Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Association for Academic Surgery

The Bottom Line: Trauma Center Viability During COVID-19

Christina Colosimo, DO, MS,* Lilly Sirover, John Porter, MD, and Nicole Fox, MD, MPH

Cooper University Hospital, Trauma, Camden, New Jersey

ABSTRACT

Introduction: The COVID-19 pandemic was a potential threat to the viability of trauma centers and health systems in general. We sought to answer the question of how COVID-19 was associated with patient characteristics as well as trauma center volume, finances, and viability.

Methods: We reviewed 6375 patients admitted to our verified Level 1 trauma center during two time periods: pre-COVID (February 2019-February 2020) and COVID (March 2020-March 2021). Three thousand ninety-nine patients were admitted pre-COVID and 3276 were admitted during COVID. Data including case-mix index (CMI), total contribution margin, insurance status, age, race, gender, ethnicity, and injury mechanism were collected from the trauma registry and finance databases and analyzed. A $P < 0.05$ was considered significant.

Results: Trauma admissions decreased initially during COVID but returned to and ultimately surpassed admission trends pre-COVID. Trauma revenue and patient acuity increased significantly along with a decrease in the number of underinsured patients during COVID. When evaluating all service lines, the trauma center was the highest contributor to overall hospital revenue.

Conclusions: Despite a decrease in admissions for other service lines and a pause in elective surgeries during the pandemic, the trauma center remained unaffected. In addition, trauma was the most significant contributor to the bottom line of the health system. These findings underscore the need to maintain and even increase trauma center resources and staffing to ensure that optimal care is provided to critically ill and injured patients.

© 2022 Elsevier Inc. All rights reserved.

Introduction

The COVID-19 pandemic required hospitals to re-evaluate how they could safely deliver patient care and determine what services were considered essential. This resulted in a pause on elective surgeries and other services based on recommendations from the Center for Medicare Services (CMS). Some health systems reduced employee salaries or furloughed their employees. The American Hospital Association calculated a loss of at least $323 billion in 2020 and between $53-120 billion in 2021 to hospitals and health systems. In 2020 in the state of New Jersey a mid-year
analysis showed that almost 60% of the state’s hospitals were in the red with a statewide operating margin of negative 4%. COVID-19 required hospitals to take measures such as: “redirecting resources to increase staffing, boost supplies of personal protective equipment, pharmaceuticals and ventilators and modify operations and facilities to expand capacity”. These changes in staffing and resources were potentially threatening to trauma center viability. Our institution deployed trauma surgeons to round on medical ICU overflow throughout the early stages of the pandemic. Nurses were also required to cross-train and cover unfamiliar units depending on patient volume and acuity.

It is estimated that the yearly cost of maintaining a level 1 trauma center is roughly 10 million dollars. It is reasonable to assume that if trauma volumes dropped during the pandemic, this cost would not be justified or resources would need to be reallocated. In Lombardia, Italy, for example, regional systems were reorganized based on the American College of Surgeons Committee on Trauma (ACS-COT) guidelines for COVID response. Most level 2 trauma centers were partially or totally converted into COVID-19 hospitals. Factors such as loss of health care, financial support from the government, and changes in injury mechanism were predicted to negatively impact trauma departments. Harborview developed recommendations for trauma centers to maintain their readiness in the COVID-19 pandemic and ensure comprehensive care of the trauma patient at pre-pandemic levels.

Despite the pandemic, Cooper University Hospital’s American College of Surgeons (ACS) verified trauma center experienced high and consistent patient volumes. Our study aims to show how COVID-19 was associated with our trauma center’s finances and overall viability. We analyzed medical, financial, and demographic data to determine whether there were significant changes in patient volume, patient acuity, injury mechanism, and total contribution margin. The goal of this analysis was to provide objective data to ensure appropriate resource allocation for the trauma center to maintain readiness.

Materials and Methods

Six thousand three hundred and seventy-five injured patients were admitted to the trauma center during the study period. IRB approval was not required per institutional guidelines since these were deidentified registry and financial data used for quality improvement purposes. Pre-COVID was defined as (February 2019-February 2020), and COVID was defined as (March 2020-March 2021). Three thousand ninety-nine patients were admitted pre-COVID and 3276 were admitted during COVID. Financial data were analyzed in regard to the hospital’s total contribution margin. Total contribution margin is defined as revenue remaining after subtracting the variable costs. Also included in the analysis were Case-Mix Index (CMI), length of stay, critical care status, insurance status, age, and total trauma admissions. The CMI is the average relative diagnosis related group (DRG) weight of a hospital’s inpatient discharges calculated by adding the Medicare Severity-Diagnosis Related Group (MS-DRG) weight for each discharge and dividing the total by the number of discharges.

Trauma registry data from the department were analyzed in order to obtain the most accurate data on patient demographics and injury characteristics. We compared 9452 patients admitted to Cooper’s trauma center during the same time periods as the data we used to study the finance department. 4562 patients were admitted pre-COVID and 4890 patients were admitted during COVID. This data best reflected how injury mechanism, injury severity, and demographics changed between these two periods of time. The difference of 3077 patients between databases is explained by the ways in which patients are classified in the trauma registry versus the hospital financial database. The Cooper University Hospital trauma performance improvement plan specifies that to ensure consistent data collection across states into the National Trauma Data Standard, trauma patients are defined as a patient sustaining a traumatic injury within 14 days of initial encounter. In addition, they must meet specific diagnostic and institutional criteria. Examples of these criteria would be specific ICD-10 codes, trauma team activations, and patients who died with a traumatic mechanism. In contrast, the financial database attributes patients to the trauma service line who had ANY evaluation by the trauma team. This could include, for example, patients involved in a traumatic event that subsequently had no injuries identified on further workup or patients that sustained injuries outside of the 14-day window that were evaluated and cared for by the trauma service.

Graph analysis was used to compare trends in hospital admissions during the two time periods. P-value calculations were used to determine whether changes in various factors associated with trauma economics were significant during COVID. To analyze hospital financial data the individual service line contributions in dollars were calculated as a percentage of the hospital’s total contribution margin. Admissions by individual service line were calculated as a percentage of total hospital admissions and chi-square analysis was performed. Continuous data were evaluated for distribution normality using the test of skewness (sk). Normally distributed data were analyzed using an independent t-test. Data that were not normally distributed were analyzed using the Mann–Whitney U-test. For categorical data, the Fisher’s exact test and the chi-square test were used with Yates correction. If P values were <0.05, changes were considered significant.

Results

During COVID, there were 3099 patients admitted (9%). Before COVID, there were 3276 trauma patients admitted to the hospital (7%). Sixty-two percent of patients were male with a median age of 47 years (Table 1). Fall was the most prevalent mechanism throughout both time periods followed by motor vehicle crashes (Fig. 1). During COVID, trauma admissions decreased slightly early in the pandemic, but returned to and surpassed admission trends pre-COVID (Fig. 2). During both time periods, partial activations were the highest at our trauma center (Fig. 3). Partial activations included transfers.
Full and partial activations were higher during COVID; however, consults were higher in the pre-COVID period.

In terms of trauma center finances, the total contribution margin was $72,227,075 during COVID and $68,770,687 pre COVID. Trauma patients during COVID were an overall higher percentage of total admissions to the hospital (8% versus 7%). Average case-mix index (patient acuity) and injury severity as measured by ISS were higher during COVID and the percentage of uninsured patients was lower (Table 2). The percentage of Medicare patients, average length of stay and number of admissions to the ICU were similar.

Trauma contributed $72,227,075 to the hospital’s total contribution margin during COVID and was the second highest contributor to the total hospital contribution margin at 21% (Tables 3 and 4). Overall, across the 24-month period, trauma contributed most significantly to the hospital’s total revenue with a contribution margin of $140,997,762.

**Discussion**

It is well established that trauma centers serve as a vital national resource. The timely care of critically ill and injured patients at a trauma center reduces morbidity and mortality. Reducing trauma center resources will have significant repercussions. It is clear from the data presented that despite prior predictions traumatic injuries persisted despite the pandemic. If trauma departments are not equipped with necessary resources, then they will not be able to provide essential care. In addition, trauma centers often serve vulnerable communities, who rely on trauma centers being prepared and accessible.

Although prior research was correct in their conclusion that trauma services are dependent on patient volume, trauma volumes varied during the pandemic. A recent analysis in Los Angeles, CA demonstrated that a transient decrease in trauma volume was followed by a quick return to baseline levels. The authors concluded that “trauma centers should prioritize maintaining access, capacity, and functionality during pandemics and other national emergencies”.

This reflects the experience in Camden, NJ where an initial decrease in volume occurred, followed by an increase over the rest of the comparison months (Fig. 2). There was an increase in hospital admissions between the two time periods (pre-COVID 9% and during COVID 10%) (Table 5). Critically ill and injured patients continued to present to Cooper’s trauma service, with an increase in patient acuity. The average patient CMI during COVID was 3 (increased from 2). This increase in CMI is important as CMI shifts of even 0.1000 can have a significant impact on hospital finances. While it is expensive to maintain trauma departments, it is crucial for hospitals to recognize the value and importance of heavily resourcing this department.

An increase in specific injury mechanisms was observed. There are several possible reasons why motor vehicle collisions increased during quarantines. According to the National Highway Traffic Safety Administration, even though Americans drove less miles during 2020, the number of fatal motor vehicle traffic collisions significantly increased. Thirty-eight thousand six hundred and eighty drivers died due to MVCs, which is the largest number of crash fatalities since 2007. With roads being less populated, it is possible drivers were more inclined to drive faster, unrestrained, or under the influence of alcohol. These risky behaviors contributed to the increase in motor vehicle mechanisms. The number of older patients presenting with injuries from falls may be a result of decreased physical activity. Older individuals may not be able to exercise due to quarantine, lack of equipment, or fear of...
sharing equipment at a public gym.\textsuperscript{15} As a result of less activity, older individuals may experience weakness and be more susceptible to falls that require medical attention. Another explanation was increased isolation, which could lead to less assistance and supervision. Finally, the increase in penetrating trauma could be a result of increased stress associated with stay-at-home orders or financial distress. Firearm violence increased nationally as demonstrated in several studies.\textsuperscript{10,14} A study from the University of Pennsylvania concluded that gunshot wounds increased by 39\% after March 16, 2020.\textsuperscript{16}

Prior research predicted that high unemployment rates would cause patients to lose health care insurance, which in turn would lead to decreased trauma center profitability.\textsuperscript{2} Our findings demonstrate that the number of uninsured patients presenting to trauma services decreased from 14\% to 10\% uninsured during COVID. There was no difference in percentage of Medicare patients (19\% versus 19\%). This data suggests that consequences of the pandemic related to employment and insurance did not significantly alter Cooper’s trauma finances.

Trauma centers are profitable in many hospitals and maintain revenue with consistent patient volumes as compared to other service lines with more variability. As demonstrated by Table 4, Cooper’s trauma services contributed approximately 21\% to the hospital’s overall total contribution margin pre-COVID, during COVID, and overall. Trauma departments are consistent and reliable in contributing to hospital revenue, as trauma will continue despite crises. In fact, during the COVID pandemic the amount of revenue was increased from the year prior.

This study has some limitations. First, it is a retrospective evaluation using data from the trauma registry and the hospital finance database. In addition, clinical outcomes such as adjusted mortality and overall quality metrics were not evaluated. Finally, it is important to note that the results are specific to Cooper and its trauma department. There was a discrepancy in the number of patients recorded in the financial database and trauma registry. Different classification systems can account for this discrepancy. Nonetheless, these results should convince other hospitals to analyze their finances because making decisions regarding resource allocation. As suggested by our data, trauma will continue even during a global health crisis. It is imperative that hospitals recognize the importance of maintaining the trauma center and resourcing it appropriately to ensure safe and effective patient care.

### Conclusions

The trauma center can be a consistent and significant contributor to health system finances even in times of a global pandemic.
Reducing staffing or resources to a trauma department is negatively correlated to hospital revenue and patient care. Our findings underscore the need to maintain and increase trauma center resources and staffing to ensure that they can provide optimal care for critically ill and injured patients and be prepared for future crises.

Study Type
Retrospective study.

Level of Evidence
Level VI.

Authors Contributions
CC—Preformed analysis, wrote the paper. LS—collected the data, conceived and designed analysis, preformed analysis, wrote the paper. JP—edited the manuscript. NF—conceived and designed analysis, wrote the paper, edited the manuscript.

Disclosure
None declared.

Funding
None.

Table 5 – Admissions by service line (percentage).

| Service line       | Pre-COVID | COVID  | P-value |
|--------------------|-----------|--------|---------|
| Adult medicine     | 24%       | 28%    | <0.001  |
| Bone and joint     | 6%        | 5%     | 0.002   |
| Cancer             | 11%       | 9%     | <0.001  |
| Cardiovascular     | 11%       | 11%    | 0.639   |
| Neurosciences      | 6%        | 6%     | 0.517   |
| Surgical subspecialties | 14%  | 14%   | 0.082   |
| Trauma             | 7%        | 8%     | <0.001  |
| Unclassified       | 0%        | 0%     | 0.002   |
| Women and children | 21%       | 19%    | <0.001  |

Bold text indicates trauma numbers.

References
1. Non-emergent, elective medical services, and treatment recommendations. 2020. Available at: https://www.cms.gov/files/document/cms-non-emergent-elective-medical-recommendations.pdf. Accessed June 15, 2022.
2. Hospitals and health systems continue to face unprecedented financial challenges due to COVID-19. 2020. Available at: https://www.aha.org/system/files/media/file/2020/06/aha-covid19-financial-impact-report.pdf. Accessed June 15, 2022.
3. COVID-19 in 2021: the potential effect on hospital revenues. 2021. Available at: https://www.aha.org/system/files/media/file/2021/02/KH-2021-COVID-Impact-Report_FINAL.pdf#page=2. Accessed June 15, 2022.
4. COVID-19’s impact on patient volume in the post-acute setting. CHART Bulletin Series. 2021;22:1-6.
5. Ashley DW, Mullins RF, Dente CJ, et al. How much green does it take to be orange? Determining the cost associated with trauma center readiness. J Trauma Acute Care Surg. 2019;86:765–773.
6. Bank M, O’Neill P, Prince J, Simon R, Teperman S, Winchell R. Early report from the greater New York chapter of the American College of surgeons committee on trauma on the COVID-19 crisis. 2020. Available at: https://www.facs.org/-/media/files/covid19/nyc_chapter_acs_cot_covid19_crisis.ashx. Accessed June 15, 2022.
7. Giudici R, Lancioni A, Gay H, et al. Impact of the COVID-19 outbreak on severe trauma trends and healthcare system reassessment in Lombardia, Italy: an analysis from the regional trauma registry. World J Emerg Surg. 2021;16:39.
8. Choi J, Carlos G, Nassar AK, Knowlton LM, Spain DA. The impact of trauma systems on patient outcomes. Curr Probl Surg. 2021;58:100849.
9. Alharbi RJ, Shrestha S, Lewis V, Miller C. The effectiveness of trauma care systems at different stages of development in reducing mortality: a systematic review and meta-analysis. World J Emerg Surg. 2021;16:38.
10. Haut ER, Leeds IL, Livingston DH. The effect on trauma care secondary to the COVID-19 pandemic: collateral damage from diversion of resources. Ann Surg. 2020;272:e204–e207.
11. Cuschieri J, Robinson B, Lynch J, et al. The covid-19 pandemic: lessons learned for sustained trauma preparedness and responses. Ann Surg. 2021;273:1051–1059.
12. Ghafti C, Matsushima K, Ding L, et al. In trauma admissions during the COVID-19 pandemic in Los Angeles county, California. JAMA Netw Open. 2021;4:e211320.
13. Cobb B. Case mix index pain points. Available at: https://www.mmplusinc.com/kb-articles/case-mix-index-pain-points. Accessed August 7, 2022.
14. Media NHTSA. National Highway traffic safety administration. Available at: https://www.nhtsa.gov/press-releases/2020-fatality-data-show-increased-traffic-fatalities-during-pandemic. Accessed June 15, 2021.
15. De La Cámara MA, Jiménez-Fuente A, Pardos AI. Falls in older adults: the new pandemic in the post COVID-19 era? Med Hypotheses. 2020;145:110321.
16. Abdallah HO, Zhao C. New study reveals disturbing surge in violent injuries during stay-at-home orders citing a media write up for a study. Which to cite? Available at: https://www.facs.org/media/press-releases/2020/violent-injuries-110920. Accessed June 15, 2022.