**ENGINEERING STRATEGIES FOR HANDLING COVID-19 FOR ENVIRONMENTAL HEALTH AND ECONOMIC HEALTH AND ECONOMIC SUSTAINABILITY**

**DONE BY**

**OGBONNA VICTOR**

**MATRIC NO. 17/ENG04/048**

**DEPARTMENT OF ELECTRICAL/ELECTRONICS ENGINEERING**

**ABSTRACT**

The practice of medicine is no longer an independent arena. The art of medicine is exclusively exposed through its inherent interdisciplinary nature. Research scientists continue to elegantly discover what exists within various diseases; they inform the biomedical community of what already exists. Engineers utilize this information to create that which is yet to exist ; they develop novel tools that can be implemented into clinical practice. And the physician of the future holds the honorable responsibility of bridging the gap between these once distant worlds. A physician of the future connects the dots, and pushes the limits of what we can offer patients. A physician of the future constantly searchers for the answers through an interdisciplinary approach involving bioengineers and scientists.

Bioinformatics and open access medical data has ushered in an era of medical practice infused with information unseen hitherto. And now, the responsibility to formulate solutions to unresolved clinical problems rests within the collaborative efforts of the biomedical community.

It is clear to me that because we live in such a technologically advanced era, we simultaneously hold the noble responsibility of acting altruistically to translate technology into better cures for cancer, more effective therapies for neuropsychiatric diseases, and improved diagnostic techniques. From neurosurgery and family medicine, to lung disease and kidney failure, all sectors of medicine will need to embrace the future face of medicine.

It is clear, though:

The future of medicine has arrived. And how we respond is merely a personal choice.

TABLE OF CONTENT

**CHAPTER ONE…………………………………............................................………………......….…4**

History of Engineering in medicine…………………………………................................................4

What is biomedical engineering…………………………………............................................….:…4

**CHAPTER TWO…………………………………............................................………………….…......6**

 Elect/elect engineering in medicine…………………………………..................................................6

 Function of ventilators…………………………………............................................………………..8

 History of ventilators…………………………………............................................…………………7

 Principles of ventilators........................................…………………………………….………..11

**CHAPTER THREE 12**

Importance of communication, connectivity (5G) and Robotics in Handling a pandemic 12

 Way 5G and robotics can be applied in the medical field 12

**CONCLUSION 16**

**REFRENCE………………………………………………………………………………………………17**

**CHAPTER ONE**

**HISTORY OF ENGINEERING IN MEDICINE**

Physicians and nurses care for patients and administer treatments. Pharmacists measure and deliver medications. Lab techs perform tests using intricate equipment. Administrators ensure the facility is running smoothly. Healthcare facilities tend to have staffs of thousands, most of which the roles are easy to understand- save the biomedical engineer.

Seen as coldly logical, technical, and concerned primarily with manufacturing, engineers seem to be out-of-place in hospitals, clinics, and other care facilities, but biomedical engineers are indispensable members of a healthcare team. This guide will help patients and others understand the role of the biomedical engineer in healthcare as well as his or her specific duties in healthcare facilities.

The history of the IEEE EMBS runs hand in hand with the history of Biomedical Engineering both as a scientific discipline and as a profession.

**WHAT IS BIOMEDICAL ENGINEERING**

Biomedical engineering (BME) or medical engineering is the application of engineering principles and design concepts to medicine and biology for healthcare purposes (e.g. diagnostic or therapeutic).

This field seeks to close the gap between engineering and medicine, combining the design and problem solving skills of engineering with medical biological sciences to advance health care treatment, including diagnosis, monitoring, and therapy. Also included under the scope of a biomedical engineer is the management of current medical equipment within hospitals while adhering to relevant industry standards. This involves making equipment recommendations, procurement, routine testing and preventive maintenance, a role also known as a Biomedical Equipment Technician (BMET) or as clinical engineering.

Biomedical engineering has recently emerged as its own study, as compared to many other engineering fields. Such an evolution is common as a new field transitions from being an interdisciplinary specialization among already-established fields, to being considered a field in itself. Much of the work in biomedical engineering consists of research and development, spanning a broad array of subfields (see below). Prominent biomedical engineering applications include the development of biocompatible prostheses, various diagnostic and therapeutic medical devices ranging from clinical equipment to micro-implants common imaging equipment such as MRIs and EKG/ECGs, regenerative tissue growth, pharmaceutical drugs and therapeutic biologicals.

**CHAPTER 2**

**ELECRTRICAL/ELECTRONICS ENGINNERING IN MEDICINE**

Electronics has long made an undeniable and valuable contribution in the field of medicine. New medical electronic devices are based on available medical knowledge combined with technologies available in the electronics field. Electronics in medicine has a wide range of applications, from diagnostics to therapy, always aiming to provide new tools to improve the well-being of the population.

Implantable medical electronic devices, such as pacemakers, implantable cardioverter defibrillators and neurostimulators (spinal-cord stimulators, deep-brain stimulators and cochlear implants, etc.), manage and treat physiological conditions within the human body, for example cardiac arrhythmia, chronic pain, Parkinson’s disease and profound deafness. The patient’s demands for improved life quality drive the implantable medical electronic devices to grow fast in a rate of double-digitals over last decade. These implantable electronic devices typically consist of microelectronic circuits hermetically sealed in a metal or ceramic package. To protect the microelectronic circuits in the sealed package, the package is required to be hermetically sealed for implantation in human body. The moisture from body fluid can directly cause the failure of microelectronic circuits in case of hermeticity loss. The implantable medical electronic devices are generally considered as the most reliable assemblies and the reliability is the top priority for commercially distributed devices over performance, size and cost. Among all failures of the implantable medical electronic devices, hermeticity loss is one of the top failure modes.

There are different strategies that can be put in place for the enhancement of environmental health and to help in curbing pandemics, in the case of the coronavirus(COVID-19) due to the complexity of the virus it tends to affect the respiratory ducts living patients docile due to the lack of air caused by fibrosis however electronics engineering can be implemented in the case of ventilation process, machines can be built to help in assisting respiration an example of thus electrical machines is a ventilator

**WHAT IS A VENTILATOR**

A ventilator is a machine that provides mechanical ventilation by moving breathable air into and out of the lungs, to deliver breaths to a patient who is physically unable to breathe, or breathing insufficiently. Modern ventilators are computerized microprocessor controlled machines, but patients can also be ventilated with a simple, hand-operated bag valve mask. Ventilators are chiefly used in intensive care medicine, home care, and emergency medicine (as standalone units) and in anesthesiology (as a component of an anesthesia machine).

Ventilators are sometimes called respirators, a term commonly used for them in the 1950s (particularly the "Bird respirator”). However, in contemporary hospital and medical terminology, a respirator is a protective face mask

**FUNCTION OF A VENTILATOR**

In its simplest form, a modern positive pressure ventilator consists of a compressible [air](https://en.wikipedia.org/wiki/Air%22%20%5Co%20%22Air) reservoir or turbine, air and [oxygen](https://en.wikipedia.org/wiki/Oxygen%22%20%5Co%20%22Oxygen) supplies, a set of valves and tubes, and a disposable or reusable "patient circuit". The air reservoir is pneumatically compressed several times a minute to deliver room-air, or in most cases, an air/oxygen mixture to the patient. If a turbine is used, the turbine pushes air through the ventilator, with a flow valve adjusting pressure to meet patient-specific parameters. When over pressure is released, the patient will exhale passively due to the [lungs](https://en.wikipedia.org/wiki/Lung%22%20%5Co%20%22Lung)' elasticity, the exhaled air being released usually through a [one-way valve](https://en.wikipedia.org/wiki/One-way_valve%22%20%5Co%20%22One-way%20valve) within the patient circuit called the patient manifold.

Ventilators may also be equipped with monitoring and alarm systems for patient-related parameters (e.g. pressure, volume, and flow) and ventilator function (e.g. air leakage, power failure, mechanical failure), backup batteries, oxygen tanks, and remote control. The pneumatic system is nowadays often replaced by a computer-controlled [turbo pump](https://en.wikipedia.org/wiki/Turbopump%22%20%5Co%20%22Turbopump).

Modern ventilators are electronically controlled by a small [embedded system](https://en.wikipedia.org/wiki/Embedded_system%22%20%5Co%20%22Embedded%20system) to allow exact adaptation of pressure and flow characteristics to an individual patient's needs. Fine-tuned ventilator settings also serve to make ventilation more tolerable and comfortable for the patient. In Canada and the United States, [respiratory therapists](https://en.wikipedia.org/wiki/Respiratory_therapists%22%20%5Co%20%22Respiratory%20therapists) are responsible for tuning these settings, while biomedical technologists are responsible for the maintenance. In the United Kingdom and Europe the management of the patient's interaction with the ventilator is done by [critical care](https://en.wikipedia.org/wiki/Critical_care_nursing%22%20%5Co%20%22Critical%20care%20nursing) nurses.

The patient circuit usually consists of a set of three durables, yet lightweight plastic tubes, separated by function (e.g. inhaled air, patient pressure, exhaled air). Determined by the type of ventilation needed, the patient-end of the circuit may be either noninvasive or invasive.

Noninvasive methods, such as continuous positive airway pressure (CPAP) and [non-invasive ventilation](https://en.wikipedia.org/wiki/Non-invasive_ventilation%22%20%5Co%20%22Non-invasive%20ventilation), which are adequate for patients who require a ventilator only while sleeping and resting, mainly employ a nasal mask. Invasive methods require [intubation](https://en.wikipedia.org/wiki/Intubation%22%20%5Co%20%22Intubation), which for long-term ventilator dependence will normally be a [tracheotomy](https://en.wikipedia.org/wiki/Tracheotomy%22%20%5Co%20%22Tracheotomy) cannula, as this is much more comfortable and practical for long-term care than is larynx or nasal intubation.

**HISTORY OF VENTILATORS**

The history of mechanical ventilation begins with various versions of what was eventually called the [iron lung](https://en.wikipedia.org/wiki/Negative_pressure_ventilator%22%20%5Co%20%22Negative%20pressure%20ventilator), a form of noninvasive negative pressure ventilator widely used during the [polio](https://en.wikipedia.org/wiki/Poliomyelitis%22%20%5Co%20%22Poliomyelitis) epidemics of the twentieth century after the introduction of the "Drinker respirator" in 1928, improvements introduced by [John Haven Emerson](https://en.wikipedia.org/wiki/John_Haven_Emerson%22%20%5Co%20%22John%20Haven%20Emerson) in 1931, and the [Both respirator](https://en.wikipedia.org/wiki/Both_respirator%22%20%5Co%20%22Both%20respirator) in 1937. Other forms of noninvasive ventilators, also used widely for polio patients, include [Biphasic Cuirass Ventilation](https://en.wikipedia.org/wiki/Biphasic_Cuirass_Ventilation%22%20%5Co%20%22Biphasic%20Cuirass%20Ventilation), the rocking bed, and rather primitive positive pressure machines.

In 1949, John Haven Emerson developed a mechanical assister for anaesthesia with the cooperation of the anaesthesia department at [Harvard University](https://en.wikipedia.org/wiki/Harvard_University%22%20%5Co%20%22Harvard%20University). Mechanical ventilators began to be used increasingly in anaesthesia and intensive care during the 1950s. Their development was stimulated both by the need to treat polio patients and the increasing use of [muscle relaxants](https://en.wikipedia.org/wiki/Muscle_relaxant%22%20%5Co%20%22Muscle%20relaxant) during anaesthesia. Relaxant drugs paralyse the patient and improve operating conditions for the surgeon but also paralyse the respiratory muscles.

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**An East-Radcliffe respirator model from the mid-twentieth century**

In the United Kingdom, the East Radcliffe and Beaver models were early examples. The former used a [Sturmey-Archer](https://en.wikipedia.org/wiki/Sturmey-Archer%22%20%5Co%20%22Sturmey-Archer) bicycle [hub gear](https://en.wikipedia.org/wiki/Hub_gear%22%20%5Co%20%22Hub%20gear) to provide a range of speeds, and the latter an automotive [windscreen wiper](https://en.wikipedia.org/wiki/Windscreen_wiper%22%20%5Co%20%22Windscreen%20wiper) motor to drive the bellows used to inflate the lungs.[[5]](https://en.wikipedia.org/wiki/Ventilator%22%20%5Cl%20%22cite_note-pmid13320798-5) Electric motors were, however, a problem in the operating theatres of that time, as their use caused an explosion hazard in the presence of flammable anaesthetics such as [ether](https://en.wikipedia.org/wiki/Diethyl_ether%22%20%5Co%20%22Diethyl%20ether) and [cyclopropane](https://en.wikipedia.org/wiki/Cyclopropane%22%20%5Co%20%22Cyclopropane). In 1952, Roger Manley of the [Westminster Hospital](https://en.wikipedia.org/wiki/Westminster_Hospital%22%20%5Co%20%22Westminster%20Hospital), London, developed a ventilator which was entirely gas-driven and became the most popular model used in Europe. It was an elegant design, and became a great favourite with European anaesthetists for four decades, prior to the introduction of models controlled by electronics. It was independent of electrical power and caused no explosion hazard. The original Mark I unit was developed to become the Manley Mark II in collaboration with the Blease company, which manufactured many thousands of these units. Its principle of operation was very simple, an incoming gas flow was used to lift a weighted bellows unit, which fell intermittently under gravity, forcing breathing gases into the patient's lungs. The inflation pressure could be varied by sliding the movable weight on top of the bellows. The volume of gas delivered was adjustable using a curved slider, which restricted bellows excursion. Residual pressure after the completion of expiration was also configurable, using a small weighted arm visible to the lower right of the front panel. This was a robust unit and its availability encouraged the introduction of positive pressure ventilation techniques into mainstream European anesthetic practice.

The 1955 release of [Forrest Bird](https://en.wikipedia.org/wiki/Forrest_Bird%22%20%5Co%20%22Forrest%20Bird)'s "Bird Universal Medical Respirator" in the United States changed the way mechanical ventilation was performed, with the small green box becoming a familiar piece of medical equipment.[[6]](https://en.wikipedia.org/wiki/Ventilator%22%20%5Cl%20%22cite_note-AboutBird-6) The unit was sold as the Bird Mark 7 Respirator and informally called the "Bird". It was a [pneumatic](https://en.wikipedia.org/wiki/Pneumatics%22%20%5Co%20%22Pneumatics) device and therefore required no [electrical power](https://en.wikipedia.org/wiki/Electrical_power%22%20%5Co%20%22Electrical%20power) source to operate.

In 1965, the Army Emergency Respirator was developed in collaboration with the Harry Diamond Laboratories (now part of the [U.S. Army Research Laboratory](https://en.wikipedia.org/wiki/United_States_Army_Research_Laboratory%22%20%5Co%20%22United%20States%20Army%20Research%20Laboratory)) and [Walter Reed Army Institute of Research](https://en.wikipedia.org/wiki/Walter_Reed_Army_Institute_of_Research%22%20%5Co%20%22Walter%20Reed%20Army%20Institute%20of%20Research). Its design incorporated the principle of fluid amplification in order to govern pneumatic functions. Fluid amplification allowed the respirator to be manufactured entirely without moving parts, yet capable of complex resuscitative functions. Elimination of moving parts increased performance reliability and minimized maintenance. The mask is composed of a [poly(methyl methacrylate)](https://en.wikipedia.org/wiki/Poly%28methyl_methacrylate%29%22%20%5Co%20%22Poly%28methyl%20methacrylate%29) (commercially known as [Lucite](https://en.wikipedia.org/wiki/Poly%28methyl_methacrylate%29%22%20%5Co%20%22Poly%28methyl%20methacrylate%29)) block, about the size of a pack of cards, with machined channels and a cemented or screwed-in cover plate. The reduction of moving parts cut manufacturing costs and increased durability.

The bistable fluid amplifier design allowed the respirator to function as both a respiratory assistor and controller. It could functionally transition between assistor and controller automatically, based on the patient's needs. The dynamic pressure and turbulent jet flow of gas from inhalation to exhalation allowed the respirator to synchronize with the breathing of the patient.

Intensive care environments around the world revolutionized in 1971 by the introduction of the first SERVO 900 ventilator (Elema-Schönander). It was a small, silent and effective electronic ventilator, with the famous SERVO feedback system controlling what had been set and regulating delivery. For the first time, the machine could deliver the set volume in volume control ventilation.

Ventilators used under increased pressure (hyperbaric) require special precautions and few ventilators can operate under these conditions. In 1979, Sechrist Industries introduced their Model 500A ventilator which was specifically designed for use with [hyperbaric chambers](https://en.wikipedia.org/wiki/Hyperbaric_chamber%22%20%5Co%20%22Hyperbaric%20chamber).

**PRINCIPLE OF VENTILATORS**

Breathe in, breathe out

The principal function of a ventilator is to pump or blow oxygen-rich air into the lungs; this is referred to as “oxygenation”. Ventilators also assist in the removal of carbon dioxide from the lungs, and this is referred to as “ventilation”.

One basic type of ventilator is the Bag Valve Mask (BVM). The BVM, also known as the Ambu Bag, is operated manually by a person squeezing a self-inflating bladder. This is an essential tool for ambulance crews, first responders and critical care units. It is light, compact and easy to use.

However, in situations where a steady and controlled air exchange (oxygen in, carbon dioxide out) is needed, mechanical ventilators are required. These look like a quintessential medical product.

**CHAPTER 3**

**IMPORTANCE OF COMMUNICATION, CONNECTIVITY AND ROBOTICS IN HANDLING A PANDEMIC**

Robotic medicine may be the weapon the world needs to combat the coronavirus.

The COVID-19 viral outbreak, which began in Wuhan, China, is now spreading to many countries, including South Korea, Iran and Italy, and CDC officials warned Tuesday that an outbreak in the U.S. is likely.

Telemedicine is playing a key role. Robotic devices and camera technology from companies such as InTouch Health and Zoom Video Communications are being used with coronavirus patients and in broader communication during the crisis.

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**WAYS 5G AND ROBOTICS CAN BE APPLIED IN THE MEDICAL FIELD**

With top government health officials warning it is only a matter of time before there is a COVID-19 outbreak in the U.S., it's not likely that specialized masks and respirators, or canned goods and Clorox, will be sufficient to fight a global pandemic. Viral outbreaks like COVID-19 highlight the growing role new medical technology — in particular, ideas from the field of robotics — can play in fighting the spread of novel infectious diseases. But medical experts say it will be a mistake if innovation rolls out only when the world is on edge.

"Extreme cases make us rethink how we do things," says Dr. Robin Murphy, Raytheon professor of computer science & engineering at Texas A&M University. The 2014 Ebola outbreak in Texas, the first in the U.S., led to years of study by Murphy and others on emergency response and the integration of robotics with medicine to help limit pathways for a highly contagious disease to spread. .

**Remote surgery and patient care**

Many believe that 5G will revolutionize how medical staff perform surgery and administer medical treatments. These innovations include “tele-presence,” where a surgeon watch a real-time operation and can provide expert support, and “tele-surgery,” where the doctor actually operates the surgical device remotely.

4G networks are not suitable for these types of applications because the lag time between input and output can sometimes be as long as 2 seconds—a delay long enough to prove devastating in an operating room.

5G, on the other hand, aims to reduce latency to an almost instantaneous 2 milliseconds between devices.

Further, as 5G services expand for the medical field, it may no longer be necessary for patients to be transported a specific clinic or specialist. Instead, they can undergo a remote consultation, saving both doctor and patient time and making it possible for individuals who struggle to receive care to be more appropriately treated.

Recently, the first laparoscopy surgical procedure—in which a fiber-optic instrument is inserted through the abdominal wall—was performed at the Skolkovo Innovation Center in Moscow using 5G. The procedure, which involved the use of a laparoscope and 4K camera connected to the 5g network, resulted in the successful removal of a cancer tumor.

**Medical data**

Finally, 5G promises to transform medical field by drastically increasing the amount and quality of valuable medical data that can be gathered and processed at high speed. From medical records to larger image files from MRI or CAT scans, a single patient can generate hundreds of gigabytes of data each day. The transfer of this data can be hugely aided by the implementation of a 5G, improving care by reducing the time it takes to reach a diagnosis and to begin treatment.

In addition, surgeons can receive real-time data from their patients during surgery, and medical specialists will all be able to work together from across the world.

**Pathology and diagnoses**

A few weeks ago, [Samsung Medical Center (SMC) and Korean telecom KT Corporation announced their partnership to develop 5G medical services](https://www.prnewswire.com/news-releases/kt-and-samsung-medical-center-to-build-5g-smart-hospital-300989452.html%22%20%5Ct%20%22_blank) to support the development of smart hospitals, including improving pathology services, or the study of a disease or ailment’s causes and effects.

KT has built an enterprise-dedicated 5G network at SMC, which includes a 5G-powered digital pathological analysis. According to the companies, the digital pathological analysis is a world-first example of using 5G technology for on-site medical problems.

Previously, diagnostic pathology at the Korean hospital involved sending tissues taken from the patient during surgery to pathologists in an adjacent room, a process that required roughly 20 minutes and made on-site group analyses a challenge.

Now, doctors will be able to utilize the high speed and low latency of the 5G network to efficiently and quickly access pathological data obtained during surgery, as well as access relevant materials and files from anywhere in the world, which ensures better medical services. Obtaining this information quickly is critical in determining the conditions of patients during a procedure.

In China, [ZTE and China Telecom are claiming to have developed China’s first 5G remote diagnosis of the new coronavirus pneumonia](https://www.rcrwireless.com/20200127/5g/zte-china-telecom-complete-5g-remote-diagnosis-new-coronavirus%22%20%5Ct%20%22_blank) backed up with the latest 5G technology.

The pneumonia-like virus was first reported in Wuhan, China, on December 31, 2019, and has subsequently spread to various other countries, causing worldwide concern.

Since the outbreak, ZTE and China Telecom have been moving quickly. First, the two built interconnected 5G indoor base stations on January 25, connecting the conference room for remote diagnosis and treatment in West China Hospital to the remote diagnosis and treatment system; and then, completed the construction, optimization, speed test and commissioning of the 5G indoor distribution system at another core point of the remote diagnosis and treatment system the following day.

**CONCLUSION**

I have been able to outline ways engineering can be effectively used in the medical field and how connectivity will support growth in a modern society. Engineering has a vital role in improving health and healthcare services. The Royal Academy of Engineering is active in the field of biomedical engineering through the Panel for Biomedical Engineering. The group provides advice to government, organises briefing seminars and engages with the policy community to promote awareness of new technologies, their applications and implications for the delivery of healthcare. We also hope to see a change of mentality in leaders and citizens in order to make all of this a reality. Everyone has a big role to play in order to ascertain good healthcare and economic sustainability in our country.

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