The Use of Robotics in the Medical Field

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In the modern era, more and more people are being exposed to the existence of the use of robots in medicine. Their development is poised to completely revolutionize how medicine is practiced. Artificial intelligence and computer usage continue to contribute to the rise of innovative designs and effectiveness in utilizing machinery to operate on patients. The term 'robot' was originally derived from a Czechoslovakian word 'robata' meaning forced labor or servitude. Karel Copek first coined the term 'robot' in a satirical play to protest the industrialization of Europe.[1] Modern definition of robots describe them as "Any machine or mechanical device that operates automatically with humanlike skill.". For the development of robotics, great strides have been taken to increase their utility. In the modern era, robots are utilized for highly precise, dangerous or specific tasks in both industry and research that were formerly difficult or impossible to do with human labor. However, compared to other fields such as manufacturing, exploration, or research, robotics has been significantly slower to enter the medical field.[2] And for good reason: The usage of robotics in medicine has many benefits, but its economic and technological limitations are far too great for them to feasibly be integrated into current-day medicinary practices on a large scale.

Although the idea of mechanical beings can be seen as far back as Homer's *Iliad*, it was Leonardo DaVinci's plans for a humanoid robot stemming from his study of the Vitruvian Man that mark the first written link between the investigation of robotics and anatomy.[3] However, it was not until the late twentieth century that the connection

[1] Faust, Russel A. *Robotics in Surgery: History, Current, and Future Applications*. Nova Science Publishers, 2007. P.3
[2] Lanfranco, Anthony R, et al. "Robotic Surgery: a Current Perspective." *Annals of Surgery*, U.S. National Library of Medicine, Jan. 2004, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1356187/
[3] Lerner and K. Lee Lerner, Gale, 2012. "Biorobotics." In Context Series. *Gale In Context: High School*, https://link.gale.com/apps/doc/JMPCJR667911788/SUIC?u=watkinson&sid=SUIC&xid=38fbaffc. Accessed 9 Nov. 2020.

between the practical application of robotics and biological systems made progress. Medical robots first started 35 years ago when an industrial robot and computer navigation were combined in order to insert a probe to obtain a biopsy specimen from a human brain. Following that, robots that could do urological procedures and total hip arthroplasty were introduced. However, their fully autonomous nature was not popular with practicing surgeons because of their complexity and lack of force feedback. They were later replaced by robots made to be under the direct control of surgeons.[4] Robotics medical assistants monitor patients' vital statistics and alert nurses and doctors in cases of emergencies.[5] In this way, there has been less need for nurses monitoring a patient in every room and has even allowed for multiple patients to be monitored at once. However, the developments of robots for use medically has been significantly slower than it has been for other industries. This pattern has changed, so that robotic use for medical purposes in recent years has risen leaps and bounds.[6] In April 2013, Thailand spent approximately $70 million to develop and promote the medical robotics industry in the country. China, Singapore, India, and Mexico have also seen major investments into robotic medical systems.[7]

Prosthetics and Orthotics

Prosthetics and orthotics are a field in which major developments have been made to implement robotics. The integration of robots and prosthetics is an example of

[4] Gyles, Carlton. “Robots in Medicine.” *The Canadian Veterinary Journal = La Revue Veterinaire Canadienne*, Canadian Veterinary Medical Association, Aug. 2019, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6625162/
[5] “How Are Robots Changing Healthcare?” *Healthcare Administration Degree Programs*, www.healthcare-administration-degree.net/faq/how-are-robots-changing-healthcare/#:~:text=Robots in medicine help by,places and transport dangerous substances.
[6] Lanfranco, Anthony R, et al. “Robotic Surgery: a Current Perspective.”
[7] Rohan. “Medical Robots Market.” *Market Research Firm*, www.marketsandmarkets.com/ResearchInsight/medical-robotic-systems.asp.

biomechatronics, which seeks to integrate biological systems with mechatronics. Oftentimes, these robotic prosthetics use myoelectric systems to function, meaning that the mechanical limbs use electricity from muscles to operate. The original idea to create a robotic hand to imitate a human hand came in 1963, when a robotic arm called the *Rancho Arm* was designed to assist handicapped patients in California. It contained numerous joints, enabling flexibility almost reaching that of a human arm. Soon, variations of this idea were created following the *Rancho Arm's* creation. A notable design was the *Silver Arm* which was created in 1974. It was designed to mimic the movement of human fingers, along with the use of pressure sensors that sent information back to a control computer.[8] The degree to which development of robotic limbs has increased has been dramatic within the last two decades. Robotic limbs with bionic skin and neural systems are allowing a great degree of user control over their limbs.[9]

Brain-controlled myoelectric prosthetics have become a vibrant field of research, which generally involves putting electrodes in the motor cortex that infers what the brain wants to do and allows for the robotic limb to follow suit.[10] These "neuroprosthetics" have realized dreams that amputees and paralysed patients previously would not have even hoped for. Researchers at the University of Chicago have taken that even further and are attempting to develop robotic prosthetics with a sense of touch.[11]

Robotic exoskeletons are finding greater use in rehabilitation. They have been used extensively in helping paralyzed patients to walk or correcting malformations within

[8] Lerner and K. Lee Lerner, Gale, 2012. "Biorobotics."
[9] Gyles, Carlton. "Robots in Medicine."
[10] Lo, Chris. "The Magic Touch: Bringing Sensory Feedback to Brain-Controlled Prosthetics." *Medical Device Network@2x*, 3 Dec. 2020, www.medicaldevice-network.com/features/future-prosthetics/.
[11] Lo, Chris. "The Magic Touch: Bringing Sensory Feedback to Brain-Controlled Prosthetics."

the body.[12] In this way, robotic ortheses have completely changed the severity of certain injuries. What was once impossible to do after being paralyzed, such as walking, is no longer as threatening as it once was. Before, it was significantly harder to rehabilitate patients with inherent issues that limited mobility, but the robotic ortheses that do not require as much need for biological systems have allowed a counter to what would once be life-altering injuries. It is therefore undoubtedly apparent that robotic advancement in prosthetics and orthotics has allowed for the recovery of patients to become more complete and let them return to their normal lives.

Surgery

Robot-assisted surgery is one of the most recent developments in robotic use in medicine. The motivation behind using robots in surgical procedures stems from the desire to overcome current laparoscopic techniques and expand the benefits of minimally-invasive surgery.[13] The first instance of surgery being done by industrial robots was in 1985, where a modified robot was used to do a brain biopsy with a 0.05mm accuracy. This serves as a prototype for the *Neuromate*, a robot used for image guidance during brain surgeries. Actual minimal invasive surgery began in 1987, with the first laparoscopic cholecystectomy, an operation which involves the removal of the gallbladder.[14] Since then, laparoscopic procedures have increased with technological advancement and skill of surgeons. The benefits of minimally invasive surgery are popular amongst doctors and patients. Incisions are significantly smaller,

[12] Gyles, Carlton. “Robots in Medicine.”
[13] Faust, Russel A. *Robotics in Surgery: History, Current, and Future Applications*.
[14] Lanfranco, Anthony R, et al. “Robotic Surgery: a Current Perspective.”

there is a smaller risk of infection, and hospital stays are shorter.[15]In 1994, research led to the creation of the first robotic radiosurgery system called *Cyberknife*. It was a non-surgical way for treating inoperable tumors. *Cyberknife* enabled compensation for movement of the heart, lungs, and other important body parts while operating with the precision of a surgeon. Cardiac surgeries and procedures have potentially serious issues, such as bleeding after the surgery, iatrogenic stroke, or myocardial infarction during the surgery. In robotic heart surgery, most of it is controlled by a centralized processing unit. *Cathbot*, an example of such a robot, combines a 3d imaging device with vision-based robot control that utilizes feedback from visual images to control the movement of the robot and catheter. The catheter itself is able to both compensate for the movement of the heart by bracing itself against tissue walls and also work on repairing the tissue. The imaging allows for constant feedback to the processing unit and the surgical team, without needing a large incision in the chest. The imaging also enables the surgeon to evaluate the effectiveness of the repair operation immediately. The robot works with the patients' structures within their body to make for an efficient procedure.[16] Both *Cyberknife* and *Cathbot* utilized the capabilities of robots that was beyond humans and could even be used for other medical procedures. Furthermore, because the procedure is significantly less invasive, it could open up these types of operations to a wider range of patients. An example would be older or immunocompromised patients who would not be medically fit enough for traditional open heart surgery.

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[15] "Minimally Invasive or Laparoscopic: Benefits of Robotic Surgery." *MedStar Franklin Square Medical Center*, www.medstarfranklinsquare.org/our-services/surgical-services/treatments/robotic-surgery/benefits-of-robotic-surgery/.

[16] Lerner and K. Lee Lerner, Gale, 2012. "Biorobotics."

Limitations

Despite the many benefits of robots in medical fields, there are still many drawbacks. The cost of robotic orthoses and prostheses, for instance, are rather high. In fact, there is a growing debate of whether to allocate funds more towards lower-cost and less lifelike prosthetics and orthotics so that they can reach a further patient base.[17] Unfortunate though it is, the more complex a robotic limb is, the more upkeep and initial cost it will require. In the United States, where the cost of medical care is high enough as it is, the cost of robotic prosthetics will be too high for many amputees to afford. This pattern would only be further exacerbated in poorer countries, in which the cost of a robotic arm would be even further out of a patient's ability to pay.

Robotic surgery also has many flaws. One significant problem is its lack of force feedback.[18] In case the robot arm goes towards an area that may cause complications, such as accidentally rupturing an important part of the body, the surgeon would not receive the sensory feedback and may be liable to ignore the complication without realizing. Additionally, robot-assisted abdominal surgery showed increased operating time, with no change in rates of complications and mortality in comparison to those of laparoscopic surgery.[19] Other clinical studies on robot-assisted surgery on the thorax has also shown minimal advantages for the costly surgical method.[20] In addition to the

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[17] Lerner and K. Lee Lerner, "Biorobotics."
[18] Faust, Russel A. *Robotics in Surgery: History, Current, and Future Applications*.
[19] Gutt, C. N., et al. "Robot-Assisted Abdominal Surgery." *Latest TOC RSS*, John Wiley & Sons, Ltd., 1 Nov. 2004, www.ingentaconnect.com/content/jws/bjs/2004/00000091/00000011/art00003.
[20] Boltzmann, Ludwig. Science X. "Robot-Assisted Surgery: Few Advantages, High Costs." *Medical Xpress - Medical Research Advances and Health News*, Medical Xpress, 28 May 2019, https://medicalxpress.com/news/2019-05-robot-assisted-surgery-advantages-high.html?utm_source=TrendMD&utm_medium=cpc&utm_campaign=MedicalXpress_TrendMD_1

questionable benefits of choosing robotic surgery over traditional methods, the cost of robot-assisted surgery is astounding. The American Congress of Obstetricians and Gynecologists has stated that robotic hysterectomy should only be used for highly complex operations only.[21] The prediction for complete integration of robotic procedures for all hysterectomies would add an estimated 960 million dollars annually in the US. The *Da Vinci* robot, one of the most commonly used robotic systems, costs between 1.5 million dollars and 2.5 million USD per unit. *Cyberknife* as well, can cost anywhere between 4 to 7 million dollar per unit. Not only does obtaining the unit come at a high price, but the annual maintenance cost of the average robot approximates to 125,000 dollars, further adding to the already exuberant cost of robotic surgery. In August 2018, it was estimated that the average cost of each robotic surgery is 3,568 USD, adding to the cost of the procedure.[22] There are some issues regarding how much research has been done on the topic of robotic surgery. Robotics surgery is a new field, and as such, the general consensus is that more long-term research has to be undertaken to fully understand its benefits and drawbacks.[23]

The unfortunate truth is that the usage of robotics in medicine with its technological and economic limitations are far too great for them to be largely integrated into current-day medicine. It is undeniable that robotic orthoses and prosthesis have enabled the physically disabled to do tasks they would not normally have been able to. Robotic surgery has opened the possibility of certain procedures being available to the

[21] "Robotic surgery for hysterectomy often not best option, Ob/Gyn group says; expensive procedure adds little to routine care and should be reserved for complex cases, experts say." *Consumer Health News*, 15 Mar. 2013. *Gale In Context: High School*, https://link.gale.com/apps/doc/A322561931/SUIC?u=watkinson&sid=SUIC&xid=ceffa3b9. Accessed 8 Dec. 2020.
[22] Rohan. “Medical Robots Market.” Nov 2020. *Market Research Firm*,
[23] Faust, Russel A. *Robotics in Surgery: History, Current, and Future Applications*.

population that would not have been able to undergo certain operations. Despite this, it is true technological limitations also exist. A common problem with orthoses and prostheses is that individuals need them to be fitted to their body, meaning that the robotic limbs cannot be easily mass-produced. A technological issue with surgery is the limitations of a robot. Robots are designed to do specific tasks, and as such cannot be used for a wide variety of operations, meaning that their utility is quite low. The issue of sensory feedback is another problem that would need addressing, as that limitation can make procedures extremely deadly.

Another issue are the costs of robotic orthoses, prostheses, and surgical procedures are too high for it to become widespread. The cost of attaining and maintaining these medical tools is comparatively higher than even normal procedures and can put a heavy monetary burden on patients, government, or insurance, depending on which country is the operation being done in. By raising the average cost of a medical device or procedure, medicine would head further into a direction where it would cost too much for the impoverished to feasibly be able to afford it. One community that would be affected especially hardly are the physically disabled who need prostheses and orthoses, who already have a hard time making money because of their medical problems and would not be able to afford robotic limbs. In other words, robotic prostheses and orthoses have to become cheaper to even be able to sell to the people who need them in the first place. Other impoverished people, especially in third-world countries would also be heavily impacted. The ability to sell robotic medical equipment in third-world countries would be difficult, especially if the cost of traditional medical procedures is already too high for them.

That is not to say that the development of robotic medical equipment should be restricted in any way, or that robotic developments are somehow out of reach for more impoverished countries. There has been a significant increase in demand in the APAC regions, especially in Japan and China, both of whom have invested heavily into their medicinal infrastructure, which encompases medicinal robotic development. There is also projected growth for medical robotics in countries like South Korea, Mexico, Thailand and Brazil. The Minister of Science and Technology of Thailand allocated 2 million Baht (~70 million USD) to develop robotic surgical systems within the country. The country is also known for importing medical robots worth 780 million Baht (~$25 million) every year. In other countries such as India, treatment using “Cyberknife” costs 60-80% less than it does in the U.S.[24]

A common pattern in technological development is that it becomes cheaper over time. It is not correct to think that robotic medical technologies will always be as expensive as they are today. Just as the car was once expensive and made only for the truly rich, it has now become more or less affordable for nearly anyone of economic class. It is prudent to keep in mind that robotic medicine is still a comparatively new field, and an emerging technology. Over time, developments will continue to make robots cheaper and more affordable for the common people. Robotic medicine may not be able to feasibly become the norm for the average person in modern society, due to its high cost being far above the average pay grade for most of the world, however that is not to say that it can not be widespread in the future.

[24] Rohan. “Medical Robots Market.” Nov 2020. *Market Research Firm*,