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Beyond the operating room: the roles of anaesthesiologists in pandemics

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Anaesthesiology finds itself again entwined with a global pandemic. The contagious and potentially devastating nature of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has violently disrupted anaesthesia practice. However, the coronavirus disease 2019 (COVID-19) public health crisis provides an opportunity to examine how anaesthesiology has contributed to confronting this and other pandemics, and, in turn, how pandemics have influenced our specialty.

At a glance, anaesthesiology and epidemiology seem to have little in common. But, from its inception, anaesthesiology has had a major impact on public health. John Snow, considered by many as the father of epidemiology, and Jerome Adams, the current Surgeon General of the USA, are both anaesthesiologists. This serendipity reflects the historic spectrum of events over which anaesthesiology has made extensive contributions to the management of epidemics.

More than 70 yr ago, E. M. ‘Manny’ Papper[1] published an article in the *New England Journal of Medicine* entitled, ‘Some contributions of anaesthesiology to the general practice of medicine’. ‘It appears evident,’ Papper stated, ‘that many physicians are totally unaware of the kind of knowledge that the anaesthesiologist has at his command’.[1] Just as the COVID-19 pandemic has tested our specialty, previous epidemics revealed anaesthesiologists’ unique skill set to our medical colleagues. Here, we focus on how historical cholera, polio, and SARS epidemics redefined the role of anaesthesiology, and how anaesthesiologists in turn helped develop contact tracing, intensive care, and infection control. Lessons learnt from these previous epidemics provide guidance in our management of COVID-19 today. Anaesthesiologists continue to lead in the front lines, maintaining a tradition of ingenuity and dedication.

Snow, cholera, and contact tracing

As a pioneer of anaesthesiology, John Snow (1813–58) elucidated the science behind the fledgling field. His methodical work with inhalational anaesthetics, such as his development of the dose-titrated delivery of chloroform, was amongst the first to characterise the stages of anaesthesia.[2] John Snow applied the same rigorous science in his research of the 1848 London cholera epidemic. He rejected the prevailing miasma theory, which postulated that cholera was transmitted through the ‘bad air’ of decomposing organic matter. By mapping the density of cholera cases, Snow traced the most significant caseload to a certain water company, and then to a specific Broad Street water pump. Snow effectively deduced the true waterborne transmission of cholera, all before the advent of germ theory. The removal of said pump handle saw the decline of the cholera epidemic.[3]

Snow’s work set the foundation for modern contact tracing. Coronavirus disease 2019 presents a unique challenge given its proportion of asymptomatic carriers. Countries, such as South Korea, Taiwan, and New Zealand, have, however, combined contact tracing and testing to good effect. It is now recognised that the swift enactment of contact tracing is critical, particularly given modern globalisation.[4] The lack of international, concerted contact tracing in February and March stymied containment efforts as the number of viral infections increased exponentially. Contact tracing may be of greater practical value at waning caseloads. If privacy concerns are adequately addressed, digital contact tracing may be a significant tool to aid efforts at reopening. It is remarkable that a technique developed by this anaesthesiologist more than 170 yr ago remains so relevant today.

As for the governmental policies regarding the pandemic, we may also borrow some of Snow’s scepticism. He was convinced by the science of his epidemiological studies, rather than by popular sentiment. Just as germ theory overcame miasma theory through hard data, COVID-19 policies have increasingly turned to scientific evidence. Social distancing and contact precautions now reflect our growing understanding of droplet transmission and aerosolization risk. Support of unsubstantiated therapies, such as hydroxychloroquine, has been questioned by large-scale studies.[5] In these matters, we have seen that administrative policies are not infallible, but are best guided by robust science. Much like Snow, we should engage in an evidence-based, apolitical approach to the ongoing pandemic and medicine in general.

Polio and the development of intensive care

Much more can be said of the contributions of anaesthesiology to intensive care. Lesser known is the role of anaesthesiologists in their inception. Up until the 1950s, the role of anaesthesiologists beyond the operating theatre remained unclear. Anaesthetics, imprecisely administered, could lead to lethal complications. It was therefore out of necessity that anaesthesiologists became intimately acquainted with abnormalities of respiratory and circulatory physiology.[1] Whilst this familiarity remains true for anaesthesiologists today, these qualities were crucial in confronting the 20th century polio epidemics, which altered the course of anaesthesiology.

The disease processes of COVID-19 and polio are fundamentally distinct, as are their respiratory implications. Until 1953, polio seasonally ravaged populations with partial paralysis. The deadlier bulbar variety targeted motor neurones and rendered patients unable to breathe. Coronavirus disease 2019 provokes insidious inflammatory damage to the lung parenchyma itself. Polio and COVID-19 require different approaches in respiratory support; striking parallels, however, remain in the management of these two diseases. Both have challenged the brightest clinicians of their times. Although the pathology was poorly understood, bulbar poliomyelitis spurred advances in ventilator support. The former standard of negative-pressure ventilation with 'iron lungs' was largely incompatible with the irregular breathing associated with bulbar poliomyelitis, and mortality was up to 90%.[6] Physicians sought better outcomes with other ventilation modalities. The renowned anaesthesiologist Arthur Guedel (1883–956) is credited with introducing the cuffed tracheal tube in 1932. Originally intended to reduce aspiration risk, cuffed tubes enabled administration of positive-pressure ventilation.[7] As early as the 1948 California polio outbreak, patients were observed to fare better with intermittent positive-pressure ventilation.[8] Positive-pressure interventions demanded expertise in cardiorespiratory physiology, skills towards which anaesthesiologists were already primed.

It was under these circumstances that anaesthesiologist Bjørn Ibsen (1915–2007) confronted the 1952 Copenhagen polio epidemic. His actions, in turn, set in motion development of intensive care medicine. Through his training in anaesthesiology, Ibsen was acutely aware of the benefits of positive-pressure ventilation. His clinical intuition regarding physiological abnormalities helped him deduce the cause of the 'mysterious alkalosis' of bulbar polio patients. This challenge was compounded by limitations of existing apparatus, which could only report increased CO_2 content of blood. Physicians were therefore blinded to the low pH and high $P\text{a}CO_2$ of bulbar poliomyelitis patients.[9] Ibsen proposed that, rather than metabolic alkalosis, the elevated bicarbonate stemmed from hypercapnia and severe hypoventilation.[7] He set medical students to manually ventilate bulbar patients around the clock, efforts that reduced mortality from 90% to <25%.[6] Even more profound was Ibsen's idea to '[place] patients together geographically and [place] nursing staff to cope with a possible problem'.[9] This was the first ICU, and an anaesthesiologist led its development.[9]

Ibsen's management of the polio epidemic cemented the role of anaesthesiologists as cardiorespiratory specialists. As anaesthesiologists entered intensive care medicine, they brought with them lessons from the operating theatre. Intensive care units now continuously monitor and manipulate haemodynamics and ventilation. Later, anaesthesiologists addressed unmet clinical needs through innovations still relevant today. John W. Severinghaus[10] introduced the first blood gas analyser in 1957, which enabled the measurement of serum pH, P_{O_2}, and P_{CO_2}. Henning Ruben (1914–2004) innovated the air mask bag unit, commonly known as the 'Ambu bag', which remains a mainstay in cardiopulmonary resuscitation.[11]

The role of anaesthesiology in the COVID-19 response reflects the legacy of these pioneers. Just as the polio epidemics drew on anaesthesiologists from operating theatres for cardiorespiratory support, so has the COVID-19 pandemic. The co-localisation of specifically trained staff, once translated to ICUs, is now reflected in the COVID-19 floors of general medicine. Geographic consolidation of COVID-19 cases is beneficial both for infection control and for training in COVID-19 care. Whilst proper training is essential to better patient outcomes, we must also address the pathophysiology of COVID-19. We have just begun to comprehend the multisystem consequences of its characteristic endothelial injury, spanning from acute respiratory failure to hypercoagulability.

The respiratory failure associated with COVID-19 has been observed to differ from conventional acute respiratory distress syndrome (ARDS). Because of the unique disruption of pulmonary vasoregulation, COVID-19 patients are often refractory to conventional ARDS protocols.[12] We must therefore resort to our clinical acumen to modify ventilation protocols. Low-grade evidence suggests that prone positioning may improve oxygenation and decrease mortality in awake, non-intubated COVID-19 patients with severe acute respiratory distress.[13,14] There is also some evidence that early intubation and effective sedation may reduce inspiratory drive and prevent further lung injury.[12] Anaesthesiologists provide this crucial airway management, resuscitation, and ventilation support. In the absence of effective pharmacological treatment, respiratory support is essential to treating the often fatal COVID-19 respiratory distress syndrome.

SARS, emerging pathogens, and infection prevention and control

With the emergence of new pathogens, anaesthesiologists have become increasingly cognisant of infection prevention and control. Even before COVID-19, the risks of anaesthesiologists involve exposure to blood, secretions, and needle-stick injury. Before the onset of human immunodeficiency virus/acquired immune deficiency syndrome (HIV/AIDS) in the 1980s, anaesthesiologists routinely worked barehanded, using reusable masks, airways, and laryngoscopes. Anaesthesia breathing circuits were also reusable and sometimes not washed between patients. The HIV/AIDS epidemic provided an impetus for the specialty to develop safer practices. Anaesthesiologists began emphasising double-gloving, eye protection, and proper sharps disposal.

It was, however, not until the 2002 SARS-CoV-1 (SARS) crisis that anaesthesiologists recognised their field-specific vulnerabilities. Similar to the COVID-19 pandemic, globalisation facilitated rapid transmission of SARS, which uniquely concentrated within hospital settings. In Toronto, Canada, the North American epicentre of SARS, more than half of infected patients were healthcare workers.[15] Anaesthesiologists were tasked with sedation and airway management of SARS patients, and were particularly at risk for infection because of exposure to the high viral loads of respiratory secretions. Whilst transmission of SARS was incompletely understood, the medical community recognised the need for infection control policies. A 2003 editorial in the *British Journal of Anaesthesia* noted that, 'our current infection control practices may have been adequate in the past, but they have been exposed as entirely inadequate in the presence of the highly infectious SARS virus. Anaesthetists must be rigorous about the application of standard precautions in everyday practice. In the presence of a known or suspected SARS patient, full droplet and contact precautions must be applied. For additional safety, until the exact nature of transmission of the coronavirus is elucidated, airborne precautions should be taken with high-risk procedures'.[15] Although nearly 20 yr old, these recommendations for routine handwashing, double-gloving, and face-mask use remain the current recommended practices for COVID-19 management. Drawing upon the lessons from SARS, anaesthesiologists are advocates for planned intubations, negative-pressure operating theatres, and consistent use of personal protective equipment.

The scale of the COVID-19 pandemic has presented unforeseen challenges, including shortages of personal protective equipment. To limit transmission of COVID-19, infection control practices for healthcare workers are paramount. Anaesthesiologists are at additional risk of contamination given their role in aerosol-generating procedures.[16] Observance of infection control is therefore critical in minimising viral transmission to the provider and cross-infection between patients. Anaesthesiologists have developed novel plastic barriers to reduce droplet spray during tracheal intubation procedures,[17–19] and improvised personal protective equipment from readily available parts.[20]

Conclusions

Pandemics of cholera, polio, and SARS are not entirely relegated to history. Each has durably reshaped the roles and practice of anaesthesiology. The contributions of anaesthesiologists to these diseases prepared us for dealing with the COVID-19 pandemic. How might COVID-19 in turn shape the future practice of anaesthesiology? With resumption of elective procedures, anaesthesiologists will remain conscientious about respiratory precautions and aerosolization risks, and the occupational hazards of the specialty. The vital role of anaesthesiologists will also be better appreciated by both colleagues and the public, with the realisation that anaesthesiologists are indispensable and adaptable physicians beyond the operating theatre.

Coronavirus disease 2019 has undoubtedly challenged the medical profession in innumerable ways. Anaesthesiologists have been thrust to the front lines and are often responsible for the most vulnerable patients. The practice of anaesthesiology, however, retains its fluidity, readily merging knowledge from the operating theatre, ICU, and medicine/surgical ward. This uniquely interdisciplinary skill set has enabled our colleagues to continue researching treatments and improvising equipment whilst facing shortages and uncertainty. These may be unprecedented times, but the specialty has had a long and consistent history of confronting and overcoming epidemics. Anaesthesiologists are uniquely positioned to influence the resumption of normal hospital activities and the preparation for future public health threats.

Author contributions

RO researched and prepared the manuscript.
RC researched and prepared the manuscript.

Declarations of interest

The authors declare that they have no conflicts of interest.

References

1. Papper EM. Some contributions of anesthesiology to the general practice of medicine. *N Engl J Med* 1950; **243**: 734–7
2. Snow J. On the inhalation of chloroform and ether. With description of an apparatus. *Lancet* 1848; **51**: 177–80
3. Snow J. *On the mode of communication of cholera*. John Churchill: London; 1855
4. Hellewell J, Abbott S, Gimma A, et al. Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts. *Lancet Glob Health* 2020; **8**: e488–96
5. Geleris J, Sun Y, Platt J, et al. Observational study of hydroxychloroquine in hospitalized patients with COVID-19. *N Engl J Med* 2020; **382**: 2411–8. https://doi.org/10.1056/NEJMoa2012410. Adv Access published on May 7
6. West JB. The physiological challenges of the 1952 Copenhagen poliomyelitis epidemic and a renaissance in clinical respiratory physiology. *J Appl Physiol* 2005; **99**: 424–32
7. Robinson DH, Toledo AH. Historical development of modern anesthesia. *J Invest Surg* 2012; **25**: 141–9
8. Bower A, Bennett V, Dillon J, Axelrod B. Investigation on the care and treatment of poliomyelitis patients. *Ann West Med Surg* 1950; **4**: 561–82
9. Calmes SH. Why a paper on anesthesia and polio in 2016? *Anesth Analg* 2016; **122**: 1748–51
10. Severinghaus JW. Career perspective: John W. Severinghaus. *Extrem Physiol Med* 2013; **2**: 29
11. Khoury A, Hugonnot S, Cossus J, et al. From mouth-to-mouth to bag-valve-mask ventilation: evolution and characteristics of actual devices—a review of the literature. *Biomed Res Int* 2014; **2014**: 1–6
12. Marini J, Gattinoni M. Management of COVID-19 respiratory distress. *JAMA* 2020; **323**: 2329–30
13. Elharrar X, Trigui Y, Dols A-M, et al. Use of prone positioning in nonintubated patients with COVID-19 and hypoxemic acute respiratory failure. *JAMA* 2020; **323**: 2336–8
14. McNicholas B, Cosgrave D, Giacomini C, Brennan A, Laffey JG. Prone positioning in COVID-19 acute respiratory failure: just do it? *Br J Anaesth* 2020. https://doi.org/10.1016/j.bja.2020.06.003. Adv Access Published June 8
15. Kamming D, Gardam M, Chung F. Editorial I: anaesthesia and SARS. *Br J Anaesth* 2003; **90**: 715–8
16. Odor PM, Neun M, Bampoe S, et al. Anaesthesia and COVID-19: infection control. *Br J Anaesth* 2020. https://doi.org/10.1016/j.bja.2020.03.025. Adv Access Published April 8
17. Matava C, Yu J, Denning S. Clear plastic drapes may be effective at limiting aerosolization and droplet spray during extubation: implications for COVID-19. *Can J Anaesth* 2020; **67**: 902–4
18. Dalli J, Khan MF, Marsh B, Nolan K, Cahill RA. Evaluating intubation boxes for airway management. *Br J Anaesth*

2020. https://doi.org/10.1016/j.bja.2020.05.006. Adv Access published on May 14

19. Gould CL, Alexander PDG, Allen CN, McGrath BA, Shelton CL. Protecting staff and patients during airway management in the COVID-19 pandemic: are intubation boxes safe? *Br J Anaesth* 2020. https://doi.org/10.1016/j.bja.2020.05.001. Adv Access Published May 12

20. Khoo D, Yen C-C, Chow WT, et al. Ultra-portable low-cost improvised powered air-purifying respirator: feasibility study. *Br J Anaesth* 2020. https://doi.org/10.1016/j.bja.2020.04.082. Adv Access Published May 6

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Cardiopulmonary exercise testing in the COVID-19 endemic phase

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The coronavirus disease 2019 (COVID-19) pandemic has presented significant challenges to healthcare systems across the world. The substantial need to provide acute COVID-19-related care resulted in non-COVID-19 care being immediately curtailed, with significant implications for the provision of normal or 'routine' healthcare. As the pressure from acute COVID-19 care begins to regress, it is timely to consider how certain services, including those undertaking physiological measurements, will re-open and how they will function within the constraints dictated by a COVID-19 endemic working environment.

Over the past decade, there has been evolving recognition of the importance and value of clinical cardiopulmonary exercise testing (CPET) within healthcare settings.[1] Primarily, CPET is used to evaluate the integrative response to incremental exercise, enabling clinicians to characterise cardiorespiratory fitness and reasons for physical impairment.[2] It is recognised that CPET plays an important role in clinical arenas including determining surgical operability and evaluating the risk of perioperative death and postoperative complications.[3] It also has a function in supporting preoperative planning algorithms,[4] and developing management strategies for pathological conditions (e.g. heart failure)[5] and in disease prognostication (e.g. pulmonary hypertension).[6] Whilst there is considerable uncertainty regarding the ability to safely undertake CPET at present, it remains an integral investigative tool in clinical practice, and urgent consideration needs to be given to determine how best to deliver CPET services in the COVID-19 endemic phase.

Role and delivery of CPET in the COVID-19 endemic phase

CPET remains highly relevant and indicated to help plan major surgical procedures for malignancy, even within a COVID-19 endemic phase. It is envisaged that an additional requirement for these procedures will emerge from requests to evaluate individuals recovering from severe COVID-19 infection.[7] In this context, measurements obtained from an assessment of cardiorespiratory responses to physiological stress could provide insight regarding the integrity of the pulmonary–vascular interface and characterisation of any impairment or abnormal cardiorespiratory function. CPET characterises oxygen consumption ($\dot{V}O_2$) for a given level of external work, and the relationship between carbon dioxide output and ventilation (e.g. as characterised by the $\dot{V}_E/\dot{V}CO_2$ slope) can detail pulmonary dead space. It also characterises exercise-associated desaturation and hypoxaemia (i.e. by allowing evaluation of the alveolar–arterial O_2 gradient and arterial to end-tidal CO_2 difference), and can be used to identify alterations in breathing patterns that may be relevant in the aetiology of exertional dyspnoea.[8] Data from severe acute respiratory syndrome (SARS)-related illness showed significant exercise limitation in the months after hospital discharge, and the pathophysiological mechanisms were described eloquently using CPET.[9] Functional disability and recovery have also been reported in the 5 yr after acute respiratory distress syndrome (ARDS).[10] In individuals requiring invasive ventilatory support for COVID-19, the