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Review Article

Technology-Driven Medical Innovations & Devices

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Abstract: The Industrial Revolution was an era that began in Britain around 1850s, where production shifted from hand tools to complex machines that were powered by water and steam. The era provides clues about how societies transform with technological advancement, which has brought to reality some of the fictional marvels that were once restricted to comic books. Interestingly, we are living the reality of some of those marvels in this era. Also, some of McLuhan's theoretical projection of the 1960s about technology shrinking the world into a global village have come true. These realities provided the foundation for this study about some of the technology-driven medical innovations.
Keywords: Industrial Revolution, Innovations & Devices**.**

INTRODUCTION

This study arose from two main sources. Looking back, it became clear that our world has already accomplished beyond some of the engineering feats presented in the comic books in circulation during my childhood. The second source was the fulfillment of McLuhan's theoretical projection of the 1960s that technological interconnections would shrink the world into a global village. This study examines some of the modern technology-driven medical devices that are changing many aspects of medical practice. It provides a window into the future of medical technology, practice, and services. It also gives the reader an idea about what to expect in a future doctor's or hospital visit in terms of medical procedures.

Growing up, a curiosity for technology-driven medical innovations became a personal preoccupation, partly due to the fascination developed from reading comic books. The world in those books always seemed one step ahead of reality in terms of technology. On October 10, 1991 Marvel Comics Group published X-Men #1, written by Chris Claremont and the characters developed by Jim Lee. This issue sparked an uncontrollable urge to imagine a world with the same technologies. Communication devices, means of transportation, and weapons of warfare in the comic books seemed to be ahead of the advances of the real world [1]. Another factor that contributed to my curiosity about the technology in comic books was my personal experience with amputation, which required the use of prosthetic arms that were nothing close to those presented in the comic books. In X-Men comic books characters, such as *Forge*, wore enhanced cybernetic prosthetics that were smooth, seamless, and more advanced than those in use in the real world.

The prosthetic arms I grew up with were bulky, uncomfortable, and non-practical, as opposed to those in the comic books. Not only were the prosthetics clunky but other medical devices of the time, such as infusion pumps and film-based X-ray technologies, were also were bulky and inconvenient. Over the years, they have been modified, improved, or transformed and made more convenient than they were then [2]. The technological strides in the medical field appear to have either caught up with the world of fantasy depicted in comic books or gone ahead of it.

Canadian sociologist and media theorist Herbert Marshal McLuhan described the world we live in as a global village, a transformation that would be made possible by technological advances [3]. He was ahead of his time by choosing the term *global village* to describe his observation about an electronic nervous system (the media) that was integrating the planet.

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Though most people did not take his observation seriously at the time, he popularized the concept by linking it to the unifying effects of the communication technology. Despite his effort, some people like British journalist Malcom Muggeridge and George Woodcock, in their Vancouver, Canada, radio discussion of civilization and literature tonight, described him as "the destroyer of our civilization [4]".

No one can argue the reality of his observation in the new millennium, as we now live in a world of shared ideas that is fast becoming a monolithic cyber-society [5]. Technological advances in the new millennium have, indeed, integrated the world into a global village, where business is conducted around the globe and enabling people to interact and share ideas with others. No longer is distance the barrier that it once was.

The world of "apps"

About a hundred years ago, one in every three American workers was employed on a farm, but in the new millennium, probably less than two percent of the population produces the bulk of the food in the market. The availability of "apps" for everything and the tremendous ease of access to information have stirred up a spirit of innovation and entrepreneurship that has become a disruption to the traditional forms of businesses.

Such innovations are evident in start-up businesses like Twitter, Instagram, Airbnb, Uber, self-driving cars, hand held communication devices, and a plethora of other technology-driven devices. The trend has led communication theorists to question the degree to which human thought or action is influenced by technological factors. This line of thought is called technological determinism, which is a way to understand technology and its effects [5].

One of the unsung technological marvels of this world is the smart phone, also called mobile phone, a hand-held device that can be connected wirelessly to any device by software applications. This device and other technological innovations provide limitless possibilities for the medical innovations spearheaded by the Internet. Khosla [6] suggests that the innovations are enabling physicians to obtain more accurate diagnostic results than they were in the past. The reality is that we live in a world where a cursory look at a smart watch allows one to track one's heart rate and view one's stress level by simply placing a finger on a smart phone.

Mobile applications, also called mobile apps, are software applications or programs that run on smart phones and mobile communication devices. Mobile medical apps are regulated by the U.S. Food and Drug Administration (FDA). The FDA defines a Mobile Medical App as a device or an accessory to a regulated medical device or one that transforms a mobile platform into a regulated medical device [7]. The widespread adoption and use of mobile technologies is opening new and innovative ways to improve health services [7]. There are many health monitor apps in the market, and each new device tends to be more sophisticated and efficient than its predecessor.

Technology-Driven Medical Innovations

One notable smartphone app is the Samsung Health. The Samsung Galaxy S5 mobile phone came equipped with a built-in heart rate monitor, powered by a tiny sensor located on the back of the phone below the camera. The monitor records the heart rate within seconds by simply placing a finger on it [8]. The reading can then be used for stress level or elevated heart rate detection. The device was also equipped with a built-in pedometer that can track daily activity. The multifunctional app includes a nutrition tracker, activity monitor and the capability to synchronize with other wearable technologies. As of the time of this writing, the Samsung Galaxy in the market was S10, which included a more sophisticated version of the Samsung Health app than all its predecessors. Mobile health apps exist in a neutral area between highly regulated medical devices and computer applications that are not regulated as much [9].

Peek Retina is another app. It is a clip-on camera adapter that fits onto a smartphone. The adapter pairs with an app on the mobile device to enable eye care professionals to conduct eye examinations without the use of ophthalmoscopes or other bulky equipment [10]. The Peek Retina is so revolutionary that it allows doctors to treat patients in remote under-developed parts of the world. The app can function as a basic eye exam device or used to diagnose cataracts and other serious eye problems.

Dr. Andrew Bastawrous, the inventor, said that Peek Retina will help doctors in under-developed countries such as Mali and Malawi, working on children in a coma caused by malaria, meningitis, or other diseases. The device will enable the physicians to detect early signs of the disease that often appears behind the retina. They will then be able to check for potential brain swelling before deciding on the appropriate treatment [11].

The technology within these devices has enabled significant collaborations among health professionals. One example of such collaborations is the *iBGStar*, a glucose-monitoring device for diabetics [12]. It can be used when plugged into an *i*Phone or *i*Pad to measure glucose levels in the patient's blood, through a technology called *WaveSense*, developed by Aga Matrix, a company headquartered in Salem, New Hampshire [13]. When a test strip is put into the device and a drop of blood applied from a tiny pinprick, the

glucose level appears on a small display screen. It is then stored by an app on the *i*Phone [13].

Propeller Health has developed a smart inhaler sensor that measures a patient's use of the inhaler. Known as the Propeller Metered Dose Inhaler Sensor, it collects and updates patient data to the app so that patients and healthcare professionals can monitor the progress [14]. The device helps to prevent symptoms of chronic obstructive pulmonary disease and coach patients on how to avoid triggers. The inhale, which can be connected to smartphones through Bluetooth, is 30 percent smaller than previous makes.

The next medical gadget known as *Quell,* is a pain relief device that attaches to the user's calf. It uses electrodes to send neural pulses to the brain to cause the release of endogenous opioids [15]. The process, known as Transcutaneous Electric Nerve Stimulation [16], allows the device to send the data to a mobile phone for easy access to the health providers. It also helps to prevent future pain. This FDA-approved gadget can last 40 hours on a single charge. Quell is 10 percent drug free. It is extremely important for chronic pain sufferers, because most medications can trigger a dependency effect on users [17]. About eight percent of the users report an improvement on their pain. It is the only FDA-approved device for use during the day and when the patient is sleeping. Patients may also calibrate the device and measure their progress with the smartphone app.

There are a few similar standalone devices such as the electroencephalogram (EEG), a test that assesses the electrical activity in the brain. Brain cells transfer information through electrical impulses. An EEG can be used to detect potential problems with the brain activity such as seizures, sleep disorder, and dementia. The process usually takes from 30 to 60 minutes to complete, while the patient is lying down on his/her back with electrodes strapped to their scalp with an adhesive [18].

Vandrico Solutions Incorporated is a technology company that develops and licenses software and wearable technology. The company has been in the news for the development of mining helmets and software for Google Glass [19]. The company, based Vancouver, Canada, has caught the attention of the medical world for its wearable technologies database. Some of the items featured in their database include the Emotiv Insight, a wearable EEG headset that can transmit meaningful brainwave data wirelessly to a smartphone or computer in high resolution. The device is compatible with Android, iOS & Windows. It offers five EEG sensors and two reference sensors providing information on brain activity. The measurements are based on six key cognitive and emotional metrics: focus, stress, excitement, relaxation, interest and engagement. These measurements allow individuals to monitor their cognitive health [20].

Smart Cap, the next device, is a fatigue monitoring system designed for industrial purposes. This wearable device is designed to keep truck drivers safe [21]. Fatigue processor cards are stored in card docks, where they are connected to a Bluetooth wireless technology to provide real-time information to the operator. It relays visual and audio alarm whenever the user starts to fall asleep. Smart Cap functions with the use of small EEG sensors that pick up electric signals from the brain [21]. The signals are then analyzed to determine the level of the patient's drowsiness using the EdenSafe Universal Fatigue Algorithm [20].

According to *Organdonor.gov*, there are over 100,000 men, women, and children on the national transplant waiting list [22]. And on the average, 22 people die each day waiting for a transplant [22]. In 2015, more than four of every five donations came from deceased donors. In an effort to help those who need transplants, medical professionals are researching the possibility of a 3-D organ printing device [23]. In 2000, bioengineer Thomas Boland, began experimenting with a modified inkjet printer [24]. When he emptied a cartridge and filled it with collagen and DNA fragments, he was able to print his initials using Microsoft Word. In 2003, Boland filed the first patent for printing cells.

Organovo, one of the leading bioprinting technology companies headquartered in San Diego, California, developed a 3-D bio-printed kidney with ExVive. Printed models of human tissue are created using exclusive 3-D bioprinting technology [25]. The tissues contain exact and reproducible results that can remain fully functional and stable for up to 28 days. The company is continuing its effort to develop the technology that will eventually reproduce human organs for transplant. It has partnered with other biopharmaceutical companies to design tissues for disease modeling and toxicology. The living tissue test provides researchers with the opportunity to test drugs before administering them to a living person. The process aims to close the gap between preclinical testing and clinical trials [28].

The concept of a medical tricorder is closer to reality than science fiction fans may think. Dr. McCoy of *Star Trek* television program would pull out his handy tricorder to analyze a patient's medical well-being with a quick scan that provides a full diagnostic analysis. In theory, a medical tricorder is a handheld portable computer used to scan and assess medical conditions [26]. The device is in its rudimentary stage as of this writing. Organizations such as the X Prize Foundation offered a $10 million-dollar prize to more than 200 teams across the world to develop a tricorder that can diagnose a set of 15 conditions including

pneumonia, diabetes, and sleep apnea [26]. Though the medical technology may be years away from a literal tricorder reality, there are similar point-of-care devices that are close to it.

Another device that is in development is the smart lenses for the treatment of diabetes. The lenses have contact sensors that are placed between two layers of lens. A hole in the lens allows tear fluid to seep into the sensor to measure blood sugar levels. A wireless antenna acts as a controller that relays and transmits information or data to an external device [17]. The contact lens analyzes blood glucose level every second and transmits the data to an associated app that is accessible by personal smartphone. When a patient's blood sugar crosses certain thresholds, the app provides instant notification to contact a physician. To make it useable in the healthcare field, it must meet all the FDA specifications and requirements. To facilitate that process, a company known as *Verily* has entered into a partnership with Alcon, Novartis' eye care division [17]. This partnership with Alcon, a company experienced in eye care products, is likely to accelerate the Food and Drug Administration (FDA) approval.

Smart contact lenses may sound like science fiction, but super-human vision is getting ready to be marketed to the public [27]. Some smart contact lenses are like implants that do not require surgery and can be removed by the user. But the lenses developed by Verily do not have that same flexibility [27]. Verily Company conducted extensive research before developing the smart contact lenses. The patent filed by the company indicates that the patient's lenses are removable so that some liquid can be injected into the eye. The fluid fuses with the eye's lens capsule as it becomes solid. Inside the artificial lens are storage, battery, sensors, and other electronic devices that enable the artificial lens to focus a light on the retina and improve vision without glasses [27].

A British tech company, QuantuMDx, developed an analyzer called Q-Poc that can diagnose cancer and infectious diseases in minutes. The device runs on solar-powered batteries and can read samples through a small cartridge. Q-Poc can also detect tuberculosis and is being enhanced to test for other disease conditions as well [29]. The device has built-in cellphone technology that allows for the test results to be geo-stamped (GPS) and shared in real time. Q-Poc differs from most conventional point-of-care diagnostic tools because it analyzes the DNA of pathogens rather than the proteins [28].

Engineers and scientists at Duke University are at the early stages of developing a robot named TRINA, short for Tele-Robotic Intelligent Nursing Assistant [29]. Department of Electrical and Computer Engineering Associate Professor Kris Hauser, says that the robots could become a surrogate in dangerous places. TRINA was developed, in part, due to the Ebola outbreak in 2014. The goal was to use it to serve infectious disease patients, especially those with compromised immune systems, and for toxic spills clean up or related problems. TRINA can only perform simple tasks, like turning patients over. But it still needs an actual person to control its operations [29].

Another company, Hstar Technologies, launched a research project in 2009 to deliver safe patient lifting. The robotic nursing assistant (RoNA) does the heavy lifting as it can move in any direction, work in confined spaces, and move in areas where portable lifting systems cannot. RoNA can lift up to 500 pounds and reduce incidences of clinician workplace injuries related workers' compensation claims and lost work time [30]. As of 2011, Hstar Technologies received $1.5 million dollars in grants from the Small Business Innovation Research program for RoNA and cRoNA (combat RoNA) for military use [31]. Hstar's COO, Dr. Yi-Je Lim, said that RoNA's product line includes a cost-reduced version which is in high demand among nursing homes and in-home caregivers [32].

iRobot and InTouch Health successfully developed a robot named RP-VITA, short for Remote Presence Virtual + Independent Telemedicine Assistant that has already been approved by the Food and Drug Administration (FDA). In the robot is a built-in obstacle detection and avoidance technology. The built-in device is a mobile cart with a two-way video screen and medical monitoring equipment, programmed to maneuver through hospital halls. The human-sized five-foot-six-inch robot is designed to allow doctors to connect directly to hospital systems and remotely examine patients [33].

Researchers at the University of Strathclyde (Glasgow, Scotland) reported the development of a new light fixture called Indigo-Clean that can continuously kill harmful bacteria linked to hospital-acquired infections [34]. The light, which has the capability to function continuously without an operator, kills bacteria in the air and on all surfaces. It also complies with all internationally recognized standards for patient safety. The light was displayed at the Association for Professionals in Infection Control and Epidemiology (APIC) in Nashville, Tennessee, USA. Indigo-Clean uses a narrow spectrum of visible indigo-colored light, a high-intensity narrow spectrum light that is absorbed by molecules within the bacteria, to produce a chemical reaction that kills the bacteria from the inside [3].

It seems like engineers at John Hopkins University (JHU) are bringing science fiction technology closer to reality with a next-generation prosthetic [35]. The applied physics lab at JHU has developed a robotic arm that has 26 joints and the capacity to lift weights of up to 45 pounds [36]. What

makes this arm particularly different from the others is that it can be controlled with the operator's mind.

After a surgical procedure that remaps nerve endings of an amputated stump, the amputee's brain sends signals to the prosthetic, giving the user the ability and flexibility to control its movements. The process requires targeted muscle re-innervation to reassign nerves that were once controlled by the hand, so that they can be controlled by the amputee's stump. The prosthetic is mounted directly to the user's limb at the end of the process [35].

The technology is called Modular Prosthetic Limb [36]. In 2014, Dean Kamen's 'Luke Arm' for amputees received the Food and Drug Administration's (FDA) approval for commercialization [36]. The official name of the Luke Arm is the DEKA Arm System. The limb is described as one of the most advanced robotic arms for amputees [36].

CONCLUSION

The aim of this paper was to chronicle some of the advances in technology-driven medical devices that demonstrate the coming into fruition of some of the technological fantasies found in the comic books of the 1990s. It was also to demonstrate the reality of the theoretical projections of Marshall McLuhan in the early 1960s. The few that are described in this study clearly indicate that though humans may never be able to stop human death, they have continued to rethink the old technologies and develop new ones that help to reduce human pain and suffering. These strides will continue to change the course of medical procedures and health services toward building and maintaining healthier and productive societies.

Smartphone apps are becoming increasingly interactive with a wide range of specialized programs [5], including those in the medical field. Many technological inroads have been made to increase the ability of consumers to use mobile apps to stay healthy. In March 2014, an online survey was conducted by *Statista* on the primary reasons for the widespread use of mobile health app in the U.S. The study found that 28 percent of the respondents used their mobile health apps to track the awareness of health issues. Considering the ever-increasing number of smartphone users, it seems obvious that the percentage of respondents would have been significantly higher had the research been conducted in 2019.

It is obvious that we have come a long way in terms of technology from the days of the Industrial Revolution in Britain. During the Industrial Revolution, machines replaced many factory jobs and increased productivity. The same is true to this day with the new wave of technological innovations in every field of human production. The reality is that while some the number of jobs is either shrinking or disappearing, there is a corresponding rise in the number of new ones as well as the opportunities for new ones.

These advances in technology point to one important key to survival, and that is education. It appears that education and re-training will take center stage in our lives as we struggle to survive the onslaught of new technologies. Investing in education will be more important as the source for creating a supply of the much-needed skilled workers whose expertise and productivity can meet the ever-increasing demands of society.

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