Deconstructing improvements and hospital variation in COVID-19 mortality rates during the early pandemic wave: the effects of wave evolution and advances in testing, treatment, and hospital care quality

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The COVID-19 pandemic has contributed to millions of deaths around the world and placed unprecedented strains on healthcare systems. Several studies early in the pandemic demonstrated substantial variation in COVID-19-associated mortality rates among hospitalised patients across and within countries, suggesting that hospital factors such as bed capacity, adequacy of staffing, supplies of ventilators and other critical equipment, and/or quality of care had a major impact on patient outcomes.[1–3] These analyses have been difficult to interpret, however, because variation in outcomes may also reflect community-based factors beyond the control of hospitals such as differences in testing capacity, thresholds for hospital admission, and patient case mix. Nonetheless, rigorously examining trends in COVID-19 outcomes and the contribution of potentially modifiable hospital factors to mortality is critical given the spectre of additional variant-fueled surges as well as future novel threats.

An article in this issue of *BMJ Quality & Safety* by Bottle and colleagues[4] sheds welcome new light on this topic. The authors sought to quantify variation in COVID-19 mortality rates between hospitals and over time in England in the first pandemic wave (March–July 2020) using detailed patient and hospital-level administrative data to explain those variations in the early (March–April 2020) and late study period (May–July 2020). In all, their analysis included 74 781 patients admitted with a primary diagnosis of COVID-19 to 124 acute hospitals. Their first major finding was that there was a massive decline in crude in-hospital mortality rates from 33% in March 2020 to 13% in July 2020. Improvements in survival were seen in all age groups, with younger patients seeing the largest relative decline in mortality, as well as in hospitals with relatively low and high COVID-19 mortality rates. Numerous patient-level predictors of mortality were identified, many of which are consistent with prior evidence, including age, male sex, non-white race, and obesity and other comorbidities. Interestingly, the present study showed that some of these were only significant predictors in either the early study period (obesity, diabetes, emergency admissions in the previous 12 months and ethnicity) or late period (emergency vs non-emergency admission and chronic obstructive pulmonary disease). This interaction between predictors and time period may be important to account for in future studies assessing trends in COVID-19 mortality. The authors also analysed hospital-level predictors, which included the daily number of COVID-19 admissions and the mean weekly number of total occupied beds, hospitalised and mechanically ventilated patients with COVID-19, and staff absences related to COVID-19. Of these, only the number of daily COVID-19 admissions in a hospital during the late study period was associated with increased mortality; more

specifically, the odds of a patient with COVID-19 dying increased by 7% with each additional COVID-19 patient admitted to that hospital per day up until four admissions per day, with no further increase in mortality beyond that number.

The other major finding in the study by Bottle and colleagues was that hospitals had substantial variation in crude COVID-19 mortality rates, ranging from 16% to 46% in the early study period and 4% to 46% in the late study period.[4] Overall, 44% and 22% of hospitals qualified as either high or low mortality outliers at ≥2 SD in the early study period and late study period, respectively. This variation was substantially attenuated following risk-adjustment, indicating that there were major differences in the medical complexity of COVID-19 patients being cared for across hospitals. However, the variation remained statistically significant following risk adjustment, with 20% and 8% of hospitals still qualifying as outliers in the early and late periods.

The finding that crude COVID-19 mortality rates among hospitalised patients decreased over time is encouraging, particularly given the relatively short period under study. However, these mortality improvements are likely attributable in large part to an increasingly less adverse patient case mix. Such changes may have resulted from increased case ascertainment resulting from better access and use of COVID-19 tests, detecting cases that on average have lower risk for death, as testing was initially limited to the most severely ill patients. In many countries, the first wave also disproportionately affected the most frail and vulnerable patients resulting in progressive depletion of the 'pool' of highest risk patients and thereby indirectly resulting in secular improvements in case fatality.[5] At the same time, other studies that have incorporated risk adjustment into trend analyses have also reported declining mortality rates during 'wave 1' of the COVID-19 pandemic among hospitalised and ICU patients in England and other countries, suggesting that better care has also contributed .[6–8] Interestingly, much of the improvements in mortality reported in the study by Bottle and colleagues occurred before evidence emerged regarding the effectiveness of corticosteroids for reducing mortality in June 2020, although corticosteroids were likely being used in some patients with COVID-19 prior to that point given that many UK hospitals formed part of the related RECOVERY trial.[9] The mortality reduction over time, then, also likely reflects rapid improvements in the general care of patients with COVID-19 with growing evidence, experience and dissemination of consensus treatment guidelines. Notable early changes in COVID-19 care that may have contributed to this favourable trend include shifting away from early intubation and greater use of high-flow oxygen, non-invasive ventilation; proning in ventilated and non-ventilated patients; and increasing confidence in the effectiveness of personal protective equipment that likely facilitated essential medical care and resumption of ICU procedures that were initially deferred due to concerns about aerosolisation (such as bronchoscopies and tracheostomies).[10–14]

It is also encouraging that hospital variation in COVID-19 mortality rates was substantially attenuated after case-mix adjustment and that most hospital-level variables studied in this analysis were not associated with worse outcomes. This suggests that hospitals in England were able to provide relatively consistent quality of care for patients with COVID-19 in the early pandemic surge despite the enormous pressures on staff and facilities. Even the residual hospital variation in this study should be interpreted cautiously; although there was detailed risk adjustment using administrative data, the authors were unable to adjust for important factors like severity of illness at the time of admission. Prior studies have demonstrated the importance and impact of physiological risk-adjustment on hospital mortality rankings for severe infections.[15]

Nonetheless, even though Bottle *et al*[4] overall found that hospitals' mortality in the early period correlated weakly with that in the late period, some hospitals clearly remained in the highest risk-adjusted mortality quartile in both periods while other hospitals moved from the lowest to higher mortality quartiles. Since the authors found that the number of daily COVID-19 admissions was associated with greater likelihood of death among patients with COVID-19 in the later months of the study, this suggests that strains on hospitals' staff and other resources may have contributed to worse outcomes. This hypothesis is bolstered by several studies showing similar findings in the USA, where hospitals are more diverse with respect to access, size, resources and services. One national cohort study of patients with COVID-19 treated in US hospitals, for example, found that although most hospitals achieved improvements in risk-adjusted COVID-19 mortality rates, the factor most strongly associated with poor or worsening hospital outcomes was high or increasing burden of cases in the communities they served.[16] Another analysis of patients with COVID-19 treated in the ICU at 88 Veterans Affairs hospitals during periods of increased ICU demand found increased risk-adjusted mortality rates compared with low periods of ICU demand.[17] Lastly, a study of patients with COVID-19 admitted to 558 US hospitals between March and August 2020 found that a surging case load (defined using a severity-weighted measure of COVID-19 case load relative to pre-COVID bed capacity) was strongly associated with COVID-19 mortality across both ICU and non-ICU patients.[18] Most strikingly, this analysis estimated that nearly one in four COVID-19 deaths in the USA during the early wave were potentially attributable to hospitals strained by surging caseloads.

What lessons can we learn and apply from this collective experience with the early COVID-19 wave?

With regard to trends, the dramatic improvements in COVID-19 mortality over just a few months suggest that the rapid dissemination and uptake of new evidence were amazingly successful. Professional societies and expert panels mobilised quickly to review and synthesise available evidence into best practice guidelines, with frequent updates as new evidence emerged. Hospitals organised COVID-19-focused journal clubs, research conferences, collaborative case discussions and committees that adopted published guidelines into local management protocols. All of these achievements should serve as a model for responses to novel threats.

The observation that mortality rates were higher in overburdened hospitals, however, should reinforce the importance of a coordinated regional approach to mitigate uneven surges in patient volume. During times of crisis, hospitals simply cannot afford to operate in silos. Although coordination has improved in many countries over the past year, there is still room to increase coordination between regional health departments and hospitals to better track bed capacity and staffing; share essential resources including ventilators, personal protective equipment and testing supplies; proactively manage access to long-term care and skilled nursing facilities; plan reductions in elective procedures; and reallocate both patients with COVID-19 and without COVID-19 when needed.[19 20] This would not only lead to better patient outcomes but also help decompress overburdened healthcare workers—a group that has suffered enormous stress from COVID-19 and remains at ongoing high risk of burnout.[21 22]

The COVID-19 pandemic has taken a devastating toll on society and our healthcare systems. Although increasing vaccinations and lower case counts of severe disease in many countries are cause for optimism, it is incumbent on us to translate both the positive and the negative lessons of the initial COVID-19 response to better serve our patients and colleagues during subsequent waves of the present and future pandemics.

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