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# The Impact of the COVID-19 Pandemic on Traumatic Brain Injury Management: Lessons Learned Over the First Year

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## Key words

- COVID-19
- Traumatic brain injury
- Referral
- Management
- Rehabilitation

## Abbreviations and Acronyms

**COVID-19:** Coronavirus 2019

**ICU:** Intensive care unit

**OR:** Operating room

**PPE:** Personal protective equipment

**TBI:** Traumatic brain injury

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Citation: *World Neurosurg.* (2021) 156:28-32.

<https://doi.org/10.1016/j.wneu.2021.09.030>

Journal homepage: [www.journals.elsevier.com/world-neurosurgery](http://www.journals.elsevier.com/world-neurosurgery)

Available online: [www.sciencedirect.com](http://www.sciencedirect.com)

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## INTRODUCTION

The coronavirus 2019 (COVID-19) pandemic has placed a remarkable strain on health care systems around the world. The first recorded COVID-19 cases in December 2019 were followed by rapid worldwide spread, with the World Health Association declaring a pandemic in March 2020.<sup>1</sup> To combat rising COVID-19 cases and prevent the overwhelming of health care systems, governments instructed people to stay at home and limit face-to-face contact. Health care services scrambled to re-allocate resources to deal with the high influx of COVID-19 patients, shortage of intensive care unit (ICU) beds and staff, resulting in hospitals stopping elective surgeries and converting operating rooms into make-shift ICU wards.<sup>2</sup> The re-allocation of resources, implementation of new guidelines on surgical prioritization,<sup>3</sup> and reduction of transmission has had a

The COVID-19 pandemic has had widespread consequences on health care systems around the world. It resulted in extensive changes to the referral patterns, management, and rehabilitation of surgical conditions. We aimed to evaluate the effect the COVID-19 pandemic has had on traumatic brain injury (TBI) specifically. We reviewed the literature published on COVID-19 and TBI referrals, management, and rehabilitation. Significant changes were seen in the referral patterns of TBIs worldwide, explained by changes in societal behaviors and changes in the mechanism of injury. Implementation of strict infection control measures and COVID-19 screening was commonplace, with some reporting changes to operating room protocols. TBI was more likely to be conservatively managed. Rehabilitation services were restricted, with a greater shift towards telemedicine to provide rehabilitative therapy remotely.

wide-ranging impact on neurosurgical workflow and traumatic brain injury (TBI).

As the COVID-19 pandemic continues into its second year, we look back at its effect on 4 aspects of TBI: changes to its incidence, management, changes to operating capacity and protocols, and neurorehabilitation.

## TBI REFERRALS

Throughout the early phases of the pandemic, there were grave concerns about the decrease in the number of acutely unwell patients seeking medical care. Patients' healthcare avoidance was born out of worry, as public perception of hospitals and primary care centres shifted to being sources of COVID-19 infection.<sup>4</sup> Patients with life-threatening conditions were avoiding medical attention and delaying treatment leading to poorer outcomes and death.<sup>5</sup>

Changes in neurosurgical referrals for TBI during the pandemic were evident worldwide. Retrospective, single centred studies comparing TBI referral volumes during lockdowns with previous years and months preceding the pandemic showed a decrease in the incidence of TBI referrals and admissions during lockdown periods.<sup>6-17</sup> Most notably, a retrospective study of 2293 electronic referrals to a level 1 trauma centre in northern England

demonstrated a 49.6% decrease in TBI referrals [ $P < 0.001$ ] during the United Kingdom's (UK) first national lockdown when compared to the prior months.<sup>9</sup> Such studies, however, must be interpreted with caution due to their retrospective natures and single-centre methodologies. Their results may be unrepresentative of regional/national TBI incidence and provide undue attention to anomalous findings. Despite seeing decreases in TBI referrals and admissions associated with the implementation of lockdowns, the relaxation of such measures was accompanied by increases in TBIs,<sup>6,7,9</sup> with one Indian neurosurgical department seeing a post-lockdown increase in head injury admissions of 117% [ $P < 0.0001$ ].<sup>18</sup>

The observed changes may be explained by the societal and habitual changes resulting from lockdowns and their effects on mechanisms of injury. In previous years, falls and road traffic accidents (RTA) predominated as the main mechanisms of TBI worldwide.<sup>19-21</sup> The restrictions on movement imposed by lockdown measures resulted in people staying at home. Working from home and school closures resulted in global reductions in road traffic levels,<sup>22</sup> leading to a theoretical decrease in TBIs. Analysis of the mechanisms of injury showed rates of TBIs associated with RTAs had decreased

dramatically during lockdowns.<sup>8,10,18,23-25</sup> Conversely, during the latter stages of lockdown, some studies showed that rates of RTA associated TBIs increased to levels above those experienced before COVID-19.<sup>18,23,26</sup> One possible explanation for this change is that quieter, uncongested roads due to travel restrictions encouraged careless driving and excessive use of speed,<sup>27,28</sup> resulting in increased RTAs and more severe TBIs.<sup>18,26,29</sup> Evidence of more aggressive and risky driving behaviours have been demonstrated when comparing the driving data compiled by an insurance telematics platform from Greece and the Kingdom of Saudi Arabia before and during the pandemic. Across the 167,466 journeys analysed during the pandemic, increased driving speeds were seen along with more aggressive acceleration and braking patterns and more frequent use of mobile phones whilst driving.<sup>30</sup>

A 22% decrease in RTA-associated fatalities were seen in the UK between January to June 2020 compared to the same period in 2019. However, traffic levels decreased by 30%, resulting in a 14% increase in RTA fatalities per 1 billion miles.<sup>31</sup>

In the United States, significant increases in ballistic-related neurotrauma were noted in Pennsylvania and Florida, despite the implementation of stay-at-home orders.<sup>8,15</sup> This is in keeping with the general trend across the United States with increased incidence of ballistic trauma during the COVID-19 pandemic, along with increases in firearms sales.<sup>32-34</sup>

Very few studies showed significant epidemiological changes to TBI resulting from the pandemic. Evidence of significant differences in terms of sex was limited and often provided conflicting pictures,<sup>23,25,26</sup> possibly due to regional variation. Many studies compared the age of TBI patients before and during the pandemic and showed no significant change in the mean and median ages.<sup>18,24-26</sup> Most interesting was a study by Algattas et al. which showed no significant change in the median age of neurotrauma patients. However, when comparing age groups, significant differences were seen in their age distribution.<sup>15</sup> Of the individuals sustaining neurotrauma in Pennsylvania,

USA, proportionate increases were seen amongst <15 and >65-year-olds during the pandemic. Furthermore, Algattas et al. showed neurotrauma was significantly more likely to occur indoors at private residences,<sup>15</sup> accompanied by significant increases in falls.<sup>8,15,25</sup> However, this trend was not consistent across the literature. Nonetheless, this emphasises that mean and median ages alone are blunt metrics for detecting differences in age distribution and highlights the need for further detailed analysis of the age distribution of TBI over the pandemic.

Questions remain about the extent to which people sustaining head trauma were avoiding medical attention. A study of 191 patients admitted with chronic subdural haematomas (cSDH) over two months during the pandemic showed that the time between patients' admission and their original head injury had almost doubled compared with the same period in 2019 [ $P = 0.00754$ ].<sup>35</sup> Another study showed that delayed medical treatment resulted in cSDHs patients presenting with more severe symptoms and had poorer outcomes.<sup>36</sup>

One of the challenges posed by future pandemics will be managing public perception of hospitals and other healthcare centres. There is a need to ensure sufficient awareness and compliance with public health measures, balanced against inadvertent scaremongering leading to healthcare avoidance from the people who most desperately need it.

## TBI MANAGEMENT

Throughout the pandemic, TBIs have continued to be treated with the highest priority. The indications for its surgical management has remained largely unchanged.<sup>3</sup> At the beginning of the pandemic, shortages of staff, ICU beds, and the aim of keeping hospital admissions to a minimum led to the suspension of elective surgical procedures and an emphasis on surgical prioritization.

Infection control measures led to hospitals segregated with areas dedicated to patients with or suspected of having COVID-19 and areas for patients who had tested negative. Many hospitals had separate operating rooms (ORs) dedicated to treating COVID-19 positive

patients.<sup>17,18,37,38</sup> Patients were screened for COVID-19 on admission and suspected of being COVID-19 positive until proven otherwise.<sup>18,38,39</sup> Screening was mainly done by nasopharyngeal swab,<sup>13,37,38</sup> with some centers additionally requiring radiologic imaging as a further screening measure.<sup>38,40,41</sup> Such screening measures take time to return results and may delay treatment. Due to the urgent need for surgical intervention in TBI, the COVID-19 status of some TBI patients could not be ascertained before going to the OR, and in such cases were treated as being COVID-19 positive<sup>13,18,39</sup> with screening occurring postoperatively.<sup>18,40,42</sup>

Several changes were seen within the OR to limit COVID-19 transmission. COVID-19 ORs were negatively pressured to contain infective aerosols.<sup>13,39-42</sup> Some centers aimed to intubate patients as efficiently as possible, ensuring that patients were sufficiently paralyzed before attempting intubation to avoid excessive coughing.<sup>41</sup> Level 3 personal protective equipment (PPE) was used when operating on suspected/confirmed COVID-19 patients. PPE included N95/FFP3 masks and 2 layers of surgical gloves.<sup>18,39-42</sup> Some centers advocated the use of experienced surgeons working in pairs to keep operating time to a minimum,<sup>39-42</sup> with one center aiming to carry out decompressive craniectomies and intracranial pressure monitoring within 2 hours.<sup>41</sup> With neurosurgical staffing levels stretched due to illness and junior staff redeployed to other clinical areas, it may not always have been feasible to have 2 senior surgeons operating together without compromising staffing levels and emergency operating capacity.

TBI was more likely to be managed conservatively during the pandemic.<sup>18,24,26</sup> A retrospective cohort study of 597 TBI patients at the University Hospital of Wales by Manivannan et al.<sup>24</sup> demonstrated a significant decrease in surgical management for TBI, with a corresponding increase in conservative management. Furthermore, TBI patients were more likely to be managed locally with neurosurgical input, remote from the neurosurgical center.<sup>24</sup> This is in part a reflection of the milder TBI experienced by Manivannan et al. during

the pandemic. However, Goyal et al.<sup>18</sup> similarly experienced a significant increase in the proportion of conservatively managed TBI, despite significant increases in TBI severity, with a resultant significant increase in mortality. An increase in TBI severity due to changes in the mechanism of injury and delayed access to health care could result in more TBI patients being unsuitable for surgical management. Thinly stretched health care systems with staff shortages and reduced operating capacity further compound the need for more conservative management and remote neurosurgical input. Under-resourced health care systems could be disproportionately affected due to their inherently reduced ability to deal with the pressures imposed by the pandemic. In future, operating capacities must be preserved and expanded where necessary, with surgical prioritization enforced. Redeployment of junior neurosurgical staff should be avoided to ensure that senior neurosurgeons are not overburdened and available to operate when needed.

A single-center retrospective study of patients with TBI and subarachnoid hemorrhages admitted to a Finnish neuro-ICU between January and May 2020 showed a significant decrease in the number of decompressive craniectomies performed during the latter half of the study period when compared with the previous year.<sup>43</sup> However, decompressive craniectomy rates and patients' Glasgow Coma Score remained unchanged over the entire study period, consistent with other studies.<sup>12,25</sup>

The need to increase ICU bed capacity for COVID-19 patients came at the expense of dedicated neuro-ICU beds. A survey of 25 neurosurgical centers across 18 European countries showed that 16 centers (64%) had seen a decrease in neuro-ICU beds, with a mean decrease in neuro-ICU beds of 62% across the neurosurgical centers.<sup>44</sup> However, with the suspension of elective procedures and decreases in TBI cases, neuro-ICU beds may have been surplus to requirement during the pandemic. Indeed, across Europe, it seems that TBI has been adequately treated. A multicenter study, spanning three Central European countries with a combined population of 30 million, showed no increase in 30-day mortality of

TBI patients during 2020 compared with previous years, with the Czech Republic seeing a statistically significant decrease in 30-day mortality.<sup>11</sup> It may not be reflective of TBI mortality worldwide during the pandemic, especially in countries with under-resourced health care systems, with 2 studies from Indian neurosurgical centers showing statistically significant increases in TBI mortality during the pandemic.<sup>18,23</sup> Nevertheless, the evidence is currently lacking, with a need for further extensive research into the effect of the COVID-19 pandemic on TBI mortality worldwide.

### NEUROREHABILITATION

Following a TBI, individuals may be left living with the aftermath for years afterwards. Depending on its severity, TBIs can result in cognitive, social, behavioral and motor deficits having lasting effects on the individual and their ability to perform activities of daily living, requiring extensive rehabilitative therapy to restore lost neurologic functions and promote independence.

Neurorehabilitation commonly takes place within the inpatient and outpatient settings. Patient discharge from rehabilitation units was accelerated during the COVID-19 pandemic to limit exposure risk. Rehabilitation programs were shortened and intensified,<sup>45,46</sup> focusing on the essential aspects of their patients' rehabilitation, along with achievable goals within a short timeframe.<sup>47</sup> Rehabilitative therapy was provided at patients' bedsides where possible to limit the movement of patients and staff.<sup>46,47</sup> With centers restricting access to gyms,<sup>46,47</sup> one center elected to offer therapy sessions outdoors.<sup>46</sup> Further infection control measures included extensive sanitization, the use of PPE, COVID-19 screening, and restriction/suspension of visitation by relatives and caregivers.<sup>46,47</sup>

Outpatient services were reduced or suspended, replaced by remote tele-rehabilitation using telephonic and Internet-based communication platforms.<sup>45-49</sup> The introduction of tele-rehabilitation allowed TBI patients to engage with rehabilitative therapies from home, facilitating communication between patients, caregivers, and health care

workers.<sup>50</sup> Moreover, it allowed health care workers to virtually see their patients' domestic challenges first-hand and their interactions with family and friends in a relaxed setting. Furthermore, in the context of a pandemic, engaging with telerehabilitation does not necessitate the use of PPE that a face-to-face session would, which is particularly important in TBI given that face masks obscure facial expressions and muffle voices, which can be a barrier to successful social interactions in individuals living with TBIs.<sup>51</sup> The benefits of telerehabilitation are evident. The COVID-19 pandemic has acted as a catalyst to drive meaningful change in the field of neurorehabilitation. However, reliance on remote medicine has its limitations. Its dependence on reliable Internet connectivity, the prerequisite access to compatible devices, and patients' ability to use such devices are the principal drawbacks to telerehabilitation.<sup>48,49</sup> The virtual interaction between health care professionals and patients does not lend itself naturally to thorough physical examination, placing a stronger emphasis on a thorough history. Despite this, limited physical examination is possible, with Caze et al. reporting incorporating vestibular ocular motor screening assessments into their virtual consultations.<sup>49</sup> It relied on the clinician first demonstrating and then instructing the patient to perform the steps themselves. Such simple assessments may be possible in patients with mild TBI but may not be possible to conduct in patients with severe TBI and gross cognitive and motor deficits. Moreover, virtually testing muscle tone and reflexes would be highly challenging.

With the COVID-19 pandemic necessitating fundamental changes to societal and social conventions, it stands to reason that the daily challenges faced by TBI patients have been exacerbated. However, Morrow et al. reported that when surveyed, the pandemic had a lesser effect on the general mental and physical wellbeing of TBI patients relative to their uninjured comparators.<sup>51</sup> Restrictions on hospital visitation have undoubtedly affected patients' families. The inability to be at the patient's bedside following a TBI has deprived relatives of an opportunity to come to terms with their injury, advocate



for the patient and stay informed of management plans, although the use of telecommunication has gone some way to alleviate relatives' distress.<sup>52</sup>

It would be fair to presume that the COVID-19 pandemic has had deleterious consequences on the rehabilitation and recovery of TBI patients worldwide. However, the current lack of empirical evidence on the matter means that we may not realize the pandemics' true consequences on the rehabilitation of TBI patients for years to come.

## CONCLUSIONS

The COVID-19 pandemic may not have vastly changed the way patients with TBIs are managed, but the current evidence suggests a significant change in the number of people acquiring TBIs, the mechanism of their injuries, and the effect on their rehabilitation. There is a need for further large, multicenter retrospective studies to assess its true impact on TBI. Although some countries are beginning to see some light at the end of the tunnel, others are being plunged back into depths of disease. The COVID-19 pandemic will be meticulously dissected and analyzed in future years, and its lessons will be learned in hindsight. Such lessons will be invaluable when facing future pandemics.

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*Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.*

*Received 13 August 2021; accepted 7 September 2021*

*Citation: World Neurosurg. (2021) 156:28-32.*

*<https://doi.org/10.1016/j.wneu.2021.09.030>*

*Journal homepage: [www.journals.elsevier.com/world-neurosurgery](http://www.journals.elsevier.com/world-neurosurgery)*

*Available online: [www.sciencedirect.com](http://www.sciencedirect.com)*

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