Through Plagues and Pandemics: The Evolution of Medical Face Masks

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KEYWORDS: face masks, pandemic, COVID-19

Paul Fürst, engraving, c. 1721, of a plague doctor of Marseilles (introduced as 'Dr. Beaky of Rome'). His nose-case is filled with herbal material to keep off the plague. [CC-PD]

PLAGUES AND PANDEMICS

The first face masks were created to combat the earliest plagues. The Bubonic Plague, otherwise known as the Black Death, spread throughout the Roman Empire in the 6th Century AD.[1] When Gregory I became Pope in 590 AD, an outbreak was reaching Rome. To combat the disease he ordered unending prayer. At the time, sneezing was thought to be an early symptom of the plague, thus stating "God bless you" became a common phrase spoken to help halt the disease.[2]

The plague ravaged Europe and Asia from the 14th to the 17th Centuries and is estimated to have killed 200 million people in the 14th Century alone.[2] Plague doctors wore the iconic bird-beak masks in which the beaks were filled with a mixture of herbs such as garlic and rue to block the odors of the dead and dying that were ever-present.[1,4] This form of protection was thought to neutralize the "miasma" in the air which was thought to be the cause of the illness.[3]

In 1867, the British surgeon **JOSEPH LISTER** (1827–1912) brought about the age of antisepsis, championing the use of carbolic acid to sterilize surgical instruments and clean wounds. At the time, **LOUIS PASTEUR** (1822–1895), the French microbiologist and chemist, had recently described the presence of germs as the microscopic source of infection. Lister suggested eliminating germs through the use of antiseptic substances.[6]

JOHANN MIKULICZ-RADECKI (1850–1905), Chair of the Department of Surgery at the University of Breslau, worked with local bacteriologist, **CARL FLÜGGE** (1847–1923), who showed that ordinary conversation could disseminate respiratory droplets with bacteria. This led Mickulicz-Radecki to create and wear a face mask in 1897, which he described as a "piece of gauze tied by two strings to the cap, and sweeping across the face so as to cover the nose, mouth and beard."[6]

The Manchurian Plague, 1910–1911

The Manchurian Plague of 1910–1911 started along the Russian border of Manchuria, an area of Northeast Asia, and quickly spread south along the railways. The pneumonic form of plague killed every person it infected. Most believed it was spread by rodents so the idea that it was airborne caused fear. The masks during the Manchurian Plague consisted of a 4x6 inch cotton rectangle secured over the mouth by a long piece of gauze. The gauze was folded so that the rectangle was contained within the gauze lengthwise. The ends of the gauze were then cut so that one end had two flaps and the other had an opening for the flaps to tie into behind the head. The flaps and opening were placed around the ears, similar to modern face masks, to secure the mask in place. The ends were then tied together to finish the contraption.[4] The final product was similar in appearance to a modern day cotton face mask, but the covering over the mouth and nose area were thicker than they are now. The mask was made for the entire population; however, the harsh winter conditions may have adversely affected the efficacy of the mask.[4] This plague and the widespread usage of masks had a cultural effect on the Manchurian population. The collective effort by the population to wear masks in order to curb the epidemic led to a shift from the belief in superstitions and the supernatural towards an acceptance of science to help combat the plague.[4]

The Spanish Influenza of 1918–1919

The Spanish Influenza of 1918–1919 brought worldwide hardship and halted the normalcy of everyday life. The Spanish Flu did not originate in Spain, but because Spain was a neutral country in World War I with a free media; the outbreak was covered from the start, with it being first reported in May of 1918. During this time, there was a shortage of healthcare workers because those caring for the sick were themselves ill with the virus. The First World War added to the severity of the pandemic as soldiers' immune systems, already weakened by the stress and ravages of war, allowed the virus to spread throughout the trenches. Increased travel due to the war effort further contributed to the spread of the

virus.[2] Deaths worldwide were estimated to be 50 million, with 675,000 deaths in the United States.[7] During the 1918–1919 influenza pandemic, masks were mandatory for medical workers, police officers, and in certain American cities (citizens in San Francisco were fined $5 if they were caught in public without a mask), but the mandate of face masks was not without protest.[5] By this time, most masks were made of layers of cotton gauze with occasionally another layer of a less porous material surrounded by a metal frame. Furthermore, these masks were reusable and could be sterilized.[5] The 1918–1919 influenza pandemic ended approximately 18 months after its outbreak. The wearing of face masks was thought to have played an important role in helping stop the spread of the disease during its course.[2]

THE DEVELOPMENT AND EVOLUTION OF FACE MASKS

As discussed earlier, one of the first surgical masks, composed of a single layer of gauze, was described by Johann Mikulicz-Radecki in 1897. In 1899, Flugge, who was working with tuberculosis, demonstrated that ordinary conversation could disseminate bacteria-filled droplets from the nose and mouth. The droplet theory of infection substantiated the need for an effective face mask. In 1905, **ALICE HAMILTON** (1869–1970), a Chicago physician, proposed that scarlet fever was transmitted through droplet infection and recommended doctors wear masks at the time of surgery because of heavy droplet transmission from the mouth and nose while talking and teaching. This may have been the first recommendation that surgeons wear masks. While the use of gauze face masks to protect patients against wound infections was widespread in operating rooms by the late 1920s, the following decade saw a burst of innovation in surgical mask design. Some designs were especially creative: one mask proposed in 1930 consisted of a 14-karat gold-filled frame covered with wax paper, and another consisted of a paper napkin, two paper clips or safety pins, and two rubber bands. The introduction of antibiotics in the 1940s briefly decreased interest in surgical masks, but it was soon discovered that antibiotics were not a substitute for good aseptic technique.[8]

The standardization and testing of surgical face masks began in earnest in the 1950s, establishing the basis for our present-day practices. Numerous tests were conducted to assess the effectiveness of masks in preventing the dissemination of germs from the wearer. Some tests involved placing petri dishes or glass slides at varied intervals from an individual to pick up exhaled germs. Other more tech-savvy tests visualized droplets and aerosols using high-speed cameras and strobe lights. Many of the principles established by these tests remain important to keep in mind today. For instance, it was discovered that the closeness of fit of the mask to the face is just as important as the material, that semi-porous filtering masks are more effective than nonporous deflector masks, and that masks quickly lose their filtration capability once wet.[9]

In the modern era, there has been a scarcity of experimental evidence to support the effectiveness of face masks in the prevention of surgical site infections.[6] What literature there is on the subject is dated and has had poorly explained methodology. Furthermore, it is uncertain that the results of these studies can be extrapolated to today given the usage of new antiseptic techniques since their completion. Face masks have also been thought to have utility in that they act as a physical barrier against blood and bodily fluid splashes during surgery. Despite clear evidence that face masks act to protect the staff from macroscopic facial contamination, there are studies that suggest that they fail to protect surgeons from sub-micrometer contaminants. The use of face shields may help mitigate this risk. Given that there has been little evidence that face masks cause harm, proponents err on the side of caution and encourage their continued use, stressing there is no room for complacency when it comes to both patient and surgeon safety.

The Hawk's Nest Tunnel disaster

Respirator-type masks that protect the wearer from inhaling pathogens have become heavily associated with the medical field today during the COVID-19 pandemic. These respirators were originally developed in the mining industry. In 1919, the U.S. Bureau of Mines (USBM) began working to address the high fatality rate of mineworkers by establishing the first respirator certification program.[10] From the beginning, inequalities existed in workers' access to respiratory protection, as exemplified by one of the deadliest disasters in American industrial history, the Hawk's Nest Tunnel disaster of the 1930s. From 1930–1935, three thousand men, the majority of whom were Black migrant workers from the South, worked on the construction of a tunnel near Gauley Bridge, West Virginia. In the construction process, they found the mineral silica and were forced to mine it without any respiratory protection. As a result, an estimated one-third of the workers died from acute silicosis and related conditions. Notably, the dangers of silica dust were well-known to the company, as their engineers wore respirators inside the tunnel.[11] The disaster accelerated the adoption of standards for dust, fume, and mist respirators, but it was not until the passage of the Occupational Safety and Health Act of 1970 that the federal government began requiring employers to provide adequate respiratory protection to all workers.

In 1972, the USBM approved the first single-use N95 respirator, which is the respirator-type mask that many of us are familiar with today. The designation of "N95" is a government efficiency rating that means the mask blocks about 95 percent of particles that are 0.3 microns in size or larger.[12] The material in these respirators is designed to trap small particles using a method called corona electrostatic charging, which allows the fabric to filter particles ten times more efficiently than uncharged fabrics. The importance of the electrostatic charge also means that a wet N95 mask loses its effectiveness. The

adoption of respirator-type masks in the medical field began in the 1990s, when healthcare workers began wearing them to protect themselves from drug-resistant tuberculosis, and their use in healthcare and other industries continues to the present day. Unfortunately, with the scarcity of personal protective equipment during the COVID-19 pandemic, complaints of unequal access to respiratory protection in the workplace have again arisen, with accounts of allied health professionals, interpreters, and room cleaners not receiving the same level of protection as doctors and nurses, despite their equally close contact with COVID-19 patients.[13]

FACE MASKS TODAY

SARS-CoV-2 is a viral respiratory illness, which has grown within six months from an outbreak in Wuhan, China to a pandemic that has claimed over a million lives. To stem the spread of the virus, face masks have been one measure at the center of the debate around health guidance, in addition to social distancing, shut-downs, testing, and quarantining.

The guidance around mask usage, through the World Health Organization (WHO) and the United States Centers for Disease Control and Prevention (CDC), has shifted over the course of the pandemic. These shifts are attributed to new evidence that has come to light on the asymptomatic transmission of SARS-CoV-2, whereby an infected individual can spread the virus through aerosol, before or without the presence of symptoms.[14] The initial WHO recommendations, in January 2020, recommended medical mask use only for individuals with respiratory symptoms and for healthcare workers.[15] However, by June 2020, the agency's guidance was recommending cloth mask use among the general population, with medical mask use still restricted for vulnerable populations, those with respiratory symptoms, and healthcare workers.[16]

Despite the recent WHO guidance, the implementation of these guidelines has varied geographically. In China, mask usage reflected cultural norms around hygiene and collective health benefits. In contrast, in countries like the United States, which value individualism, mask-wearing had not initially been readily accepted.[17] The lack of compliance conveys an urgency to communicate proper information about mask type and usage to the U.S. population. There are several types of masks that are being commonly used during the pandemic, including medical masks (such as N95 respirators and surgical masks) and cloth masks, often made out of common household materials, such as bandanas or T-shirts. The varying characteristics of mask materials affect their effectiveness, particularly in the context of source control, restricting an infected person's viral shedding to protect others in close proximity.[14,16]

N95 respirators, reserved primarily for healthcare workers, are made of multiple fibers of polymer, and have the added benefit of protecting the wearer with a nearly one hundred percent filtration efficiency.[18] With the shortage in the supply of personal protective equipment (PPE), even healthcare workers were finding a need to reuse these masks. However, a recent study found that autoclave sterilization procedures reduced the filtration efficiency of N95 respirators, particularly for small- to medium-sized particles, indicating that multiple uses of these masks come with disadvantages to personal safety.[19] The N95 mask with a valve is a variation that is also being commonly used. However, this mask has a one-way filtration system, such that, contrary to the source control method, it only protects the wearer by filtering inhaled air, without conferring protection to people nearby.[14] Thus, for public health purposes of mitigating COVID-19 spread, this type of mask should be avoided. Surgical masks are made of multiple layers of propylene, and demonstrate a filtration capability not by physically blocking the particle through Van der Waals interactions with the fibers, but rather by creating an electrostatic charge difference between the fiber and particle.[18] However, exposure to moisture, perhaps from long-term use, sterilization procedures, or other means, could reduce the electrostatic nature of the mask, reducing its effectiveness.[19]

Cloth masks, recommended for use for the general public, are less effective at protecting the wearer, but can substantially reduce spread of the virus. A recent study visualized the spread of aerosol particles ejected from respiratory jets by utilizing mask-wearing mannequins and found that each cloth mask reduced propulsion by at least half the distance of an uncovered individual.[20] Although bandanas had the highest thread count per inch, they only reduced propulsion to 4 feet, while a folded handkerchief limited propulsion to just over one foot, and a stitched mask made of quilting cotton limited propulsion to just 2.5 inches. Thus, aside from thread count, a greater number of layers of material in the mask also contributes to limiting propulsion, while increasing filtration efficiency as well, although an increase in layers can reduce mask breathability.[18,20] Even though cloth masks do not match the efficacy of N-95 respirators and surgical masks, expansive use of these masks can drastically reduce spread.[14] Mask fit and placement play an important role in preventing droplet escape. The most common sites of droplet escape include the top of a mask (which can be seen as fogging of glasses or eye protection) when there is not a tight fit at the nose as well as from the sides of the mask by the cheeks.[20] Curtailing the spread of the virus requires wearing a mask when there is limited social distancing, and keeping the mask covering the mouth and nose while speaking, to limit droplet propulsion. Our understanding of how to best utilize face masks and their effectiveness continues to evolve. We thus recommend checking up to date information on the websites for the CDC (https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover-guidance.html) and WHO (https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/when-and-how-to-use-masks).

Mask wearing is not a new phenomenon when it comes to protecting ourselves from pandemics. People have used masks for hundreds of years in an early, but not completely understood, attempt to halt the spread of disease. Progressively we have begun to better understand the science behind protective equipment since the last pandemic at the beginning of the 20th century. From the Black Death to the Manchurian Plague to the 1918–1919 Influenza Pandemic to the COVID-19 Pandemic today, the use of facial coverings has been a simple but powerful tool to help combat infectious disease. ❖

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Acknowledgment

This manuscript was written as part of the 2020 BrownConnect Summer Institute (BCSI) Program.

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