Lessons from Epidemics, Pandemics, and Surgery

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As of August 2020, the ongoing Coronavirus Disease 2019 (COVID-19) pandemic has resulted in more than 18 million confirmed cases and nearly 700,000 deaths worldwide.[1] The healthcare system has also been forced to adapt to the pandemic. For example, after cancellation of elective operations, some surgeons found themselves in nontraditional healthcare roles. But although the COVID-19 pandemic is the most substantial infectious disease challenge faced by many surgeons in their practice lifetime, pandemics can also be transformative. In response to previous epidemics and pandemics, including the Black Death, Spanish Flu, Human Immunodeficiency Virus (HIV), Severe Acute Respiratory Syndrome (SARS), and Ebola, surgeons have had to adapt to constraints and evolve their practice of surgery. Our goal was to explore how surgeons responded to these historic infectious threats and identify how these threats affected the practice of surgery in the form of a historical summary. Insights gained from previous pandemics may provide some solace to those currently responding to COVID-19, and help us look forward to some of the good that may result from an otherwise negative situation.

THE BLACK DEATH

Background

Plague is a clinical condition caused by the bacteria *Yersinia pestis*. The bacterium can be transmitted to humans by the bite of an infected flea, contact with contaminated fluid or tissue, or through infectious droplets.[2] Clinically, human disease is divided into bubonic, septicemic, or pneumonic plague, depending on the route of transmission and clinical manifestations.[2] Plague can be highly lethal, with pneumonic plague having fatality rates of nearly 100% without treatment.[2] The Black Death was a combination of bubonic, septicemic, and pneumonic plague outbreaks that killed 350 to 475 million—30% to 60% of Eurasia and North Africa's population—during the 1300s.[3]

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Impact on surgery

At the time, there were 3 classes of medical practitioners in Europe: physicians, surgeons, and barber surgeons.[4] Physicians were commonly well respected and university-educated scholars who subscribed to the ancient Greek humoral theory of illness.[4] They sought to balance humors—phlegm, black bile, yellow bile, and blood—and used medicines such as laxatives and enemas.[5] In comparison, surgeons lacked the prestige of physicians; their techniques of bloodletting and boil-lancing were deemed crude and unnecessary.[5] Barber surgeons shared the inferior status of surgeons, but their practice was limited to extracting teeth and bloodletting.[5]

During this time, physicians sought to solidify their prestige and codify the existing schism between physicians and surgeons by caring for desperate patients.[4] However, humorism was unsuccessful treatment against plague and led to public dissatisfaction and distrust of the medical establishment.[5] The combined failings of existing medical technology and void left by physicians fleeing to the countryside created an opportunity for surgical societies to coalesce and develop into trusted healthcare entities.[5]

Surgical guilds proliferated and developed formalized governing structures. For example, the Parisian surgical guild began to regulate surgical practice, requiring that all surgeons in Paris be examined and approved by a master surgeon and an examination board of 6 surgeons.[6] To distance themselves from barber surgeons, surgeons began wearing long robes, imitating the garb of their physician counterparts.[5] Surgical training was legitimized as emphasis was placed on didactics, and surgical students were required to learn Latin.[4] During this time period, surgical manuals became increasingly common. In contrast to work written by physicians during the same time period, surgical manuals tended to describe practical treatments rather than theories of humors.[5] Two surgical manuals published during the this time period—Guy de Chauliac's *Cyrurgie* and John Arderne's *Practica*—were translated to vernacular language to be accessible to the public.[4] The manuals incorporated personal anecdotes and observations to provide novel insight into how experienced surgeons practiced techniques such as lancing.[4] Additionally, cadaveric dissection taught by surgeons was increasingly used in an effort to understand human anatomy across European medical schools, reducing stigma historically associated with surgery.[4] The

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Abbreviations and Acronyms

COVID-19	= Coronavirus Disease 2019
EVD	= Ebola virus disease
OR	= operating room
PPE	= personal protective equipment
SARS-CoV	= severe acute respiratory syndrome-related coronavirus

Black Death provided a catalyst for growth of surgical societies throughout medieval Europe by highlighting inadequacies of existing medical therapy.

THE SPANISH FLU

Background

Human flu pandemics are caused by influenza A, an Orthomyxoviridae that is divided into subtypes based on 2 surface proteins: hemagglutinin (H) and neuraminidase (N). The H1N1 influenza A virus responsible for the 1918 flu pandemic, colloquially termed the Spanish Flu, was transmitted via contact with contaminated fluid or tissue or through infectious droplets.[7] Common clinical manifestations included cough, lack of appetite, headache, fever, fatigue, and pneumonia—the predominant cause of death.[7] Influenza infected 25% of the global population, and its death toll of 20 to 50 million was greater than all casualties of World War I. Although most influenza outbreaks disproportionately affect extremes of the age spectrum, this influenza strain had a uniquely high mortality rate for young adults.[8] In 1918 and 1919, 99% of influenza death in the US occurred in those younger than age 65, and nearly half the deaths were in those ages 20 to 40.

The Spanish Flu pandemic placed immense burden on the civilian healthcare system, as wartime demands created an acute shortage of healthcare providers, which proved detrimental to patient care. For example, at the peak of the outbreak, more than 25% of patients at a Philadelphia hospital died nightly, many without seeing a nurse or doctor. Many hospitals turned patients away and mortuaries overflowed, some handling 10 times the normal capacity.[9]

Impact on surgery

The Spanish Flu pandemic advanced principles that continue to inform surgical practice: hygiene and personal protective equipment. As influenza overwhelmed civilian healthcare systems, field hospitals were erected in schools, gathering halls, and large private residences.[10] In response to a large volume of seriously ill patients, the Massachusetts State Guard built the Camp Brooks Open Air Hospital near Boston.[11] A combination of fresh air, scrupulous hygiene standards, and reusable masks—relatively novel concepts compared to the crowded hospitals, rampant at the time—substantially reduced infection and death.[11,12] Compared with a 40% mortality rate for influenza patients admitted to conventional hospitals in the area, the mortality rate reported at Camp Brooks was approximately 10%. Of several measures introduced at Camp Brooks, widespread use of protective masks was most noteworthy. Any provider interacting with patients was required to wear an improvised mask consisting of 5 layers of gauze on a wire frame (made from a gravy strainer) covering the nose and mouth.[12] Providers were instructed to avoid touching the mask.[11] Supervisors ensured masks contained fresh gauze, replacing and sterilizing them every 2 hours.[11] Some hospital staff even wore special blouses akin to modern surgical scrubs.[11] In addition to improving local infection prevention tactics in the hospital setting, nonpharmaceutical interventions, such as social distancing and mask mandates, were implemented at the municipal level, with varying success.[13] The 1918 Spanish Flu pandemic saw the widespread implementation of hospital hygiene and public health measures informed by germ theory that remain foundational to modern surgery.

HIV/AIDS

Background

Infection with human immunodeficiency virus (HIV), a *Lentivirus*, can cause acquired immunodeficiency syndrome (AIDS), and is believed to have originated from chimpanzees in the Democratic Republic of Congo around 1920. HIV is most commonly acquired via sexual activity and sharing needles or syringes. Common clinical manifestations include fever, fatigue, and swollen lymph nodes. In advanced stages, the virus impairs the body's cellular immunity and patients become susceptible to a range of opportunistic infections, the leading cause of death. The US HIV/AIDS epidemic began in 1981. As of 2016, an estimated 1.2 million people in the US are living with HIV, of whom 1 in 7 are unaware of their carrier status. With antiretroviral drug advances, the number of deaths among adults and adolescents has declined from a peak of 50,876 deaths in 1995 to 15,820 deaths in 2018.[14,15]

Impact on surgery

Before understanding the true risk of infection and development of effective antiretrovirals, the HIV/AIDS epidemic induced fear and discrimination against groups such as homosexuals, African Americans, and intravenous drug users. Surgeons potentially risked infection when treating patients with HIV/AIDS, as antiretroviral drugs were not available. Both before and after modes of transmission were elucidated, physicians refused to treat patients with HIV/AIDS.[16] One surgeon stated, "I've got to be selfish. It's an incurable disease that's uniformly fatal, and I'm constantly at risk for getting it. I've got to think about myself. I've got to think about my family. That responsibility is greater than to the patient."[17]

Initial legal challenges to physician refusal to treat patients with HIV/AIDS were curtailed by a "no duty rule," which stated that barring a pre-existing relationship, no physician has a duty to treat any particular patient.[18] Freedom of choice for physicians had historically been supported by professional organizations such as the American Medical Association (AMA).[18] Absent legal imperatives, the debate over treating HIV/AIDS patients evolved around the ethical argument that physicians have an obligation akin to that of firefighters and police officers, and they must accept a certain level of risk inherent to the profession.[19] In 1988, the AMA concluded that "a physician may not ethically refuse to treat a patient whose condition is within the physician's current realm of competence solely because the patient is seropositive. Persons who are seropositive should not be subjected to discrimination based on fear or prejudice."[19] With the passage of the Americans with Disabilities Act in 1990, discrimination based on seropositivity was made illegal.

Although initial debates concentrated on patient-to-provider transmission of the virus, discussion of provider-to-patient transmission also became controversial. Some argued that physicians with HIV/AIDS should relinquish practice of "seriously invasive procedures."[20] In 1988, the AMA issued a "zero-risk" policy, stating that if risk of transmission of an infectious disease from physician to patient exists, disclosure of the risk to patients is inadequate. Patients should expect that their physicians will not increase their risk of contracting an infectious disease, even minimally.[21] Present-day policies regarding physicians with HIV/AIDS became established after a decade of evidence showing that provider-to-patient transmission of HIV is exceedingly rare. Today, surgeons with HIV/AIDS may continue to practice and perform invasive procedures unless there is clear evidence of an inability to meet basic infection control procedures, or the surgeon is functionally unable to care for patients.[22] The HIV/AIDS epidemic raised ethical debates regarding the surgeons' duty to treat patients at the risk of their own health. The principles of accepting a reasonable level of risk and not discriminating based on seropositivity have prevailed.

SARS

Background

Infection with severe acute respiratory syndrome-related coronavirus (SARS-CoV), a *Betacoronavirus*, caused an epidemic across 29 countries in 2003. SARS-CoV is believed to be of zoonotic origin—perhaps bats—and first infected humans in Guangdong Province, China in 2002.[23] Most cases of human-to-human transmission occurred via respiratory droplets in healthcare settings without adequate infection control practices.[24] Dry cough, shortness of breath, and diarrhea were typical early symptoms; severe cases progressed onto respiratory distress and failure.[24] Worldwide, 8,098 people were infected and 774 died, a 10% mortality rate. When SARS-CoV was first reported, no diagnostic tests or vaccines were immediately available. The importance of rapid identification of the etiologic agent was recognized by an unprecedented collaboration among scientists who identified the responsible virus and its entire genome within weeks.[25]

In an increasingly connected world, efforts to contain a virus that easily spread beyond sovereign borders could not be relegated to any individual country. The importance of a global public health response led by an international body like the World Health Organization (WHO) became clear. The WHO coordinated international epidemiologic investigations and provided clinical and logistical support to officials in affected countries. After an international effort, the WHO declared SARS-CoV contained in July of 2003, though several SARS-CoV cases were reported until May of 2004.[24,26]

Impact on surgery

The highly infectious nature of SARS-CoV required existing infection control measures to adapt.

Hospitals in Toronto and Singapore exemplified adaptive infectious control practices. In Toronto, an investigation identified several opportunities for infection: bilevel positive airway pressure and high-frequency oscillatory ventilation emitting respiratory droplets; a lack of adequate sedation that resulted in patient agitation and coughing; and a repeated requirement to clean copious secretions from obstructed ventilator tubing.[27] The Ontario Ministry of Health and Long-Term Care responded by mandating additional protections for high-risk airway management situations, including a covered helmet with a respirator and a full-length gown worn over standard personal protective equipment (PPE).[28] Surgical procedures were also altered to further protect healthcare providers.[29] For example, in a small case series of 3 patients with SARS- CoV, providers attempted to prevent aerosolizing viral particles during tracheostomy by minimizing

Table 1. Summary of Lessons from Past Epidemics and Pandemics

Epidemic/pandemic	Lessons learned
Black Death	The Black Death provided a catalyst for growth of surgical societies throughout medieval Europe by highlighting the inadequacies of existing medical therapies. medical therapy.
Spanish Flu	The 1918 Spanish Flu pandemic saw the widespread implementation of hospital hygiene and public health measures informed by germ theory that remain foundational to modern surgery.
HIV/AIDS	The HIV/AIDS epidemic raised ethical debates regarding the surgeon's duty to treat patients at the risk of their own health. The principles of accepting a reasonable level of risk and not discriminating based on seropositivity have prevailed.
SARS	The SARS outbreak demonstrated how systemic responses to highly infectious diseases must be flexible. The cancellation of elective surgeries and implementation of enhanced personal protective equipment highlighted the importance of adaptive infection control measures.
Ebola	The West Africa Ebola epidemic revealed the vulnerability surgeons in resource-poor healthcare systems face during infectious disease epidemics.
COVID-19	The COVID-19 pandemic is once again challenging the surgical community to adapt and advance by demanding flexibility and innovation to address struggles old and new.

diathermy, ensuring full paralysis, and stopping mechanical ventilation once the airway was entered.[29] Six months after these 3 tracheostomies, all involved staff remained free of SARS-CoV.[29]

The first wave of infections in Singapore was largely from intrahospital transmissions; 42% of initial cases were healthcare providers. During the epidemic, the designated hospital in Singapore for treating patients with SARS-CoV performed 41 operations.[30] One-hundred twenty-four operating room (OR) staff were directly involved in the management of these patients, yet none contracted the virus.[30] The avoidance of new infections in the OR was attributed to 3 levels of staff protection.[30] First, newly standardized PPE—an N95 mask, a surgical cap, eye protection (goggles or face shield), a gown, and gloves—was required for all patient contact throughout the hospital.[30] Enhanced PPE, which included shoe covers and a positive air-powered respirator, was required for high-risk procedures in all patients and any procedures in high-risk patients.[30] Second, staff education on properly donning and doffing PPE was emphasized.[30] Third, the hospital conducted audits of infection control measures.[30]

The SARS outbreak also challenged logistics of performing surgery. In Singapore's designated hospital for treatment patients with SARS-CoV, all elective operations were initially canceled.[30] As SARS-CoV became better understood and diagnostic tests became available, elective procedures in patients without SARS-CoV were progressively restarted, with logistical adjustments. Disposable equipment was used whenever possible and dedicated routes and elevators were used for patient transport. Patients with probable or unknown contact with SARS-CoV underwent surgery in designated SARS-CoV operating rooms, which underwent structural modifications to minimize contaminated air outflow.[30] ORs were decontaminated after every operation, and 1-hour intervals between procedures were mandated to dilute airborne contaminants. All contact episodes between OR staff and patients were recorded to facilitate contact tracing, and a dedicated nurse oversaw strict adherence to all infectious control measures. Guidance on enhanced PPE and OR logistics developed during the SARS outbreak later informed response to the Middle East respiratory syndrome outbreak in 2012.[31] The SARS outbreak demonstrated how systemic responses to highly infectious diseases must be flexible. The cancellation of elective operation and implementation of enhanced PPE highlighted the importance of adaptive infection control measures.

EBOLA

Background

Ebola virus disease (EVD) is a clinical syndrome caused by a group of viruses within the genus *Ebolavirus*.[32] Transmitted via contact with contaminated fluid or tissue or through infectious droplets, EVD symptoms included fever, abdominal pain, and gastrointestinal disturbance.[32] In March 2014, the World Health Organization reported the first EVD cases in southeastern Guinea.[33] The West Africa Ebola epidemic followed, with an outbreak rapidly spreading to Guinea's bordering countries, Liberia and Sierra Leone. With response efforts hampered by limited surveillance systems and poor public health infrastructure, the outbreak reached the densely populated capitals of all 3 countries by July 2014 and resulted in more than 28,600 cases and 11,325 deaths (40% mortality rate).[33] Similar to the SARS epidemic, healthcare workers were disproportionately infected during the Ebola epidemic. From the start of the outbreak through November 2015, 881 confirmed healthcare provider infections and 513 deaths were reported in Guinea, Sierra Leone, and Liberia combined.[34] Guinea lost 1%, Sierra Leone lost 7%, and Liberia lost 8% of their healthcare workforce to EVD.[35]

Impact on surgery

The EVD symptoms—fever, abdominal pain, and gastrointestinal disturbance—overlapped with those of acute abdominal pathologies, and many hospitals in affected regions lacked advanced imaging to differentiate surgical conditions.[36] Surgical volumes plummeted, and many patients died, not from EVD, but from untreated surgical conditions such as perforated ulcers and incarcerated hernias.[37,38] For example, in August 2014, the number of operations at Connaught Hospital, Sierra Leone's only tertiary referral center, fell to 19% from the 2013 level.[39] When 2 of 8 practicing surgeons at the hospital died of EVD, operations fell to 3% of the 2013 level, and all emergency operations were postponed until after EVD tests.[39] Connaught Hospital illustrated immense burdens epidemics impose on surgeons practicing in low resource settings.

Having experienced the potential for any infectious outbreak to spread globally, healthcare organizations rapidly developed protocols to guide EVD care and management.[38] In the US, the American College of Surgeons (ACS) adapted Centers for Disease Control and Prevention (CDC) guidelines for operating on patients with suspected EVD.[40] The CDC guidelines included delaying elective procedures for patients with suspected or confirmed EVD and performing only emergent procedures for persons under investigation and early confirmed cases.[41] Operative interventions that minimized fluid exposure (ie minimally invasive approaches) and nonoperative management for conditions such as appendicitis, were emphasized. The CDC also published guidelines on donning and doffing PPE, and designating operating rooms for procedures on patients with EVD, practices evolved during the SARS outbreak.[41] However, CDC guidelines were often challenging for hospitals in West Africa to follow. The recommended PPE—full gowns, leg coverings, surgical hoods, powered air-purifying respirators, and double gloves—were simply unavailable, forcing surgeons to improvise at the expense of safety.[38] The West Africa Ebola epidemic revealed the vulnerability that surgeons in resource-poor healthcare systems face during infectious disease epidemics.

COVID-19 AND THE FUTURE

Historical epidemics and pandemics have challenged the surgical community to adapt and advance in unprecedented ways. These challenges have fostered development of modern surgical care and will continue to alter the trajectory of the field. The ongoing COVID-19 pandemic is no exception. The American College of Surgeons (ACS) has published "COVID-19 and Surgery," a comprehensive evidence-based resource to guide surgeons through challenges of the ongoing pandemic.[42] This organized response by a professional society has roots dating back to surgical guilds and efforts by surgeons to advance pragmatic solutions during the Black Death. "COVID-19 and Surgery" includes guidance on clinical care, PPE, ethical considerations, research, and legislation based on lessons from past infectious disease outbreaks.[42] For example, ethical frameworks for allocating scarce resources, such as ICU beds, ventilators, PPE, antiviral medications, and investigational vaccines draw from the same ethical principles of beneficence, justice, and respect for persons reinforced during the HIV/AIDS epidemic.[42] To allocate a limited supply of remdesivir, an antiviral medication being used to treat COVID-19, Pennsylvania endorsed a controversial weighted lottery that considers factors like socioeconomic status based on the ethical principle of justice.[43] Additionally, enhanced PPE recommendations were informed by lessons learned from the SARS and Ebola epidemics.[42]

Familiar challenges continue. Similar to the Ebola epidemic, the COVID-19 pandemic poses special concern for resource-poor environments such as rural community hospitals. In response to PPE shortages, the Defense Production Act, donations, and sterilization procedures have been leveraged to accelerate production and maintain inventory. For example, ultraviolet germicidal irradiation and vaporous hydrogen peroxide have been used to disinfect N95 masks.[44] Reusable PPE may help surgeons in hospitals with PPE shortages stay safe throughout the pandemic. As public health measures restricting elective procedures are relaxed, surgeons and hospitals must balance patient needs with safety and equipment availability. Past epidemics have taught us to prepare for this task. To minimize transmission risk, hospitals can now refer to the "American Hospital Association Road Map to Resuming Elective Surgeries," published in conjunction with the ACS, the American Society of Anesthesiologists, and the Association of periOperative Registered Nurses.[45] Contingency planning for potential resurgence of cases, preparations for an unstable workforce, and preoperative testing for patients undergoing surgery—many of which are lessons from the Ebola epidemic—may facilitate resumption of surgical operations.

The surgical community has already developed and implemented several innovations. One such innovation is a clear sterile drape that forms a barrier between the operative field and the surgeon during invasive procedures such as tracheostomy.[46] Outside the operating room, clear plastic intubation boxes with protective sleeves are being used to shield providers during aerosol-generating procedures.[47] Tele and digital medicine has also proven critical to reducing SARS-CoV-2 exposure and ensuring continuity of care for patients with chronic conditions. Previously touted as an opportunity to expand healthcare access to rural and underserved populations, tele and digital medicine's role has expanded to preoperative assessment, postoperative evaluation, and other surgical follow-up visits. Having shown similar health outcomes as in-person visits and with ancillary benefits such as reduced travel costs and time away from work, tele and digital medicine will likely play an increasingly prominent role in caring for surgical patients.[48-50]

As the pandemic continues, the welfare of surgical frontline workers ought to be prioritized, as many are experiencing burnout, fatigue, anxiety, and other physical and mental burdens. We may be living in uncertain and unique times, yet the surgical community is no stranger to uncharted territory. Lessons applied from the past contribute to today's innovation and will undoubtedly inform tomorrow's direction (Table 1).

Author Contributions

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Acquisition of data: Hakes, Choi
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