Acute Care Surgeons' Response to the COVID-19 Pandemic

Observations and Strategies From the Epicenter of the American Crisis

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The COVID-19 pandemic has strained global health systems with a severity that has not been seen in over a century. New York City (NYC) has emerged as the epicenter of the disease outbreak in the United States (US) and is currently on track to become the city with the greatest caseload in the world. At the time of this writing, almost half of all US deaths are in New York State.[1] The massive influx of COVID-19-affected patients has strained many hospitals to the point that they are no longer able to provide basic clinical services and all hospitals are now operating under varying degrees of emergency triage algorithms.

NYC Health & Hospitals (H&H) is the largest municipal hospital system in the United States. The 11 acute-care facilities comprise 21% of the total hospital beds available in NYC.[2] As acute care surgeons at NYC H&H/Bellevue, our objective is to describe the strategies that were employed to achieve system-wide coordination, as well as institution- and service-specific reorganization, so as to maximize our ability to safely manage the relentless influx of patients affected by the disease, while minimizing adverse effects on emergency surgery and trauma services.

MAXIMIZING SURGE CAPACITY

Separating Noninfected From Infected Cohorts

In nonsurge conditions, adult critical care services at NYC Health & Hospitals/Bellevue are typically divided into 4 intensive care units (ICUs): medical (MICU), surgical (SICU), surgical step-down (SDU), neurosurgery (NICU), and a coronary care unit (CCU), with a total of 54 critical-care capable single-bed rooms on 1 hospital floor. Other areas that typically house critically ill patients include a 21-bed post-anesthesia care unit (PACU), a 5-bed cardiovascular post-anesthesia care unit, and a 10-bed emergency/trauma ICU; these 3 latter units are large clinical areas without individual patient rooms. To create the maximal number of adequately staffed critical care beds, several administrative decisions and organizational changes were necessary (Table 1).

First, all elective surgeries were suspended to improve the bed flow based on the anticipated surge of patients. Inpatient wards were re-organized in an attempt to co-locate COVID and non-COVID patients as much as possible. Next, all non-COVID critical care patients (MICU, SICU, NSICU, and CCU) were cohorted into 1 unit (PACU) over the period of 10 days as the COVID patient volume steadily increased. The 54-bed ICU was prioritized for incoming COVID patients to take advantage of the larger spaces and single-bed rooms, to maximize the ability for immediate co-location, and to maximize flow out of the emergency department (ED), which was a critical priority. Once vacant, each ICU cubicle was converted to a negative pressure room by installation of a high-efficiency particulate air filter and an external exhaust duct was directed through the outside window. Over the course of a week, all 54 beds were filled with a COVID patient, nearly all on ventilators. Concurrent to this, there was a concerted effort to move patients out to long-term facilities or to home as soon as safely feasible, whereas a precipitous and steady drop in volumes of non-COVID admissions across all ICUs was also recognized. As our medical intensivist colleagues were spearheading the COVID treatment efforts and developing this expertise, the surgical and anesthesia intensivists took over the care of the non-COVID MICU patients, and assisted as medical consultants for the NSICU (a role previously performed by the MICU) to help offload their clinical burden. Although this was a designated non-COVID unit, beds were spaced >1 meter apart to minimize nosocomial outbreaks in the event the virus was introduced to the unit.[3] In the PACU, patients were constantly monitored for any evidence of COVID infection and were moved out and into the COVID ICU if concerns (eg, unexplained fever, hypoxemia, cough or imaging findings concerning for COVID) arose. A trauma patient who presented after a fall from standing, a CCU patient with an acute myocardial infarction, a neurosurgery patient, and a postoperative cardiac surgery patient were all identified as COVID-positive and needed to be quickly moved out; testing delays including multi-day turnover for results across NYC contributed to these early challenges. Because we were limited to one area for vulnerable non-COVID critical care patients, it was vitally important to prevent the area from becoming compromised. As soon as rapid testing was introduced, we adopted a policy that required screening of patients in the emergency department (ED) before admission to this unit.[4] In the first 24 hours after instituting this policy, we identified 2 trauma patients who presented for an unrelated mechanism (1 fall, 1 assault) as SARS-CoV-2-positive. Despite our best efforts at separation of COVID

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L.K., M.B., and S.M.C. performed and provided perspectives on tracheostomy; M.J.K., S.G.F., and M.T. developed the acute peritoneal dialysis program, performed and troubleshot the bedside procedure, and trained/credentialed support staff; S.G.F., M.B., M.P., J.C., N.L., A.U., and C.B. coordinated and the systems-level disaster response; S.G.F., S.M.C., J.C., R.N.L., H.L.P., and C.B. edited manuscript and provided guidance. All authors have made substantial contributions to conception and design of the initiatives integral to our response to the pandemic. All authors have drafted or critically revised the manuscript for important intellectual content, and all authors give final approval of this version to be published.

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TABLE 1. Changes Adopted in Preparation for COVID-19 Pandemic Outbreak in NYC

Adoption of New Processes	Action
Maximizing surge capacity	Suspension of elective surgeries
	Concerted effort to discharge admitted patients
	Conversion of procedural areas into COVID ICUs
Regional coordination within the system	Daily conference calls to address resources and capacity
	Maintenance of essential services (eg, trauma, stroke, cardiac)
Safety precautions for patients and personnel	Separating noninfected from infected cohorts
	Limiting number of personnel entering patient rooms
	Full PPE for all personnel with direct COVID patient contact
	Implementation of nonoperative management when appropriate
	Development of negative pressure operating rooms
	Use of Flyte Surgical helmet for select operative cases
	Use of smoke evacuators and filtration systems during laparoscopy
Surgical procedures related to the care of the COVID patient	Bedside tracheostomy
	Bedside placement of peritoneal dialysis catheters

from non-COVID patients, 1 trauma patient who had been admitted before the outbreak subsequently contracted the virus and developed COVID.

Changes in Organizational Structure and Workflow

The first COVID+ admission to Bellevue Hospital was Thursday, March 12. The following day and in advance of the NYC mayoral executive order, Bellevue made the decision to suspend all nonurgent surgeries.[5] As a level 1 trauma center, we initially continued to see a steady influx of trauma patients, especially in the early phase of the pandemic; this volume rapidly declined following Governor Cuomo's "New York State on Pause" order.[6] The volume of emergency general surgery (EGS) patients, although initially steady, also precipitously dropped as COVID case numbers grew.

Similar to stroke and cardiac care, trauma expertise is a limited resource, and because over half of our surgery faculty were rendered idle due to the cancellation of elective cases, this caused us to restructure. All nontrauma general surgery services (eg, surgical oncology, colorectal, minimally invasive, and bariatric) were combined into 1 general surgery service which became responsible for all EGS cases (Fig. 1).[9] This new full-time general surgery service enabled the acute care surgeons to continue to care for trauma patients in an uninterrupted fashion, while also managing the combined non-COVID MICU/SICU and participating in emergency planning discussions. Simultaneously, general surgeons and surgery

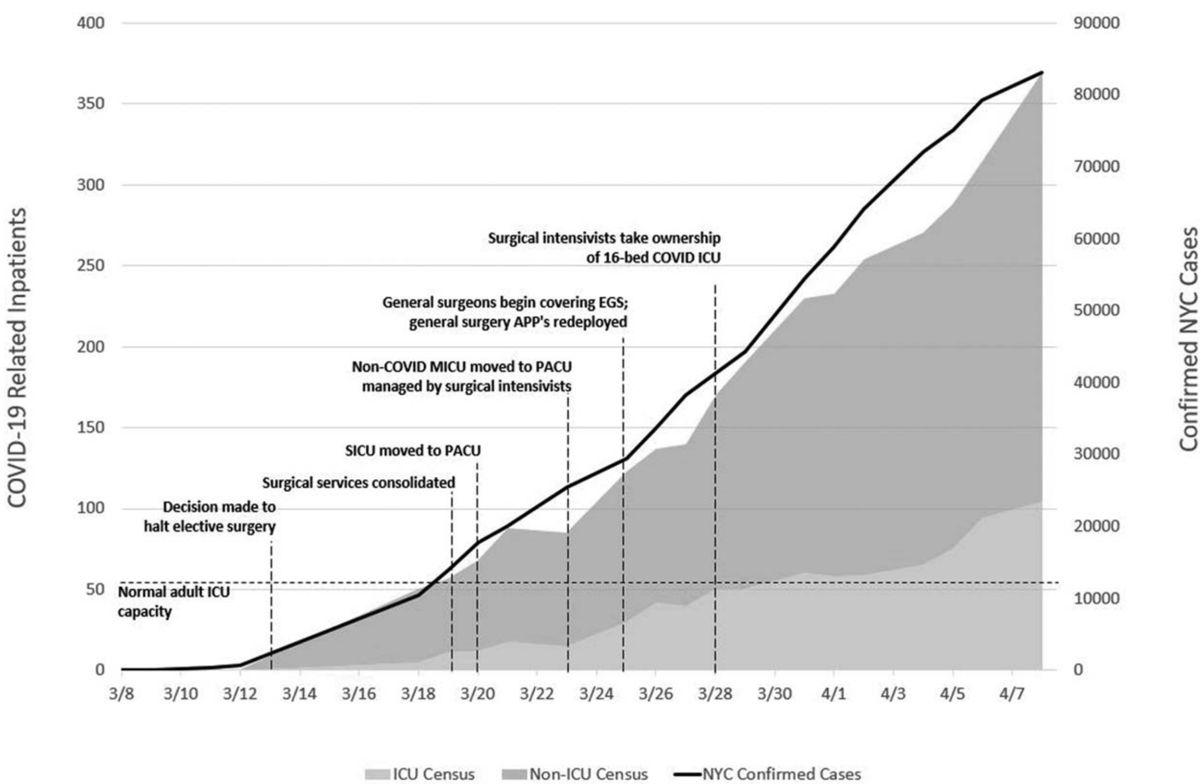

FIGURE 1. Disaster preparedness and COVID19-related hospital admissions at NYC Health & Hospitals/Bellevue[9].

residents were not only able to remain as an available workforce to serve in other capacities, but many also began taking critical care refresher courses and modules in preparation for re-deployment to the COVID ICUs.[7,8]

In time, the volume of ICU-level COVID patients grew to a level that overburdened our medical intensivist colleagues. At that point, the surgical intensivists, along with two anesthesia intensivists, took ownership of a 16-bed COVID ICU, rounding 7 days per week and managing the care of these patients. This allowed the medicine service to regroup, to gather additional volunteer doctors, nurses, and advanced practice providers, and to expand even further into newly created ''pop-up'' ICU spaces.

At the time of this writing and aided by a sharp drop in volume, our current trauma patient flow has not been largely interrupted. The trauma leadership deemed it critical to maintain flow by preserving the functionality of the trauma bay, operating room (OR), and non-COVID ICU space; if any of these areas were to be encroached upon, the trauma center would not be able to function and injured patient care would be compromised. In a city as large as NYC, it was imperative to maintain this state of preparedness. Up to this point, the Bellevue trauma bay remains open, the trauma OR is available, and the SICU has capacity. Although much of this may be due to internal restructuring, a significant decrease in the number of trauma activations attributed to social restrictions proved vital. We do remain concerned that if these restrictions are lifted before hospital and critical care resources return to near-normal, an influx of trauma patients superimposed on a heavy burden of lingering ICU-level COVID cases may prove to be challenging.

Converting Procedural Areas to COVID ICUs as Part of Surge Planning

As part of the statewide surge capacity planning, periprocedural areas were the most suitable to be converted to ICU spaces, including the endoscopy suite, the PACU, the OR holding area, and the ORs. In terms of planning, each OR has 2 oxygen booms; with the use of an oxygen splitter, 4 ventilated patients can be cared for in each OR, as long as the electric circuitry capacity is adequate (electrical upgrades were required to improve the capacity and ensure >1 emergency electrical circuit was available in each room). In this manner, we were able to yield 52 ICU slots from 10 operating rooms and the holding area (as of yet, this has not become necessary), leaving 4 operating rooms for surgical procedures including traumas. These 4 ORs were located at the end of the OR suite; a temporary wall was constructed to separate this operative wing from the ''ICU wing'' should it become necessary to place COVID patients there, and a separate entrance to the new operative suite was designated to limit COVID exposure to non-COVID operative patients. Similarly, the endoscopy suite which included 4 procedural rooms and a recovery space was converted into a 10-bed ICU, which began receiving COVID patients once the 54-bed ICU filled. In addition, many areas of the hospital which had been ICUs in the past but had long since been used for other purposes were refurbished to create new ICU spaces.

Trauma Systems and Regional Coordination

The gradual spread of SARS-CoV-2 throughout the world has affected different countries and cities at different times and rates. The same is true for boroughs and hospitals within NYC. At the beginning of the outbreak, several hospitals saw a far greater numbers of patients than others. To prevent any 1 hospital within the NYC H&H from becoming overwhelmed, a strategy was developed to share key information across the system, across all ICU directors, trauma directors, and hospital administration. Conference calls allowed for coordination and rapid transfer of patients from overburdened facilities to facilities that still had capacity to accept patients. Realizing that census and occupancy were not enough to adequately capture each facility's strain, we integrated data including room occupancy, staffing, census, acuity of illness, as well as ventilator availability and other critical infrastructure to create a daily summary, including a color-coded chart that summarized the strain on the system as a whole (Fig. 2). This strategy proved to be very successful and allowed hospitals with no capacity to transfer to facilities which, although strained, could better shoulder additional burden. NYC H&H/Bellevue was able to support H&H facilities in other boroughs (eg, Queens) by accepting up to 40 patients (10 ICU status; 30 floor status) for 4 consecutive days (at the time of submission of this manuscript). This plan proved effective toward managing the system's ability to safely care for as many patients as possible.

SAFETY PRECAUTIONS FOR PERSONNEL

Shortages of personal protective equipment (PPE) are prevalent throughout the country. Although acknowledging the suboptimal nature of the situation, our institution has encouraged both extended-use and re-use of PPE when appropriate, as long as it is not damaged or contaminated. In an effort to maximize staff safety and conserve supply, we have instituted changes to the usual workflow both inside and outside of the OR.

During the SARS pandemic, Tien et al[10] demonstrated that despite appropriate use of CDC-recommended PPE, staff may still

Surge Status Report

Facility	3/23	3/24	3/25	3/26	3/27	3/28	3/29	3/30	3/31	4/1	4/2	4/3	4/4	4/5	4/6	4/7
A	2	2	2	3	2	3	2	3	3	3	3	3	3	3	3	3
B	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3
C	3	3	3	3	2	2	3	3	3	3	3	3	3	3	3	3
D	1	2	2	2	2	3	2	3	3	3	3	3	3	3	3	3
E	1	2	2	3	3	3	3	3	3	4	3	3	3	3	3	3
F	1	1	1	1	2	2	3	3	3	3	3	3	3	3	3	3
G	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4	4
H	No surge	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3
I	1	No surge	No surge	No surge	2	2	2	2	2	2	2	3	3	2	3	3
J	2	2	2	2	3	4	4	3	4	4	4	4	4	4	4	4
K	2	2	2	3	3	3	3	3	3	3	3	4	3	3	3	3

No surge: still within capacity normally utilized for sick medical patients with appropriate staffing
Level 1: utilizing other ICUs that are usually not used for sick medical patients (e.g. CCU/SICU/step down)
Level 2: utilizing atypical spaces such as PACU/pediatric ICU/other OR anticipate ventilator shortage within days
Level 3: utilizing extraordinary spaces (OR/general wards/parking lot) OR running out of ventilators imminently
Level 4: utilizing ALL extraordinary spaces to maximum capacity (each operating room has multiple ICU patients, ambulatory/peri-operative spaces used as ICU space, etc) OR there are <3 ventilators remaining in the hospital OR patients are doubled/tripled up in typical ICU spaces designed for one patient
Level 5: no space available for ICU patients OR no ventilators available in the hospital

FIGURE 2. NYC system-wide public hospital ICU surge report.

become infected, particularly during challenging situations such as a difficult airway scenario. During the first week of the epidemic, at our institution, 6% of seemingly non-COVID acute trauma patients presenting to the ED were found to have symptoms and subsequently were identified as infected; this rose steadily to 30% of all trauma admissions by the fourth week due to the high prevalence of community spread in NYC. Many trauma activations involve superspreading procedures (eg, endotracheal intubation), so we adopted a policy consistent with published guidance limiting the number of trauma team members entering the trauma resuscitation room.[11] This policy involves a maximum of 3 team members for a partial activation, and 6 team members for a full team activation. Remaining team members wait outside the room and are called in only if necessary. For all activations, our local policy is that all trauma team members entering the room must wear full PPE, including an N95 mask, eye shield, gown, gloves, and cap.

In accordance with recommendations of multiple national surgical societies, we have also limited the amount of surgery performed, and preferentially opt for nonoperative management and therapies if possible.[12] If surgery is necessary, we have adopted practices described during the 2005 SARS pandemic: for COVID-positive patients, this includes performing bedside procedures when possible to eliminate transport, minimizing the number of assistants to only those absolutely necessary, eliminating the circulator, and prioritizing cases to only senior staff with the greatest experience.[10] In the event that the formal OR space becomes necessary, we have designated a negative-pressure OR.[13] We have also adopted use of the Flyte Surgical Helmet (Stryker, Inc; Kalamazoo, Michigan), an Association for the Advancement of Medical Instrumentation (AAMI) Level 4 protective helmet typically used in orthopedic surgery, for select procedures. Although it is impermeable to blood and liquid viral penetration under regular circumstances, a risk of aerosolized exposure still exists, and therefore we continue to wear full PPE under the helmet.[14,15] Although the Flyte helmet is not labeled for use for this purpose, the combination of these 2 techniques was reported to be effective during SARS.[10]

SURGERY-SPECIFIC CHANGES

Endotracheal Intubation

For COVID or suspected COVID patients, the negative-pressure OR is utilized and, when clinical circumstances allow, the number of personnel present for endotracheal intubation is minimized usually with only the anesthesiologist present. The surgery team and circulator enter the room after 5 minutes given the potential for a superspreading event, as complete air change at a minimum of 12 times per hour should minimize the risk of aerosols.[16]

Tracheostomy

There is currently great controversy over the practice of performing tracheostomy on COVID-positive patients. During the SARS pandemic, surgeons had a high threshold for performing these procedures due to high mortality rates in the intubated patient population. Typically, tracheostomy performed with the primary goal of long-term weaning would only be done in patients in the convalescent phase with a good prognosis for survival.[17] Although we agree in principle with this assessment, at our institution we are currently faced with several challenges that have lowered the threshold of our acute care surgeons to perform these procedures. First, the sheer volume of patients that we are treating has strained our personnel, limiting the time medical staff, nurses, and respiratory therapists can spend on individual patient care, including basic pulmonary toilet. This concern has also been highlighted by our colleagues in Pennsylvania and is compounded by the large amount of respiratory secretions observed in these patients.[17] This has led to multiple cases of life-threatening mucus plugging, potentially necessitating emergency bronchoscopy or endotracheal tube exchange, superspreading events which put staff at risk by forcing them to hastily don PPE before entering the room. Performing a tracheostomy in an elective, prepared setting with appropriate PPE may decrease the frequency of these events. Also, replacing an inner cannula is faster, simpler, and likely safer, and tracheostomy care is simply more practical. Second, like many of our colleagues around the world, we are finding that many of these patients are difficult to adequately sedate. Use of propofol is limited due to hypertriglyceridemia in a subset of COVID-19 patients that develop secondary hemophagocytic lymphohistiocytosis, requiring the use of combinations of alternative agents.[18] A national shortage already exists for propofol and fentanyl, and given that NYC has yet to reach its peak, these shortages will likely become more limiting in time.[19] Performing earlier tracheostomy in these patients may allow for a decrease in sedative medication use,[20] which may conserve resources in the event of a prolonged pandemic. An unplanned extubation in these patients can lead to severe harm or death and places responding staff at risk. Paralytics are similarly in short supply with limited availability of continuous infusions, and patients with tracheostomies may have less ventilator dyssynchrony.[21]

We have opted to perform these procedures at the bedside to limit the interruption of closed-circuit ventilation and to avoid the movement of these high-risk patients along hallways that may become contaminated. Currently, patients who have been intubated $\geq$5 days, requiring $FiO_2 \leq 60\%$ and PEEP 10 without significant organ dysfunction beyond respiratory failure are considered for tracheostomy. Definitive indications and optimal timing for tracheostomy in COVID+ patients are unknown, as we are only beginning to study the outcomes of this patient population. In addition, there is a paucity of data regarding the safety of this procedure to providers. Until more data are available, we are proceeding with this procedure following a protocol designed to minimize exposure to health care providers. We don full PPE, including an N95 mask, and use the Flyte surgical helmet to supplement standard airborne precautions (Fig. 3). Tien et al described the use of the Flyte helmet for tracheostomy during SARS, and reported that all staff involved in the procedures remained healthy for 6 months; it should be used *in addition* to standard airborne precautions, including an N95 mask.[10,15] To limit superspreading, we have adopted a hybrid open/percutaneous approach for tracheostomy in these patients utilizing a more extensive cutdown to minimize both bleeding complications (ie, many of these patients have significant acute kidney injury with uremia) and bronchoscopy time. Two attending surgeons and an anesthesiologist have performed each procedure. The hybrid technique utilizes an extensive cutdown to visualize the pretracheal fascia. Utilizing endotracheal tube position on the most recent chest X-ray as a guide and keeping the cuff inflated, we advance the tube to the level of the carina to avoid puncturing the cuff. The needle is then inserted into the trachea and the guidewire introduced after aspiration of air. The needle is removed, the endotracheal tube is retracted, apnea is induced, and only then is the bronchoscope inserted to confirm the position of the wire. After confirmation, the bronchoscope is quickly withdrawn to minimize superspreading, and the tracheostomy is inserted after serial dilatations. Finally, the bronchoscope is quickly re-inserted through the tracheostomy to confirm proper placement. All steps, including bronchoscopy, are performed under a clear drape from the time of entry into the trachea.

Laparoscopy

There is a paucity of evidence regarding the use of laparoscopy with respect to potential aerosolization of viral particles and

FIGURE 3. Bedside hybrid-percutaneous tracheostomy, performed in a negative-pressure room with providers wearing Flyte helmets over standard airborne PPE.

how this may affect staff safety. In general, we have adopted the approach recommended by the Society of American Gastrointestinal and Endoscopic Surgeons, which recommend measures to minimize the free release of insufflated gas.[22] These measures include use of smoke evacuators, filtration systems, and evacuation of all pneumoperitoneum into closed systems, among others.

Renal Replacement Therapy

The large number of patients with multiorgan dysfunction has strained hospital resources, including the capacity to provide both intermittent and continuous renal replacement therapy. Although media focus has consistently been on ventilators, dialysis systems have been strained more than anticipated throughout NYC. Contributing factors to this include the number of available machines, depletion of supply of filters, the reduced number of credentialed nursing and support staff (many due to illness), and the increased workload of ICU nurses who are each caring for $\geq$3 critically ill patients. Several studies have demonstrated that the use of peritoneal dialysis (PD) in critically ill patients with AKI may be a viable alternative, although an imperfect one in the face of multi-organ system failure.[23,24] We have adopted the practice of placing PD catheters for several reasons: it allows us to maintain renal replacement therapy (RRT) capacity for the unprecedented demand, it helps maintain a manageable patient and work load for the ICU staff, and PD is relatively simple to operate, which allows for the rapid training and credentialing of additional providers without any previous dialysis expertise.[24] At our institution, both ophthalmologists and dermatologists have been trained are actively assisting in this endeavor.

In the absence of readily available equipment or staff, COVID+ patients with worsening AKI who meet indications for the initiation of RRT are referred for PD catheter placement. The acute care surgeons (as well as some of our elective general surgeons) review these patients for contraindications, which include ascites, hyperkalemia >6.5 mEq/L refractory to medical management or with evidence of cardiac arrythmia/instability, current prone position, severe intra-abdominal hypertension, significant previous abdominal surgery or known adhesions (relative), and determine whether they are suitable candidates. PD catheters are placed at the bedside utilizing an open cutdown technique. This technique eliminates the need for additional equipment, such as fluoroscopy, and can be done relatively quickly (~20 minutes) at the bedside by experienced providers. To ensure operator safety, the pre-procedure algorithm (ie, before prepping the abdomen) recommends ensuring paralysis in advance and assessing ventilator tubing connections and endotracheal tube cuff inflation to eliminate air leak.

COMMUNICATION

In an effort to maintain the health and safety of our providers given social distancing mandates, all nonessential activities (eg, formal education, administrative and quality improvement meetings, and community outreach initiatives) were put on hold or done remotely, and nonclinical staff who were not directly involved in disaster response coordination were instructed to work from home if possible. The decrease in the number of regular personnel about the facility, coupled with the decrease in face-to-face discussions, created a transient information void for departmental providers. This was mitigated by prioritizing consistent communication. A daily e-mail was sent from departmental and hospital leadership summarizing major developments, including updates on PPE supplies, space changes, ventilator and dialysis challenges, daily COVID-related admissions and discharge numbers, and ICU and ward utilization. It also clearly described any new goals that needed to be met. Changes in roles and responsibilities and related questions and concerns raised by faculty, residents, or advanced care providers were presented and discussed by telephone or video conference calls. These informational interventions were well-received and likely contributed to the maintenance of staff morale and to the reduction of anxiety.

CONCLUSIONS

Acute outbreaks of diseases such as coronavirus may strain the resources and personnel of hospitals and healthcare systems around the globe. Although COVID-19 is primarily considered a nonsurgical disease, acute care surgeons can serve an important role as core intensivists and as operators in those required procedures that will advance care. They can also utilize their expertise and experience with mass-casualty incidents to aid with hospital and systems preparedness. There still remains much to be learned about the proper prevention and treatment of this deadly disease, and given how early it is in the pandemic, it is entirely possible that certain interventions may in time prove not to be beneficial. We continue to believe, however, that acute care surgeons have an important role to play in their hospitals' preparation, and should put both their procedural and managerial skills to use to aid in the response.

REFERENCES

1. NYS Health Profiles: 214 Hospitals in New York with Total Beds. [New York State Department of Health web site]. Available at: http://profiles.health.ny.gov/hospital/bed_type/Total+Beds. Accessed April 21, 2020.
2. McKinley J. New York City Region Is Now an Epicenter of the Coronavirus Pandemic. [The New York Times (Online) web site]. March 22, 2020. Available at: http://nytimes.com/2020/03/22/nyregion/Coronavirus-new-York-epicenter.html. Accessed March 22, 2020.

3. Yu IT, Xie ZH, Tsoi KK, et al. Why did outbreaks of severe acute respiratory syndrome occur in some hospital wards but not in others? *Clin Infect Dis*. 2007;44:1017–1025.
4. Lauer SA, Grantz KH, Bi Q, et al. The incubation period of Coronavirus Disease 2019 (COVID-19) from publicly reported confirmed cases: estimation and application. *Ann Intern Med*. 2020. Mar 10; [Epub ahead of print]. Accessed on 04/04/2020. Available at: http://annals.org/aim/fullarticle/2762808/incubation-period-coronavirus-disease-2019-covid-19-from-publicly-reported.
5. Transcript: Mayor de Blasio Holds Media Availability on COVID-19 [NYC.-gov web site]. March 16, 2020. Available at: https://www1.nyc.gov/office-of-the-mayor/news/156-20/transcript-mayor-de-blasio-holds-media-availability-covid-19. Accessed April 4, 2020.
6. Governor Cuomo Signs the ''New York State on PAUSE'' Executive Order [NY.gov web site]. March 20, 2020. Available at: https://www.governor.ny.gov/news/governor-cuomo-signs-new-york-state-pause-executive-order. Accessed April 4, 2020.
7. Tsao HM, Sun YC, Liou DM. A rational approach to estimating the surgical demand elasticity needed to guide manpower reallocation during contagious outbreaks. *PLoS One*. 2015;10:1–7.
8. Critical Care for the Non-ICU Clinician [Society of Critical Care Medicine Web Site]. Available at: https://covid19.sccm.org/nonicu.htm. Accessed April 4, 2020.
9. COVID-19: Data [NYC Department of Health web site]. April 4, 2020. Available at: https://www1.nyc.gov/site/doh/covid/covid-19-data.page. Accessed April 4, 2020.
10. Tien HC, Chughtai T, Jogeklar A, et al. Elective and emergency surgery in patients with severe acute respiratory syndrome (SARS). *Can J Surg*. 2005;48:71–74.
11. Maintaining Trauma Center Access and Care during the COVID-19 Pandemic: Guidance Document for Trauma Medical Directors [American College of Surgeons Committee on Trauma web site]. Available at: https://www.facs.org/quality-programs/trauma/maintaining-access. Accessed April 4, 2020.
12. COVID-19: Elective Case Triage Guidelines for Surgical Care [American College of Surgeons web site]. March 24, 2020. Available at: https://www.facs.org/covid-19/clinical-guidance/elective-case. Accessed April 4, 2020.
13. Park J, Yoo SY, Ko JH, et al. Infection prevention measures for surgical procedures during a middle east respiratory syndrome outbreak in a tertiary care hospital in South Korea. *Sci Rep*. 2020;10:1–8.
14. NIOSH Personal Protective Equipment Information (PPE-Info) [Centers for Disease Control and Prevention web site]. November 20, 2015. Available at: https://wwwn.cdc.gov/PPEInfo/Standards/Info/ANSI/AAMIPB70Class4. Accessed April 4, 2020.
15. Derrick JL, Gomersall CD. Surgical helmets and SARS infection. *Emerg Infect Dis*. 2004;10:277–279.
16. Background C. Air. Guidelines for Environmental Infection Control in Health-Care Facilities [Centers for Disease Control and Prevention web site]. July 22, 2019. Available from: https://www.cdc.gov/infectioncontrol/guidelines/environmental/background/air.html. Accessed April 4, 2020.
17. Chao TN, Braslow BM, Martin ND, et al. Tracheotomy in ventilated patients with COVID-19. Ann Surg. 2020; [Epub ahead of print]. Accessed on 04/10/2020. Available at: https://journals.lww.com/annalsofsurgery/Documents/Tracheotomy%20in%20ventilated%20patients%20with%20COVID19.pdf.
18. Mehta P, McAuley DF, Brown M, et al. COVID-19: consider cytokine storm syndromes and immunosuppresion. *Lancet*. 2020;395:1033–1034.
19. Block M. U.S. May Get More Ventilators But Run Out of Medicine For COVID-19 Patients [National Public Radio web site]. April 04, 2020. Available at: https://www.npr.org/2020/04/04/826961777/u-s-may-get-more-ventilators-but-run-out-of-medicine-for-covid-19-patients. Accessed April 4, 2020.
20. Freeman BD. Tracheostomy update: when and how. *Crit Care Clin*. 2017; 33:311–322.
21. Diehl JL, El Atrous S, Touchard D, et al. Changes in the work of breathing induced by tracheotomy in ventilator-dependent patients. *Am J Respir Crit Care Med*. 1999;159:383–388.
22. Pryor A. SAGES and EAES Recommendations Regarding Surgical Response to COVID-19 Crisis [SAGES web site]. March 29, 2020. Available at: https://www.sages.org/recommendations-surgical-response-covid-19/. Accessed April 4, 2020.
23. Ponce D, Berbel MN, Abrão JMG, et al. A randomized clinical trial of high volume peritoneal dialysis versus extended daily hemodialysis for acute kidney injury patients. *Int Urol Nephrol*. 2013;45:869–878.
24. George J, Varma S, Kumar S, et al. Comparing continuous venovenous hemodiafiltration and peritoneal dialysis in critically ill patients with acute kidney injury: a pilot study. *Perit Dial Int*. 2011;31:422–429.