent to which planned surgeries could be performed under the conditions of increased COVID-19 intensive care cases. This analysis provides insights into healthcare system resilience and the ability to maintain regular healthcare services during global health crises.

Method

The data collection covered the COVID-19 pandemic period from the beginning of 2020 to the end of 2022. The number of COVID-19 cases in the ICU and elective surgeries performed at Charité-Universitätsmedizin Berlin were recorded on a daily basis. Regression analysis was conducted to analyze the relationship between the number of COVID-19 cases (intensive care patients) and the number of surgeries performed.

Results

A clear negative relationship was found to exist between the number of COVID-19 intensive care patients and the number of elective surgeries performed. This reflected the fluctuations of the pandemic waves and the measures taken

by hospital management (lockdown, personnel). The analysis showed that an increase in COVID-19 intensive care cases due to COVID-19 led to a reduction of elective surgeries.

Conclusion

Pandemics can trigger different courses in the affected population in terms of their clinical relevance. There is a high risk of maintaining intensive medical care. Health facilities that are intended to provide maximum care for pandemic patients should develop concepts for internal surgical and intensive care logistics at an early stage and agree with regional clinics on patient transfer options.

Take-home message

Effective resource allocation strategies are critical when it comes to maintaining a balance between emergency care for pandemic patients and the continuation of elective surgery, which is critical to the overall health and well-being of patients. By understanding the relationships between ICU occupancy during a pandemic and the reduction of elective surgeries as shown here, healthcare systems can develop better strategies to increase their resilience in future health crises.

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Competing interests

The authors declare no competing interests.

Keywords

COVID-19 – Intensive Care Patients – Surgery – Pandemic Management – ICU

Introduction

The COVID-19 pandemic, which swept across the globe from 2020 to 2022, presented an unprecedented challenge to healthcare systems worldwide. As hospitals grappled with the surge in coronavirus cases, resources were strained, and healthcare professionals faced difficult decisions regarding the allocation of limited resources. One critical aspect affected by the pandemic was the provision of elective surgeries, procedures that are planned in advance and are often non-emergent but essential for maintaining patient health and well-being, among other things.

Elective measures are a solid marker of how stable regular surgeries are in a hospital while also fulfilling elementary functions within the healthcare system. In addition to preventing any deterioration of the patient's state of health and avoiding subsequent interventions due to the delay, other factors are also of relevance [1,2].

One such factor is the psychological burden placed on many patients caused by cancelled procedures, which often cause anxiety in patients as individuals [3]. This might result in unexpected disadvantages in already difficult times of crisis. While a study has found no significant differences in distress levels between pre-pandemic and pandemic postponements, both groups were seen to have experienced high levels of psychological distress [4]. However, in the case of selected cardiac surgeries, postponements were not associated with increased psychological distress or complications [5].

On the one hand, cancellations of elective surgeries also results in financial losses for hospitals, on the other hand, not all healthcare staff whose schedules become available due to these cancellations can be reassigned to pandemic-related care. Highly specialized medicine does not allow everyone involved to utilize their everyday professional skills in crisis situations. Furthermore, the infection as well as the period until recovery and, if applicable, the state of

performance afterwards should not be underestimated [6]. It is also crucial to recognize that medical staff themselves are affected by the pandemic which makes them unavailable for surgeries. It can therefore be assumed that the staffing situation will worsen asymmetrically, resulting in further cancellations and delays. Understanding whether and how the number of cases will now affect regular surgeries to remain capable of acting in the long term will accompany the healthcare system from the first hour of a crisis.

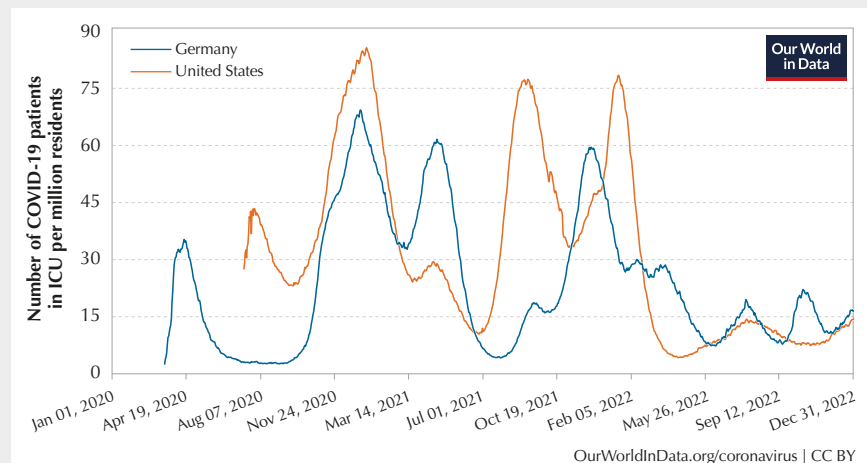
During the pandemic, hospitals and healthcare facilities had to adapt rapidly to the evolving situation, prioritizing the treatment of patients with COVID-19 while simultaneously addressing the needs of other patients also requiring medical attention. These dynamics led to significant changes in the scheduling and availability of elective surgeries, with many procedures having to be postponed or cancelled to reallocate resources, i. e. intensive care unit (ICU) beds, ventilators, and medical staff involving patients with COVID-19.

A study in the United States suggested that up to 25 % of COVID-19 deaths might have been due to inadequate access to intensive care. As the number of patients increased dramatically during

the COVID-19 pandemic, there was a shortage of intensive beds and hospital staff [7]. A survey from **Our World in Data** (Fig. 1) reflected the differences between the number of patients with COVID-19 in the ICU in the US and Germany due to the different COVID-19 pandemic management during the third infection wave from July 2021 until March 2022. According to an early report [8], Germany had sufficient capacity in intensive care units during the first wave due to a large number of hospital beds and careful planning. Nevertheless, healthcare workers struggled with shortages of personal protective equipment (PPE). The lockdown during the first wave of the COVID-19 pandemic led to a decline in planned operations of around 40 % in Germany, although this rate fluctuated significantly when comparing the individual federal states. This may have been due to geographical differences in the rate of spread of COVID-19 [9].

In the second wave, it turned out that the actual capacity of the ICUs was lower than originally estimated due to a lack of beds that were registered by the DIVI report but were not available to use as ICU beds (see DIVI registry 10)). In addition, staff were required to be trained to care for all available beds. Staff training

Figure 1



Daily number of patients with COVID-19 in ICUs per million residents in the United States and Germany from March 2020 to December 2022 (Data source: Official data collated by Our World in Data [14]).

was performed throughout Europe by the CoBaTrICE [11] program using modern virtual reality simulation-based training methods. In addition, telemedicine was performed in Germany, e. g. by the Charité using the “Enhanced Recovery after Intensive Care” (ERIC) innovation fond concept [12]. ERIC was used within the SAVE-Berlin@Covid-19 program of the Berlin Senate, using evidence-based interdisciplinary ICU rounds performed by ICU specialists at the Charité to support ICUs located within the Berlin region [13]. In addition, national and international telemedicine ICU specialist support teams covered the shortages of ICU training for all requested needs of the government pertaining to all beds available.

In retrospect, the question arises as to how strongly the measures resulting from the pandemic influenced regular hospital surgeries, which within this paper was investigated using the example of elective surgery.

Understanding the relationship between the number of patients with COVID-19 requiring intensive care and the provision of elective surgeries is essential for evaluating the impact of the pandemic on healthcare delivery and patient outcomes. By analyzing trends in ICU admissions and the performance of elective surgeries during the pandemic, insights can be gained into the challenges faced by healthcare systems, the trade-offs in resource allocation, and the potential long-term implications for patient care and healthcare policy.

In this study, we focused on the relationship between the number of COVID-19 intensive care patients and the volume of elective surgeries performed during the pandemic from 2020 to 2022. By examining data from healthcare facilities and regions heavily impacted by the pandemic, we sought to elucidate patterns, correlations, and any potential causal relationships existing between these two key aspects of healthcare delivery. Such insights can be useful to inform future pandemic preparedness efforts, resource allocation strategies, and healthcare policy decisions aimed

at maintaining essential healthcare services while effectively responding to public health crises.

Methods

Data from the beginning of 2020 to the end of 2022 were collected and analyzed, covering the COVID-19 pandemic period. The dataset is derived from two primary sources 1) the internal surgical documentation from Charité-Universitätsmedizin Berlin, which includes the number of surgeries performed per day, and 2) hospital occupancy data and DRG coding for COVID-19 ICU cases. Only COVID-19 patients requiring intensive care were included, based on the daily registered COVID-19 ICU cases and elective surgeries (surgery planned and carried out according to the surgical schedule for the respective day). Given that all severe COVID-19 cases were transferred to the Charité through the SAVE-Berlin@Covid-19 telemedicine-supported resource allocation-system [12], specific resource adaptations were made. To accommodate the influx of patients, 40 additional ICU beds were opened at the Charité. Consequently, fewer surgeries were scheduled at the Charité, as anesthesiology staff were primarily reassigned to manage the 40 ICU beds.

The proportion of urgent, unplanned surgeries (classification N0 to N4) [15] was constant over the entire period, accounting for approximately 46 % of the daily scheduled procedures.

Linear regression analysis was conducted to assess the relationship between the number of COVID-19 ICU patients and the number of elective surgeries performed. All assumptions were tested prior to running the analysis, thus confirming the chosen statistical method.

To ensure accurate results, potential confounding factors that could skew the data were filtered out before the analysis. Since no planned surgeries were scheduled on weekends, weekend data were omitted. Similarly, all holidays, including the end-of-year period (December 23 to January 1), were excluded.

Additionally, any days affected by staff strikes at the Charité were removed from the dataset. Ultimately, the initial phase of the COVID-19 crisis (January 1, 2020, to May 31, 2020) was excluded due to the dire situation, uncertainties, resource constraints and staff shortages, which led to the suspension of all non-critical surgeries.

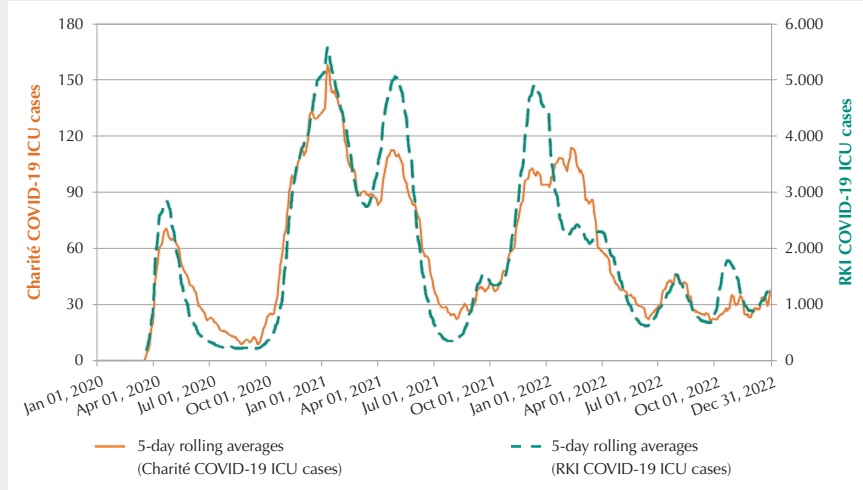
Results

The first case of COVID-19 in Germany was reported to have occurred in Bavaria on January 27, 2020 [12]. Risk assessments and technical guidelines for testing, case finding, contact tracing, hygiene, and disease management, as well as various other documents, were made available. The Robert-Koch-Institute (RKI), Germany's public health institute, began issuing daily situation reports for the national and international public health sectors on January 23 [16].

Following the approach used by the RKI, the daily occupancy trend of the ICU beds used by the COVID-19 patients at Charité-Universitätsmedizin Berlin was calculated. Figure 2 presents the 2-day rolling averages of COVID-19 cases in Germany (based on RKI data) alongside the 5-day rolling averages of patients with COVID-19 at the Charité. The temporal trends remained largely consistent, with only slight deviations visible in August 2022. According to the ICU DIVI registry, ICU bed capacity – both nationally and at the Charité – remained sufficient due to the efficient resource allocation facilitated by SAVE-Berlin@Covid-19 [10]. On average, between 120–140 ICU beds were operational at any given time. The greater need for capacity adjustments such as finding additional ICU beds and cancelling elective surgeries was primarily necessary in the period between late October 2020 to early February 2021.

Assuming that the requirements of the German government and the resulting activities of hospital management over time reflect elective surgeries based on patients with COVID-19 in the ICU, we carried out annual regression analyses.

Figure 2



The 2-day rolling averages of COVID-19 cases in Germany (data of RKI) and the 5-day rolling averages of COVID-19 ICU patients in Charité-Universitätsmedizin Berlin.

Figure 3a shows the annual time course of 2020 for the number of COVID-19 ICU cases and elective surgeries carried out and for which ICU beds had to be available. The results indicated that if the number of COVID-19 cases in the ICUs rose, the number of elective surgeries decreased. Linear regression analysis was conducted to evaluate the extent to which COVID-19 ICU cases could predict the number of elective surgeries (Fig. 3b). A significant regression was found ($F(1,144) = 429.7$, $p < .001$). R^2 was 0.75, indicating that the predictor 'COVID-19 ICU cases' explained 75 % of the variance in the number of elective surgeries. The regression coefficient for COVID-19 ICU cases was found to be -0.75. The number of surgeries ($Y_{\text{surgeries}}$) depends on the number of COVID-19 ICU cases ($X_{\text{COVID-19 ICU cases}}$) and is expressed by the following regression equation:

$$Y_{\text{surgeries}} = 277 - 0.75 \cdot X_{\text{COVID-19 ICU cases}}$$

This means that in 2020, one increase in the number of COVID-19 ICU cases corresponded to 0.75 surgeries that could not be performed as a result of the pandemic. To illustrate, an increase of four patients with COVID-19 in the ICU led to the cancellation of three sched-

ed surgeries. Confidence intervals show that we can be 95 % certain that the slope to predict the number of elective surgeries from the COVID-19 ICU cases ranges between [-0.82, -0.68].

In 2021, the time course of surgeries clearly reflects the timeline of the pandemic (Figure 4a). After the winter peak, a decrease in the number of COVID-19 cases was documented, but a second peak occurred in the spring, followed by the relaxed phase in summer. The following winter peak was comparable to the spring peak. Figure 4b shows the relation between the number of surgeries and COVID-19 ICU cases in 2021. The linear regression analysis revealed a statistically significant model, ($F(1,217) = 458.7$, $p < .001$), with an R^2 of 0.68 and a 95 % confidence interval of [-0.68, -0.56]. This finding suggests that COVID-19 ICU cases accounted for 68 % of the variance in the number of elective surgeries performed. The regression coefficient for COVID-19 ICU cases was determined to be -0.62. The following regression equation expresses the relationship between the number of surgeries ($Y_{\text{surgeries}}$) and the number of COVID-19 intensive care cases ($X_{\text{COVID-19 ICU cases}}$):

$$Y_{\text{surgeries}} = 273.5 - 0.62 \cdot X_{\text{COVID-19 ICU cases}}$$

This indicated that an average decrease of 0.62 surgeries was observed as a result of each additional COVID-19 ICU case. It means that for every five additional ICU cases approximately three scheduled surgeries were cancelled in 2021. Similar to 2020, COVID-19 ICU cases continued to have a large effect on the number of elective surgeries performed in 2021.

As the pandemic subsided in 2022, surgeries could be carried out again without restrictions. Figure 5b shows the scatter plot and line fit for the year of 2022. The results of the regression suggested that COVID-19 ICU cases explained 21 % of the variation in the number of surgeries, ($F(1,245) = 62.97$, $p < .001$), $R^2 = 0.21$, 95 % CI [-0.33, -0.20]. This percentage is considerably lower as compared to 2020 and 2021. The following regression equation expresses the relationship between the number of surgeries ($Y_{\text{surgeries}}$) and the number of COVID-19 intensive care cases ($X_{\text{COVID-19 ICU cases}}$):

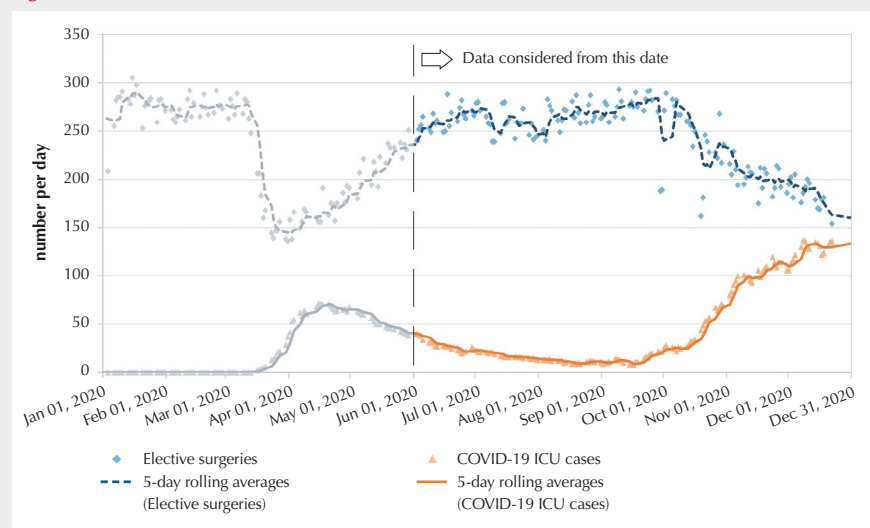
$$Y_{\text{surgeries}} = 241 - 0.27 \cdot X_{\text{COVID-19 ICU cases}}$$

This means that for each additional COVID-19 ICU case, 0.21 fewer surgeries were performed. In practical terms, an increase of approximately five patients with COVID-19 in the ICU resulted in the cancellation of one scheduled operation in 2022. This suggests that there was a reduced impact of ICU patients with COVID-19 on the number of elective surgeries compared to previous years.

Discussion

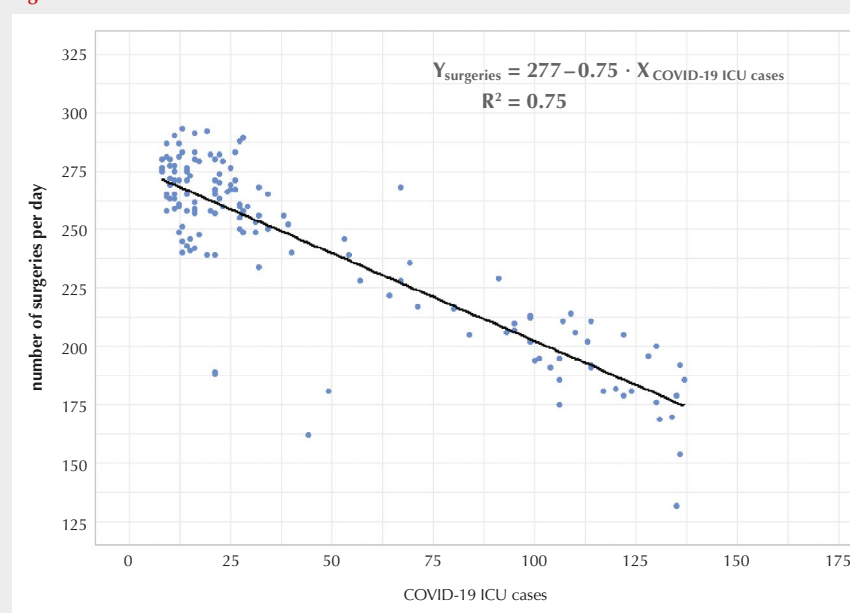
The annual time history of COVID-19 has been characterized by waves of infections, with varying intensity and impact in different regions around the world. Since its emergence in late 2019, COVID-19 has challenged healthcare systems globally, leading to a significant number of hospitalizations and, in severe cases, ICU admissions. However, during the 2021 winter surge, the health system was heavily strained. Hospitals pulled back on regularly provided services to accommodate patients with COVID-19. It also became clear that the number of

Figure 3a



Annual time course of the number of COVID-19 ICU cases in 2020 and elective surgeries carried out for which ICU beds had to be available.

Figure 3b



Number of surgeries performed in 2020 depending on COVID-19 ICU cases.

ICU beds available was not an appropriate measure of the healthcare systems' capacity, as some facilities had beds but lacked sufficient staff to adequately treat the number of patients [17].

In the initial stages of the pandemic, many countries struggled to contain the spread of the virus, leading to large

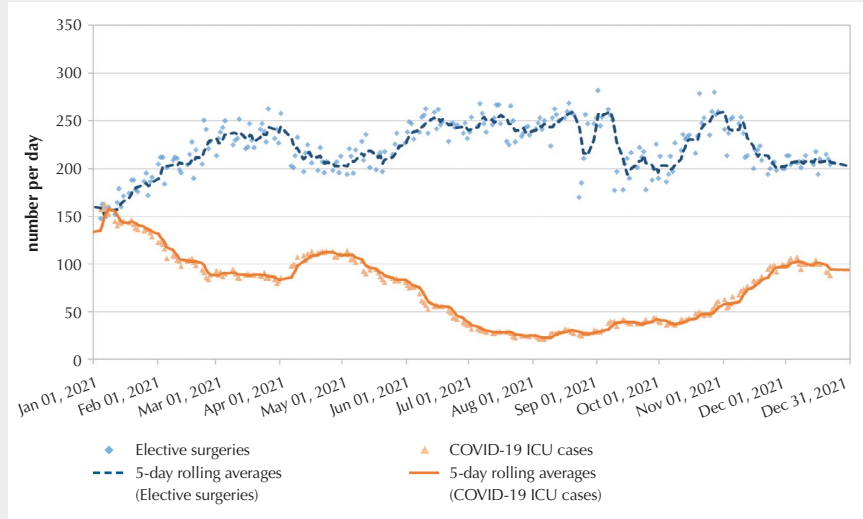
spikes in infections and subsequent strain on healthcare facilities. The first wave, which occurred in early 2020, was particularly devastating in many parts of the world, with healthcare systems overwhelmed by the sudden influx of patients with COVID-19 who required hospitalization and intensive

care. As the pandemic progressed, efforts such as social distancing, mask mandates, and vaccination campaigns were implemented to mitigate the spread of the virus and reduce the burden on healthcare systems. These measures often led to fluctuations in infection rates, resulting in subsequent waves of the virus over time. The number of patients with COVID-19 in ICUs fluctuated in parallel with the overall infection rates. During peak periods of infection, ICUs often experienced a surge in admissions as more individuals required critical care due to the severe respiratory symptoms associated with the virus. This placed immense pressure on healthcare workers and resources, prompting authorities to establish makeshift ICUs, expand existing facilities and mobilize medical personnel to cope with the demand.

This study aimed to investigate the relationship between the number of COVID-19 intensive care patients and the volume of elective surgeries performed during the COVID-19 pandemic from 2020 to 2022. By examining data from Charité-Universitätsmedizin Berlin, which was severely affected by the pandemic, we sought to elucidate patterns, correlations, and possible causal relationships between these two key aspects of healthcare.

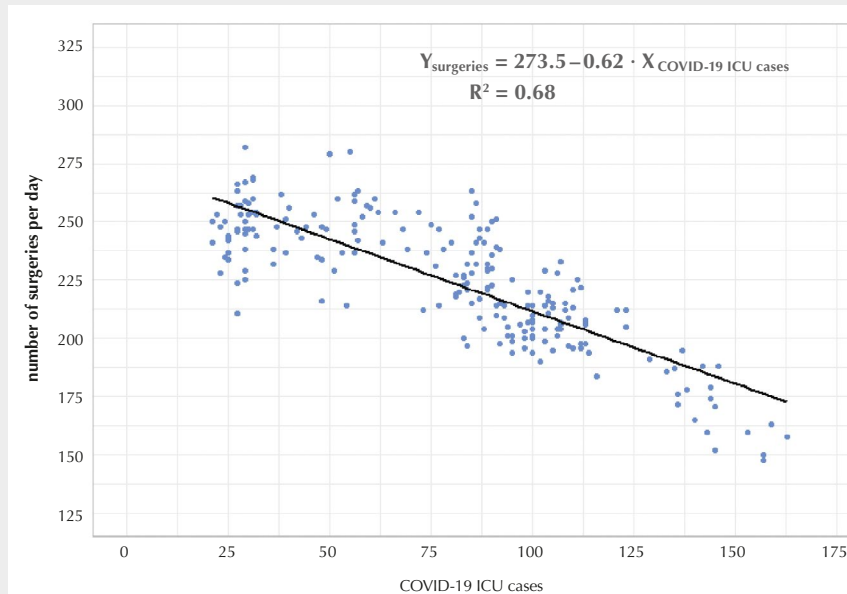
On the one hand, postoperative admission to an intensive care unit is an individual decision and depends on the patient's medical history, previous illnesses, the type of surgical procedure and the course of operation and anesthesia. Nevertheless, specific standard operation procedures (SOPs) of the Department of Anesthesiology and Intensive Care Medicine at the Charité [18] regulate, in consultation with the surgical departments, which surgical procedures generally require intensive medical care due to their complexity (e. g. postoperative ventilation, tracheotomy, perfusion control of transplants, postoperative bleeding risk, special anticoagulation strategies). On the other hand, ICU-SOPs (1) regulate the admission criteria to the ICU (catecholamine and transfusion requirements, drainage situation, etc.). This results in a plannable

Figure 4a



Annual time course of the number of COVID-19 ICU cases and elective surgeries carried out for which ICU beds had to be available in 2021.

Figure 4b



Number of surgeries performed in 2021 depending on COVID-19 ICU cases.

intensive care indication for a large number of surgical procedures, which is supplemented by individual factors of each patient perioperatively.

However, it was uncertain and unpredictable whether a linear relationship existed between the number of planned surgeries and the number of patients

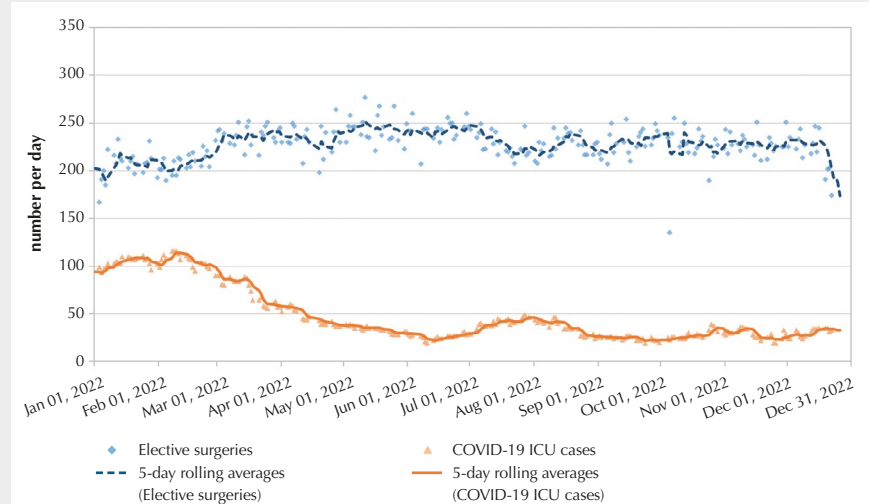
with COVID-19 requiring care in an ICU. According to the data collected in this study, an increase in COVID-19 ICU cases in 2020 was strongly associated with a decrease in elective surgeries by a factor of 0.75. This high level of explained variance underscores the significant disruption caused by the pan-

demic, where an increase of four COVID-19 ICU patients led to the cancellation of three elective surgeries. This demonstrates the ramifications for the healthcare system due to the increase in patients with COVID-19 in the ICU.

The same pattern was also observed in 2021, although its impact was slightly reduced. Despite a slightly lower R^2 value, the effect of COVID-19 ICU cases on elective surgeries remained significant, indicating ongoing challenges for hospital systems. Over time, advancements in treatment protocols, increased testing capacity, and the rollout of vaccines helped to alleviate some of the strains on ICUs. By 2022, the impact of COVID-19 ICU cases on elective surgery had markedly decreased. Several factors likely contributed to the reduced predictive power of the model in 2022. The overall impact of COVID-19 on ICU capacities had diminished due to improved treatment protocols, vaccination campaigns, and better resource management in the hospitals. Unlike in 2020 and 2021, hospitals had adapted to the pandemic, allowing for a more stable continuation of elective surgeries. Additionally, the characteristics of the COVID-19 waves changed, with fewer severe cases requiring ICU admission, reducing the direct link between ICU occupancy and surgical restrictions. Staff shortages were also less disruptive, as fewer healthcare workers were absent due to infection or quarantine. Although new variants of the virus and vaccine hesitancy continued to pose ongoing challenges, they did not lead to a significant increase in ICU admissions, which contributed to the reduced impact on elective surgeries in 2022.

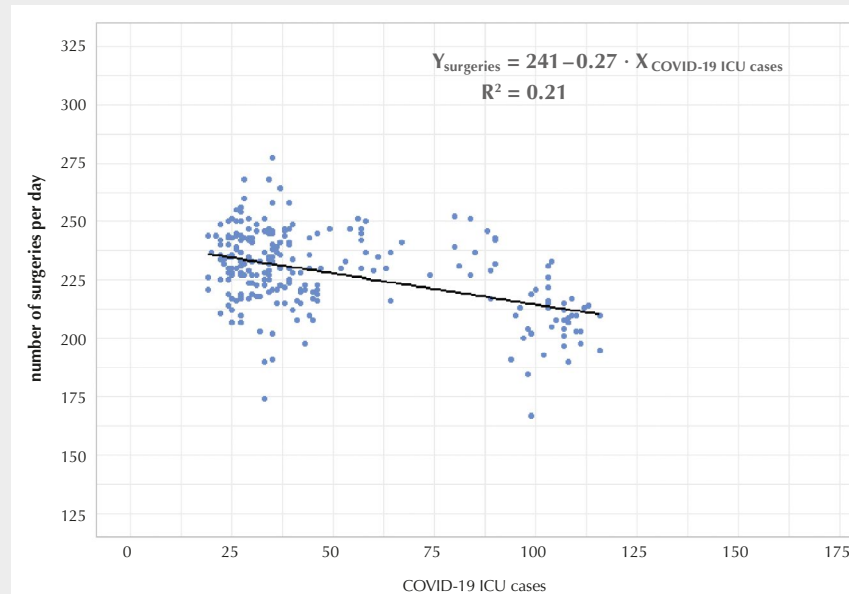
The annual time history of COVID-19 and its impact on ICU patients serve as a reminder of the importance of a robust healthcare infrastructure, proactive public health measures, and a global collaboration in combating infectious diseases. As we continue to navigate the COVID-19 pandemic, ongoing vigilance and adaptation will be crucial in minimizing its impact on healthcare systems and communities worldwide.

Figure 5a



Annual time course of the number of COVID-19 ICU cases in 2022 and the elective surgeries carried out for which ICU beds had to be made available.

Figure 5b



Number of surgeries performed in 2022 depending on COVID-19 ICU cases.

In the course of this comprehensive evaluation, the national research project ResKriVer attempted to draw conclusions for future emergency scenarios. The statistical evaluation of the available data was an elementary methodological tool. Embedded in the context of other national research efforts, a comprehensive contribution to national crisis

preparedness is thus being made. The omnipresent and indispensable importance of the health and medical sectors is illustrated by the data presented here and is also the starting point for active improvement efforts.

However, it should be noted that the results of the regression analyses only

apply to the local conditions of the Charité and the Berlin area during the Corona pandemic. Transferring the results to other hospitals is therefore not easily possible. Against this background, future studies should also discuss whether measures within the hospital organization can improve the maintenance of regular surgeries and thus elective care.

Conclusions

Pandemics can trigger different courses in the affected population in terms of their clinical relevance. In severe cases that involve patients requiring intensive care or a fatal outcome, maintaining regular medical care is exposed to high risks. In particular, the elective occupancy of surgical and intensive care wards as well as operating room capacities will be significantly affected. Health care facilities that are involved in the maximum care of pandemic patients should develop concepts for internal OR and ICU logistics at an early stage and conclude patient transfer options with regional clinics.

In addition, this study highlights the importance of a robust healthcare infrastructure and proactive public health measures in times of a pandemic. Effective resource allocation strategies are critical to maintaining a balance between emergency care for pandemic patients and the continuation of elective surgery, which is critical to the overall health and well-being of patients. By understanding the relationships shown here between ICU occupancy during a pandemic and the reduction of elective surgeries, by being confident about the ICU bed registry [9], by using concepts like SAVE-Berlin@Covid-19 [13] using telemedicine remote specialist ICU treatments, and by concentrating severe cases in certain hospitals with trained staff and available equipment,¹ and by opening beds in these hospitals treating these severe cases, healthcare systems will be able to develop better strategies to increase their resilience to future health crises.

Statements and Declarations

Competing Interests

There are no competing interests.

Funding

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Ethics declarations

The Covid-19 databases are publicly available. Ethics approval of the eICU database was not applicable because it was released under the General Data Protection Regulation of the EU.

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