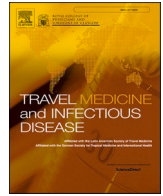




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## Correspondence

## Out-of-hospital mortality as an indicator of health care system saturation: Two waves retrospective analysis

## ARTICLE INFO

## Keywords

Coronavirus

Mortality

Severity of COVID-19

Hospital admission

Newly emerging infectious disease



Dear Editor,

We are sending this letter to share the results of our study which retrospectively looked at the relationship between hospital bed occupancy during COVID-19 peak activity and number of out-of-hospital fatalities. Understanding and quantifying this relationship will better refine control of the epidemic in Oman and fine-tune existing public health measures implemented by the Omani government – intermittent partial lockdowns, and school and commercial activity closures while functioning as proxy indicator for the health system's surge capacity.

Oman, population 4.49 million, registered its first COVID-19 case on 24<sup>th</sup> February 2020 and the virus has since spread throughout the country with two distinct peaks, one in 2020 (July–October) and another larger peak starting in March 2021. A study done in Oman revealed that out of 68,967 positive COVID-19 cases, 94% of them were mild to moderate, 4% were admitted to the general wards, 0.4% to the intensive care units, and 0.5% died [1].

To investigate the effects of peak epidemic activities on the number of out-of-hospital COVID-19 deaths, we conducted a retrospective observational study using systematically collected hospital bed occupancy and mortality data of PCR-confirmed COVID-19 patients. Daily data on COVID-19 hospital bed occupancy, ICU hospital bed occupancy and deaths from 1<sup>st</sup> of April 2020 to 20<sup>th</sup> of April 2021 were used. Mortalities were classified as in-hospital and out-of-hospital and only out-of-hospital deaths were studied. Two periods for the peaks were selected, before and after January 2021. Periods of >90% from the maximum number of hospital bed occupancy were labeled as peak activity periods for each wave. A generalized additive model was constructed to examine the number of out-of-hospital deaths (dependent variable) with the peak activity period (independent variable) controlling for time trend, seasonality (spline smooth function of date), severity index (defined as ICU bed occupancy divided by total hospital bed occupancy) and day of the week with a quasi-Poisson distribution to control for overdispersion. The natural logarithm of the total number of deaths was used as an offset in the model. Results were expressed as risk ratio with 95% confidence interval (CI). All analysis was done using R software.

Maximum hospital bed occupancy was 575 and 823 for the first and the second waves, respectively. During the study period, a total of 1911 deaths were reported out of which 118 deaths occurred out-of-hospital. Of these out-of-hospital deaths, 33 occurred during the peak activity period, Fig. 1. The results of the model revealed a significant 65% increase in the occurrence of out-of-hospital deaths in the peak compared to the non-peak periods, risk ratio = 1.65; 95% CI (1.05–2.61), P-value = 0.03]. Our model could not capture significant difference between severity index and occurrence of out-of-hospital deaths.

Our study is supported by evidence that the increase in out-of-hospital COVID-19 mortality was higher during times when the health care system almost reached its full capacity. This relation between health care system saturation and out-of-hospital deaths was also suggested by other studies from high, middle, and low-income countries [2, 3]. Friedman et al. suggested that excess out-of-hospital deaths during COVID-19 might be related to patient avoidance of the health care system, silent hypoxemia or social disparities [2]. On the other hand, Campo et al. found that myocardial infarction hospitalizations in Italy had decreased during the first wave of the COVID-19 pandemic with a concomitant increase in the out-of-hospital cardiac mortality while outcomes of admitted cases remained the same [4].

This study revealed that the period of highest bed capacity had a 65% risk of out-of-hospital deaths. These deaths could have been prevented if hospital capacity was raised at least 10%, to achieve <90% capacity. This could be achieved, for example, by the introduction of lockdown, which relieves hospital capacities through decreasing the incidence rate of COVID-19 [5].

One of the major limitations of our study is that it only considers PCR-positive COVID-19 deaths, whereas deaths might have occurred without testing. The excess mortality of home deaths in Oman during the period from March 15th to August 15th, 2020 was estimated to be 7% [6]. In addition, the same study showed that the mortality excess due to COVID-19 during that same heavily engaged health system period was estimated to be 15%. Therefore, our analysis doesn't cover non-COVID-19 out-of-hospital deaths which can also reflect the impact of health care system strain during the pandemic.

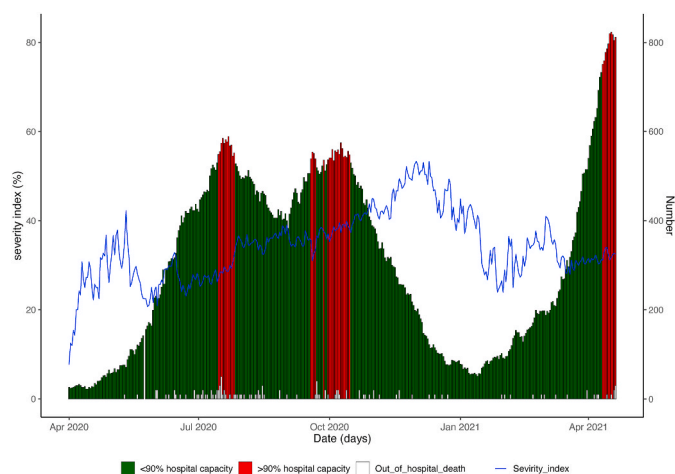
This study shows that in settings where hospitals capacity

<https://doi.org/10.1016/j.tmaid.2021.102121>

Received 9 May 2021; Accepted 11 June 2021

Available online 15 June 2021

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**Fig. 1.** Hospital bed occupancy in the hospitals (bar chart) classified by less than and more than 90% capacity, are shown in green and red, respectively. Out-of-hospital deaths are shown in a purple-colored bar chart and severity index (defined as ICU bed occupancy divided by hospital bed occupancy) as a blue line chart, from 1<sup>st</sup> April 2020 to 20<sup>th</sup> April 2021, Oman. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

monitoring is not feasible, the increase in out-of-hospital COVID-19 deaths can be used as an indicator for health care system saturation and the need for urgent intervention. The intervention should include urgent capacity expansion and implementing lockdown measures to curtail the speed of transmission in the community and surge cases requiring health care.

#### Funding

No funding was needed for this study.

#### Authors' contribution

Adil Al Wahaibi conducted the statistical analysis and wrote the draft manuscript and discussion, Ruquiah Al Shehi collected and cleaned the data, Amal Al Maani reviewed and edited the manuscript, Seif Al-Abri supervised the study and participated in all stages of manuscript preparation.

#### Declaration of competing interest

The authors declare that they have no conflict of interest.

#### Acknowledgement

The authors would like to thank Lesley Carson for her editorial assistance in finalizing the manuscript.

#### References

- [1] Al Wahaibi A, Al Rawahi B, Patel PK, Al Khalili S, Al Maani A, Al-Abri S. COVID-19 disease severity and mortality determinants: a large population-based analysis in Oman. *Trav Med Infect Dis* 2021;39:101923. <https://doi.org/10.1016/j.tmaid.2020.101923>.
- [2] Friedman J, Calderón-Villarreal A, Bojorquez I, Vera Hernández C, Schriger DL, Tovar Hirashima E. Excess out-of-hospital mortality and declining oxygen saturation: the sentinel role of emergency medical services data in the COVID-19 crisis in tijuana, Mexico. *Ann Emerg Med* 2020;76:413–26. <https://doi.org/10.1016/j.annemergmed.2020.07.035>.
- [3] Coleman KM, Saleh M, Mountantonakis SE. Association between regional distributions of SARS-CoV-2 seroconversion and out-of-hospital sudden death during the first epidemic outbreak in New York. *Heart Rhythm* 2021;18:215–8. <https://doi.org/10.1016/j.hrthm.2020.11.022>.
- [4] Campo G, Fortuna D, Berti E, De Palma R, Pasquale GD, Galvani M, et al. In- and out-of-hospital mortality for myocardial infarction during the first wave of the COVID-19 pandemic in Emilia-Romagna, Italy: a population-based observational study. *Lancet Regional Health - Europe* 2021;3:100055. <https://doi.org/10.1016/j.lanepe.2021.100055>.
- [5] Spaccaverri G, Larrieu S, Pouey J, Calba C, Benet T, Sommen C, et al. Early assessment of the impact of mitigation measures to control COVID-19 in 22 French metropolitan areas. October to November 2020 *Euro Surveill* 2020;25. <https://doi.org/10.1016/j.bjid.2020.08.002>. <https://doi.org/10.2807/1560-7917.ES.2020.25.50.2001974>.
- [6] Al Wahaibi A, Al-Maani A, Alyaquobi F, Al Harthy K, Al-Jardani A, Al Rawahi B, et al. Effects of COVID-19 on mortality: a 5-year population-based study in Oman. *Int J Infect Dis* 2021;104:102–7. <https://doi.org/10.1016/j.ijid.2020.12.054>.

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