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# The Detrimental Impact of the COVID-19 Pandemic on Major Trauma Outcomes in the Netherlands

## A Comprehensive Nationwide Study

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**Objective:** To evaluate the impact of the COVID-19 pandemic on the outcome of major trauma patients in the Netherlands.

**Summary Background Data:** Major trauma patients highly rely on immediate access to specialized services, including ICUs, shortages caused by the impact of the COVID-19 pandemic may influence their outcome.

**Methods:** A multi-center observational cohort study, based on the Dutch National Trauma Registry was performed. Characteristics, resource usage, and outcome of major trauma patients (injury severity score $\geq$16) treated at all trauma-receiving hospitals during the first COVID-19 peak (March 23 through May 10) were compared with those treated from the same period in 2018 and 2019 (reference period).

**Results:** During the peak period, 520 major trauma patients were admitted, versus 570 on average in the pre-COVID-19 years. Significantly fewer patients were admitted to ICU facilities during the peak than during the reference period (49.6% vs 55.8%; $P=0.016$). Patients with less severe traumatic brain injuries in particular were less often admitted to the ICU during the peak (40.5% vs 52.5%; $P=0.005$). Moreover, this subgroup showed an increased mortality compared to the reference period (13.5% vs 7.7%; $P=0.044$). These results were confirmed using multivariable logistic regression analyses. In addition, a significant increase in observed versus predicted mortality was recorded for patients who had a priori predicted mortality of 50% to 75% ($P=0.012$).

**Conclusions:** The COVID-19 peak had an adverse effect on trauma care as major trauma patients were less often admitted to ICU and specifically those with minor through moderate brain injury had higher mortality rates.

**Keywords:** COVID-19, impact, major trauma patient, resource utilization, trauma care

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This study was exempted from ethics review board approval because the study used coded data from the existing National Trauma Registry, and patient anonymity was warranted. However, the study was approved by the Scientific Advisory Board, and the Board of the Dutch Emergency Care Network.

Retrospective research with patient files does not fall under the scope of the Dutch legislation of the Medical Research Involving Human Subjects Act (WMO), as the research subjects are not physically involved in the research. The data being researched are also not being gathered for the sake of the research. The research subjects do not have to change their behavior for the sake of the research. Research that is not subjected to WMO legislation does not need to be reviewed by an accredited Medical Research Ethics Committee (MREC) or Central Committee on Research Involving Human Subjects (CCMO).

The lead author, MLS Driessen, affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

M.A.C.d.J. and L.P.H.L. contributed equally to this study.

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The coronavirus disease 2019 (COVID-19) pandemic dramatically changed the demand for healthcare services. It is very likely that the reallocation of medical resources to treat the high numbers of COVID-19 patients significantly impacted acute care for critically injured patients. Especially for major trauma patients, the limited capacity of highly specialized trauma center facilities, including intensive care unit (ICU) capacity, may have had a negative impact on their treatment and outcomes. However, only a few studies have investigated the effects of COVID-19 on the treatment and outcome of trauma patients.[1–7] Moreover, none of these studies, however, solely focused on major trauma patients. Furthermore, these studies were generally based in single centers, with small sample sizes.

In many countries, including the Netherlands, lockdown restrictions were imposed to reduce transmission of the COVID-19 virus and thereby reduce overall pressure on health care. Moreover, to ensure nationwide access to care and effectively distribute the increasing workload, the Dutch government instructed the Dutch Network for Emergency Care to set up a National Centre for Patient Distribution. This became operational in March 2020 during the first peak. Ambulance and helicopter services were used to equally distribute COVID-19 patients across hospitals. The Dutch Network for Emergency Care consists of 11 trauma networks, which in turn consist of a regional level 1 trauma center designated for the care of the most severely injured patients, surrounded by level 2 and 3 trauma hospitals.[8]

With the COVID-19 pandemic and long-lasting pressing demand for resources, including ICU services, an important question arose: whether access and specialized care for major trauma patients was still guaranteed. Therefore, the aim of this study was to evaluate trauma care during the early 2020 COVID-19 peak with a focus on resource use and outcomes for major trauma patients in the Netherlands, particularly for patients with traumatic brain injury (TBI), as they are frequently admitted to an ICU and are at risk of poor outcomes.[9,10]

## METHODS

### Study Design

We performed a comprehensive, nationwide, multicenter, prospective observational cohort study comparing the patient characteristics, operating room (OP) and ICU resource use and outcomes of major trauma patients treated in all trauma patient-receiving Dutch hospitals during the first COVID-19 peak and a 2-year pre-COVID-19 reference period.

The COVID-19 peak in the Netherlands was defined by the period in which the total ICU occupancy exceeded the yearly averaged ICU bed occupancy for 2018 and 2019 (Fig. 1). The 7-week COVID-19 peak period in early 2020 lasted from Monday 23 March through Sunday 10 May. The comparison period included patients admitted from Monday 26 March through Sunday May 13, 2018, and the period from Monday 25 March through Sunday May 12, 2019.

### Data Source

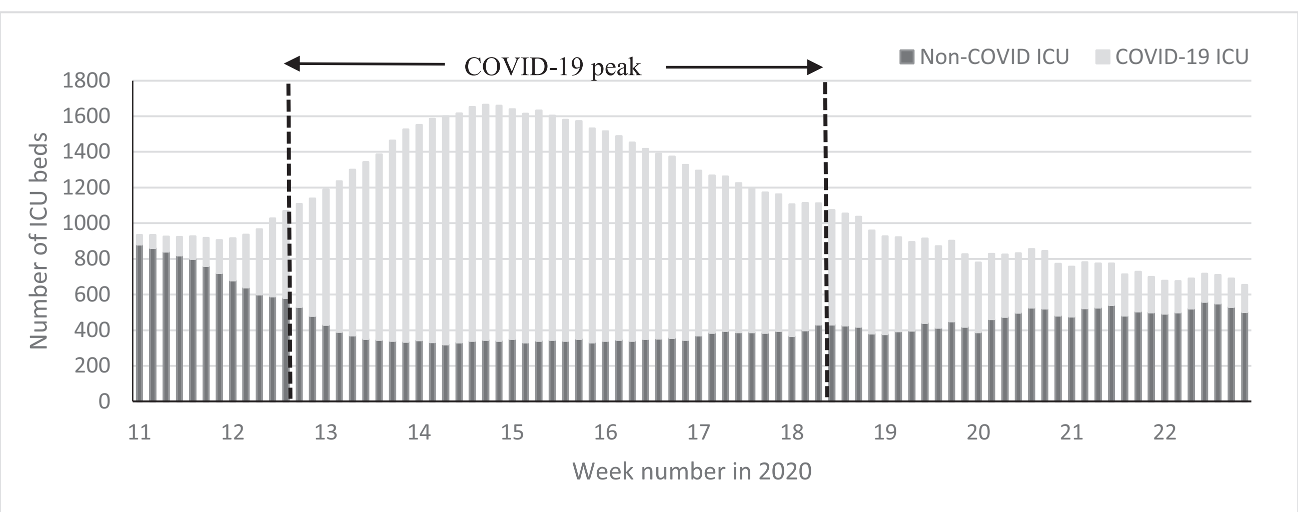
Data were extracted from the Dutch National Trauma Registry (DNTR).[8] The DNTR documents all injured patients directly admitted to a hospital through the emergency department within 48 hours after trauma, regardless of their age, injury location, and severity. Patients without vital signs upon arrival at the emergency department were excluded.[8] Patients were included based on their hospital admission date and the severity of their sustained injury. This study was exempted from ethics review board approval because the study used coded data from the existing National Trauma Registry, and patient anonymity was warranted. Patients or the public were not involved in the design, conduct, reporting, or dissemination plans of our study. The DNTR dataset includes the Utstein template items for uniform reporting of data after major trauma and covers 100% of the trauma-receiving hospitals in the Netherlands.[11] Injuries are coded according to the abbreviated injury scale (AIS) 2005 update 2008.[12] Major trauma patients were defined as having an injury severity score (ISS) $\geq$16.[13] We used categories of head AIS $\leq$3 and AIS $\geq$4 to distinguish minor to moderate brain injuries from severe TBI. Critical resources are those for which accessibility is potentially endangered during a pandemic. In this study, critical resources included acute access to OP and ICU facilities and overall ICU admission. Outcomes were measured as in-hospital and 30-day mortality and disabilities according to the glasgow outcome scale[14] at discharge. To differentiate between disabilities, fatal cases were excluded, and the glasgow outcome scale was dichotomously categorized as either no or mild disabilities versus severe disabilities or vegetative state.

To compare outcomes between the peak and reference period, we compared the predicted mortality and observed mortality for both periods. To calculate mortality probability, we applied the trauma and injury severity score method with updated coefficients based on the Dutch trauma registry data.[15] The trauma and injury severity score combines anatomical (ISS), physiological (revised trauma score), injury mechanism and age characteristics to quantify the probability of patient mortality.

Comparisons between predicted and observed outcomes were performed for 6 bands of equal mortality probability: 0% to 5%, 6% to 10%, 11% to 25%, 26% to 50%, 51% to 75%, and 76% to 100%.

### Statistical Analysis

The study was performed according to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for




(The data used in this graph were obtained from the National Centre for Patient Distribution [LCPS] and the Dutch National Intensive Care Evaluation [NICE] register).

**FIGURE 1.** Dutch national intensive care bed occupancy for an 11-week period from March 8 to May 31, 2020.

observational studies.[16] Missing values were imputed using multiple imputation in statistical program for social sciences.[17] Categorical data are described as numbers (percentages) and were compared using a chi-squared test. Continuous data are expressed as the mean [standard deviation (SD)] or median [interquartile range (IQR), 25th to 75th percentile] for normally or non-normally distributed measurements, respectively, and were compared using a *t* test or a Wilcoxon-Mann-Whitney test, as appropriate. A *P* value of $<0.05$ was considered significant. Statistical analysis was performed using international business machines statistical program for social sciences for Windows, Version 24.0. Armonk, NY: international business machines Corp.[17]

Two multivariable logistic regression models were developed to assess the odds ratios (OR) for IC admission and hospital mortality between the peak and reference period. In these models the effects of the periods (peak or reference) as independent predictors. To test for effect modification between time period and brain injury we included the interaction terms between the peak period and patients that either sustained no brain injuries or minor to moderate brain injuries. In this particular case severe brain injuries were used as the reference group. If an interaction term was not significant, it was not included in the final model. Case-mix correction was performed with the inclusion of age, sex, systolic blood pressure, respiratory rate, glasgow coma scale, ISS, ICU admission (only for the mortality model) in the models.

## RESULTS

### Number of Major Trauma Patients

A total of 520 major trauma patients (ISS$\geq$16) were acutely admitted during the first peak period (49 days), which is 8.7% lower than the average of 569 major trauma patients who were admitted during the reference period. The average weekly number of major trauma patients admitted was significantly ($P=0.027$) lower during the COVID-19 peak period (74, SD 20) than during the pre-COVID-19 era (81, SD 14).

Figure 2 shows the weekly number of admitted major trauma patients and the weekly number directly admitted to the ICU or OP. In parallel to the lower number of admitted patients, the weekly number of patients needing immediate ICU or OP care was lower than that in the reference period.

### Patient Characteristics

The baseline characteristics and the cause of injury of major trauma patients showed no significant differences between the peak and reference periods (Table 1).

### Resource Use and Outcome

Significant differences in resource use were found for median hospital length of stay (LOS), the number ICU admissions and respiratory support in the ICU (Supplemental Digital Content Table 1, http://links.lww.com/SLA/D535). During the peak period the median LOS was 7 days (IQR, 3−−13) which is significantly shorter than the 8 days (IQR, 3–16) in the reference period ($P=0.021$). The percentage of ICU-admitted major trauma patients was lower during the peak period (49.6% vs 55.8%, $P=0.016$). The major trauma patients admitted during the COVID-19 peak received respiratory support relatively more often than their counterparts during the reference period (62.4% vs 50.2%, $P=0.016$). Moreover, the percentage of major trauma patients that received respiratory support during ICU admission increased from 50.2% during the reference period to 62.4% in the peak period ($P=0.049$).

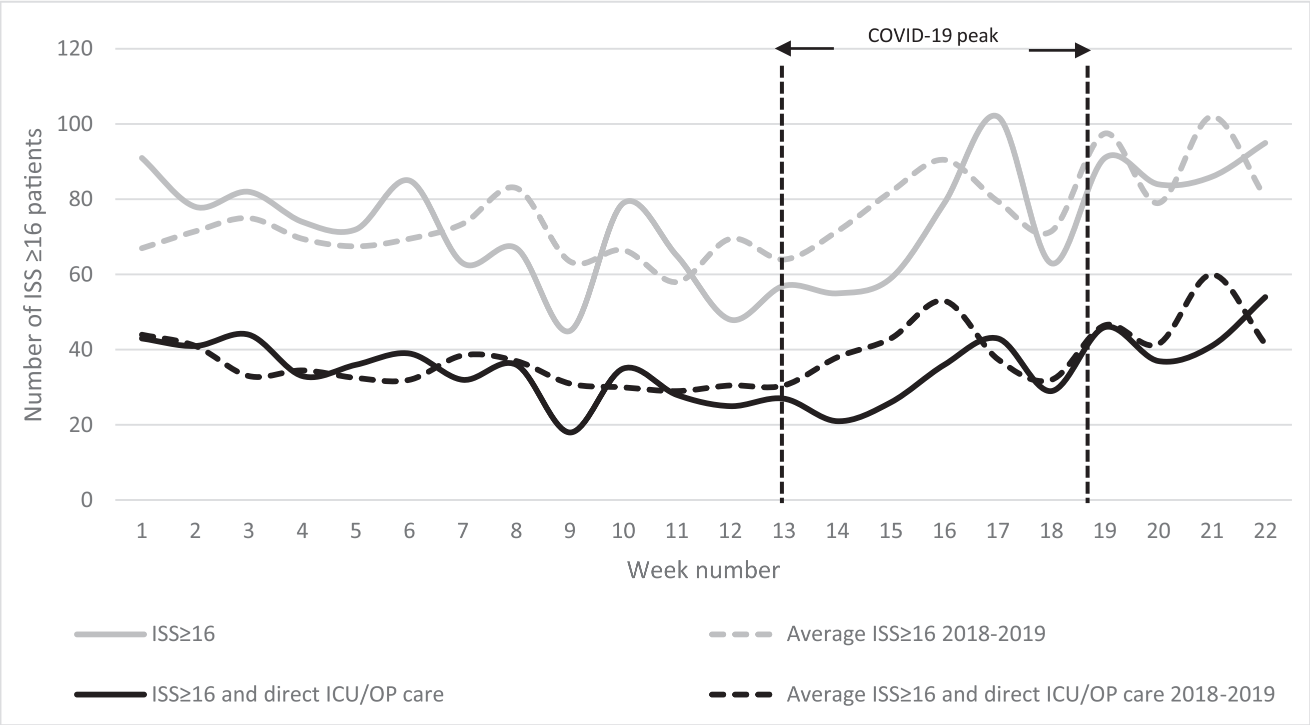



**FIGURE 2.** The weekly number of major trauma patients and the number of major trauma patients directly admitted to the ICU or operating room (OP) during the COVID-19 peak and reference periods.

**TABLE 1.** Major Trauma Patient Characteristics and Mechanisms of Injury of Patients Treated During the First COVID-19 Peak Versus the Reference Periods

| | Peak | Reference | | |
|---|---|---|---|---|
| | 2020 | 2018 | 2019 | *P* Value |
| Total included | 520 | 554 | 585 | |
| Mean inclusions per week (SD) | 74 (20) | 81 (14) | | 0.364 |
| Male sex | 347 (66.7%) | 773 (67.8%) | | 0.647 |
| Median age (IQR) | 59 (37–75) | 59 (36–75) | | 0.891 |
| Median age direct ICU admitted (IQR) | 53 (32–68) | 52 (30–68) | | 0.776 |
| Median ICU LOS (IQR) | 3 (2–6) | 3 (2–8) | | 0.013 |
| ISS Median (IQR) | 21 (17–26.7) | 21 (17–26) | | 0.729 |
| 16–24 | 317 (61.5%) | 697 (61.2%) | | |
| 25–49 | 185 (35.6%) | 407 (35.7%) | | |
| 50–75 | 18 (3.5%) | 35 (3.1%) | | |
| Blunt trauma | 508 (97.7%) | 1100 (96.6%) | | 0.154 |
| AIS ≥3 | | | | |
| Head | 275 (52.9%) | 608 (53.3%) | | 0.851 |
| Face | 25 (4.8%) | 30 (2.6%) | | 0.026 |
| Neck | 8 (1.5%) | 15 (1.3%) | | 0.082 |
| Thoracic | 209 (40.2%) | 496 (43.5%) | | 0.200 |
| Spine | 74 (14.2%) | 141 (12.3%) | | 0.306 |
| Abdominal | 49 (9.4%) | 124 (10.9%) | | 0.388 |
| Upper extremities | 8 (1.5%) | 335 (29.4%) | | 0.693 |
| Lower extremities | 92 (17.7%) | 193 (16.4%) | | 0.708 |
| External | 22 (4.2%) | 45 (3.9%) | | 0.789 |
| Injury cause | | | | 0.070 |
| Sports | 30 (5.8%) | 67 (5.9%) | | |
| RTA | 204 (39.2%) | 465 (40.8%) | | |
| Home | 216 (41.5%) | 425 (37.3%) | | |
| Work | 33 (6.4%) | 65 (5.7%) | | |
| Violence | 6 (1.1%) | 35 (3.1%) | | |
| Self-harm | 31 (6.0%) | 52 (4.6%) | | |

Peak: the period from March 23 through May 10, 2020.
Reference: the period from March 26 through May 13, 2018, and the period from March 25 through May 12, 2019.
AIS indicates abbreviated injury score; ISS, injury severity score; LOS, length of stay; RTA, road traffic accident.



Regarding the outcome measures, no significant differences between the study periods were recorded in terms of the number of patients who left the hospital with severe disabilities or in a vegetative state (32.5% vs 27.9%, $P=0.137$), or for the overall hospital mortality (18.5% vs 17.8%, $P=0.753$) or the 30-day mortality (24.4% vs 20.8%, $P=0.095$). However, for major trauma patients with a predicted mortality between 51% and 75%, a significantly higher observed mortality (74%) was recorded ($P=0.026$) during the COVID-19 peak compared with the pre-COVID-19 reference period (46%) (Fig. 3). The total percentage of ICU-admitted major trauma patients within this predictive mortality band was lower during the peak period than during the reference period (58.3% vs 87.5%, $P=0.018$).

## Traumatic Brain Injuries

The subgroup analysis of patients with TBI is shown in Table 2. There was a significant decrease in the number of ICU admissions for patients with minor to moderate TBI, defined as head AIS ≤3, during the peak versus reference period (40.5% vs 52.5%, $P=0.005$) (Table 2). The overall mortality rate for this group was significantly higher during the peak period (13.5% vs 7.7%; $P=0.044$). A further evaluation showed that the mortality rate for those not admitted to the ICU was significantly higher during the peak than during the reference period (10.3% vs 2.3%; $P=0.016$). This difference in mortality was not observed for those admitted to the ICU ($P=0.145$). The LOS was shortened among deceased patients with minor to moderate TBI admitted to the ICU, with a median of 3 days (IQR 1.25–5.75) at the peak compared to 6 days (IQR 2–––10) in the reference period ($P=0.015$).

Critical resource use and outcome for severe head injuries (AIS ≥4) did not differ between the peak and reference periods (Table 2).

## Multivariable Regression Models

In the multivariable prediction models the association between period (peak vs reference) and ICU admission and mortality ware tested as shown in Table 3. Patients admitted during the peak had a significantly lower odds ratios [0.740 (0.647–0.847)] on being ICU admitted.

The model describing for mortality did not show a significant higher odds ratio for mortality of patients admitted during the peak [0.803 (0.519–1.242)]. Patients with no TBI [0.606 (0.399–0.921)] or minor to moderate TBI [0.253 (0.198–0.325)], had overall a significantly lower odds ratio on mortality, compared to patients with severe TBI. However, the significant interaction term for peak period and TBIs showed that there is a difference between the 2 periods. The effect of the COVID peak period is higher for patients with minor to moderate TBI compared to patients with severe TBI. Patients with moderate to severe TBI had a higher risk [OR 2.510 (1.136–5.546)] of mortality during the peak in comparison with the reference period.

We also performed an additional multilevel binary logistic regression analysis to assess whether the regional trauma networks

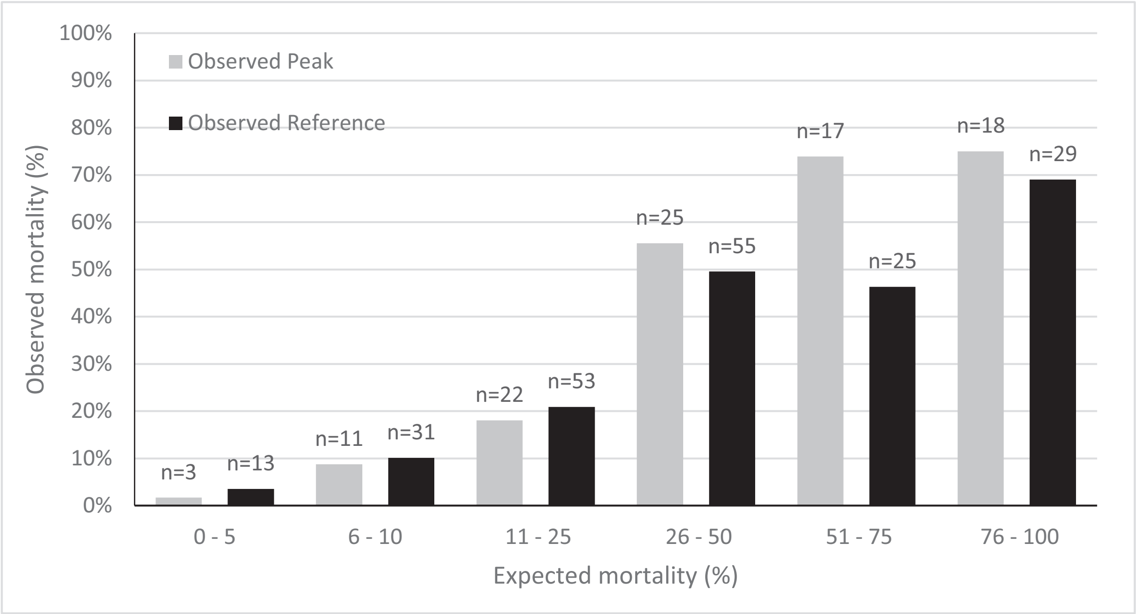



**FIGURE 3.** Major trauma patients expected and observed mortality during the first COVID-19 peak in 2020 and the reference periods in 2018 and 2019.

significantly affected the independent variables, however, no significant differences in effects were found (results not shown).

## DISCUSSION

We demonstrated that during the COVID-19-induced ICU occupancy peak, major trauma patients who would likely benefit from being closely monitored, like patients with minor to moderate TBI, were less often admitted to the ICU and showed worse outcomes. Thus, despite all efforts made to secure access to critical trauma care, the health care crisis due to COVID-19 had an adverse effect on trauma care. Trauma care could not be guaranteed to the same level as in the pre-COVID-19 era.

### Number of Major Trauma Patients

We found that during the COVID-19 peak in the Netherlands, major trauma was approximately 9% less common than during similar seasonal periods in the years before the COVID-19 pandemic. This reduction was likely caused by lockdown restrictions. However,

**TABLE 2.** The Incidence, Resource Use and Outcome for Less and More Severe Head Injuries During the Peak and Reference Period

| | Peak | Reference | | *P* Value |
|---|---|---|---|---|
| | 2020 n=520 | 2018 n=561 | 2019 n=578 | |
| Head AIS ≤3 | 163 (31.3%) | 171 (30.5%) | 181 (31.3%) | 0.857 |
| Admitted to ICU | 66 (40.5%) | 185 (52.5%) | | 0.005 |
| Mortality | 22 (13.5%) | 27 (7.7%) | | 0.044 |
| Not admitted to ICU | 10 (10.3%) | 4 (2.3%) | | 0.016 |
| Admitted to ICU | 12 (18.2%) | 23 (12.4%) | | 0.145 |
| Median LOS deceased (IQR) | | | | |
| Hospital | 3 (1.5–9) | 7 (3–14) | | <0.001 |
| ICU | 3 (1.25–5.75) | 6 (2–10) | | 0.015 |
| Head AIS ≥4 | 197 (37.9%) | 189 (33.7%) | 220 (38.1%) | 0.438 |
| Admitted to ICU | 107 (54.3%) | 230 (54.5%) | | 0.808 |
| Mortality | 51 (25.9%) | 122 (29.8%) | | 0.314 |
| Not admitted to ICU | 21 (23.3%) | 48 (26.8%) | | 0.537 |
| Admitted to ICU | 30 (28.0%) | 72 (31.3%) | | 0.444 |
| Median LOS deceased (IQR) | | | | |
| Hospital | 3 (2–6.5) | 3 (2–6) | | 0.637 |
| ICU | 7 (3–14) | 3 (2–6.5) | | 0.790 |

Peak: the period from March 23 through May 10, 2020.
Reference: the period from March 26 through May 13, 2018, and the period from March 25 through May 12, 2019.
AIS indicates abbreviated injury score; ICU, intensive care unit; LOS, length of stay.

**TABLE 3.** Multivariable Logistic Regression Models, 95% Confidence Intervals, and *P* Values for Independent Variables and Interaction Terms to Determine Their Association With ICU Admission and Mortality

| | ICU Admission (OR) | *P* Value | Mortality (OR) | *P* Value |
|---|---|---|---|---|
| Age | 0.987 (0.984–0.990) | 0.000 | 1.037 (1.029–1.045) | 0.000 |
| Male versus female | 0.941 (0.821–1.079) | 0.383 | 1.171 (0.865–1.584) | 0.307 |
| Systolic blood pressure | 0.992 (0.990–1.995) | 0.000 | 0.996 (0.991–1.001) | 0.880 |
| Respiratory rate | 1.040 (1.026–1.054) | 0.000 | 1.047 (1.018–1.078) | 0.002 |
| Glasgow coma scale | * | | * | |
| Injury severity score | 1.037 (1.020–1.054) | 0.000 | 1.090 (1.073–1.108) | 0.000 |
| ICU admission versus no ICU admission | – | – | 1.396 (1.022–1.908) | 0.001 |
| Peak versus reference period | 0.740 (0.647–0.847) | 0.015 | 0.803 (0.519–1.242) | 0.323 |
| No TBI versus severe TBI | 1.017 (0.865–1.196) | 0.838 | 0.609 (0.400–0.925) | 0.020 |
| Minor to moderate TBI versus severe TBI | 0.937 (0.799–1.099) | 0.422 | 0.253 (0.198–0.325) | 0.000 |
| Peak*no TBI | ** | | 1.285 (0.621–2.657) | 0.499 |
| Peak* minor to moderate TBI | ** | | 2.510 (1.136–5.546) | 0.023 |

Peak: the period from March 23 through May 10, 2020.
Reference: the period from March 26 through May 13, 2018, and the period from March 25 through May 12, 2019.
*Excluded from the model due to strong collinearity with TBI.
**Interaction terms without significant result were excluded from the model.
ICU indicates intensive care unit; OR, odds ratio; TBI, traumatic brain injury.

the number of major trauma patients remained substantial, demonstrating the necessity to take this into account for the modelling of epidemics and forecasts of ICU bed utilization.

## Increased Mortality and Triage of Trauma Patients

Our most compelling finding is the lower ICU admission rate and increased mortality in major trauma patients with minor to moderate TBI that were not admitted to the ICU during the peak period. We suggest that this group might have benefitted from ICU care, as the comparable group in the pre-COVID-19 period had better outcomes. This demonstrates that crucial decisions were made during the first COVID-19 peak that led to less favorable outcomes.

We speculate that competition for ICU resources led to a negative selection of major trauma patients. In the case of an obvious ICU indication forced by conditions such as prehospital intubation, severe TBI with a low glasgow coma scale, or high injury severity with prehospital interventions, ICU care is automatically assumed to be needed. In these cases, admission was unavoidable, whereas in those patients with minor to moderate TBI, ICU admission and treatment would have been ''a choice.'' This speculation is supported by our finding that during the COVID-19 peak, a larger proportion of patients in the ICU were ventilated than during the reference period. This indicates that fewer patients were admitted to the ICU for close monitoring so that any deterioration could be quickly identified.

The increased mortality of major trauma patients with a predicted mortality of approximately 51% to 75% is also worrisome. The average observed mortality within this band was 46% in the reference period, which is in sharp contrast to the 74% mortality during the COVID peak in 2020. Further analyses showed that within this band significantly less patients were admitted to ICU during peak.

In summary, our data suggests that the limited availability of ICU resources led to less favorable triaging for major trauma patients, where the situation, instead of necessity or the basic triage adage, ''do the most for the most,'' was not adhered to. When making this choice between patients, those with a higher survival probability and outlook for a better neurological prognosis should have priority over those with a more dismal prognosis or worse neurological outcome.

## Major Trauma and COVID-19

The high number of COVID-19 patients requiring respiratory support and often having prolonged ICU stays resulted in a strain on the ICU capacity in the Netherlands. This raises dilemmas about how best to allocate scarce critical resources. In defining guidelines and criteria for the selection of patients for ICU treatment (in the case of absolute scarcity), medical and ethical grounds need to be taken into account.[18] Basic ethical notions including ''to save as many lives as possible'' and triage criteria for admittance to the ICU should apply equally to COVID-19 and non-COVID-19 patients. In the Netherlands, in the pre-COVID-19 era, we found that major trauma patients admitted to the ICU had a median ICU stay of 3 days, and 1 of 4 died. COVID-19 patients have been reported to have a much longer ICU stay and a higher risk of death. International studies on ICU-admitted COVID-19 patients reported that the median length of ICU stay for critically ill COVID-19 patients was 12 days (IQR, 6–21), and the ICU mortality ranged between 30% and 48%.[19–22] These findings need to be taken into account in future resource planning and drafting of triage tools.

An important question that needs to be addressed is how to utilize our findings in planning and ensuring an equipoise distribution of care facing similar challenges going forward. One of the criteria for the Dutch level 1 trauma centers is that, at least 1 ICU bed is preserved for trauma patients at all times. However, in the case of extreme scarcity of ICU resources it is likely that this bed is used for non-trauma patients when the ICU capacity is stretched.

During the pandemic, ICU resource scarcity in the Netherlands was not solely caused by the relentless demand. Capacity expansion was limited by shortages in workforce, but also in equipment such as mechanical ventilators and protective materials. Furthermore, a nationwide system that enables real-time data on hospitals ICU availability was not in place at the time. Such a system facilitates the coordination between hospitals and helps decision makers to allocate resources. These crucial factors should be addressed to ensure a better response to pandemics in the future.

To enhance trauma care in general and particularly for those with TBIs, we would like to draw attention to the potential benefits of intermediate care units. These units reduce the gap between the wards and ICU and can act as step-up units for deteriorating and step-down units for improving patients.[23]

Considering our findings of an increased number of deaths among patients with minor to moderate TBI, we believe that close monitoring at an intermediate care unit could offer a solace. Although reducing ICU demand, and enabling close monitoring and an expedite transfer to the ICU in case of deterioration. Intermediate care units can offer a buffer capacity for the ICU. Unfortunately, the DNTR does not include detailed information on whether the hospitals they were treated had such an intermediate care unit. Hence, we were unable to assess the effects on outcomes at this time, however it seems to be of value in the future.

## Other Disease Entities

The impact of the COVID-19 pandemic on other major diseases has also been evaluated. De Rosa and colleagues[24] noticed a huge reduction in hospitalizations for myocardial infarction in Italy during the pandemic, with increased fatality and complication rates. However, in their case, the admissions declined with a further concentration of the most severe cases, in contrast to the study presented here. In oncology care, a substantial increase in the number of avoidable cancer deaths was also reported.[25] The authors speculated that this was probably due to the backlog of diagnostic procedures.[25] Additionally, patients with neurological conditions were reported to experience negative impacts on their conditions. Zhao and colleagues[26] reported on the impact of the pandemic on stroke care in China, as did Rinkel et al,[27] who observed a 24% decrease in suspected stroke presentations in the Amsterdam region in the Netherlands during the COVID-19 outbreak. In contrast to our findings, there was no evidence for a decrease in the quality of acute care.

In contrast to our study, all of the previous studies examined care at the local or regional levels only. To the best of our knowledge, this is the first study to provide a nationwide comprehensive overview of the epidemiology and effects on major trauma care during the COVID-19 pandemic, with far-reaching consequences for the organization, design, and allocation of care and resources during such a crisis. This study also has limitations. A coinciding COVID-19 infection is likely to negatively affect outcomes after trauma. Unfortunately, the COVID-19 infection status of major trauma patients is not documented in the DNTR, and the anonymization process prevents retracement. Because this study contains data only from the first COVID-19 peak period, further research is needed to assess the long-term impact of the COVID-19 pandemic on trauma-related injuries.

## CONCLUSIONS

The number of major trauma patients significantly declined during the first COVID-19 peak, likely due to the restrictive regulations of society. Nevertheless, competition for the restricted available ICU beds coincided with diminished ICU admission rates for major trauma patients and increased mortality among specifically major trauma patients who sustained minor to moderate TBI or had a predicted mortality rate between 51% and 75%.

## ACKNOWLEDGMENTS

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