Public Health 185 (2020) 99–101

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Short Communication

Early assessment of the impact of mitigation measures on the COVID-19 outbreak in Italy

C. Vicentini*, V. Bordino, P. Gardois, C.M. Zotti

Department of Public Health and Paediatrics, University of Turin, Via Santena 5 bis, 10126, Turin, Italy

ARTICLE INFO

Article history:
Received 28 April 2020
Accepted 10 June 2020
Available online 22 June 2020

Keywords:
COVID-19
SARS-CoV-2
Mitigation
Containment
Intensive care

ABSTRACT

Background: On March 11, 2020, the World Health Organization characterized the novel coronavirus disease 2019 (COVID-19) outbreak as a pandemic. The first cases in Italy were reported on January 30, 2020, and the outbreak quickly escalated. On March 19, 2020, deaths in Italy surpassed those in China. The Italian government implemented progressively restrictive measures leading to a nationwide lockdown on March 8, 2020. This study aimed to assess the impact of mitigation measures implemented in Italy on the spread of COVID-19.

Methods: Publicly available data were used to evaluate changes in the growth curve of the number of patients hospitalized in intensive care (IC) at three time intervals between February 19, 2020, and April 9, 2020, after the implementation of progressive measures: (1) containment and travel restrictions, (2) lockdown of the epicenter of the outbreak, and (3) school closures and nationwide lockdown. The models that showed the highest reliability according to the Akaike information criterion and based on data from the three time intervals were projected to assess how the epidemic would have evolved if no other measure had been implemented.

Results: The most reliable models were (1) exponential, (2) quadratic, and (3) cubic ($R^2 = 0.99$, >0.99, and > 0.99 respectively), indicating a progressive decrease in the growth of the curve.

Conclusion: This study suggests the measures were effective in flattening the epidemic curve and bought valuable time, allowing for the number of IC beds to be nearly doubled before the national health system reached maximum capacity.

© 2020 The Royal Society for Public Health. Published by Elsevier Ltd. All rights reserved.

On March 11, 2020, the World Health Organization (WHO) declared the current novel coronavirus disease 2019 (COVID-19) outbreak could be characterized as a pandemic.[1] As of April 28, 2020, almost every country has reported cases, with nearly three million cases worldwide.[2] Since the first cases of COVID-19 were reported in Wuhan, China, in December 2019, cases rapidly spread across the country and internationally. Community measures and travel restrictions were implemented in China within weeks. Initial measures such as isolation of detected cases, contact tracing, and quarantining soon proved ineffective in halting widespread community transmission; hence, drastic community containment with social distancing was implemented and the entire province of Hubei was placed under enforced lockdown, approximately three weeks after the outbreak began.[3] The rigorous lockdown measures implemented in China allowed to contain the epidemic, with clusters of cases still occurring to date.[2]

Despite travel restrictions, COVID-19 has spread extensively. As of April 28, 2020, the most affected countries in terms of number of cases are the United States, Spain, Italy, Germany, and the United Kingdom.[2] Italy currently has reported almost 200,000 cases, and since the beginning of the outbreak, 26,640 deaths have occurred in Italy related to COVID-19.[2] With intensive care (IC) units close to maximum capacity,[4] healthcare workers under enormous physical and psychological pressure, and resources severely depleted, the Italian national health system is enduring an unprecedented strain.

The Italian government has implemented increasingly restrictive measures to flatten the epidemic curve and allow hospitals to cope with the increasing number of patients requiring IC. On January 30, 2020, the first two cases of COVID-19 in Italy were confirmed, and travel restrictions and containment measures were implemented. Municipalities at the epicenter of the outbreak (the

* Corresponding author. Department of Public Health and Paediatrics, Università di Torino, Via Santena 5 bis, 10126, Turin, Italy. Tel.: +39 011 6705830; fax: +39 011 6705889.
E-mail address: costanza.vicentini@unito.it (C. Vicentini).

https://doi.org/10.1016/j.puhe.2020.06.028
0033-3506/© 2020 The Royal Society for Public Health. Published by Elsevier Ltd. All rights reserved.

red zone), mainly in the regions of Lombardy and Veneto, were placed under lockdown from February 23, 2020. On March 5, 2020, schools across Italy were closed, and on March 8, 2020, a lockdown of the entire country was announced. We aimed to assess the impact of these measures on the spread of COVID-19 in Italy.

Publicly available data[5] were used to evaluate changes in the growth curve of the number of patients hospitalized in IC at three time intervals between February 19, 2020 and April 9, 2020, after the implementation of progressive measures: (t1) containment and travel restrictions, (t2) lockdown of the epicenter of the outbreak, and (t3) nationwide lockdown.

Growth curves were estimated based on the number of patients hospitalized in IC due to infection with COVID-19 during the three time intervals. A delay of 5 days was considered to account for the estimated incubation period of COVID-19, and an additional delay of 4 days was considered to account for the time from onset of symptoms until hospitalization in IC,[6] and therefore, the effect of the measures was assessed from the 9th day after the implementation of each measure.

The Akaike information criterion was used to compare a set of statistical models chosen *a priori*, selected based on prior analyses of the Italian and Chinese epidemic curves.[3,4] The exponential model was the most reliable for t1, with a doubling time of 2.48 (95% confidence interval, CI: 2.21–2.79) and a R^2 of 0.99. The quadratic model showed the highest reliability during t2, with $R^2 > 0.99$. The cubic model better fit data from the t3, with $R^2 > 0.99$.

Following the methodology applied by Lau et al. to evaluate the impact of lockdown in China,[3] growth curves were extended to represent the potential number of patients that would have been hospitalized in IC if further measures to control the outbreak had not been implemented, using the most reliable model for each time interval (Fig. 1).

The total number of IC beds estimated on March 8, 2020, was 5200 and is estimated to have been increased to around 8000 beds as of March 24, 2020.[4] As shown in Fig. 1, the number of patients in IC would have intercepted maximum capacity on March 14, 2020, if the increase had followed the exponential curve fitted on t1 data (and given the unlikely assumption that all IC beds could be used for patients with COVID-19). According to the quadratic curve fitted on t2 data, the date of intercept with the threshold of 5200 beds was delayed until March 28, 2020. Considering the increase in IC capacity, the threshold of 8000 beds would have been reached on April 5, 2020. The cubic curve fitted on t3 data peaked on April 1, 2020, and then decreased, never reaching either threshold. According to Italian Ministry of Health data, in 2017, the occupancy rate of IC beds in public hospitals was 48.4%.[7] Therefore, the number of available IC beds on March 8, 2020, was closer to 2600 and increased to approximately 5400 on March 24, 2020.

According to the preliminary analysis conducted in this study, the growth rate of the number of patients hospitalized in IC due to COVID-19 has slowed since public health measures with the objective of mitigating the outbreak were implemented in Italy, suggesting the effectiveness of these measures. The reduced growth rate in the number of IC patients bought valuable time, allowing for the number of IC beds to be nearly doubled before the national health system was completely overwhelmed.

Our findings are in line with the analysis conducted by Lau et al. supporting the positive impact of mitigation measures on the COVID-19 outbreak in China.[3] Recently, a modeling analysis projected Italian data according to the epidemic curve of the outbreak in the Hubei Province.[4] According to this model, the cumulative number of cases should have started diverging from the exponential trend 20 days after the beginning of the outbreak and reached its peak 10 days later, although the most recent Italian data indicate

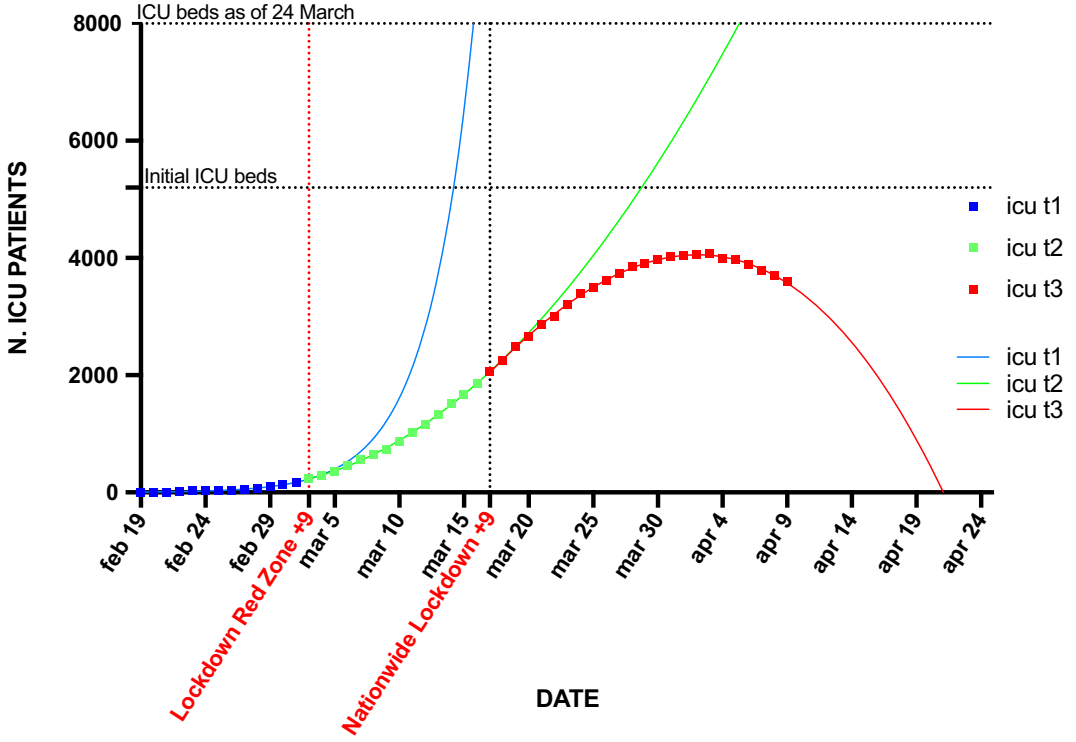

Fig. 1. The number of patients infected with COVID-19 in intensive care (IC) in Italy, from February 19, 2020 to April 9, 2020, and projections of the number of patients in IC if no further measures to control the outbreak had been implemented based on growth curves at three time intervals. Squares: notified number of patients in IC due to COVID-19. Lines: projections based on growth curves. Dotted vertical lines: lockdown of the red zone, school closures, and nationwide lockdown (with a 9 day delay to account for incubation and time from onset of symptoms until hospitalization in IC). Dotted horizontal lines: maximum capacity of IC beds at March 8, 2020 and March 24, 2020. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.) COVID-19, coronavirus disease 2019.

the epidemic curve was lengthened of around 10 days, reaching the plateau around 40 days after the beginning of the outbreak.

Several reasons could explain the different shape the epidemic curve is assuming in Italy compared with China. First, transmission dynamics might not have been the same due to geographic, demographic, and social differences between our countries. Furthermore, the extraordinary public health measures that were applied in both countries differed in timing and implementation. From a societal perspective, it would have been difficult to forcefully implement a complete shutdown of our country overnight. The Italian government proceeded toward nationwide lockdown by taking progressive steps.

The effectiveness of the containment and mitigation measures implemented in countries such as China, Hong Kong, Japan, and Singapore is encouraging.[8] Further efforts should be made in our country to increase the resilience of our health system, such as improving testing strategies, increasing laboratory capacity, and supporting home diagnosis and treatment.[8] This crisis has highlighted fragilities in our health system that can no longer be ignored, such as the fragmentation due to the regionally based organisation and delivery of health services, and chronic underfunding, especially concerning family medicine. The system has been slow to react, difficult to coordinate, and extremely homogeneous in its response.[9] Hopefully, the incredible hardships that Italy is facing and the severe costs of the extreme measures that had to be implemented will lead to rethink priorities and reshape our national health system.

Our study had several limitations. First, due to the study design, causation cannot be established based on our results. Second, it is not possible to determine the separate effect of each measure, or which one had the greatest impact, as in our study, we evaluated their cumulative effect. Third, considering the ongoing changes in case definitions and variations in protocols for the selection of patients to test for COVID-19, which may not have been applied homogeneously due to resource constraints, the number of notified cases might not reflect the actual prevalence of COVID-19 in our country.[10] The number of patients in IC, however, is an indicator less likely to be affected by underascertainment.

The present study suggests the broad-scale mitigation measures implemented in Italy could have helped flatten the epidemic curve and delay its peak, providing time to increase IC capacity. The results of this study provide timely scientific support for the mitigation measures implemented in our country and hopefully will encourage policymakers to continue making brave choices.

Considering the outbreak of COVID-19 has reached pandemic proportions, other countries should prepare for a scenario similar to the one currently unfolding in Italy. Our study provides insights that could be useful for other countries facing this epidemic.

Author statements

Acknowledgements

The authors gratefully acknowledge the Italian Ministry of Health and Civil Protection for divulging the data on the COVID-19 epidemic in Italy.

Ethical approval

None sought.

Funding

None declared.

Competing interests

None declared.

Authors' contributions

C.V. and V.B. contributed in conception and design of the study. V.B. contributed in statistical analysis of the study. C.V., V.B., and C.M.Z. contributed in interpretation of data. C.V.contributed in drafting of the article. P.G. and C.M.Z. contributed in critical revision for important intellectual content. C.M.Z. contributed in the final approval of the article.

References

1. World Health Organization. WHO coronavirus disease 2019 (COVID-19) situation report – 51, https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200311-sitrep-51-covid-19.pdf?sfvrsn=1ba62e57_10 (accessed April 28, 2020).
2. World Health Organization. WHO coronavirus disease 2019 (COVID-19) situation report – 98, https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200409-sitrep-80-covid-19.pdf?sfvrsn=1b685d64_2 (accessed April 28, 2020).
3. Lau H, Khosrawipour V, Kocbach P, Mikolajczyk A, Schubert J, Bania J, et al. The positive impact of lockdown in Wuhan on containing the COVID-19 outbreak in China. *J Trav Med* 2020. https://doi.org/10.1093/jtm/taaa037.
4. Remuzzi A, Remuzzi G. COVID-19 and Italy: what next? *Lancet* 2020. https://doi.org/10.1016/S0140-6736(20)30627-9.
5. Ministero della Salute. Nuovo coronavirus - dedicated web page, http://www.salute.gov.it/nuovocoronavirus (accessed April 28, 2020).
6. Istituto Superiore di Sanità. Report COVID-2019, 20 Marzo, https://www.epicentro.iss.it/coronavirus/bollettino/Report-COVID-2019_20_marzo.pdf (accessed April 28, 2020).
7. Ministero della Salute. Annuario Statistico del Servizio Sanitario Nazionale, http://www.salute.gov.it/imgs/C_17_pubblicazioni_2879_allegato.pdf (accessed April 28, 2020).
8. Anderson RM, Heesterbeek H, Klinkenberg D, Hollingsworth TD. How will country-based mitigation measures influence the course of the COVID-19 epidemic? *Lancet* 2020. https://doi.org/10.1016/S0140-6736(20)30567-5.
9. Armocida B, Formenti B, Ussai S, Palestra F, Missoni E. The Italian health system and the COVID-19 challenge. *Lancet Publ Health* 2020. https://doi.org/10.1016/S2468-2667(20)30074-8.
10. Tuite AR, Ng V, Rees E, Fisman D. Estimation of COVID-19 outbreak size in Italy. *Lancet Infect Dis* 2020. https://doi.org/10.1016/S1473-3099(20)30227-9.