Neurosurgery Operating Room Efficiency During the COVID-19 Era

Stefan W. Koester, MS, Puja Jagasia, BS, Campbell Liles, MD, Robert J. Dambrino IV, MD, Michael Feldman, MD, Letha Mathews, MBBS, Vikram Tiwari, PhD, and Lola Chambless, MD

ABSTRACT

Background: The COVID-19 pandemic has had broad effects on surgical care, including operating room (OR) staffing, personal protective equipment (PPE) utilization, and newly implemented anti-infective measures. Our aim was to assess neurosurgery OR efficiency before the COVID-19 pandemic, during peak COVID-19, and during current times.

Methods: Institutional perioperative databases at a single, high-volume neurosurgical center were queried for operations performed from December 2019 until October 2021. March 12, 2020, the day that the state of Tennessee declared a state of emergency, was chosen as the onset of the COVID-19 pandemic. The 90-day periods before and after this day were used to define the pre-COVID-19, peak-COVID-19, and post-peak restrictions time periods for comparative analysis. Outcomes included delay in first-start and OR turnover time between neurosurgical cases. Preset threshold times were used in analyses to adjust for normal leniency in OR scheduling (15 minutes for first start and 90 minutes for turnover). Univariate analysis used Wilcoxon rank-sum test for continuous outcomes, while chi-square test and Fisher's exact test were used for categorical comparisons. Significance was defined as $P < .05$.

Results: First-start time was analyzed in 426 pre-COVID-19, 357 peak-restrictions, and 2304 post-peak-restrictions cases. The unadjusted mean delay length was found to be significantly different between the time periods, but the magnitude of increase in minutes was immaterial (mean [SD] minutes, 6 [18] vs 10 [21] vs 8 [20], respectively; $P = .004$). The adjusted average delay length and proportion of cases delayed beyond the 15-minute threshold were not significantly different. The proportion of cases that started early, as well as significantly early past a 15-minute threshold, have not been impacted. There was no significant change in turnover time during peak restrictions relative to the pre-COVID-19 period (88 [100] minutes vs 85 [95] minutes), and turnover time has since remained unchanged (83 [87] minutes).

Conclusion: Our center was able to maintain OR efficiency before, during, and after peak restrictions even while instituting advanced infection-control strategies. While there were significant changes, delays were relatively small in magnitude.

Keywords: operating room timing, hospital efficiency, socioeconomics, pandemic.

The COVID-19 pandemic has led to major changes in patient care both from a surgical perspective and in regard to inpatient hospital course. Safety protocols nationwide have been implemented to protect both patients and providers. Some elements of surgical care have drastically changed, including operating room (OR) staffing, personal protective equipment (PPE) utilization, and increased sterilization measures. Furloughs, layoffs, and reassignments due to the focus on nonelective and COVID-19–related cases challenged OR staffing and efficiency. Operating room staff with COVID-19 exposures or COVID-19 infections also caused last-minute changes in staffing. All of these scenarios can cause issues due to actual understaffing or due to staff members being pushed into highly specialized areas, such as neurosurgery, in which they have very little experience. A further obstacle to OR efficiency included policy changes involving

From the Department of Neurological Surgery, Vanderbilt University Medical Center, Nashville, TN (Stefan W. Koester, Puja Jagasia, and Drs. Liles, Dambrino IV, Feldman, and Chambless), and the Department of Anesthesiology, Vanderbilt University Medical Center, Nashville, TN (Drs. Mathews and Tiwari).

PPE utilization, sterilization measures, and supply chain shortages of necessary resources such as PPE.

Neurosurgery in particular has been susceptible to COVID-19–related system-wide changes given operator proximity to the patient's respiratory passages, frequency of emergent cases, and varying anesthetic needs, as well as the high level of specialization needed to perform neurosurgical care. Previous studies have shown a change in the makeup of neurosurgical patients seeking care, as well as in the acuity of neurological consult of these patients.[1] A study in orthopedic surgery by Andreata et al demonstrated worsened OR efficiency, with significantly increased first-start and turnover times.[2] In the COVID-19 era, OR quality and safety are crucially important to both patients and providers. Providing this safe and effective care in an efficient manner is important for optimal neurosurgical management in the long term.[3] Moreover, the financial burden of implementing new protocols and standards can be compounded by additional financial losses due to reduced OR efficiency.

Methods

To analyze the effect of COVID-19 on neurosurgical OR efficiency, institutional perioperative databases at a single high-volume center were queried for operations performed from December 2019 until October 2021. March 12, 2020, was chosen as the onset of COVID-19 for analytic purposes, as this was the date when the state of Tennessee declared a state of emergency. The 90-day periods before and after this date were used for comparative analysis for pre-COVID-19, peak COVID-19, and post-peak-restrictions time periods. The peak COVID-19 period was defined as the 90-day period following the initial onset of COVID-19 and the surge of cases. For comparison purposes, post-peak COVID-19 was defined as the months following the first peak until October 2021 (approximately 17 months). COVID-19 burden was determined using a COVID-19 single-institution census of confirmed cases by polymerase chain reaction (PCR) for which the average number of cases of COVID-19 during a given month was determined. This number is a scaled trend, and a true number of COVID-19 cases in our hospital was not reported.

Neurosurgical and neuroendovascular cases were included in the analysis. Outcomes included delay in first-start and OR turnover time between neurosurgical cases, defined as the time from the patient leaving the room until the next patient entered the room. Preset threshold times were used in analyses to adjust for normal leniency in OR scheduling (15 minutes for first start and 90 minutes for turnover, which is a standard for our single-institution perioperative center). Statistical analyses, including data aggregation, were performed using R, version 4.0.1 (R Foundation for Statistical Computing). Patients' demographic and clinical characteristics were analyzed using an independent 2-sample *t*-test for interval variables and a chi-square test for categorical variables. Significance was defined as $P < .05$.

Results

First-Start Time

First-start time was analyzed in 426 pre-COVID-19, 357 peak-COVID-19, and 2304 post-peak-COVID-19 cases. The unadjusted mean delay length was significantly different between the time periods, but the magnitude of increase in minutes was immaterial (mean [SD] minutes, 6 [18] vs 10 [21] vs 8 [20], respectively; $P = .004$) (**Table 1**). The adjusted average delay length and proportion of cases delayed beyond the 15-minute threshold were not significantly different, but they have been slightly higher since the onset of COVID-19. The proportion of cases that have started early, as well as significantly early past a 15-minute threshold, have also trended down since the onset of the COVID-19 pandemic, but this difference was again not significant. The temporal relationship of first-start delay, both unadjusted and adjusted, from December 2019 to October 2021 is shown in **Figure 1**. The trend of increasing delay is loosely associated with the COVID-19 burden experienced by our hospital. The start of COVID-19 as well as both COVID-19 peaks have been associated with increased delays in our hospital.

Turnover Time

Turnover time was assessed in 437 pre-COVID-19, 278 peak-restrictions, and 2411 post-peak-restrictions cases. Turnover time during peak restrictions was not

Table 1. **First-Start Time Analysis**

Variable	Pre-COVID-19 (n=426)	Peak-COVID-19 (n=357)	Post Peak-COVID-19 (n=2304)	*P* value
Delay length, mean (SD), minutes	6 (18)	10 (21)	8 (20)	.004
Number (%) of cases delayed >15 minutes	49 (12)	57 (16)	370 (16)	.055
Number of minutes operations were delayed >15 minutes, mean (SD)	37 (35)	43 (36)	40 (34)	.27
Number (%) of early cases	96 (23)	60 (17)	476 (21)	.13
Number (%) of early cases >15 minutes	29 (6.8)	16 (4.5)	100 (4.3)	.085
Overall service composition, No. (%)				.014
Neurointerventional	76 (18)	45 (13)	438 (19)	
Neurosurgery	350 (82)	312 (87)	1866 (81)	

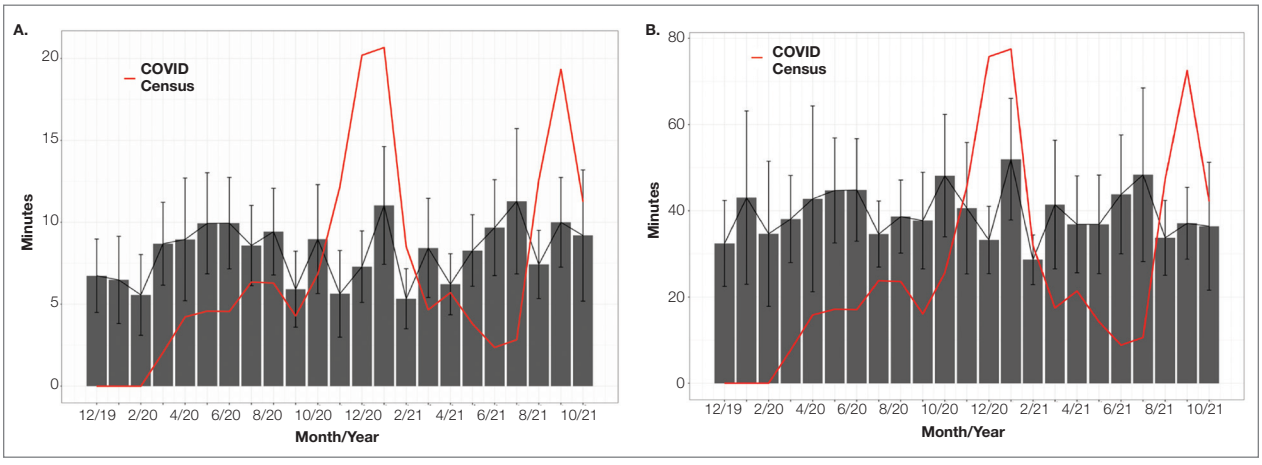

Figure 1. (A) Unadjusted and (B) adjusted first-start delay in operating room efficiency relative to COVID-19 census.

significantly different from pre-COVID-19 (88 [100] vs 85 [95]) and has since remained relatively unchanged (83 [87], *P* = .78). A similar trend held for comparisons of proportion of cases with turnover time past 90 minutes and average times past the 90-minute threshold (**Table 2**). The temporal relationship between COVID-19 burden and turnover time, both unadjusted and adjusted, from December 2019 to October 2021 is shown in **Figure 2**. Both figures demonstrate a slight initial increase in turnover time delay at the start of COVID-19, which stabilized with little variation thereafter.

Discussion

We analyzed the OR efficiency metrics of first-start and turnover time during the 90-day period before COVID-19 (pre-COVID-19), the 90 days following Tennessee declaring a state of emergency (peak COVID-19), and the time following this period (post-COVID-19) for all neurosurgical and neuroendovascular cases at Vanderbilt University Medical Center (VUMC). We found a significant difference in unadjusted mean delay length in first-start time between the time periods, but the magnitude of increase in minutes was immaterial (mean [SD] minutes for pre-COVID-19, peak-COVID-19, and post-COVID-19: 6 [18] vs 10 [21] vs 8 [20], respectively; *P* = .004). No significant increase in turnover time between cases was found between these 3 time periods. Based on metrics from first-start delay and turnover time, our center was able to maintain OR efficiency before, during, and after peak COVID-19.

Table 2. **Turnover Time Analysis**

Variable	Pre-COVID-19 (n=437)	Peak-COVID-19 (n=278)	Post-Peak-COVID-19 (n=2411)	*P* value
Turnover time, mean (SD), minutes	85 (95)	88 (100)	83 (87)	.78
Number (%) of cases with turnover time >90 minutes	89 (20)	59 (21)	498 (21)	.96
Number of minutes turnover time exceeded 90 minutes, mean (SD)	215 (149)	217 (159)	204 (131)	.95
Overall service composition, No. (%)				<.001
Neurointerventional	88 (20)	44 (16)	705 (29)	
Neurosurgery	349 (80)	234 (84)	1706 (71)	

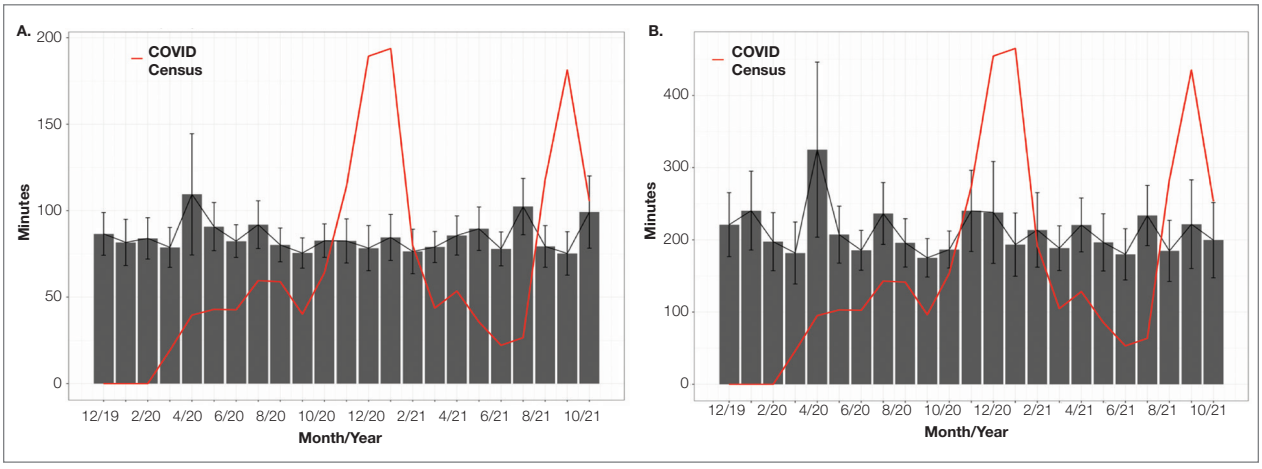

Figure 2. (A) Unadjusted and (B) adjusted turnover time in operating room efficiency relative to COVID-19 census.

After the Centers for Disease Control and Prevention released guidelines recommending deferring elective procedures to conserve beds and PPE, VUMC made the decision to suspend all elective surgical procedures from March 18 to April 24, 2020. Prior research conducted during the COVID-19 pandemic has demonstrated more than 400 types of surgical procedures with negatively impacted outcomes when compared to surgical outcomes from the same time frame in 2018 and 2019.[4] For more than 20 of these types of procedures, there was a significant association between procedure delay and adverse patient outcomes.[4] Testing protocols for patients prior to surgery varied throughout the pandemic based on vaccination status and type of procedure. Before vaccines became widely available, all patients were required to obtain a PCR SARS-CoV-2 test within 48 to 72 hours of the scheduled procedure. If the patient's procedure was urgent and testing was not feasible, the patient was treated as a SARS-CoV-2–positive patient, which required all health care workers involved in the case to wear gowns, gloves, surgical masks, and eye protection. Testing patients preoperatively likely helped to maintain OR efficiency since not all patients received test results prior to the scheduled procedure, leading to cancellations of cases and therefore more staff available for fewer cases.

After vaccines became widely available to the public, testing requirements for patients preoperatively were relaxed, and only patients who were not fully vaccinated or severely immunocompromised were required to test prior to procedures. However, approximately 40% of the population in Tennessee was fully vaccinated in 2021, which reflects the patient population of VUMC.[5] This means that many patients who received care at VUMC were still tested prior to procedures.

Adopting adequate safety protocols was found to be key for OR efficiency during the COVID-19 pandemic since performing surgery increased the risk of infection for each health care worker in the OR.[6] VUMC protocols identified procedures that required enhanced safety measures to prevent infection of health care workers and avoid staffing shortages, which would decrease OR efficiency. Protocols mandated that only anesthesia team members were allowed to be in the OR during intubation and extubation of patients, which could be one factor leading to increased delays and decreased efficiency for some institutions. Methods for neurosurgeons to decrease risk of infection in the OR include postponing all nonurgent cases, reappraising the necessity for general anesthesia and endotracheal intubation, considering alternative surgical approaches that avoid the respiratory tract, and limiting the use of aerosol-generating instruments.[7,8] VUMC's success in implementing these protocols likely explains why our center was able to maintain OR efficiency throughout the COVID-19 pandemic.

A study conducted by Andreata et al showed a significantly increased mean first-case delay and a nonsignificant increased turnover time in orthopedic surgeries in Northern Italy when comparing surgeries performed during the COVID-19 pandemic to those performed prior to COVID-19.[2] Other studies have indicated a similar trend in decreased OR efficiency during COVID-19 in other areas around the world.[9,10] These findings are not consistent with our own findings for neurosurgical and neuroendovascular surgeries at VUMC, and any change at our institution was relatively immaterial. Factors that threatened to change OR efficiency—but did not result in meaningful changes in our institutional experience—include delays due to pending COVID-19 test results, safety procedures such as PPE donning, and planning difficulties to ensure the existence of teams with non-overlapping providers in the case of a surgeon being infected.[2,11-13]

Globally, many surgery centers halted all elective surgeries during the initial COVID-19 spike to prevent a PPE shortage and mitigate risk of infection of patients and health care workers.[8,12,14] However, there is no centralized definition of which neurosurgical procedures are elective, so that decision was made on a surgeon or center level, which could lead to variability in efficiency trends.[14] One study on neurosurgical procedures during COVID-19 found a 30% decline in all cases and a 23% decline in emergent procedures, showing that the decrease in volume was not only due to cancellation of elective procedures.[15] This decrease in elective and emergent surgeries created a backlog of surgeries as well as a loss in health care revenue, and caused many patients to go without adequate health care.[10] Looking forward, it is imperative that surgical centers study trends in OR efficiency from COVID-19 and learn how to better maintain OR efficiency during future pandemic conditions to prevent a backlog of cases, loss of health care revenue, and decreased health care access.

Limitations

Our data are from a single center and therefore may not be representative of experiences of other hospitals due to different populations and different impacts from COVID-19. However, given our center's high volume and diverse patient population, we believe our analysis highlights important trends in neurosurgery practice. Notably, data for patient and OR timing are digitally generated and are entered manually by nurses in the electronic medical record, making it prone to errors and variability. This is in our experience, and if any error is present, we believe it is minimal.

Conclusion

The COVID-19 pandemic has had far-reaching effects on health care worldwide, including neurosurgical care. OR efficiency across the United States generally worsened given the stresses of supply chain issues, staffing shortages, and cancellations. At our institution, we were able to maintain OR efficiency during the known COVID-19 peaks until October 2021. Continually functional neurosurgical ORs are important in preventing delays in care and maintaining a steady revenue in order for hospitals and other health care entities to remain solvent. Further study of OR efficiency is needed for health care systems to prepare for future pandemics and other resource-straining events in order to provide optimal patient care.

Corresponding author: Campbell Liles, MD, Vanderbilt University Medical Center, Department of Neurological Surgery, 1161 21st Ave. South, T4224 Medical Center North, Nashville, TN 37232-2380; david.c.liles.1@vumc.org

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