WHITE PAPER

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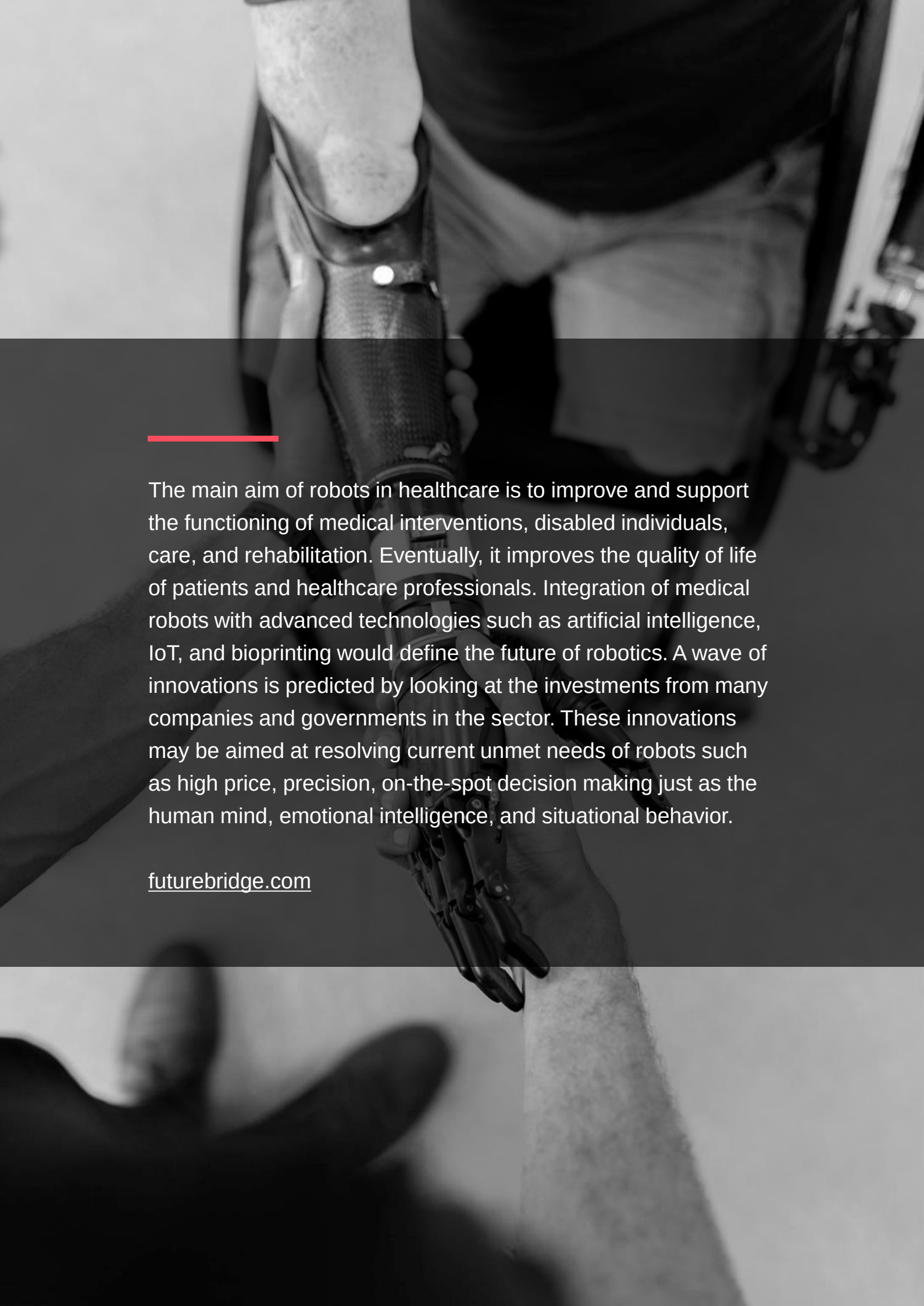
Robots are Revolutionizing Healthcare Industry

FutureBridge



The main aim of robots in healthcare is to improve and support the functioning of medical interventions, disabled individuals, care, and rehabilitation. Eventually, it improves the quality of life of patients and healthcare professionals. Integration of medical robots with advanced technologies such as artificial intelligence, IoT, and bioprinting would define the future of robotics. A wave of innovations is predicted by looking at the investments from many companies and governments in the sector. These innovations may be aimed at resolving current unmet needs of robots such as high price, precision, on-the-spot decision making just as the human mind, emotional intelligence, and situational behavior.

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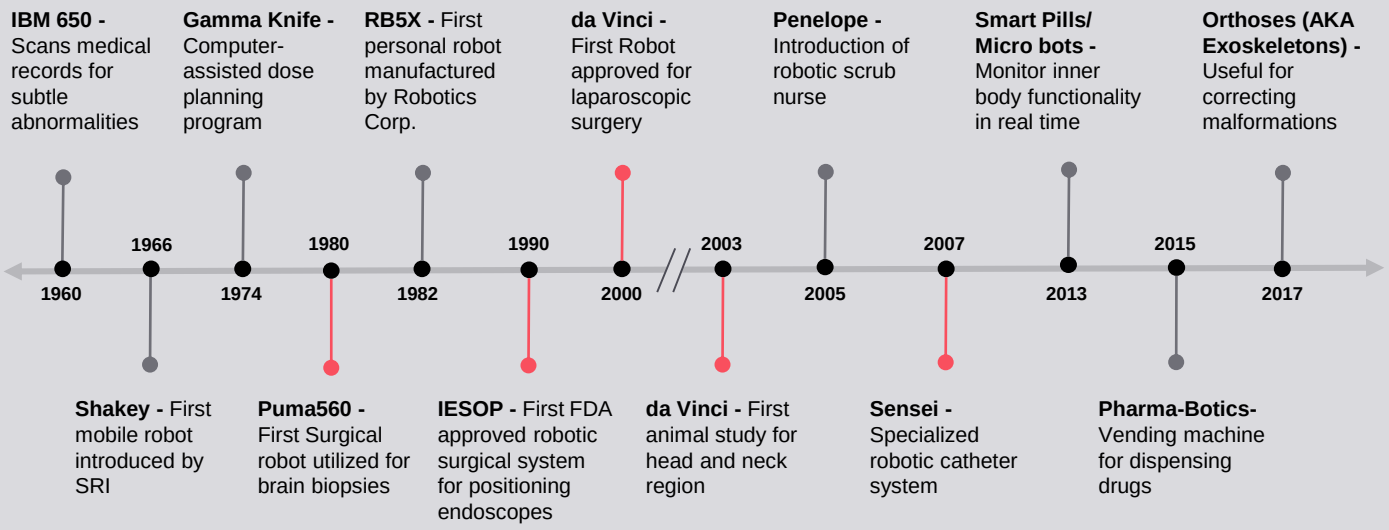
Introduction

The word ‘robot’ was coined by the Robotic Institute of America in the 1940s as a machine that performs the mechanical functions of a human being but lacks sensitivity as that of a human being. Initially, the robots were designed to work like humans, but later it was observed that they can be used for a lot more applications due to their ability of multitasking in a much efficient and faster way. In the last few decades, the utilization of robotic devices has evolved from spearheading tests in an automated medical procedure to the broad utilization of robots in pretty much every part of the healthcare sector. *Exhibit 1* represents the evolution of medical robots over the last few decades.

EXHIBIT 1: Evolution of medical robots



Note: RED marked timeline is for surgical robotic evolution
Source: FutureBridge analysis

Medical robotics is causing a change in outlook in treatment and diagnostics.. Robotics provides a better solution for the healthcare and medical industry through many benefits such as cost reduction of medical treatment, minimizing the risk of surgical procedures, time-saving, and improvement of healthcare outcomes. Robotically driven healthcare has helped in improving the treatment outcomes with negligible error encounters, thereby improving patient experience.

The robotic applications are extensive and have contributed specifically to the enrichment of the surgical sub-specialties based on advantages such as increased surgeon control and autonomy, superior instrument dexterity and tissue handling, improved three-dimensional visualization, and improved accuracy in complex

procedures. The da Vinci surgery system was the first FDA-approved (2000) robotic system encompassing surgical instruments and camera/scope devices. The “Endo-wrist” features of the da Vinci surgery system precisely replicate skilled movements of a surgeon at the controls. Since then it has become one of the most ubiquitous and recognized systems throughout the world in the robotic surgery era, which served as the building block for future robotic surgeries.[1]

Developed countries are fueling innovations in this sector through loads of investments. European Commission aims at accelerating the research and development in robotics for healthcare with the commencement of a new research project through €16 million funding . The world’s elderly population of age 60 years and above is expected to reach 78 million according to the US Census, which means there will be a significant shortage of nurses to take care of elderly people. The rise in robotic nurses is expected by 2035 and the market is expected to reach $480 million between 2015 and 2020.
Prominent surgical robots like Da Vinci developed by Intuitive Surgical have completed five million surgeries in 2018. More than 4,500 surgical robots are sold by the company worldwide. Intuitive Surgical expanded its footprint in Sunnyvale in 2019 by investing over $15 million. Such investments underline massive success in surgical robots .
Medical robots are capable of carrying out a wide range of functions, ranging from assisting surgeons in performing minimally invasive surgeries, to performing clinical diagnostics. In broad terms, medical robotics can be used in the following various forms:

- **Minimally invasive surgical robots:** Assist physicians to perform surgeries with high accuracy and minimally invasive surgical procedures
- **Diagnostic devices:** Capture and process the information essential for effective medical treatment
- **Advanced prosthetic:** Mind-controlled prosthetics to aid in coordination and mobility
- **Telepresence technology:** Advanced video conferencing to provide stimuli to the user's senses that make them feel as though they are in another place
- **Hospital automation:** Automated robots to give medications to the patients and safely disinfect rooms and surfaces
- **Assistant robots:** Assist the patients requiring medical attention

Reasons inhibiting robots to be mainstream

The Gartner research has suggested that one in three jobs that exist today will be converted to smart machines, robots, and softwares by 2025. However, there are a few job sectors where robots dare not venture, where human intelligence still beats artificial intelligence perception and manipulation, social intelligence, and creativity.

- **Sympathy & Empathy:** A robot can personalize all the elements of the customer relationship, but only humans can make a relationship truly personal. E.g. calming an angry or panicked patient, humans outperform as robots are pre-written programs with limited emotions, while humans are equipped with diverse emotions related to diverse situations.
- **Social intelligence:** Social intelligence is another bottleneck, as machines can't yet compete with humans at work involving negotiation, persuasion, or care. In particular, machines struggle to recognize and respond to human emotions.
- **Creative thinking:** Algorithms are getting systematically better. This means that robots are now excellent at predicting customer behavior but cannot still form new and valuable ideas such as poetry, music, recipes, jokes, fashion design, or scientific theories.
- **Perception and manipulation:** Humans outpace robots when it comes to perception and motor skills, especially in unstructured work environments such as surgeries. Robots can perform minimally invasive surgeries, thus improving precision and speeding recovery, but may be indecisive in case of any surgical complications.

Factors encouraging the growth of medical robots

Medical professionals use robots for everything from surgery and rehabilitation to non-invasive general hospital and pharmacy applications. This usage shows no signs of slowing down and is predicted to grow year on year. Table 1 shows how robotics is assisting various stakeholders in the healthcare sector. The medical robotics market has increased almost sevenfold since 2012. Today, a good percentage of the world population is aging rapidly and co-morbidities will continue to rise largely as a result of lifestyles associated with economic development such as smoking, obesity, harmful consumption of alcohol, unhealthy diet, and sedentary lifestyle. Further, the continuously changing landscape of healthcare has led to the

emergence of several significant factors that are likely to strengthen the case for more ambitious adoption of advanced medical technologies, including medical robotics. Those factors include:

- **Chronic disease prevalence:** According to the World Health Organization (WHO), chronic disease growth is expected to rise by 57% by the year 2020. With this disease growth rate, the need for automation in several aspects of the healthcare sector is anticipated.
- **Shortage of healthcare providers:** According to the United Nations Population Fund (UNFPA), the world is aging rapidly; between 2015 and 2050, the proportion of the world's population over 60 years will nearly double from 12% to 22%. By 2050, the world's population of age 60 years and above is expected to reach 2 billion, up from 900 million in 2015. Therefore, a significant shortage of nurses to take care of elderly people is expected, which will eventually increase the demand for robotic nurses.
- **Growth of minimally invasive surgeries:** The medical industry is inclining towards less invasive surgical techniques offering effective treatment to patients, reducing the recovery time, and improving the clinical success rate. In some cases, medical robotic devices have outperformed invasive surgeries.
- **Shortage of trained medical personnel:** By the year 2030, the shortfall of physicians in the US is projected to exceed 100,000, with rural and underserved populations expected to be especially hard hit. Thus, to overcome such a situation advanced medical robotics could play an important role in addressing the shortage.

TABLE 1: Implementation of robotics to assist various stakeholders in healthcare sector

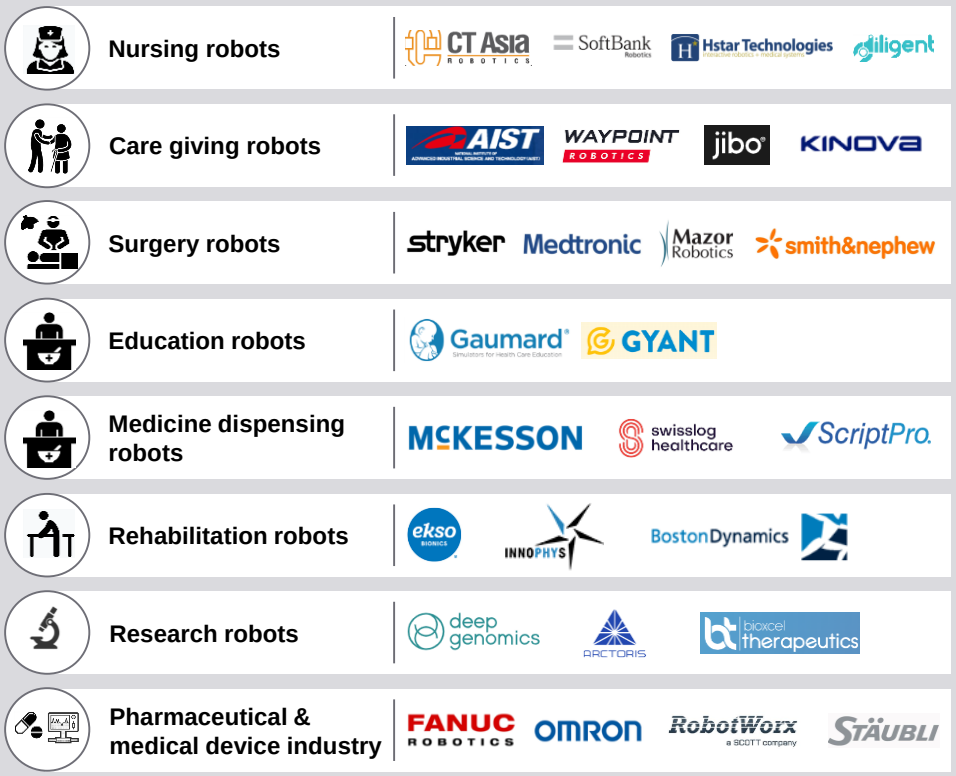
Stakeholder	Role	Implementation
Physicians	▪ Accurate choice of therapy ▪ Documentation of structured data ▪ Reducing surgical risks ▪ Remote patient monitoring	▪ Implementation of artificial intelligence in choosing therapies ▪ Analyzing large patient data set and performing data modelling ▪ Robotic assistance in surgical techniques ▪ Guidance to patients in an emergency via telemedicine
Nurses	▪ Care of patient pool ▪ Slicing off redundant tasks ▪ Education	▪ Large scale patient monitoring via virtual robotics ▪ Generating alerts for human intervention in patient wards ▪ Telepresence for teaching purposes
Care-givers	▪ Social assistance for the aging population ▪ Home care assistance ▪ Patient education	▪ Old age patient care through socially assistive robotics ▪ Engagement and interaction towards disease education and identification
Hospitals	▪ Mobile logistics ▪ Data tracking ▪ Medication dispensing	▪ Autonomous robotic transport for medicine and surgical tools supply ▪ Point of care medication dispensing through automated machinery
Pharmaceutical companies	▪ Manufacturing of personalized medicine ▪ Reducing operational cost ▪ Decreasing human errors ▪ Automated drug discovery and development	▪ Use of artificial intelligence for lead identification ▪ Automation line through IoT integrated platforms for manufacturing and packaging of drugs ▪ Use of advanced robotics in screening and identifying drug candidates
Medical device companies	▪ Process streamlining ▪ Assembly testing and inspection ▪ Consistency in regulatory compliance	▪ Sensory robotics offering efficient packaging of finished goods ▪ Programmed path to maintain consistency in quality check and regulatory compliance

Source: FutureBridge analysis

Application Examples

Robotic application has paved its way into the healthcare industry and its products in the healthcare market. According to a published report, assisting in surgery, life science research, and telemedicine are the most promising areas for robotic applications in the healthcare industry. *Exhibit 2* provides an illustrative list of entities working on medical robots.

EXHIBIT 2: Few active entities working on medical robots



Source: FutureBridge analysis

- **Nursing robots:** Robotic nurses can be utilized for assistance in hospitals to execute monotonous human-like physical activities.
  - Robot Dinsow (CT Asia Robotics) can monitor elderly patients through video and also provides alert notifications to the patients about their medication time and dosage. The robot is currently used in Thailand and Japan.
  - Robot Pepper (Soft bank Robotics) is deployed at the reception of two Belgian hospitals to guide the patients in the specific wardroom. Its unique features consist of 20 language skills and can connect to the emotional needs of individual patients.

  - Dustin (Duquesne University) is a telemedicine robotic platform that can interact with students once connected via the iPad or any computer. It also provides live video assistance in case of emergencies.

- **Research robots:** Smart robots can accelerate the drug development process in the pharmaceutical/biotechnology field using advanced research capabilities such as artificial intelligence, big data analysis, etc.
  - Eve (Cambridge, Wales, and Manchester University) is a drug discovery robot that is created by the collaborative efforts of three universities. The major advantage includes its rapid ability to screen 1000 compounds in a single day, which has led to the discovery of an anti-malarial drug.
  - Bioxcel Therapeutics is developing an AI platform to rapidly identify new candidates in the immune-oncology and neuroscience fields. Many other start-ups such as Genomics, Arcotris, etc. are enabling advanced robotic solutions to meet the current drug exploration activities.
- **Care-givers:** Socially assistive robots can act as care providers to elderly patients while in hospitals or home-based care and help in their daily chores. These robots also provide reminders to patients about daily dosing time.
  - Robot Paro bot (AIST) imitates seal voice to relax patients. It has five types of sensors and is commonly used in extended care facilities and hospitals to improve patient interaction with caregivers.
  - Keepon robot developed by an individual by Hideki Kozima at NICT, Japan is a unique robot that studies autistic behavioral changes in kids and monitors mental health.
- **Patient education and counseling:** Robots dedicated as an assistant in providing medical education to patients directly. These bots perform tasks such as disease diagnosis, clinic finding, and counseling to patients for utmost care
  - Buoy Health has developed an AI-enabled platform that listens and interacts with patients in real-time to identify symptoms and diagnose disease.
  - Gyant chatbot is another example of an AI-enabled real-time platform to improve patient experience and assist them in identifying the disease, doctors, or clinics.
- **Surgeons:** Minimally invasive surgeries can be executed more precisely with less significant pain using these robotic technologies.
  - DaVinci system (Intuitive Surgical) is a ubiquitous robotic system with precise incision capability. Surgeons can completely control the system and perform complex surgeries with reduced risk. Moreover, this robot assists surgeons in the execution of complex surgeries.
  - Mako knee surgical robot (Stryker) enables the creation of patient-specific 3D models of knee joints based on CT scans obtained pre-operatively. The

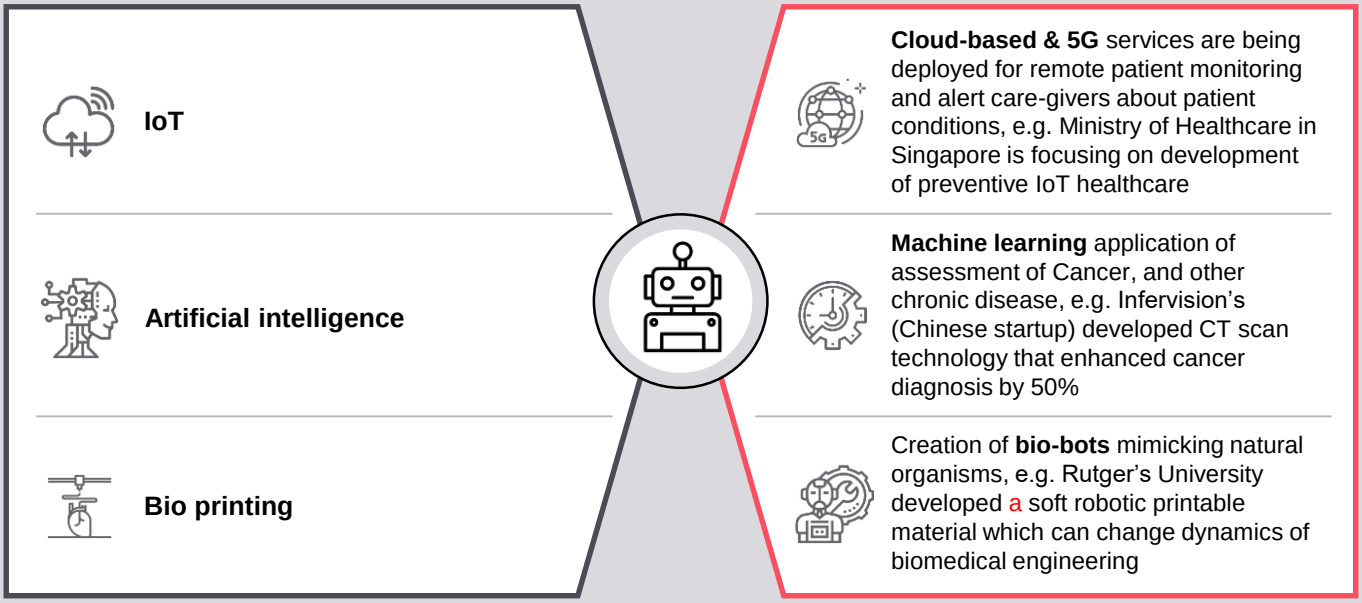
system is advantageous in severe knee inflammation, rheumatoid arthritis, and post-traumatic arthritis.

- **Rehabilitation:** The robots help disabled patients in standing up, balancing, and gait.
  - Orthoses is a robotic exoskeleton system that can assist paralyzed people in limb motions. It works on pre-set user-defined commands feuded into the robot but advances are being made towards mind-controlling features for orthoses.
- **Carriers in hospitals:** Robots can be used to transport medical equipment from one destination to another without human intervention.
  - Helpmate (Pyrix) is a carrier bot programmed to transport surgical tools, x-ray images, food, and medication supplies from a point A to B within the hospital.
- **Medication dispensation and medical assistance/education:** The bots assist medical personnel and improve working conditions in the hospital environment. While some bots were created to provide virtual education and training to medical professionals.
  - Robot-Rx (Mckensson) is used in hospitals for automating personalized medication processes. It acts like a vending machine that dispenses medication through automated processing. Also, it monitors and creates alerts on the depletion of medicines in-store.
  - Quentus AI-based software platform automates and prioritizes patient safety.
  - Pediatric HAL (Gaumard Scientific) is a simulating bot that is used for the training of nurses in pediatric care. This robot acts like a 5-year-old child which can interact with nurses, this robot enables training candidates to study symptoms and vital signs in diseased conditions.
- **Medical device industry & pharmaceutical research advancement:** Industries are working towards the development of robotic integrated advanced technologies to improve manufacturing solutions, quality testing of products, and finished product manufacturing.
  - Delta-style M series has been deployed by Fanuc, a US-based company for accurate and smart handling such as inline visual tracking and precision handling to increase productivity.
  - Delta robot solution (Sysmac) is an integrated robotic solution to reduce problems related to production and reduce the programming time of the manufacturers.
  - CoLAB (collaborative laboratory) is developed by HighRes Biosolutions that can test >30,000 compounds for drug efficacy and has a working capacity of 24 hours a day.

  - 3Scan is a proprietary microscopic visualization system to generate 3D spatial screening maps and has the capability to process >3000 tissue slices.

- **Future of integrating robotics with advanced technologies**.
  The future of robotics in healthcare is predicted to be exponentially increasing. Researchers and companies are trying to integrate robotics with advanced technologies such as artificial intelligence, the internet of things (IoT), and bioprinting. *Exhibit 3* provides an illustrative application of robotics integrated advanced technologies.

EXHIBIT 3: Integration of robotics with advanced technologies



Source: FutureBridge analysis

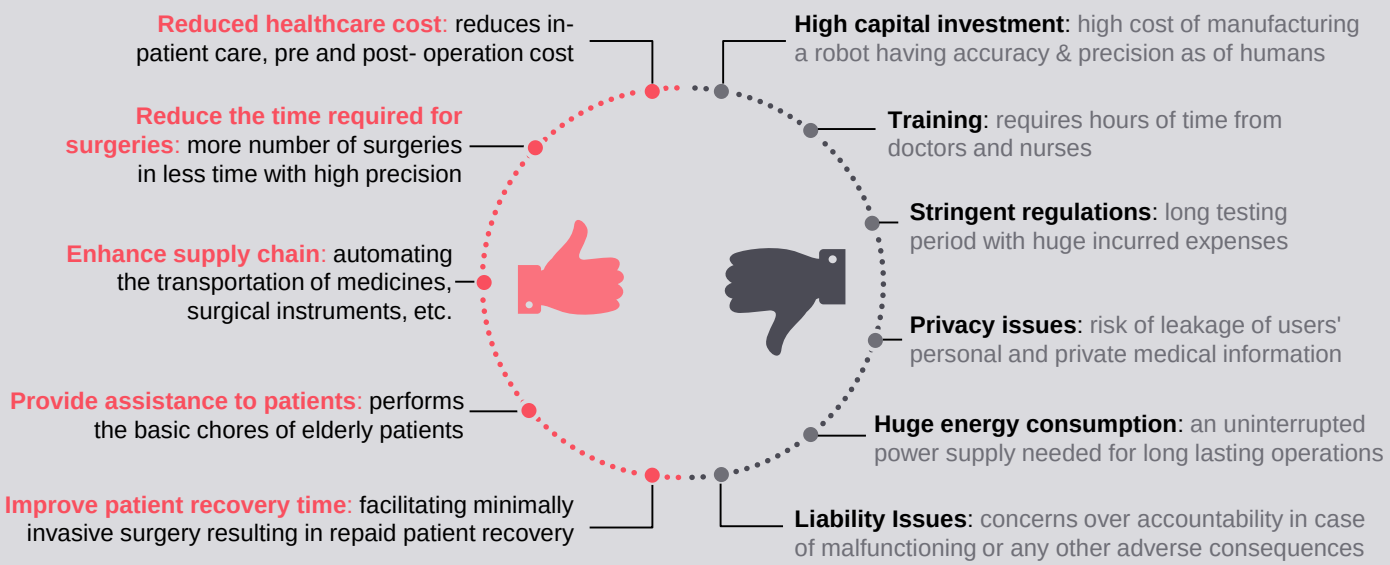
Drivers for adoption of robotics in healthcare

- **Reduction in healthcare cost:** The homecare robotic assistive systems have replaced expensive patient care services and assisted in supporting the independent living of the disabled and the aging population. Surgical robots are economical in terms of decreased pre and post-operation costs and lengthy stays at hospitals. The pharmacy and nursing robots achieve cost benefits by reducing manpower and lowering error-free medication delivery.

- **Reduce the time required for surgeries:** Surgeons can perform the surgeries in less time using robots due to their ability to help them in aligning the angles of surgical tools on-target sites in all three dimensions during the surgery. With the help of robots, surgeons can perform more surgeries with high precision and success rate as compared to what they did without the use of robots.
- **Enhance supply chain:** Automated systems help in transporting bulky supplies such as medicines, surgical instruments, machines, etc. from one place to another requiring minimal human efforts. The automated robot can move across the hospital rooms, operating theatre, and other departments at any time to provide programmed or on-demand deliveries.
- **Provide assistance or comfort to patients:** There is a rapid increase in the number of elderly patients across the world. They require much more attention to perform basic chores. Robots can assist elderly patients to do basic chores such as get out of bed, sit in a wheelchair, etc.
- **Improve patient recovery time:** Using robots in critical surgeries minimizes the chances of human errors. The keyhole surgery using robots can accurately work through very small incisions resulting in rapid patient recovery.

Exhibit 4 illustrates a brief about the drivers and challenges for the adoption of robotics in healthcare.

EXHIBIT 4: Drivers & challenges for the adoption of robotics in healthcare



Source: FutureBridge analysis

Challenges for the adoption of robotics in healthcare

- **High capital investment:** One biggest challenge of robotics in healthcare is its cost of manufacturing. Building a robot that can accurately reproduce the way the surgeon's hand moves is quite costly, around $1M. Companies are coming up with cost-effective robots using advanced technologies such as 3D printing. E.g., SS Innovations has recently launched an affordable robotic surgical system that can perform complex motion controls using the actin robotic control toolkit.
- **Extensive training:** One of the major challenges of medical robots is the huge amount of time invested in training them to perform the tasks. Hours of doctor's and nurse's time is required for training a robot. Certification for some medical robots requires 100+ hours of training.
- **Stringent regulations:** Regulatory approval is one of the major roadblocks for medical robots. The robot manufacturing companies have to follow rigorous regulatory approval schemes from the US, European Union, Japan, and other regulatory agencies. The approval requires a long testing period with huge incurred expenses. To overcome these constrains the companies must be accustomed to all the regulatory guidelines and well prepared with monetary planning.
- **Privacy issues:** End-users of the robots are concerned about leakage of medical information such as patient history, etc. The companies developing robots feed huge data about users' personal and private medical information to train them using advanced technologies like artificial intelligence and machine learning. This information is prone to cyber-attacks that can be protected by adhering to safety standards and security requirements by regulator bodies such as General Data Protection Regulation (GDPR), ISO80001, and AAMI/UL2800 series of standards.
- **Huge energy consumption:** Robots being electronic machines, have huge energy requirements. They require an uninterrupted power supply, thus need new power sources and energy harvesting technologies for long-lasting operations. Saft batteries, a Chinese company has developed long-life, highly reliable nickel batteries for robotics applications in defense, deep offshore, and healthcare to address the issues of high energy supplies and uninterrupted power supply.
- **Liability issues:** Due to the mechanical nature of the robots, it is impossible to make them liable in case of malfunctioning or any other adverse consequences that occurred during their usage. This could raise concerns related to accountability amongst manufacturers, programmers, and providers. This issue can be addressed by designing a legal regime identifying product liability.

Conclusion

Robots are actively becoming part of the modern healthcare ecosystem benefiting all the stakeholders across the value chain. Advances in sensors, communication, and motion control technologies have facilitated medical robots to be more precise and autonomous. The recent developments in surgical robots have widened the scope from assisting surgeons to single-handedly perform complex surgeries. The capability to sense, think, and act makes robotics a revolutionary technology for the healthcare industry. With the pace of evolution of the medical robot, the major factors that will play a role in the success in designing the robots for medical applications are clinical safety, product safety, and quality management compliance. The future lies in the integration of medical robots with advanced technologies such as artificial intelligence, IoT, and bioprinting. With the introduction of 5G technology, the field of robotics is further expected to counter latency-related issues. The funding to researchers from the governments in the field will further pave the way towards the use of medical robots for the welfare of humanity.

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