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The Industrial Revolution and the Advent of Modern Surgery

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Abstract

In the early nineteenth century, surgery was a much less refined and respected profession than it is today. Due to the very slow progression of the practice, surgery was risky and often ineffective. Furthermore, the applications of surgery were very limited at that time. It is widely accepted that the advent of anesthesia and aseptic technique are largely responsible for the modernization of surgery—they produced changes that would revolutionize the profession. Before the introduction of these surgical principles, very little surgical progress was seen. Although we know that these technologies played an important role in the advancement of surgery, we still have yet to fully understand what led to the establishment of these technologies. The goal of this paper is to understand how the societal trends of the Industrial Revolution are directly linked to these innovations and ultimately, the introduction of modern surgery.

Introduction

Due to modern surgical methods, chances of full recovery from surgery are remarkably high, and procedures are completely painless. Today, surgery is a highly respected profession, and its presence dramatically impacts our lives. In fact, Americans "undergo an average of 9.2 surgical procedures per lifetime" (Lee *et al.*, 2002). Through modern technology, a lung's lobe can be removed through a two-millimeter incision or a fetus's malformed spinal cord can be repaired while the fetus is still in the womb. Modern surgery reflects the pinnacle of science and technology, and it has revolutionized the way we treat disease.

In the eighteenth century, surgery was a much coarser profession and the public greatly feared it. This fear was well-founded, as surgery was often horribly unsuccessful. Mortality rates rose to almost 50% for even routine operations (Godlee, 1918, p. 122). Even if the operation was successful, patients endured enormous pain as the surgery was performed with little more than a bottle of whiskey as an anesthetic. Consequently, both patients and surgeons saw surgery as a last resort, and surgery was not the highly regarded practice it now is. Rather, it was attempted only when no other treatment would work or the patient could no longer bear the suffering of his affliction. Often, patients would even choose to risk death over enduring the pain of surgery. Additionally, due to limited medical knowledge and the intense pain of surgery, early surgeons were very constrained in their work. A surgeon's work was generally limited to "treatment of fractures and other injuries, the drainage of localized infections, and removal of superficial lesions," and this severely limited the applications of surgery (Ellis, 2009, p. 46).

All of these factors—technological, social, and professional—contributed to the notion that surgery was more of a "craft" and less of an "art", perceived as inferior to true medicine. At this time, traditional barber-surgeons also practiced alongside emerging college-trained surgeons, creating a divide in medical education and care (Ellis, 2009, p. 47).[1] While the new, educated surgeons worked to advance surgery and legitimize it as a medical profession, surgery was unable to achieve real progress due to the unstandardized nature of surgical training. What changed? While medical scholars generally agree that many of the most important advancements in surgery arose during the European Industrial Revolution, there is no firm research that suggests why this actually occurred. This paper will outline several factors in the European Industrial Revolution that may have driven the advancement of surgery. Elements such as urbanization and industrialization increased demand for medical attention, while improved education created an environment that promoted free exchange of ideas. This led to the foundation of revolutionary

[1] Barber-surgeons practiced from the Middle Ages until the mid-1700's. In addition to cutting hair, they would also perform dental or surgical procedures as prescribed by a physician.

concepts such as anesthesia and antisepsis—concepts that finally modernized surgical practice and led to the revolution of this field.

The Industrial Revolution: Transforming Society and Economy

In the nineteenth century, the Industrial Revolution reached its peak in Europe. At this time, Europeans witnessed major innovations that impacted various facets of their lives and began to gain access to new technologies and manufacturing methods that helped the European economy flourish. Jan de Vries, a historian and professor at UC Berkeley, notes "the most important such monument in economic history is the Industrial Revolution" (De Vries, 1994, p. 249). At this time, many Europeans moved from their rural houses to pursue new wealth and opportunity in flourishing urban cities. This process, known as urbanization, led to many changes across Europe. The economic impacts of this era were undeniably pronounced and these impacts then led to many changes in the daily lives of Europeans, as they were forced to adapt to a rapidly changing and modern society.

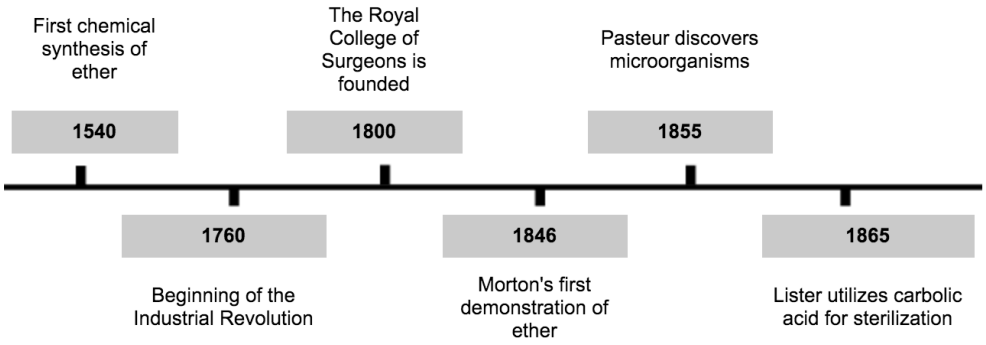

FIGURE 1. Timeline of Major Events

With the dawn of new industry and urbanization, the Industrial Revolution brought several new issues to the forefront of society, and many Europeans worked to reform problems that arose at this time. One primary concern of the era was public health. It is important to understand various aspects of the Industrial Revolution and how they impacted approaches to health care, medicine, and surgery. Intently studying this time period yields valuable insight into the connection between economy, society, and medicine as they evolve over time.

The Evolution of Medical Education (1800–1850)

In the late eighteenth century, Europe began a shift away from agriculture and craftsmanship as new industries and markets were introduced to society. With this societal shift, European governments began to emphasize universal public education to "stabilize society" and prepare Europeans for the rapid technical advancements of their society (Carl, 2009, p. 504). Additionally, the rise of capitalism in this era meant that

Europeans could take advantage of this education in order to advance their earnings or status. For the first time, Europe had become a socially mobile society, and schooling was the primary means by which one could become socially mobile. While the development of universal education was of paramount concern to European leaders, it is also important to consider how this translated to improved medical education and surgical training.

The educational advancements that came during the Industrial Revolution created an environment where new surgical students could learn more effectively and practicing surgeons could more easily share their work. As mentioned previously, the social status and work of a surgeon was not held in the same regard as that of a physician, and it was much easier to become a surgeon than a physician. In fact, only 179 English physicians were licensed in 1800 compared to 8000 English surgeons (Marland, 1987, p. 265). This divide existed largely because of the varying educational requirements for these professions at the turn of the century. While physicians of this time were formally educated at a medical university, aspiring surgeons needed only an apprenticeship to train for their work (Peterson, 1978, p. 9). This meant that surgical training was not standardized in any way and the quality of education varied widely.

In England, newly established groups like the Royal College of Surgeons of England began to improve and standardize the training of future surgeons. For instance, no man could legally practice surgery unless formally recognized by the Royal College of Surgeons of England. Such standardization was paramount to the future revolution in surgery. This standardization of surgical education also legitimized the profession from society's point of view. While still greatly feared due to the immense pain and low success rates of surgery, surgery became somewhat more respected simply because the public trusted the newly formalized education that each surgeon received.

While surgery was finally becoming a more legitimate profession, it still greatly lacked any new medical advancement or knowledge. Still, the admission of surgeons to medical colleges meant that this practice could finally become more critically studied. It also offered a place for experienced surgeons to pass on their techniques as well as develop new ones among their colleagues. The improved medical education system that arose from the Industrial Revolution allowed for an efficient exchange of ideas that led to new innovations. Harold Ellis, one of the most respected modern English surgeons writes, "Few, if any, discoveries…are sudden affairs" (Ellis, 2009, p. 82). Rather, he argues that the careful interplay and exchange of ideas at this time led to new innovations in surgery. This concept will be explored later through the examination of new frontiers in surgery, such as asepsis and anesthesia. Although the increase of sickness and injury that came with the Industrial Revolution did lead to new advancements in surgery, it is important to understand that many advances

in surgery and medicine may have never been realized without the major improvements to medical education in the nineteenth century.

The Death of Pain: Surgical Anesthesia (1846–1855)

Life's saddest voice, the birthright wail of pain.
–From "The Birth and Death of Pain" by Dr. S. Weir Mitchell

Even with new revolutions in the teaching and academic study of surgery, surgical progress was greatly hindered by one factor: pain. In the eighteenth century, before modern anesthesia was invented, surgery was performed with the patient completely conscious, and this severely limited the ability of surgeons to perform complex operations. Surgery became deeply associated with the pain it caused and because of the pain, surgeons worked as fast as possible and were thus limited in their ability to perform complex operations. Surgery before anesthesia was gruesome and horrific for the patient, and sick Europeans would often elect to risk death rather than face the pain of surgery.

Interestingly, ether, the first modern anesthetic, was first synthesized back in 1540 by a German physician and botanist named Valerius Cordus**,** and doctors also began exploring the pain-dulling effect of other chemicals such as nitrous oxide as early as the late eighteenth century.[2] Despite these earlier developments, none of this research was widely popularized among the medical community and the adoption of anesthesia did not begin until the mid-nineteenth century. This could be partially attributed to ether's intoxicating effects, which meant it was often abused as a "party amusement." Given its reputation, physicians and the public may have had reservations about this chemical entering the medical and academic world. It is also possible that doctors did not investigate anesthetic methods due to factors surrounding surgical demand. At the height of the Industrial Revolution in the nineteenth century, the demand for surgical treatment of acute injuries rose drastically (Pernick, 1985, p. 218). This can be attributed largely to urbanization and the rise of industrial cities. As urbanization progressed, the emergence of many new factory and railroad jobs posed new risks for workers. In his study of the Industrial Revolution, Peter Stanley suggests that the factory conditions of the Industrial Revolution were highly responsible for a wide variety of sickness and "added to the domestic accidents reported" (Stanley, 2003, p. 241). This explains the observed increase in the number of acute, on-the-job injuries reported at this time. In the early 1800's, many more excruciatingly painful and often-deadly surgeries were being performed, and "nineteenth-century surgeons were uniformly horrified by the grisly body count of the industrial revolution" (Pernick, 1985, p. 218). This spike in surgical procedures may have motivated scientists like Dr. William Morton to pursue improved means of pain relief.

[2] Ether is the common name of the anesthetic. The full chemical name is diethyl ether.

FIGURE 2. A replica of Morton's ether inhaler.

While some scientists had previously experimented with anesthetizing patients, none of them had successfully disseminated results of a successful operation with anesthesia until Dr. William Morton did. Although Morton was a dentist, he is credited as "the father of modern anesthetics" after pioneering the use of ether as a surgical anesthetic (Ellis, 2009, p. 72). In 1846, Dr. Morton first utilized his ether inhaler (pictured left) to render his dental patient unconscious for a tooth extraction. After the procedure, his patient testified, "I awoke and saw my tooth lying upon the floor. I did not experience the slightest pain whatever." (p. 74). News of Morton's work spread quickly throughout the growing medical community. Only a few weeks after his first successful procedure, Dr. John Collins Warren of the Massachusetts General Hospital approached Morton, hoping that he would be able to sedate one of Warren's surgical patients. Morton agreed. On October 16th, 1846, Morton unveiled his discoveries to eager students and surgeons and revealed the revolutionary impact that anesthesia would have on surgery. Soon after, ether was again tested, this time on a more severe operation: amputation. Again the operation was wildly successful and ether was proven as a solution that would change the face of surgery. The witnesses to Morton's work were certainly convinced of its potential for changing the face of surgery (Ellis, 2009, p. 77). However, many doctors were not as easily convinced of ether's merit.

FIGURE 3. *The Ether Dome*, a recreation of Morton's first surgical use of ether.

In *A Calculus of Suffering,* Martin Pernick, a historian of health and disease, cites several factors that slowed anesthesia's adoption into the medical community. According to Pernick, "the most serious criticism leveled against [anesthesia] was that it increased the surgical death rate" (Pernick, 1985, p. 217). Massachusetts General Hospital did indeed record an increased amputation mortality rate of four percent after ether's introduction (p. 217–218). This was often used to argue against anesthesia's safety. However, this thinking was not entirely correct. Pernick cites primary sources from the nineteenth century and argues that anesthesia greatly increased the number of procedures being done and therefore "led to a higher surgical infection rate" (p. 218). This higher mortality rate can then be attributed to surgical infection, not anesthesia. Since germ theory was not fully understood until twenty years later, doctors rarely sanitized their hands or equipment between their increasingly frequent operations, thereby increasing cases of deadly infection.

Although some doctors in the nineteenth century were still wary about the use of ether, it seems certain factors of the Industrial Revolution may still have encouraged anesthesia's wider adoption. Pernick notes "railroads, factories, and anesthetics appeared at virtually the same time in American urban history" (p. 218–219). Thus, the increased demand for surgery during the Industrial Revolution may be correlated to the spread of anesthesia through the medical community. This is a likely explanation because the pain-dulling effects of some chemicals were well-known over five decades before anesthesia's induction into surgical practice (Ellis, 2009, p. 73–74). The increased demand for acute injury treatment appears to have motivated research adoption of new anesthetic methods. This is reflected by the simultaneous but separate experimentation with anesthetics by many different doctors (Blatner, 2009).

After the widespread adoption of anesthesia, doctors began experimenting with new procedures and techniques. Advanced abdominal, obstetrical, and eye procedures were now feasible. Some doctors even began pioneering procedures in cardiac surgery (Stoney, 2008, p. 2). Anesthesia removed both time and pain as constraining variables in surgery, and the advancement of new procedures would have been impossible without anesthesia.

In addition, the introduction of anesthesia also improved the public opinion surrounding surgery. Before anesthesia, patients were horrified at the thought of surgery. After its conception, visions of intense pain and suffering were replaced with visions of recovery and hope. The public's shifting view of surgery helped validate the profession as a proactive treatment for medical problems, not as a final, desperate measure when "the patient could suffer his miseries no longer" (Ellis, 2009, p. 46). Consequently, scientists and the public cared more deeply about surgical discovery and innovation. Because of these factors, anesthesia remains the single most important innovation in surgery to this day. Celebrating the fifty years since anesthesia's introduction, Dr. S. Weir Mitchell wrote a poem that reinforces the lasting significance of this historical innovation.

With God-like will, decree the Death of Pain.
–From "The Birth and Death of Pain" by Dr. S. Weir Mitchell

The Emergence of Aseptic Surgery (1855–1870)

Although the introduction of anesthesia made surgery a much less gruesome ordeal, patients still died at an alarming rate. In fact, the mortality rate for a simple amputation still approached 30% in many cases. Many surgeons and physicians were troubled by the deaths of their previously healthy post-operative patients, but they could not explain their deaths until germ theory and had fully been understood. Germ theory states "infections, contagious diseases, and various other conditions result from the action of microorganisms" (Merriam-Webster, "Germ Theory"). Before the Industrial Revolution, scientists had begun to understand that disease is often caused by environmental factors. They had not, however, correctly pinpointed the actual cause of illness or infection. Real work to uncover the cause of disease began only after the deplorable health conditions of industrial Europe permeated the lives of most Europeans.

During the Industrial Revolution, Europe faced deplorable health conditions. Consequently, public health had become a primary concern of many European nations for the first time. Historian Roy Porter cites several "mortality crises, caused by waves of epidemic disease" that occurred in this time period (Porter, 1995, p. 60). Diseases including cholera, typhoid, and typhus swept across Europe. It is important to consider the advent of these diseases and how the environment at this time amplified the spread of viruses and bacteria. Most sources cite overcrowding, unclean water, and the general filthiness of growing cities

as the primary causes of this explosion of disease during the Industrial Revolution, but why did these symptoms of overcrowded and dirty cities emerge only then? According to *Encyclopedia of the age of the Industrial Revolution, 1700–1920,* urbanization was a major driving force behind the development of medicine and public health (Rider, 2007, p. 328–331). As the Industrial Revolution progressed, more jobs arose in large and industrialized cities. Consequently, countless families left their rural homes in pursuit of new wealth and opportunity. Unfortunately, many of these families found only extreme overcrowding and deplorable sanitation. Because of this massive influx of rural families, industrial cities became dirty, crowded, and dangerous. This sparked a wave of disease and infection across the largest cities. Scientific efforts were thus drastically shifted toward improving the health of these diseased areas. This drive to accelerate medicine ultimately led to very important discoveries that greatly impacted medicine as well as surgery.

One man who worked to combat this rapid spread of disease was a Frenchman named Louis Pasteur. Pasteur is credited with revising and proving germ theory through his experiments. After several years of study, he concluded, "Gases, fluids, electricity, magnetism, ozone, things known or things occult, there is nothing in the air that is conditional to life, except the germs that it carries" (Vallery-Radot *et al.*, 1923, p. 94). In his findings, Pasteur states that microscopic life forms or "germs" are carried through the air, unseen by the naked eye. These findings were revolutionary and directly combated the established notions of miasma or contagion.[3,4] Ultimately, Pasteur introduced an entirely new field of study to medicine, bacteriology. This discipline focuses on the study of microorganisms and how they can cause disease in humans. Pasteur's work was the catalyst for later work exploring surgical wound infection, and soon other scientists began to apply his ideas to new frontiers in medicine and surgery. One such innovator was Joseph Lister, "the greatest surgical benefactor to mankind" (Ellis, 2009, p. 84). Lister pioneered many new methods in surgery, including the treatment of compound fractures and arterial ligation,[5] but his most important contribution to surgery was his development of aseptic technique. Asepsis describes an environment free of microorganisms. The aim of aseptic surgery is thus to limit infection by sterilizing the operating field, the surgical instruments, and the surgeon's hands. Lister was deeply interested in suppuration (the formation of pus) and how this related to post-operatory complications; however, he was unable to attribute a cause to this phenomenon until a

[3] Known as the "bad air theory," miasma theory dates back to the Middle Ages. It states that disease is caused by miasma (a poisonous vapor in the air) that can be detected by a foul smell, often associated with the smell of decay.
[4] Contagion theory states that disease is transferred by direct skin contact with an infected individual. Although modern germ theory accepts that germs can be spread through contact, contagion theory states that direct contact is the *only* way to transmit disease.
[5] Arterial ligation refers to the closing or clamping of vascular tissue.

friend presented him with the work of Louis Pasteur.[6] This lends further evidence to the importance of scholarship and communication that was not realized until the Industrial Revolution. After hearing of Pasteur's work, Lister immediately began work to develop an effective sterilization method. To perform these sterilization procedures, Lister would spray a chemical to his instruments and the surgical area before and after operation. He had tried several different compounds, but none successfully prevented infection or suppuration. Interestingly, Lister finally succeeded by using a chemical called carbolic acid after hearing how it was used to treat sewage in the crowded city of Carlisle with great effectiveness. This illustrates yet another parallel between urbanization, poor sanitation, and medicine.

FIGURE 4. Lister's carbolic steam sprayer.

Lister's method of aseptic surgery was a critical step in the advent of modern surgical practices, and it paved the way for a wide variety of new surgical techniques. Before this time, surgeons hesitated to make incisions through healthy and intact skin since at this time, they knew that any surgical opening in the skin could develop post-operatory complications and possibly lead to death. Often, they previously resolved to simply amputate a leg with a broken bone. With decreased likelihood of infection, however, surgeons soon began experimenting with setting broken bones instead of resorting to amputation. Furthermore, the advent of sterile sutures also allowed surgeons to suture deep within the body without worry of infection or removal of the sutures. This, when combined with anesthesia, opened up a huge number of new avenues and treatments through surgical methods. Most importantly, the reduced risk of infection meant that the patient was less likely to die after a successful surgical

[6] Lister wrote, "When it had been shown by the researches of Pasteur that the septic property of the atmosphere depended…on minute organisms…it occurred to me that the decomposition of the injured part might be avoided without excluding the air, but by applying as a dressing some material capable of destroying the life of the floating particles" (Ellis, 2009, p. 85).

procedure. In the years after the introduction of aseptic technique, the mortality rate of amputations greatly declined. This drastic difference can be attributed mostly to decreased rates of infection. Without the advances in sterilization that arose from this era, surgical progress would have remained severely hindered.

Conclusion

In the years after the inception of anesthesia and aseptic surgery, surgical progress accelerated continuously, and in this time, surgery finally departed from the slow rate of progress that dates back to its inception. Dr. Charles McBurney, a prominent surgeon of the nineteenth century, argues that these two innovations transformed surgery into a "gentle art." McBurney claimed that anesthesia and asepsis would drastically shape medicine and surgery (Rogers, 1896, p. 71–72). Indeed, these advancements did allow surgeons to work for much longer times with reduced fear of infection. In addition, the unconscious state of the patient permitted operation and experimentation in new areas of the body that had previously been deemed inaccessible due to time constraints. Combining painless surgery with drastically reduced chances of infection opened entirely new avenues for surgical practice. These new avenues included exploration into internal bleeding control, which also allowed for increasingly complex operations. (Ellis, 2009, p. 87–88).

As surgery became both safer and widely applicable, the public adopted a more positive perception of the profession. This rapid growth of surgical knowledge and efficacy "excited the interest and admiration of all classes of men" (Rogers, 1896, p. 74). Future surgeons enjoyed a closer working relationship with physicians as well, and this model of collaboration between physician and surgeon is a vital component of our medical system today (p. 75). As seen through study of the Industrial Revolution, surgical innovation has the potential to be highly impacted by new pressures that arise from technological advancement and societal change. Each of these entities depends on the others. During the Industrial Revolution, these crucial interactions vastly altered the course of the surgical profession, and the lasting medical impacts of this revolutionary era are still seen today.

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Figure References

Figure 2: *Morton's Ether Inhaler*. (n.d.). Association of Anaesthetists of Great Britain and Ireland. *Oxford Medicine Online*. By Gary Enever. Web.

Figure 3: Prosperi, Warren. *The Ether Dome*. (2001). Painting. Massachusetts General Hospital, Boston, MA.

Figure 4: *Carbolic Steam Spray*. (n.d.). Glasgow Royal College of Physicians and Surgeons. *BBC News*. Web.