

The Plague Doctor, the Pandemic Doctor, and Surgical Protective Clothing

Alexis R. Steinmetz* and Ronald Rabinowitz

University of Rochester Medical Center, Department of Urology, Rochester, NY *Corresponding author University of Rochester Medical Center 601 Elmwood Ave, Rochester, NY 14620 (e-mail: alexis_steinmetz@urmc.rochester.edu)

Introduction: Infectious diseases have tormented humans for thousands of years, and severe outbreaks have led to the devastation of entire communities. Even before globalization, parasites and pathogens traveled along trade routes with their human hosts. The protective clothing worn by physicians during epidemics serves as a powerful historical record chronicling accepted theories of disease transmission and treatments. The materials and designs of modern-day protective equipment reflect the contributions of surgeons to the ways doctors protected themselves and their patients during epidemics.

Sources and Methods: Historical texts and journal articles were reviewed regarding the history, epidemiology, and pathophysiology of epidemics of plague, influenza, and coronavirus.

Results: The Justinian Plague of the 540s CE was the first pandemic to be fully documented and began the long history of plagues through the Black Death of the Middle Ages. Believing that the etiology was foul-smelling bad air (miasma), doctors protected themselves by wearing dramatic head-to-toe coverings. Heavy boots, pants, long coats, gloves, and brimmed hats were made of leather sealed with animal fat. Most important was the infamous face mask with glass eye coverings and a long beak filled with aromatics intended to purify disease-causing vapors. An appreciation of droplet theory in the 19th century made beaked masks obsolete, replacing them with cloth face masks. Surgeons continued to pioneer the development of gloves and gowns, initially to protect themselves and later to protect their patients. Their outfits were worn by healthcare workers during the epidemics of the 20th century. Similar to the plague doctors, present-day physicians treating patients suffering from COVID-19 don themselves in head-to-toe protective outerwear, although heavy leather and beaked-masks have long since been replaced by disposable fabrics and the N95 respirator.

Conclusions: The evolution of physicians' protective clothing from the iconic beaked mask of the 17th century plague doctor to the hazmat-esque suits of the COVID-19 pandemic doctor reflects the substantial advancements in the detection, treatment, and containment of communicable diseases. Much of this is due to the dedicated efforts of surgeons to better safeguard their patients as well as protect themselves against diseases contained in bodily fluids.

Keywords: plague doctor; pandemic doctor; personal protective equipment

Infectious diseases have tormented humans for thousands of years, and severe outbreaks have led to the devastation of entire communities. Even before globalization, parasites and pathogens traveled along trade routes with their human hosts. The Justinian Plague of the 540s CE was the first pandemic to be well documented and began the long history of the Black Death of the Middle Ages.(1) The protective clothing worn by physicians during epidemics serves as a powerful historical record chronicling accepted theories of disease transmission and treatments. The materials and designs of modern-day protective equipment—masks, gloves, gowns, caps, and eyewear—reflect

the contributions of surgeons to the ways doctors have protected themselves and their patients during epidemics. Our objective was to analyze the history of the surgical protective wear and how it evolved into our modern concepts of the operating room standard of care.

SOURCES Historical texts, journal articles, and media were reviewed regarding the history, epidemiology, and pathophysiology of epidemics since the first century of the common era. We also investigated the progressive development of surgical protective clothing with a focus on masks, gloves, gowns, caps, and eyewear.

RESULTS

Masks

Face coverings as a method of protecting respiratory health go back at least 2,000 years. Some of the earliest descriptions came from the Roman savant and author, Pliny the Elder (23–79 CE), who was said to have used animal bladders as masks to prevent inhalation of toxic dust while crushing minerals used for decorations.(2) Several centuries later, Leonardo da Vinci (1452–1519) also recommended covering the mouth and nose with wet cloth as protection from toxins.(2) Perhaps the first documented use by physicians can be traced back to the 17th century. Erroneously believing that the etiology of the plague was foul-smelling bad air or miasma emanating from the earth, plague doctors protected themselves with the infamous beaked masks filled with aromatics intended to purify disease-causing vapors (Figure 1).(3) While ineffective at preventing transmission of flea-borne plague, these filtering bird masks may be considered precursors to the duck-billed N95 respirator.

The 19th century brought about an era of great advancements in respiratory protective coverings, driven by the need for occupational protection for firefighters, miners, and military personnel as well as discoveries in the pathogenesis of disease transmission. In 1849, American inventor Lewis Haslett patented the forerunner of the gas mask and in 1877, George Nealy developed one of the first filter type masks for firefighters, the Nealy Smoke Mask.(4) Around that time, the evolution of scientists' understanding of disease transmission prompted the appearance of masks in the operating room. Surgeons were desperately searching for ways to decrease rates of surgical site infection as

the mortality rate after surgery was unbearably high. In 1867, the British surgeon Joseph Lister hypothesized that wound infections were caused by the microscopic germs described by Louis Pasteur.(5) Bacteriologist Carl Flügge demonstrated that bacteria could be cultured from respiratory droplets and, after learning of this work, surgeon Johann Mikulicz began wearing a face mask at the University of Breslau in 1897.(6) Mikulicz's face mask was "a piece of gauze tied by two strings to the cap, and sweeping across the face so as to cover the nose and mouth and beard".(Figure 2)(7,8) That same year, French surgeon Paul Berger began wearing a mask in the operating room in Paris.(6,7)

Not long after, the surgical masks became more widely used in an effort to prevent the spread of disease, largely as a result of two infectious outbreaks. In 1910, the young physician Dr. Wu Lien-teh famously pleaded for mask-wearing by the public to curb the spread of the plague that devastated Manchuria; he promoted a version of the surgical mask (Figure 3).(9,10) Eight years later, in 1918, facemasks were required in some cities during the so-called Spanish Flu epidemic.(11) The 20th century also advanced the evolution of masks as a more sophisticated filtration device (rather than just droplet protection), which was further advanced due to occupational safety concerns and the world wars. (12) In 1920, MSA Safety Company manufactured the Gibbs breathing apparatus, and gas masks were refined during WWII as a protection against chemical warfare. (13) The U.S. based company 3M is credited with finally combining the surgical masks with respirator devices for use in medicine. This was largely influenced by the creative genius of Sara Little Turnbull, one of America's earliest industrial designers. She was hired as a design consultant by 3M and began experimenting with a



Figure 1. A. Engraving of the Plague Doctor, Paul Fürst, c. 1656 (Wikimedia Commons, Public Domain); B. Urologic surgeon wearing typical attire (courtesy, author AS); C. Health care worker in COVID-19 pandemic (courtesy, author AS); D. Urology operating room attire during the COVID-19 pandemic (courtesy, author AS)

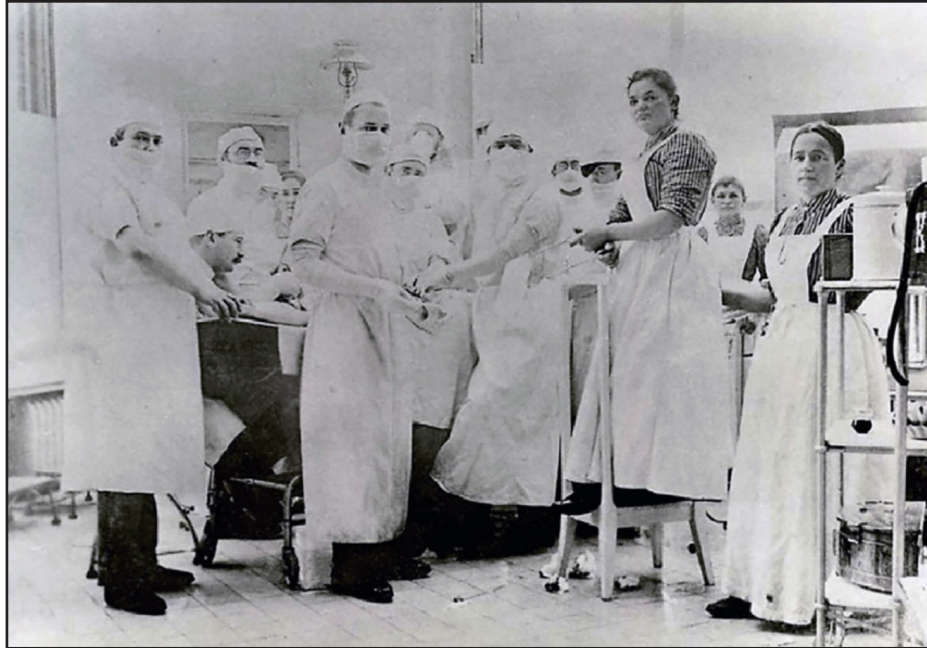


Figure 2. Johannes von Mikulicz wearing mask, gloves, and cap in the operating theatre in 1899. (Public Domain, ref. 8)

new non-woven material developed by 3M. In the late 1950s, she presented many ideas for using the material, including a molded cup bra and a medical mask. In 1961, 3M released its Bubble surgical mask that closely resembled her molded bra cup design (Figure 4).(14) The company released its first single-use N95 dust respirator in 1972, which eventually became modified and approved for preventing disease transmission.(15) Tuberculosis outbreaks in the 1990s, SARS in 2003, H1N1 in 2009, and the ongoing COVID-19 pandemic expanded the use of surgical masks and N95s by the public and health care workers.

Gloves

In modern operating rooms, it seems unfathomable that surgeons might operate with their bare hands, but this was the practice for millennia. Some of the earliest documented uses of gloves by physicians were by the 17th century plague doctors. Royal French physician Charles De'Lorme described the plague doctor uniform in 1619, which included heavy leather gloves as protection from the mysterious illness(Figure 1).(7) Early rudimentary surgical gloves were created to facilitate procedures or protect the operator from infection or caustic agents used to clean instruments, rather than for their role in antiseptic technique. In 1758, obstetrician Johann Julius Walbaum described a partial glove that mostly covered the fingers, made from sheep cecum that wouldn't cling to the vaginal wall during delivery. (16) Many years later, in 1834, the physician Robert

F. Cooke sent a letter and a solution of India rubber to a professor of surgery at the College of Physicians and Surgeons at Columbia University stating, "this, if I mistake not, will become a useful material in the surgeon's hand...by lubricating the hands with it you have an insoluble pair of India rubber gloves—perfectly impenetrable to the most malignant virus."(17) Later that decade, improved methods of processing rubber paved the way for its eventual use as surgical gloves.(18) In the 1840s, Dr. Ignaz Semmelweis (Hungary) was ridiculed for his publication suggesting that handwashing by physicians could prevent puerperal fever, and it wasn't until many years later that handwashing and glove wearing would be routine for preventing infection.(19) Much of this shift was due to Joseph Lister's appreciation of antiseptic technique. He recommended carbolic washes for hands and instruments.5 When Thomas Forster (an employee of India-Rubber Works in Surrey) received a patent for the "manufacture of gloves for surgical operations" in 1878, it followed soon after that surgical teams began wearing rubber gloves to protect their hands while cleaning instruments.(20)

Already in use by this time, the most famous and well-known story of the introduction of rubber gloves into the operating room is that of William S. Halsted (Johns Hopkins), who in 1889, commissioned the Goodyear Rubber Company to produce rubber gloves for his scrub nurse, Caroline Hampton.(20) She was suffering from severe contact dermatitis that would've



Figure 3. (Left) Drs Wu Lien-teh and F. Ebersson performing plague inhalation experiments in the open air in Mukden, 1916 (Visual Representations of the Third Plague Pandemic Photographic Database, University of Cambridge, <https://www.repository.cam.ac.uk/handle/1810/281919>); **(Right)** Anti-plague masks, 1911 Manchurian Plague. (10)

prevented her from continuing her work in the operating room—they married the following year.(18,20) Surgical glove use was further popularized when Halsted's chief resident, Joseph Bloodgood, noted that wearing gloves also prevented post-operative infection (Figure 5).(20) The technique of donning gloves for surgery was described in the early 1900s textbooks, and by 1940 gloves were commonly worn in the operating room. (21,22)

In 1965, the Ansell Rubber Company developed the first disposable medical gloves, sterilized with gamma irradiation.(23) The concept of universal precautions in the 1980s with the HIV epidemic increased the use of disposable latex gloves outside of the operating room. However, latex gloves, which are derived from plant-based rubber, can cause severe allergic reactions and are not entirely impenetrable to toxic substances. In the mid-1990s, nitrile gloves were created from synthetic rubber

and have largely replaced latex gloves. During the early months of the COVID-19 pandemic, the general public was often seen donning gloves in public.

Gowns

The blue-green scrubs (so-called because they are worn in a sterile, or "scrubbed" environment) that are now commonplace in operating rooms around the globe trace back to the 20th century. Without an understanding of the importance of sterility, prior to the 19th century surgeons simply wore their street clothes in the operating theatres.(24) In the early to mid-19th century there was a switch to black frock coats, which were eventually replaced with white smocks.(24) A surgical text published in 1894 stated that "it is safer and better that all should put on a complete change of costume rather than simply don a sterilized coat and pair of trousers over

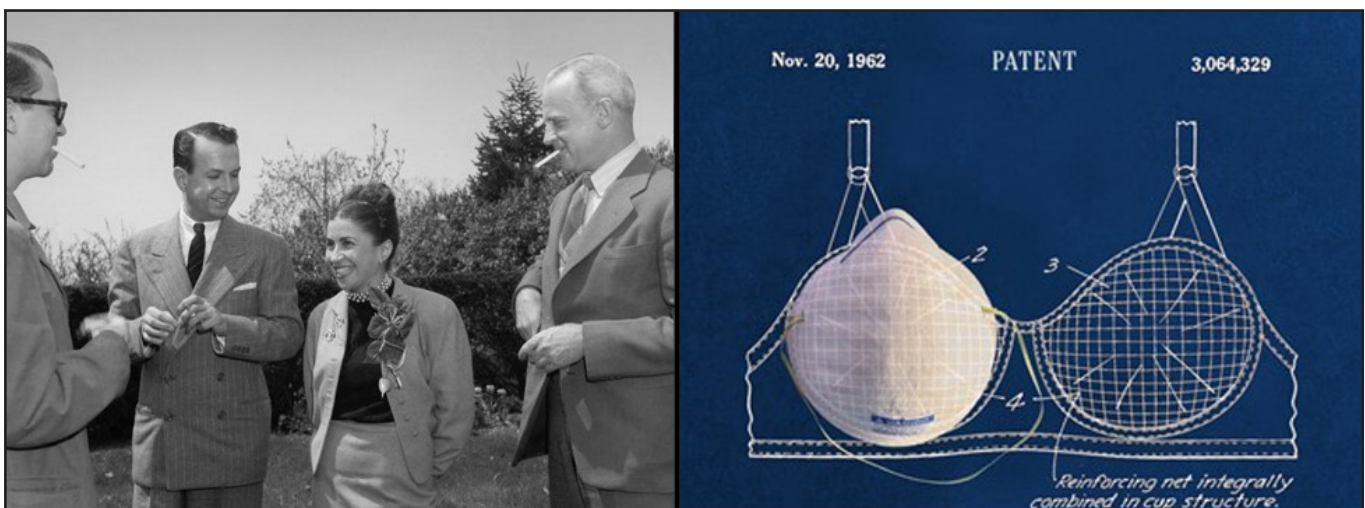


Figure 4 (Left) Sara Little Turnbull (1917-2015), second from right (© Center for Design Institute). **(Right);** 3M's bra cup patent which referenced the medical mask with a superimposed image. (© Center for Design Institute).

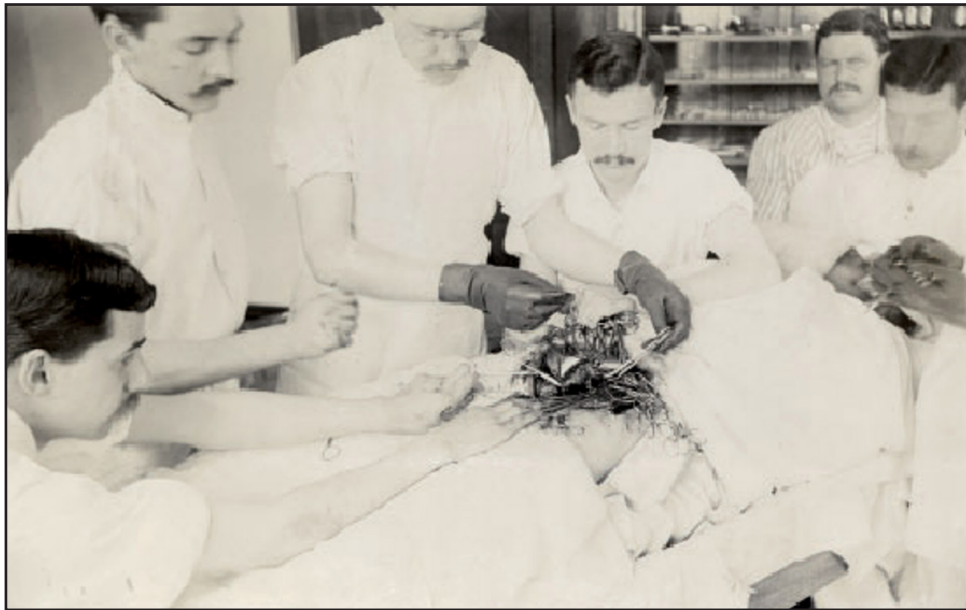


Figure 5. “The first surgical operation where the operator was wearing rubber gloves, 1893. Joseph C Bloodgood, third from the left. (24)

the ordinary clothing”.(24, 25) By the early 20th century green scrubs came into favor, reportedly because the color would cause less eye fatigue than white under the bright lights of the operating room.(26) Notably, gowns or some type of protective outwear was worn by physicians during many epidemics, starting at least with the heavy leather coat and trousers of the 17th century plague doctor (Figure 1). Throughout the 20th and 21st century epidemics, both reusable and disposable non-surgical isolation gowns evolved in tandem with their sterile, operating room approved counterparts (Figure 1 and end plate).

Caps

Religious habits were worn in early medical facilities run by nuns, and in the 1800s, hats became a standard part of the nursing uniform.(27) By the early 1900s, surgeons were photographed wearing various types of caps in the operating room, both as uniform and antisepsis. In the 1930s, surgeons were consistently wearing them. (21) Since then, scrub caps have become a longstanding symbol of the surgical profession—so much so that proposed new regulations in 2014 that attempted to ban personalized cloth caps were met with significant resistance by the surgical community.(28) More recently, descriptions of culturally appropriate surgical head coverings have been published in the surgical literature. (29) In historical depictions and photos of epidemics, health care workers can be seen with some type of head covering dating back to the 17th century plague doctor (Figure 1).

Eyewear

Eye protection represents one of the few pieces of outerwear that was not specifically developed or

advanced by surgeons. Moreover, while other aspects of surgical attire were adapted to decrease infections in patients, eye protection was added to protect the surgeon from conjunctival contamination from the patient (Figure 6). Various forms of eye protection evolved for practical use in combat, sports and recreation, as well as occupational protection.(30) Pearl diving goggles made from polished tortoise shells were described in Persia as far back as the 14th century, and a ceramic vase from 2nd or 3rd century Peru is described as a diver wearing goggles while holding fish.(31) The 17th century plague doctors’ facial protection included glass eye coverings; some of the first doctors to wear them. In 1880 Powell Johnson received an eye protector patent, a rudimentary eye shield composed of two layers of semi-opaque cloth meant for firefighters exposed to intense bright lights; almost forty years later, Garrett Morgan patented safety glasses.(32) Eye protection was thought to interfere with the vision of surgeons and wasn’t widely adopted for some time, although it did become more common in the 1980s during the HIV epidemic. It was also worn by physicians during various epidemics to protect them from exposure to splashes and respiratory secretions. Nowadays, eye protection of some form is required in operating rooms and is especially important to urologists and others who frequently deal with bodily fluids (Figure 7).



Figure 4. Team wearing eyewear and goggles puts a plague victim into a coffin in Madagascar around 1935 (National Geographic, 7/14/2020).

DISCUSSION

Much of modern-day protective clothing was initially worn by physicians who—without an understanding of disease transmission—bravely cared for those stricken with mysterious illnesses during epidemics. The need for occupational protection also drove innovation in protective clothing, especially in terms of respiratory health. The acceptance of droplet theory and the role of antisepsis in the late 1800s represents a historical milestone that was instrumental in the development of surgical attire. The gauze surgical mask has come to symbolize the way health care workers and the general public protect themselves during infectious outbreaks. Surgeons continued to pioneer the development of gloves and gowns, initially to protect themselves and later to protect their patients. Surgical attire was further adapted for health care workers during epidemics of the 20th and 21st centuries.

Similar to the plague doctors, present-day physicians treating patients suffering from COVID-19 don themselves in head-to-toe protective outerwear, although heavy leather and beaked-masks have long since been replaced by disposable fabrics and the N95 respirator.

CONCLUSION

The evolution of physicians' protective wear from the iconic beaked mask of the 17th century plague doctor to the hazmat-esque suits of the COVID-19 pandemic

doctor reflects more than a century of substantial advancements in the detection, containment, and treatment of communicable diseases. Much of this is due to the dedicated efforts of surgeons to better safeguard their patients as well as themselves. The iconic plague doctor trappings of four centuries ago corresponds to almost all of the available personal protective equipment: respirator mask, gloves, gown, goggles, cap, and face shield.

REFERENCES

1. Shelley FM: The world's population: an encyclopedia of critical issues, crises, and ever-growing countries. Santa Barbara: ABC-CLIO; 2015.
2. Sharma NM and Chaudhary AR: Evolution of masks as public health intervention in the control of respiratory outbreaks. *Natl J Community Med* 2020; 11: 138.
3. Mertz L: Miasma. *The Gale encyclopedia of public health* (2nd ed). Farmington Hills: Gale; 2020.
4. Herris WP: How regulation and innovation have shaped respiratory protection. *EHS Today* 2009; 2: 54.
5. Lister J: On the antiseptic principle in the practice of surgery. *Br Med J* 1867; 2: 246
6. Spooner JL: History of surgical face masks. *AORN J* 1967; 5: 76.

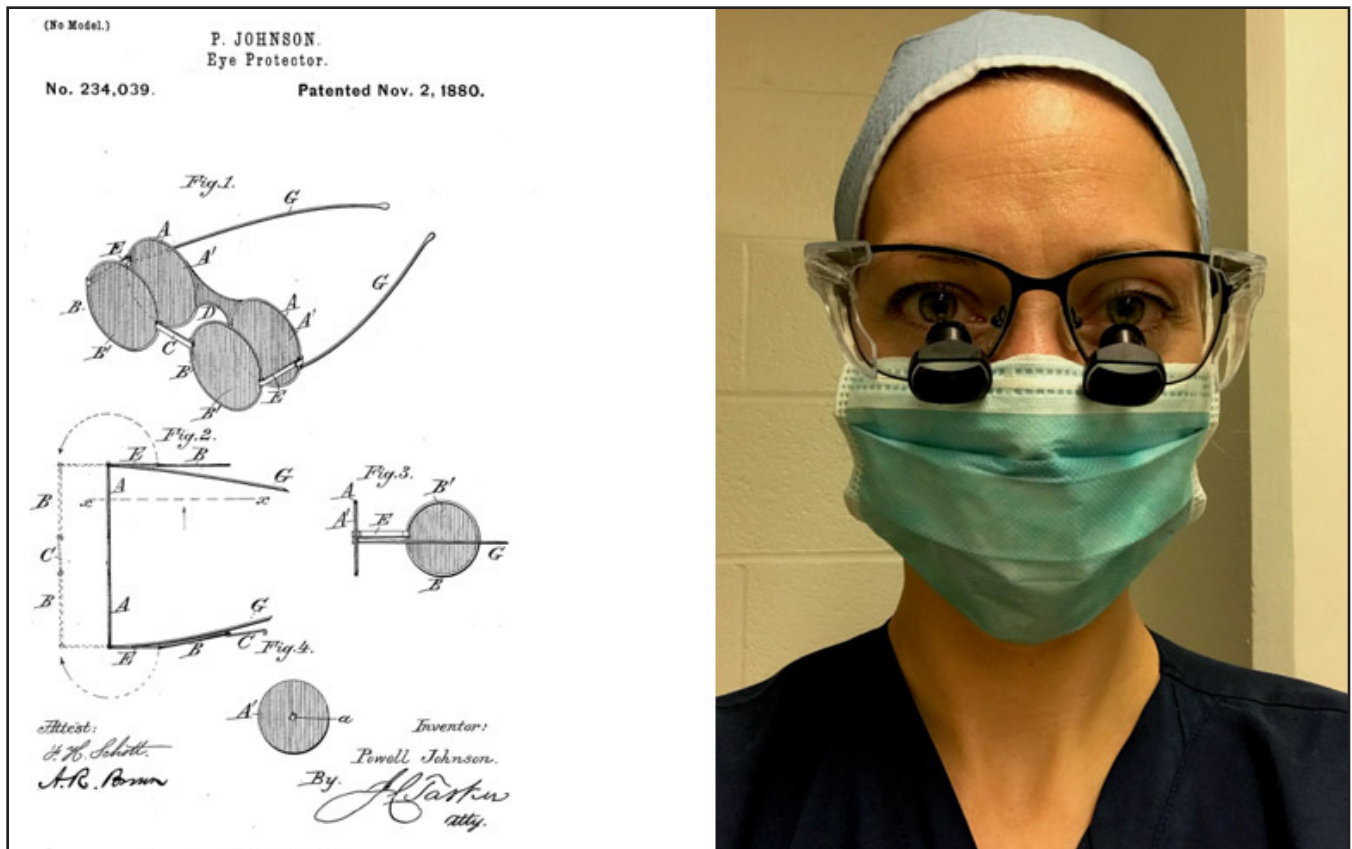
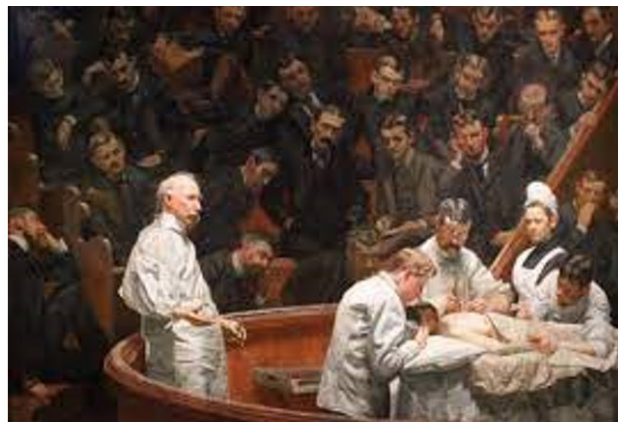


Figure 5. Surgical Eye protection. **(Left)** Powell Johnson's "Eye Protector" patent (United States Patent Office, 1880). **(Right):** Example of modern surgical eyewear (courtesy, author (AS)).

7. Strasser BJ and Schlich T: A history of the medical mask and the rise of throwaway culture. *Lancet* 2020; 396: 19.
8. Schlich T and Strasser BJ: Making the medical mask: surgery, bacteriology, and the control of infection (1870s–1920s). *Med Hist* 2022; 66: 116.
9. Lee KH, Wong DT, Ho TM, et al: Dr Wu Lien-teh: modernising post-1911 China's public health service. *Singapore Med J* 2014; 55: 99.
10. Lynteris C. Plague masks: The visual emergence of anti-epidemic personal protection equipment. *Med Anthropol* 2018; 37: 442.
11. Ott M, Shaw SF, Danila RN, et al: Lessons learned from the 1918-1919 influenza pandemic in Minneapolis and St. Paul, Minnesota. *Public Health Rep* 2007; 122: 803.
12. Schrenk HH: Testing Respiratory Protective Equipment for Approval. United States Department of the Interior Bureau of Mines; 1940.
13. Spelce D, Rehak TR, Metzler RW, et al: History of U.S. Respirator approval. *J Int Soc Respir Prot* 2018; 35: 35.
14. Ask Why – Sara Little Turnbull. Design Museum Foundation 2020. Available at: <https://designmuseumfoundation.org/ask-why/>
15. NIOSH guide to the selection and use of particulate respirators. U.S. Department of Health and Human Services 2014. Available at: <https://www.cdc.gov/niosh/docs/96-101/default.html>
16. Dyck RJ: Historical development of latex allergy. *AORN J* 2000; 72: 27.
17. Proskauer C: Development and use of the rubber glove in surgery and Gynecology. *J Hist Med Allied Sci* 1958; 13: 373.
18. Britt RC: The glove made from love: a history of surgical attire. *Am Surg* 2019; 85: 935.
19. Semmelweis I: Die aetiologie, der Begriff und die Prophylaxis des Kindbettfiebers. Pest, Wien u. Leipzig; 1861.
20. Lathan SR: Caroline Hampton Halsted: The first to use rubber gloves in the operating room. *Proc (Bayl Univ Med Cent)* 2010; 23: 389.
21. Adams LW, Aschenbrenner CA, Houle TT, et al: Uncovering the history of operating room attire through photographs. *Anesthesiology* 2016; 124: 19.
22. Blowers R, McClusky M: Design of operating-room dress for surgeons. *Lancet* 1965; 2: 681.
23. Ansell's History. Ansell Ltd 2021. Available at: <https://www.ansell.com/us/en/about-us/our-history>
24. Buicko JL, Lopez M, Lopez-Viego MA: From formalwear and frocks to scrubs and gowns: A brief history of the evolution

- of operating room attire. *J Am Coll Surg, Surgical History Journal*; 2017.
25. Robb H: Aseptic surgical technique: with especial reference to gynæcological operations. Philadelphia : JB Lippincott Company; 1894.
 26. Belkin NL: Use of scrubs and related apparel in health care facilities. *Am J Infect Control* 1997; 25: 401.
 27. Craig L: The history of nursing. Detroit: Lucent Books; 2013.
 28. Moalem J, Alseidi AA, Broghammer J, et al: Young surgeons speak up: stringent OR attire restrictions decrease morale without improving outcomes. *Bull Am Coll Surg* 2016; 101:10.
 29. Abdelwahab R, Aden A, Bearden B, et al: Surgical scrubbing and attire in the operating room and ICU: a multicultural guide. *J Am Coll Surg* 2021; 233: 321.
 30. Hoskin AK, Mackey DA, Keay L, et al: Eye injuries across history and the evolution of eye protection. *Acta Ophthalmol* 2019; 97: 637.
 31. Marx RF: The History of Underwater Exploration. New York: Dover Publications; 1990.
 32. Igo GR: How Protective Eyewear Has Changed Dramatically Over the Decades. *Occupational Health and Safety* 2017. Available at: <https://ohsonline.com/Articles/2017/06/01/How-Protective-Eyewear-Has-Changed.aspx#:~:text=Protective%20eyewear%20has%20come%20a,them%20to%20reduce%20the%20intensit>



Endplate. The evolution of PPE in the operating theater. (Left) "The Gross Clinic", Thomas Eakins (1875). Samuel Gross wears a frock coat during surgery, as do all of his attendants.(24) **(Top right).** "The Agnew Clinic", Thomas Eakins, (1889). All members of the surgical team now wear clean white gowns yet none wear gloves.(24) **(Bottom right).** Urologic surgeons in the operating room, 2021 (courtesy of the author).