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The Crucible of War: Innovation in a Pandemic

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Mini Abstract
In this perspective piece, we offer a view of the current pandemic from the front lines in New York City, focusing on key innovations happening now amidst the COVID-19 crisis.

Keywords: COVID-19; innovation; Surgery; history

New York City is the forward line of the war against COVID-19. At Columbia University Irving Medical Center, we face resource limitations and equipment shortages, diminution of our corps, and the psychological toll of daily unpredictability. At the same time, rays of light occasionally slit the smoke, offering glimmers of hope. "Necessity is the mother of all invention," goes the axiom commonly attributed to Plato. The chaos of wars, both real and metaphorical, has long been a proving ground for medical innovation and its pioneers. The fight against COVID-19 is already animating invention at our institution and around the globe.

It is fitting that our battlefield metaphors seem largely to find their origin in World War I (e.g. trenches, front lines, etc). World War I represented not just a turning point in the modernization of warfare but also a crucible of creativity in medicine, surgery, and science. While the world was entrenched in a struggle against the last viral pandemic, the Spanish Flu, in the European trenches Canadian surgeon Lawrence Bruce Robertson revolutionized transfusion medicine with the addition of citrate, allowing for conservation and transportation of blood. Triage, a concept now fundamental to disaster management, was first instituted by French doctors on European battlefields just over a century ago. Not long after, as Europe found itself in yet another war, the threat to life on the front lines gave rise to widespread use of antibiotics and vaccines for the first time. Likewise, numerous storied careers were molded by combat experience. As a major in the French Army Medical Corps during World War I, Alexis Carrel partnered with Henry Dakin to develop a wound antisepsis method that earned him the French Legion of Honor. Simultaneously, Harvey Cushing, the father of neurosurgery, made paradigm-shifting strides in the description and treatment of intracranial injuries.

As we confront a new pandemic, innovation is again emerging. At Columbia, two floors of operating rooms (ORs) have been converted into COVID-19 intensive care units (ICUs), making it the largest critical care unit in our hospital. Similar simultaneous transformations have occurred at our sister institution.[1] In Columbia's novel ICUs, experiments are being performed in which two matched patients are supported by a single ventilator.[2] This research expands existing work in ways that may yield new insights into disaster preparedness and lung physiology.[3] The elimination of outpatient visits amid the COVID-19 pandemic has catalyzed the expansion of telehealth. Thanks to recent legislation, 85 new telehealth services are now fully reimbursed by Medicare. Both the utility and feasibility of telehealth, long ago

substantiated in scholarly journals, is being proven in practice.[4] If this foothold endures, widespread use of telehealth would offer solutions to the greatest limitations in our healthcare system: access to primary care and specialist consultations, flexibility for both patients and providers, and cost reduction in primary and preventative care.

3D printing, once a novelty and an academic pursuit in medicine, has surfaced as a viable solution to shortages of personal protective equipment and ventilator components. A collaborative effort between physicians and engineers at Columbia produced reusable face shields for front line clinicians.[5] In Great Britain, a team from the University of Oxford is developing an emergency ventilator, combining 3D printed parts with components found in most hospitals.[6] These experiences with 3D printing might unleash its wider adoption in hospitals, perhaps one day with entire printer banks in central supply enabling in-house manufacturing with capacity reserves as needed. Large-scale 3D printing could eventually be deployed to print durable medical equipment tailored to individual patient specifications.

Similar accelerations of technological applications into real-world use are being seen in web-based epidemiological tools, point-of-care testing, and novel therapeutics. Products like Kinsa's (San Francisco, CA) fever map, while rudimentary, hint at the promise of how cloud computing and the internet-of-things might form the building blocks of earlier epidemic detection tools. The need for rapid viral vaccine development and production emerged from this crisis as a challenge that has yet to be solved. Still, it took only 63 days from when this virus was sequenced until a viable vaccine for testing in humans was produced--a record. We may see technology for truly rapid vaccine production before this pandemic ends. (Perhaps vaccine hesitancy will evaporate in the wake of COVID-19 as well.) In the most hopeful of futures, combinations of such detection tools and vaccination technologies may prevent viral disease from ever reaching pandemic levels again.

All around us new operational structures are taking shape. At our institution, roving response teams of surgical residents have been formed for rapid deployment to perform bedside procedures, freeing clinicians to focus on advancing the care of COVID-19 patients.[7] Meanwhile, long-standing barriers between academic silos have been shattered by a shared desperation for knowledge. Medical and surgical critical care teams have fused to meet a singular clinical challenge. In our COVID-19 intensive care units, we round virtually with an additional attending physician who is dedicated exclusively to interfacing with families. This structure alleviates in house clinicians of one of the innumerable strains on their time while

offering families in need of comfort and information both access and support. It is hard to predict which of these changes will persist beyond this pandemic, and in what form, but as the Civil War birthed modern ambulance systems and World War I yielded triage, so too may this pandemic give us lasting organizational innovations.

The pandemic has also uncovered an uncomfortable reality: when demands exceed available resources, physicians must make difficult decisions about rationing of care, prompting the dusting off of protocols developed during other epidemics.[8] The sheer volume of patients required resource allocation decisions for COVID-19 testing and hospital admission. Rationing of care does not apply only to patients affected by COVID-19. The human cost of this pandemic will include many deaths from preventable causes not named COVID-19. In response, there is a growing call to designate specific hospitals in each city to handle serious non-COVID-19 medical problems, such as cancer and heart disease. Such distribution of care would be hard to imagine in the United States, where hospital systems on the same city block compete for patients (and ventilators). But then again, everything that has happened in the last few months, especially here in New York, would have been hard to imagine. Indeed, the COVID-19 pandemic may have broader collateral effects on our healthcare system itself.

The care of patients everywhere is in desperate need of the innovations currently underway at Columbia and elsewhere. Nowhere is this more true than in the United States, and in New York particularly, where COVID-19 has disproportionately affected our most vulnerable populations. Among Columbia's first 1000 patients, compared to previously published populations, hospitalized patients in Washington Heights had more baseline comorbidities and subsequently suffered significantly worse outcomes, including higher rates of acute kidney injury and need for dialysis.[9] As heartening as the innovation around us is, these disparities highlight a continued need for broader progress within our healthcare system to provide equal access and quality of care for all.

At the time of writing, we have only just passed the COVID caseload apex here at the epicenter. Among the remaining challenges is how to safely unwind surge-phase alterations in the organization of care, like the conversion of 23 ORs into temporary ICUs. OR capacity will return only in stages, as will radiology, invasive cardiology, and so many other processes on which surgery relies. We will need to fluidly triage our backlog of cases according to clinical urgency, the improving resource climate, and the return of patient confidence. On the downslope, personal protective equipment won't likely be a limiting resource, but hospital

and ICU beds will, so we have rethought our ICU bed utilization rubric, replacing the traditional "first come, first served" model with one that matches anticipated postoperative stay with available beds. If the COVID storm cloud is to have a silver lining, we must take this once-in-a-lifetime opportunity to make changes that we couldn't – or wouldn't – make when we were going full speed. We must streamline our processes, discard archaic habits in favor of more efficient alternatives like telemedicine and resource-conscious surgery scheduling, and, perhaps most importantly, make good on the promise of high quality care for *all* of our patients, regardless of their background or socioeconomic status.

As we face these challenges in the war against COVID-19, creativity, paired with endurance, self-reflection, and the inspiration of history, will be among our greatest tools. We believe that out of the darkness of this crisis -- along with new leaders in infectious disease, public health, public policy, ethics, and palliative care -- innovative solutions will continue to come to light, reshaping our approach to human health. As Woodrow Wilson, who led the United States through the last great viral pandemic knew, "The world has a habit of going on." Although we remain in the trenches, we find hope in the examples around us of humanity's ingenuity and its enduring strength to simply go on.

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