Fourth Industrial Revolution and the Future of Neurosurgery

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Arguably, neurosurgery is the second oldest profession although it only evolved as a distinct field of surgery in the 20th century. During the last seven decades, the advent of the operating microscope, intraoperative neuro monitoring, neurointensive care, neuronavigation, and the evolution of minimally invasive and endovascular techniques have changed the landscape of neurosurgery. This editorial intends to highlight the importance of the fourth industrial revolution (Industry 4.0), its components, and how they have the prospect of being integrated into the practice of medicine, especially neurosurgery.

Industrial Revolutions (IRs) are periods in history marked by rapid technological advancements that drastically affect the economy and social structure. Since the eighteenth century, we have gone through three IRs:

1. The First IR (1760 - 1830): Transition from hand production methods to the use of machines.
2. The Second IR (1870 - 1969): Creation of steel, chemicals, and electricity which allowed for mass production of consumer goods and military equipment.
3. The Third IR (1970 - 2016): The evolution of digital technology along with the production of computers and communication technologies.

Currently, we are living in the Industry 4.0, officially introduced by Klaus Schwab in 2016.[1] This period builds on the digital revolution which is the hallmark of the third IR. The Industry 4.0 is characterized by the blurring of boundaries between physical, digital, and biological worlds that rapidly affects every facet of our lives including the way medicine is practiced.

Some technologies associated with this revolution are cloud computing, artificial intelligence (AI), nanotechnology, the Internet of Things (IoT), 3D printing, and virtual reality to name a few. Integration of these factors in medicine is rapidly changing the way doctors diagnose and treat their patients as well as how the new generation of doctors is trained. The Organization for Economic Cooperation and Development estimates that currently, more than 30% of jobs in health care are at risk of automation.[2] Hence, it is desirable for all healthcare professionals to understand the application of these technologies. Components of Industry 4.0 help health practitioners diagnose the disease and predict the outcome with an incredibly high degree of precision as evidenced by the publication of several papers.[3] As the revolution progresses and these technologies are fully integrated into medicine, a modern treatment team would likely consist of different members from digital, physical, and biological fields instead of just medical staff commonly seen today. This will create a large paradigm shift that redefines medical practice and education.

Application in Neurosurgery

AI

Artificial Intelligence is defined as the ability of a computer to carry out tasks that require human intelligence for execution. With the spread of technology far and wide, AI has been able to revolutionize many sectors including modern medicine. Potential applications of AI in neurosurgery are better accuracy in diagnosis, precision in surgical technique (as in robot-assisted surgery), and patient monitoring.[4]

3D Printing

3D printing is a manufacturing process where desired 3D objects are printed layer by layer with the help of specific digital models and devices. 3D printing is used to create specific operating tools and equipment depending

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on the need of the patient. It is also used in the production of prosthetic limbs including bionic arms.[5]

Nanotechnology

Nanotechnology is a part of science and engineering technology that takes place at the nanoscale level (about 1-100nm).[6] For comparison, a single strand of hair has a thickness of 60000 nm. It is one of the most promising technologies of the 21st century that has been applied in imaging techniques, diagnostic tools, drug delivery to the nervous system, nanomaterials for neuroprotection, and precision during surgery such as in laser-assisted vascular anastomoses.[7]

Genetic Engineering

Genetic engineering is a process that uses special devices to artificially alter the deoxyribonucleic acid (DNA) makeup of an organism. Gene therapies have been widely tested for the treatment of malignant brain tumors, as the technology aids in understanding the genetic functions of mutations and tumor progressions. Additionally, genetic engineering has also been used in the treatment of spinal instability, neurodegenerative and neurogenetic diseases, brain and spinal injuries, aneurysms, stroke, and epilepsy.[8]

Virtual Reality

Virtual reality (VR) is a simulated 3D environment that allows users to explore a surrounding in a way that replicates reality. These days, operating microscopes with integrated VR have been increasingly used which makes the surgery a lot safer and more efficient.[9] Neuronavigation is also a key component in VR which has been in use for quite some time. Another use of VR is in simulating complex surgical conditions so that trainees can be better prepared before actually operating on the patients.

Use in Developing Countries

The majority of the neurosurgical centers of high-income countries have acquired Industry 4.0 technologies. Though relatively fewer in number, these technologies have also found their way into developing countries in recent years. For example, many neuro centers in Nepal have the capability of neuronavigation, robot-assisted surgery, and 3D printing. Some are in the process of acquiring microscopes equipped with VR. As technologies get more refined and less costly, it will not be a distant dream to witness these armamentariums in every neurosurgery center in the world.

Conclusion

With these rapidly evolving scenarios, it is imperative that neurosurgeons adapt and continuously adjust to the advancements in medical and neurosurgical innovations by this fourth revolution.

Welcome to the Fourth Industrial Revolution in Neurosurgery!

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