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Letter to the Editor

# Riding the waves of COVID-19 pandemics – A call for a multiobjective compromise

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We are living in the first pandemic of the 21st century. Resource allocation is crucial; having data and being able to analyze them becomes fundamental.

Every day, we analyze the Italian raw trends of COVID-19 main variables (hospitalized, intensive care unit (ICU) beds, deaths, and positives) by means of a few deterministic nonlinear models based on historical data that allow predicting of future trends at both short- and long-time intervals [1]. These models have proved robust and efficient to describe the various pandemic waves. Probably the most valuable outcome of this analysis is that it allows anticipating the allocation of COVID-19 beds. At the very beginning of the pandemic, it was manifest that ICU beds would have been the rate-determining step of hospital treatment [2,3]. The doubling time of ICU beds was one of the key variables that followed a never before experienced exponential growth with values inferior to three days. In the following months, the same modeling approach allowed tracking the deflation of hospital resources and scheduling the reallocation of those non-COVID-19 [1]. Anticipation of the dynamics and features of both the inflation and deflation curve trends, which respectively occurred before and after the pandemic peaks, allowed better tackling of the ever-changing hospital practice. The same predictive algorithms were applied successfully to the second and third COVID-19 outbreaks in Italy and can adapt to future (COVID-2X) pandemic waves and to different nations.

As of March 2021, European nations are experiencing new outbreaks with the most plagued nations undergoing either a prolonged second wave or a rebound to a third wave or a sustained shift from second to third wave with a resulting faster deflation although the absolute numbers are still quite high (Fig. 1).

Focusing on the Italian pandemic, our quantitative modeling analysis tells that (Fig. 1):

1) the first wave had a higher impact in terms of ICU allocation with respect to the second one;
2) due to the more stringent lockdown, the after-peak descent of hospitalized patients in the first wave was faster and more stable than in the second one.
3) the second wave began in October 2020 and was shorter than the first one. At the same time, after the peak, the reduction of hospital resources allocated to COVID-19 was significantly inferior to the first wave. That was due to an inflation term in conflict with the expected deflation term, which eventually induced an oscillating and almost constant trend;
4) at present, Italy is facing the third wave, which is still at the beginning with an initial exponential growth. The doubling times of allocated resources (such as ICU beds) are significantly longer than those of the previous outbreaks. However, the number of already contagious individuals is much larger and this exposes the whole nation to a higher risk of drift also induced by virus variants.

The decelerated or postponed deflation of COVID-19 resources prolongs the medical efforts on two opposite sides: (i) the extended COVID-19 emergency calls for further efforts and diverted resources that (ii) otherwise would be allocated to elective medicine.

Possibly, the approach to tackle this new phase will be “elasticity”; health systems need to become flexible. In fact, there is a hypothetical mirror part of the graph representing the trend of the COVID-19 pandemic. This new portion of the figure would be specular and embody the diagnostic and/or therapeutic delays in non-COVID-19 patients [4]. A large fraction of the resources of all the affected countries had to be used in the fight against the virus. This resulted in a reduction of non- COVID-19 activities, with delays of diagnosis, healthcare treatments and/or follow-up in different pathologies. Since this new oscillatory phase will probably be rather long, it becomes almost impossible to maintain a sustained emergency regime of health systems. Therefore, flexibility should drive the hospital activities in adapting quickly to the ever-changing conditions by strengthening “COVID-19 forces” during outbreaks and reinforcing the “non- COVID-19 forces” during pandemic deflations.

It could be corrected to normalize the model with ICU beds availability. The flexibility of the health systems has led them to be able to create new beds even in moments of maximum pressure, such as those that occurred in April 2020. This risk would lead to a curve whose normalization would show a practically constant value of 100% of occupation.

Will the vaccination campaign change the trend? It might! Artificial Intelligence may help. For instance, it was employed to analyze the impact of restriction measures on the pandemic course.[4] Provisions, distribution, and vaccination methods are just

*Abbreviations:* ICU, Intensive Care Unit.

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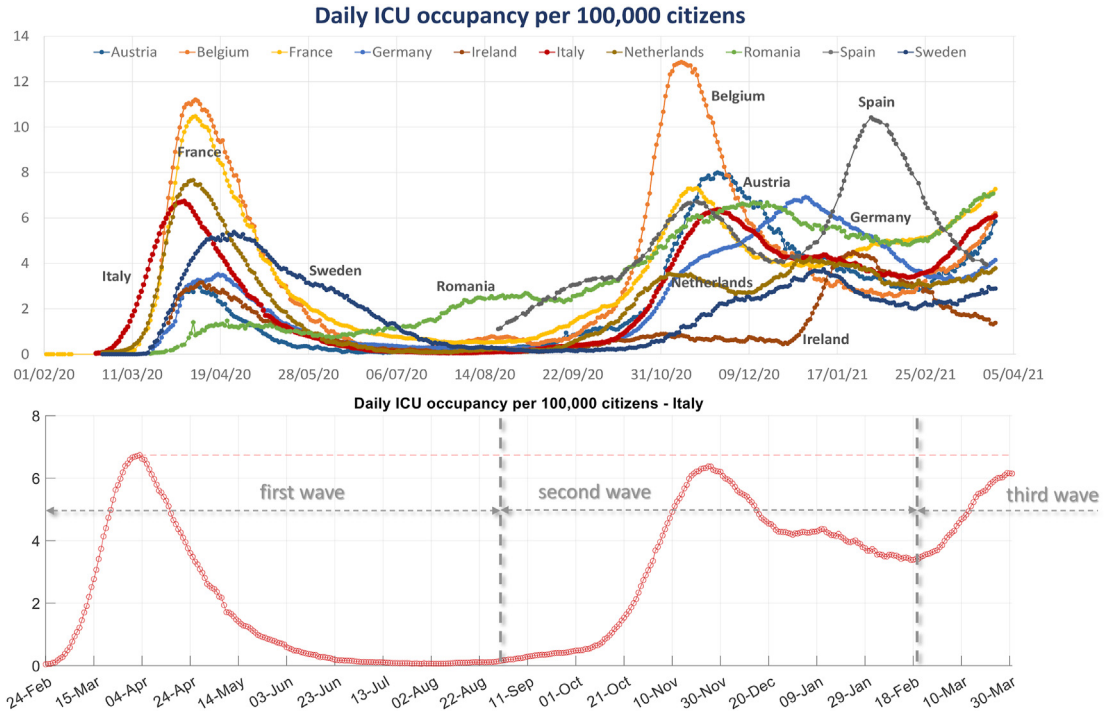


**Fig. 1.** Evolution of the COVID-19 pandemics in terms of ICU patients (per 100,000 citizens) in the most plagued nations of European Community (top panel) and detail of Italy (bottom panel). Three outbreak waves epitomize the Italian pandemic dynamics that shows a prolonged slowdown of the second one and the start of the third one. EC data of Spain do not cover the first outbreak in March 2020 (https://www.ecdc.europa.eu/en/publications-data/download-data-hospital-and-icu-admission-rates-and-current-occupancy-covid-19).

some of the factors that will influence the impact of the vaccine on the progress of the pandemic. Advanced methods could be used to draw working hypotheses and extrapolate predictions.

However, it is worth analyzing data constantly. It is necessary to determine from time to time and case by case (i.e. region or nation) the adaptive parameters of those models. Gradients of the pandemic curves are influenced by a high number of variables and may undergo sudden and substantial leaps. For instance, they change according to restriction measures and with clinical changes, often unpredictable, such as SARS-CoV-2 variants [5,6]. In particular, on this last aspect, although the model is proving valid for the new variant of COVID-19 that first was detected in the UK, new variants continue to emerge whose transmissibility, neutralizing activity and mortality are highly variable [7]. This may require further model adjustments.

In conclusion, we think that the uninterrupted analysis to describe trends and elaborate predictions is a fundamental tool to promptly modify the pandemic management plans.

## Authors contribution

EB/DM/VB:

1. Substantial contributions to the conception the conception and design of the study, acquisition of data, analysis, and interpretation of data.
2. Drafting the article and revising it critically for important intellectual content.
3. Final approval of the version to be submitted.

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