

Original Research

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Effect of Coronavirus Disease 2019 (Covid-19), a Nationwide Mass Casualty Disaster on Intensive Care Units: Clinical Outcomes and Associated Cost-of-Care

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Abstract

Objective: The COVID-19 pandemic resulted in millions of deaths worldwide and is considered a significant mass-casualty disaster (MCD). The surge of patients and scarcity of resources negatively impacted hospitals, patients and medical practice. We hypothesized ICUs during this MCD had a higher acuity of illness, and subsequently had increased lengths of stay (LOS), complication rates, death rates and costs of care. The purpose of this study was to investigate those outcomes.

Methods: This was a multicenter, retrospective study that compared intensive care admissions in 2020 to those in 2019 to evaluate patient outcomes and cost of care. Data were obtained from the Vizient Clinical Data Base/Resource Manager (Vizient Inc., Irvine, Texas, USA).

Results: Data included the number of ICU admissions, patient outcomes, case mix index and summary of cost reports. Quality outcomes were also collected, and a total of 1304981 patients from 333 hospitals were included. For all medical centers, there was a significant increase in LOS index, ICU LOS, complication rate, case mix index, total cost, and direct cost index.

Conclusion: The MCD caused by COVID-19 was associated with increased adverse outcomes and cost-of-care for ICU patients.

A mass casualty disaster (MCD) is a sudden, calamitous event that significantly disrupts the function of a community or society and causes significant human, material and economic loss.^{1,2} The influence of such an MCD is not only felt by those directly affected, but even more notably by the high-risk populations who are disproportionately harmed in the peri-disaster timeframe, as well as the institutions who care for them.^{3–7} Historically, in the healthcare system, this disproportionate strain is noticed in both the emergency room and the intensive care unit with increased adverse patient outcomes.^{7–10} This is quite tangible given the current Coronavirus disease 2019 (COVID-19) pandemic, which has resulted in over 5 million deaths worldwide and has become a MCD of biological origin.^{3,6–12}

Highlighted during the COVID-19 pandemic, elderly populations are among the most vulnerable populations impacted by MCDs due to their decreased mobility and comorbid conditions.^{13–16} Furthermore, individuals with disabilities and/or denoted to be in a high-risk group delay their presentation to seek medical care, even in the presence of worsening conditions.^{16–27} During the COVID-19 pandemic, once these patients were presented for evaluation, their symptomatology was more severe, and limited inpatient resources were restricted or diverted to care for COVID-19 patients specifically at the intensive care level.^{27–35} In this, the COVID-19 pandemic represents a sustained MCD that influenced multiple aspects of healthcare, which has been uniquely felt at the intensive care level.^{8–11,27,29}

Classically, length of stay (LOS), number of ICU days, death rate, mechanical ventilation days, readmission rates and complication frequency are used to evaluate critically ill patient outcomes.^{9–11,29,31,34–36} However, given the resource utilization needs during the COVID-19 pandemic, the economic burden is also of grave importance. The American Hospital Association estimated the financial impact of lost revenue to America's hospitals and healthcare systems at \$202.6 billion.³⁷ Most studies to date focus on total hospital charges, total hospitalization cost, and direct cost of care as economic metrics of utilization and burden.^{7,26–30} To evaluate the total healthcare strain associated with MCDs, both health and economic outcomes should be considered. There have been limited studies on the impact of MCDs and mass

casualty-associated resource redirection on concurrent intensive care unit (ICU) patient outcomes.^{7,27,38–42} However, there has thus far not been a study investigating both patient and economic outcomes for all patients admitted to an ICU in the timeframe surrounding a MCD. Additionally, the COVID-19 pandemic provides a unique opportunity to investigate the nationwide ICU patient and economic outcomes during a MCD.

We hypothesized that between 2019 and 2020, there was a difference in patient and economic outcomes for critical care patients. This was associated with the strain put on intensive care units by the sustained mass casualty disaster caused by the COVID-19 pandemic and was demonstrated by higher acuity of illness, increased LOS, ICU LOS, complication rate, death rate and cost of care in 2020 compared to a similar cohort in 2019.

Methods

Data source

The Vizient Clinical Data Base/Resource Manager™ (CDB/RM) (Irving, TX) is a collaborative national database of patient outcomes and cost-data from over 700 academic, complex-teaching, and community hospitals.⁴³ It is comprised of data submitted by each of the member institutions after patient discharge, and allows data to be compared within hospital systems, between separate institutions and nationwide. It has previously been used for performance improvement and to evaluate patient health and economic outcomes.^{44–47}

Study design

This was a retrospective and observational cohort study that compared all patients in the Vizient Database admitted to an ICU in 2020 to a historical cohort from 2019.

Timeframe

The timeframes selected were March to November, 2019 and March to November, 2020. This timeframe was selected to capture the first 9 months of the national COVID-19 response in the United States in 2020.

Data acquisition

The database was queried for all patients admitted to an ICU for the time period noted above, and from this query, patient outcomes and summary of cost reports were generated. Results were restricted to patients admitted to an ICU. Inclusion criteria were all medical centers that could contribute complete datasets for the 9-month period in both 2019 and 2020. All major geographic regions of the United States were included. Data could not be separated by race and gender. The hospital type was self-reported by each institution as tertiary academic, regional or community medical centers. Metropolitan communities were defined as those with a population greater than 100000 persons. Rural communities were defined as those with less than 25000. Suburban communities were defined as those with populations between 25000 and 100000.

Collected data description

Outcome data were reported in 2 groups: health outcomes and economic outcomes. Health outcomes observed were the mean length of stay (LOS), expected mean LOS, LOS index (ratio of observed LOS to expected LOS), mean ICU LOS, complication rate

(complications included central line-associated bloodstream infections (CLABSI), catheter-associated urinary tract infections (CAUTI) and ventilator acquired pulmonary infections (VAPI)), observed death rate percentage, expected death rate percentage, death rate index (ratio of observed death rate percentage to expected death rate percentage), and the case mix index (CMI). The CMI is calculated by Vizient™ CDM/RM summing the Medicare Severity-Diagnosis Related Group (MS-DRG) weight for each discharge and dividing the total by the number of discharges.⁴³ The CMI reflects the diversity, clinical complexity and resource needs of the patients being studied.⁴⁸

Economic outcomes investigated were the mean total cost, mean charges, observed mean direct cost, expected mean direct cost and the direct cost index (ratio of observed direct cost to expected direct cost). As mean charges vary by the health system and region, these were excluded in this analysis.

Statistical analysis

IBM SPSS Statistics for Windows, version 27.0 (Armonk, NY) was used for data analysis, and $p < .05$ were considered statistically significant. Each hospital's data were summarized over the 9 months to compare 2019 to 2020. The data were determined to be a normal distribution using the Shapiro-Wilk test. They were summarized with mean and standard deviation. Independent sample *t* - tests were used to compare subgroup means. The financial data were reviewed by the institutional health economist team.

Ethical considerations

Institutional Review Board approval was waived as no personal health information was collected during this study. We collected de-identified data from Vizient™ CDM/RM for all patients admitted to intensive care units over the study period. The data were summarized by month of admission by the Vizient™ CDM/RM prior to investigators obtaining data to prevent release of any personally identifiable health data. Results are represented accurately below.

Results

A total of 1304981 patients from 333 hospitals were included in the study. Data were further subdivided into the type of medical center: tertiary/quaternary academic, regional, and community, as well as community setting: metropolitan, suburban, and rural. (Table 1)

For all medical centers, there was a significant increase in length of stay index, ICU length of stay, complication rate, case mix index, total cost, and direct cost index. (Table 2) There was no significant difference in death rate.

In 2020, patients admitted to the ICU had a statistically significant longer length of stay and increased complication rate compared to 2019. These findings were most significant at hospitals located in metropolitan settings. (Table 2).

The severity of illness significantly increased for all medical centers. This was most noteworthy at tertiary/quaternary and urban medical centers with an observed 10% increase in illness acuity (Table 2).

The cost of hospitalization increased for all medical centers (Table 3) with an additional average of \$3624 per patient in 2020. This was highest at regional medical centers with an average total cost increase of \$5603 per patient.

Table 1. Patient volume by institution and community type

Hospital type	Patient sum, 2019	Patient sum, 2020
All hospital types	716799	588182
Tertiary academic centers	533994	434615
Regional medical centers	79491	67148
Community medical centers	103314	86419
Metropolitan set medical centers	417316	343042
Suburban set medical centers	214890	173137
Rural set medical centers	84593	72003

Table 2. Summary of patient and financial outcomes by hospital type

Outcome investigated	2019 mean (\pm SD*)	2020 mean (\pm SD)	2019 vs 2020 comparison P - value
All medical centers			
LOS index	1.06 (\pm 0.19)	1.09 (\pm 0.20)	$P = 0.015$
ICU length of stay	3.63 (\pm 1.18)	4.30 (\pm 1.37)	$P < 0.001$
Complication rate	8.90% (\pm 3.24)	9.78% (\pm 3.53)	$P < 0.001$
Death rate index	1.10 (\pm 0.36)	1.06 (\pm 0.30)	$P = 0.102$
Case mix index	2.90 (\pm 0.80)	3.18 (\pm 0.86)	$P < 0.001$
Total cost	\$ 31805 (\pm 14264)	\$ 35429 (\pm 15481)	$P < 0.001$
Direct cost index	1.08 (\pm 0.25)	1.12 (\pm 0.25)	$P = 0.017$
Tertiary/quaternary academic medical centers			
LOS index	1.16 (\pm 0.16)	1.19 (\pm 0.15)	$P = 0.059$
ICU length of stay	4.29 (\pm 1.12)	5.04 (\pm 1.29)	$P < 0.001$
Complication rate	10.55% (\pm 3.03)	11.72% (\pm 3.25)	$P < 0.001$
Death rate index	1.16 (\pm 0.37)	1.11 (\pm 0.25)	$P = 0.086$
Case mix index	3.42 (\pm 0.69)	3.76 (\pm 0.75)	$P < 0.001$
Total cost	\$39931 (\pm 15097)	\$43250 (\pm 17184)	$P = 0.038$
Direct cost index	1.16 (\pm 0.25)	1.20 (\pm 0.25)	$P = 0.068$
Regional medical centers			
LOS index	0.98 (\pm 0.15)	1.04 (\pm 0.18)	$P = 0.025$
ICU length of stay	3.05 (\pm 0.77)	3.76 (\pm 0.93)	$P < 0.001$
Complication rate	8.01% (\pm 2.32)	8.82% (\pm 2.64)	$P = 0.032$
Death rate index	1.02 (\pm 0.26)	1.02 (\pm 0.27)	$P = 0.480$
Case mix index	2.63 (\pm 0.58)	2.88 (\pm 0.56)	$P = 0.006$
Total cost	\$25713 (\pm 7969)	\$31316 (\pm 9689)	$P < 0.001$
Direct cost index	0.98 (\pm 0.21)	1.06 (\pm 0.23)	$P = 0.022$
Community medical centers			
LOS index	0.98 (\pm 0.19)	1.01 (\pm 0.22)	$P = 0.155$
ICU length of stay	3.12 (\pm 1.03)	3.69 (\pm 1.21)	$P < 0.001$
Complication rate	7.24% (\pm 2.91)	7.80% (\pm 2.98)	$P = 0.075$
Death rate index	1.07 (\pm 0.37)	1.04 (\pm 0.35)	$P = 0.307$
Case mix index	2.37 (\pm 0.59)	2.59 (\pm 0.63)	$P = 0.004$
Total cost	\$24648 (\pm 9722)	\$ 27423 (\pm 9984)	$P = 0.017$
Direct cost index	1.02 (\pm 0.22)	1.04 (\pm 0.23)	$P = 0.326$

Discussion

The COVID-19 pandemic placed a notable strain on the healthcare system resulting in increased adverse patient outcomes, delay in

care, and increased financial burdens for health systems.^{9,27,31-33,37,39,49} This study supplements existing emergency department research regarding increased adverse outcomes during periods of surge and crowding.^{10,50,51} It demonstrated the association between the COVID-19 pandemic as a MCD and the severity of illness, overall patient length of stay, inpatient complication rates and cost of care on all patients admitted to an ICU during the first 9 months of disaster response in the United States.

First, we noticed that patients admitted to the ICU in 2020 had higher severity of disease. This was seen across all hospital and community types. Higher CMIs could be secondary to increased relative severity weight from COVID-19 associated MS-DRGs. However, this is unlikely as the Center for Medicare and Medicaid Services (CMS) compensated institutions by adjusting the reimbursement rate, not the weight of illness severity.⁵³ This finding may be a means to support the preliminary research that patients delayed presentation to hospitals until their illnesses were critical.¹⁸⁻²⁷ Such delays in seeking care are likely multifactorial but could have played a role in presenting a more severe state.^{22-27,32,33,52} Possible contributors to delay in care include mandatory shutdowns, fear of infection, pandemic-related redistribution of resources, and suspension of screening programs.^{18-27,52}

Next, the data demonstrated inferior patient outcomes in the 2020 cohort. It was found that both the total and ICU LOS were increased, and there were increased rates of complications. The worsened outcomes could be attributed to multiple factors. First, as elective surgical procedures were delayed early in the pandemic, there was a likely decreased number of post-operative patients. However, though the medical acuity is lower in the post-operative patients (i.e., lower Charlson Comorbidity Index and Acute Physiology and Chronic Health Evaluation (APACHE) scores) the LOS and cost of care have been comparable for both surgical and medical admissions.⁵³ Additionally, elective surgeries resumed between 2 and 8 weeks after they were initially delayed as many health systems tried to prevent significant financial loss.^{54,55} Previously discussed, there was increased acuity as noted by the use of the CMI, which could contribute to the increased adverse outcomes. Furthermore, lack of tangible resources such as personal protective equipment (PPE), ventilators, venous access catheters and patient rooms may have contributed to the difference.⁵⁴⁻⁵⁷ Early in the pandemic, there was a severe deficit in PPE for front-line health care workers which resulted in high rates of infection and death.⁵⁴⁻⁵⁷ The lack of PPE and fear of consequences associated with unprotected patient care, likely resulted in decreased frequency of examinations, which potentially affected the ability of providers to detect fluctuations in patients' conditions.^{58,59} Additionally, in some circumstances, ICU care was being supplied by providers who had received minimal training in critical care medicine which affected their ability to pivot as needed with patient care changes.^{60,61} Finally, intangible resources such as time and the provider's emotional capacity to respond to increased stress may potentially contribute to outcomes.^{62,63} Stress in health care providers has been shown to compromise patient care resulting in worsened outcomes.⁶⁴

It was observed that the death rate for patients admitted to the ICU was not significantly changed between 2019 and 2020. Previous patient factors that have been associated with increased mortality are nosocomial infection, advanced age, elevated APACHE scores and a high number of co-morbid conditions. Systemic factors that contribute to an increased number of deaths are low annual patient volume in the ICU, non-tertiary hospital level of care and bed availability.⁶⁵⁻⁶⁹ A factor that likely

Table 3. Cost of hospitalization

Hospital type	2019 total average cost (± SD*)	2020 total average cost (± SD)	2019 vs 2020 total average cost comparison P - value	2019 mean direct cost (± SD)	2020 mean direct cost (± SD)	2019 vs 2020 direct cost comparison P - value
All hospitals	\$31805 (± 14264)	\$35429 (± 15480)	$P < 0.001$	\$18260 (± 9597)	\$20192 (± 10254)	$P = 0.006$
Tertiary/quaternary medical centers	\$39932 (± 15097)	\$43250 (± 17184)	$P = 0.038$	\$24248 (± 10190)	25927 (± 11383)	$P < 0.001$
Regional medical centers	\$25713 (± 7969)	\$31316 (± 9689)	$P < 0.001$	\$13915 (± 4875)	\$17037 (± 5899)	$P < 0.001$
Community medical centers	\$24648 (± 9722)	\$27423 (± 9984)	$P = 0.017$	\$12907 (± 5472)	\$14376 (± 5643)	$P = 0.024$

contributed to the lack of observed change in death rate was the length of the study period. This was potentially secondary to patient deaths occurring on the hospital general inpatient service or the hospice units, as the critical care beds were in high demand. The death rate has historically been impacted by increased strain on ICUs with patient surges, however this was over 7 weeks rather than 9 months.⁶⁹ The 9-month duration, and the wide spectrum of hospitals and health systems included are 2 factors that might have normalized the data of death rate data. Waves of patient surges occurred regionally at different times during the first 9 months of the COVID-19 pandemic which may have caused a false negative error in the unchanged mortality rate.⁴⁹

Lastly, the financial burden sustained by hospitals was significantly higher in 2020 compared to 2019. It is worth noting, this increased cost was in the setting of lower overall patient volumes in 2020. Each ICU patient in 2020 cost an additional average of \$3624. This was greatest at regional medical centers (\$5603) and hospitals in rural communities (\$4238). Like the inferior patient outcomes, this increase was likely multifactorial. The increased length of stay and complication rate would increase costs, although additional financial impact sources such as costs associated with supply and demand discrepancies could have contributed to the difference.

Hospitals underwent multiple changes during the COVID-19 pandemic, including establishing testing centers, increasing bed capacity and developing special pathogens isolation units.⁶⁹ Many hospitals enacted alternative staffing models, such as instructing staff to remain home to abide by social distancing guidelines—this impacted staffing ratios and utilization of critical care resources. Non-emergent surgeries, procedures and imaging were postponed. All these changes impacted hospital revenue yet allowed for the redeployment of resources to the areas of need.^{37,39} Finally, the measures taken to safeguard the health of non-COVID-19 patients and hospital staff, such as additional or repetitive testing and increased hygiene policies, likely contributed to increased costs.

Future directions

The findings in this study merit further investigation. Reasonable next steps would be a detailed investigation of the patient and provider types for the population of this study. If certain medical centers had a higher percentage of inexperienced providers, investigating the resource utilization at those centers would also be a reasonable next step. Additionally, further investigation is warranted to better understand and quantify the financial impacts of MCDs and the costs associated with hospital supply chain changes and needs.

Limitations

There were several notable limitations to this study that warrant discussion. First, this was a retrospective review which can be prone to recall and misclassification bias, and as a descriptive study, the lack of appropriate measurement expression impairs the ability to establish cause and effect relationships. Second, data were obtained from an administrative database and hospitals pay a fee to participate. This has the potential to create disparities in the data as some hospitals may not afford to pay the fee. Additionally, the maintenance of the database is dependent on reporting from each hospital and is dependent on coding strategy and clinical documentation guidelines. This creates the opportunity for variation in data, particularly the calculated expected LOS, mortality rate, and direct cost index. This is most notable in COVID-19 positive patients for whom these expected values may not be formally established. Fortunately, most institutions employ staff experts in billing and coding to optimize reimbursement, which could help minimize the variation in the data used for this study. For the data used in this study, there was no analysis by disease process or patient, and the data reported were a summary of patients admitted by month.

Additionally, we do not know the provider experience, training, or ICU team composition for each of the institutions included in the study. An inexperienced team may compensate with increased resource utilization and overly cautious management. The variability in these dynamics could contribute to the noted outcomes.

Another notable limitation is, given the composite of the information provided, the cost of care between institutions (e.g., an ICU in a major east coast city compared to an ICU in central Midwestern town) is not able to be delineated. Finally, COVID-19 was a unique MCD, and the outcomes may not be generalizable to other mass casualties.

Conclusion

The MCD caused by the SARS-CoV-2 virus was associated with increased adverse outcomes for patients admitted to ICUs nationwide. COVID-19 affected every healthcare system in the United States. ICUs were severely impacted, and this was demonstrated by the increased length of stay, increased ICU length of stay, and higher rates of complications. In addition to the poor patient outcomes, there was increased financial strain placed on healthcare systems demonstrated by higher costs of care for critically ill patients. These findings prompt the need for additional analysis to evaluate the specific causes for these noted poor outcomes.

Supplementary material. To view supplementary material for this article, please visit <https://doi.org/10.1017/dmp.2022.159>

Conflict of interest. There are no financial conflicts of interest to disclose.

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