Hospital Capacity and Operations in the Coronavirus Disease 2019 (COVID-19) Pandemic—Planning for the Nth Patient

Joseph J. Cavallo, MD; Daniel A. Donoho, MD; Howard P. Forman, MD, MBA

Introduction

The coronavirus disease 2019 (COVID-19) news coming from Italy should be sobering to health system leaders throughout the world. We are witnessing an advanced health system stretched beyond its capacity. When the capacity of the system is exceeded, rationing decisions may need to be made that extend well beyond patients with COVID-19. On March 11, the Italian College of Anesthesia, Analgesia, Resuscitation, and Intensive Care was forced to publish guidelines for rationing care. Infectious disease and epidemiology experts have been outlining the worst-case scenarios possible with the unchecked spread of a novel virus, both in terms of immunity and preparedness. Unfortunately, hospital systems are designed for average patient loads, not epidemics. Observations from Italy demonstrate what is at stake. When containment fails, the exponential growth of cases can transform a public health emergency into an operational crisis.

What Can We Learn?

Operationally, what can be gleaned from the dire situation in Italy to avoid a similar fate in other countries? The geographic and temporal clustering of outbreaks can overwhelm a health care system. Most Italian cases and deaths have been concentrated in the northern region of Lombardy, which should concern US states working to manage their own clusters, including Washington and New York. President Trump has imposed sweeping travel restrictions on visitors from China and Europe, but these restrictions will have little effect in US regions with widespread community transmission. Public containment measures implemented in recent days will take a week or longer to have an effect; with an incubation period of 2 to 7 days and a wait for test results of 2 to 3 days, new cases reflect infections from more than a week ago.

Patients with severe disease from COVID-19 require a mean of approximately 13 days of respiratory support. Such lengthy treatment time will further stress resources. This time in the system multiplied by the arrival rate (known as Little’s law) is a simple but elegant formula for modeling system capacity before a queue develops. In manufacturing or customer service, queues may result in decreased profitability and/or the loss of customers; in critical care medicine, queues can be deadly. For example, take a large hospital with 100 beds in the intensive care unit. Assume that at any given time, 70% of these beds are occupied. The remaining 30 beds are the effective extra capacity to absorb patients with COVID-19. Because of the long treatment time (approximately 13 days), the number of new patients that can be accommodated per day during an extended outbreak is low. Admitting more than 2.3 patients per day (30 beds divided by 13 days) with respiratory failure will lead to an unstable system and queues. Italy reported new cases during a 2-day period between March 14 and March 15, 2020. With as many as 15% of documented infections resulting in severe disease, rationing decisions may quickly be required.
How Can We Prepare?

By observing regional outbreaks in the context of Italy’s case growth, we can start to model and anticipate both what the ultimate capacity to provide care will be and when that capacity will be exceeded. Case growth rates of 25% to 35% per day are commonplace among affected regions. Based on trends in known cases in a specific locale, we can start to model caseloads under different scenarios. Tools designed for influenza epidemics, such as the Centers for Disease Control and Prevention FluSurge, can offer useful estimates. Preparations for expanding capacity should already be underway to address growing regional clusters of transmission (ie, so-called hotspots). Many hospitals have mass casualty protocols for catastrophic events; the COVID-19 response could require an equal mobilization of staff and resources but during a sustained period. Nearby hospital systems should communicate early and often, given that efficient case sharing and transport between hospitals could become essential. Regional networking among 15 hospitals was part of Lombardy’s early response to the massive surge of patients with COVID-19 while individual hospitals increased capacity.4

Bed capacity may not be the most crucial bottleneck for providing critical care. Observing Italy, experts are rightly concerned about the fixed number of ventilators. However, there are many other key factors to consider. Given the risk of health care worker infection5 and quarantine, will there be enough staff to provide care? Are there sufficient drug supplies for effective respiratory and cardiovascular support? Are there adequate supplies of personal protective equipment? Hospitals have prided themselves on the efficiency that comes with just-in-time supply management and minimizing empty beds, but as a result, they may be ill equipped for an epidemic surge.

Hospital administrators need to start preparing for worst case scenarios now, and thankfully, most are doing so. Toner and Waldhorn6 have assembled a comprehensive list of preventive actions. This planning and response will require a multidisciplinary effort; physicians, nurses, respiratory therapists, pharmacists, environmental services staff, supply chain managers, and many others possess needed expertise. Messaging from hospital leadership must be communicated often and clearly. The protection of staff from infection must remain a high priority.

What Lies Ahead?

Some countries, such as Taiwan,7 have been successful at combating the virus through aggressive testing and containment measures. South Korea, while initially inundated with patients from a rapidly spreading cluster, has successfully mitigated spread (at least temporarily) with minimal associated mortality. These examples provide encouragement that a well-executed public health response can minimize the potential for operational crises. The common themes in success have been massive testing, adaptive policy recommendations for different regions, and communication by public officials that is constant, transparent, and honest. The public needs to trust public officials and see the good and bad news every day.

In our interconnected world, the life-and-death consequences of health care needs exceeding the system’s capacity could hit any region at any time. It is imperative to learn the lessons of Italy and Hubei, China: waiting until an exponentially increasing epidemic becomes self-evident will ensure that draconian efforts will be required for control, and even with these measures, there will be a significant loss of life. Actions taken now by society and health care systems will determine whether history regards 2020 as a great public health achievement or an epic failure of our public health and health care infrastructure.
ARTICLE INFORMATION

Open Access: This is an open access article distributed under the terms of the CC-BY License.

Correction: This article was corrected on March 20, 2020, to fix errors in the authors’ degrees and affiliations.

Corresponding Author: Joseph Cavallo, MD, Yale Radiology and Biomedical Imaging, 330 Cedar St, TE 2-214, New Haven, CT 06520 (Joseph.Cavallo@yale.edu).

Author Affiliations: Yale Radiology and Biomedical Imaging, Yale School of Medicine, Yale University, New Haven, Connecticut (Cavallo, Forman); Yale School of Management, Yale University, New Haven, Connecticut (Cavallo, Forman); Neurosurgery, University of Southern California, Los Angeles (Donoho); Yale School of Public Health, Yale University, New Haven, Connecticut (Forman).

Correction: This article was corrected on March 20, 2020, to fix errors in the authors’ degrees and affiliations.

Corresponding Author: Joseph Cavallo, MD, Yale Radiology and Biomedical Imaging, 330 Cedar St, TE 2-214, New Haven, CT 06520 (Joseph.Cavallo@yale.edu).

Author Affiliations: Yale Radiology and Biomedical Imaging, Yale School of Medicine, Yale University, New Haven, Connecticut (Cavallo, Forman); Yale School of Management, Yale University, New Haven, Connecticut (Cavallo, Forman); Neurosurgery, University of Southern California, Los Angeles (Donoho); Yale School of Public Health, Yale University, New Haven, Connecticut (Forman).

Conflict of Interest Disclosures: None reported.

REFERENCES

1. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72,314 cases from the Chinese Center for Disease Control and Prevention. JAMA. 2020. doi:10.1001/jama.2020.2648

2. Guan WJ, Ni ZY, Hu Y, et al; China Medical Treatment Expert Group for Covid-19. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med. 2020. doi:10.1056/NEJMoa2002032

3. Halpern NA, Pastores SM. Critical care medicine beds, use, occupancy, and costs in the United States: a methodological review. Crit Care Med. 2015;43(11):2452-2459. doi:10.1097/CCM.0000000000001227

4. Grasselli G, Pesenti A, CecconI M. Critical care utilization for the COVID-19 outbreak in Lombardy, Italy: early experience and forecast during an emergency response. JAMA. 2020. doi:10.1001/jama.2020.4031

5. Wang J, Zhou M, Liu F. Exploring the reasons for healthcare workers infected with novel coronavirus disease 2019 (COVID-19) in China. J Hosp Infect. 2020. doi:10.1016/j.jhin.2020.03.002

6. Toner E, Waldhorn R. What US Hospitals should do now to prepare for a COVID-19 pandemic. Published February 27, 2020. Accessed March 13, 2020. http://www.centerforhealthsecurity.org/cbn/2020/cbnreport-02272020.html

7. Wang CJ, Ng CY, Brook RH. Response to COVID-19 in Taiwan: big data analytics, new technology, and proactive testing. JAMA. 2020. doi:10.1001/jama.2020.3151