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Impacts of Robots Synergising with Humans for Medical Surgeries: A Literature Review

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Abstract: Today, advanced robots are being used in several industries to assist humans and minimize their workload. Robots are synergising with humans to enhance their living experience. With the advent of the fourth industrial revolution, robots have been introduced in the three important sectors of human society- agriculture, manufacturing and healthcare. The use of robots has increased manifold over the past decade. Robots are now being deployed in various medical facilities to assist doctors and nurses. During the outbreak of the Covid-19 pandemic, robots are being used in various hospitals and medical facilities for sanitization and helping patients with their medications. The following study analyses the impacts of the various technological advancements being used in medical surgeries and compares them with conventional surgical methods. Finally, a conclusion has been made, based on the available data on how these new surgical trends are affecting patients with their surgeries and rehabilitation.

Keywords: Robot-assisted surgeries, Laparoscopic surgical methods, Open surgical methods, Gastrectomy, Rehabilitation, Covid-19

I. INTRODUCTION

The technology around us has evolved substantially with time. We have come a long way since the development of the first digital computer in the 1940s. The human-machine gap is gradually bridging. Machines are now able to comprehend multiple environmental constraints and thus have become more responsive. The healthcare industry is also implementing robotics for various medical research and advanced surgeries. Robots are being deployed to help people with surgeries, provide them medication and maintain hygiene. Robots are even being used to help patients with their rehabilitation process.

The use of robots in surgeries came into existence in the 1980s. The first robot-assisted surgery took place in 1985 wherein a robotic surgical arm named PUMA 560 [1] was created for neurosurgical biopsy. Since then, the employment of robots for minimally invasive surgeries has grown substantially. The most crucial breakthrough in robotic-assisted surgeries (RAS) was the invention of the Da Vinci surgical system which is today the most used system across the globe with its utilization in 2800 hospitals of the USA. [2]

The following paper analyses the impacts of robots being used in medical surgeries and compares the new trend of robot-assisted surgeries with conventional laparoscopic medical procedures. Numerous case studies have been taken into account to elucidate the use of various technologies used in healthcare along with their impacts on humans. Finally, a conclusion has been deduced based on the data sets obtained from the case studies. Analysis has been made in the end whether or not the robot-assisted surgical method is a viable replacement over conventional surgical procedures.

II. THE HUMAN-ROBOT COLLABORATION

Over the years, robots have undergone various advancements. Present-day robots come equipped with various advanced sensors and transducers that offer high precision and accuracy. They are now being used for a multitude of operations in various sectors like agriculture, healthcare, manufacturing and education. Technological improvements have even made them capable of working in conjunction and close proximity with humans [3]. This trait makes them immensely useful for medical research and to perform medical surgeries. The healthcare sector has always been of utmost importance. It undergoes continuous developments to enhance the treatment process and to increase human life expectancy. Robots are now being deployed in various medical facilities to assist humans. They not only offer surgical assistance but are also being used to provide nursing care. Various surgical procedures which were once considered arduous are now being performed easily by robots under human supervision. Some of the most common medical procedures now performed by robots are listed below:

A. Robotic Heart Surgery

The treatment of cardiac systems using robotic surgery has drastically replaced the traditional methods. Robotic heart surgery has been adopted to treat damage in the heart, repairing heart valves, and for a heart transplant. The robotic method gives a precise analysis of even the narrow blood vessels.

According to the data obtained by the JAMA Network, the number of robotic cardiac surgeries has increased from 1.8% in 2012 to 15.1% in 2018 (including the Robin heart PVA video system Robot). [4]

B. Robotic Kidney Surgery

In robotic kidney surgery, the doctor makes a small incision with the help of 3-dimensional imagery. The robotic surgery mobilizes the kidney easily and retains the kidney fluids.

This helps in the detection of the tumour at an early stage. The cutting tools used during the surgery cause only a fraction of blood loss.

The length of the incision in robotic surgery is less than an inch in contrast to 8 inches in conventional surgery. The recovery period of the patient after robotic surgery is very less as compared to conventional kidney surgery. The adoption of this technology has led to lower rates of mortality and renal failure. [5]

C. Robotic Prostate Surgery

This surgery is performed to cure localized prostate cancer spread outside the prostate gland. The traditional method for performing prostatectomy involved a single incision to remove the prostate gland and its nearby affected area. This method poses a high risk of damaging nerves present in the abdomen and hence RAS has been opted as a safer surgical method. [6]

D. Robotic Gynaecological Surgery

Today, one in every four women is affected by uterine fibroids, uterine cancer and cervical cancer. The treatment by robotic method eases the after pain and causes lower levels of blood loss. The size of the incision created during the robotic surgery is less than 1 inch.

Better visualization of the parts being operated on is obtained during robotic surgery. Whereas in traditional surgery, the physical contusion creates more pain and the duration of recovery is also longer. Hence robotic gynaecological surgery is being adopted by a majority of medical institutions. A report by Manipal Hospital stated that over 6 lakhs uterine and cervical cancers have been treated using robotic surgeries. [7]

III. ROBOT-ASSISTED SURGERIES

Robot-Assisted Surgery or RAS is a new and trending way to carry out various types of surgeries. In this type of surgery, the robotic system mimics the actions and gestures of the surgeon and operates. A camera is placed in the patient cart (the operative component of the da Vinci system which acts as a slave unit and supports the instrument and camera arms) and it shows high-quality real-time visuals which can be viewed by the surgeon. Surgical instruments are placed on the cart and the surgery is performed according to the gestures shown by the doctor. With RAS, a better and detailed view of the patient's body is visible. RAS also provides access to some unapproachable areas on the patient's body on which surgery has to be performed, thus increasing the scope of medical science. RAS offers potential merits such as high precision, less pain, less recovery time and lower blood loss levels. [5]

IV. ANALYSIS OF THE EMERGING ROBOTIC SURGICAL TRENDS IN THE HEALTHCARE SECTOR

With the offer of surgical assistance and increasing implementation of robots in surgeries, several inspections analysing the accuracy, cost, surgery-time, casualties and other factors have been made.

A. Public's view on adapting robot-assisted surgical methods

- 1) *Respondent's reviews on whether RAS can be a viable surgical option:* To examine the viewpoint and awareness of people towards RAS, a survey was conducted on people of Kuwait. It was found that 30.9% of people were apprehensive about the failure of robotic methods and would prefer human-based surgery. 33.6% of people were in a dilemma about which method they would choose. 35.4% were pragmatic about RAS and would pick it if they had a chance to get operated by it. A pie chart depicting the reviews is shown below (Fig. 1). [8]

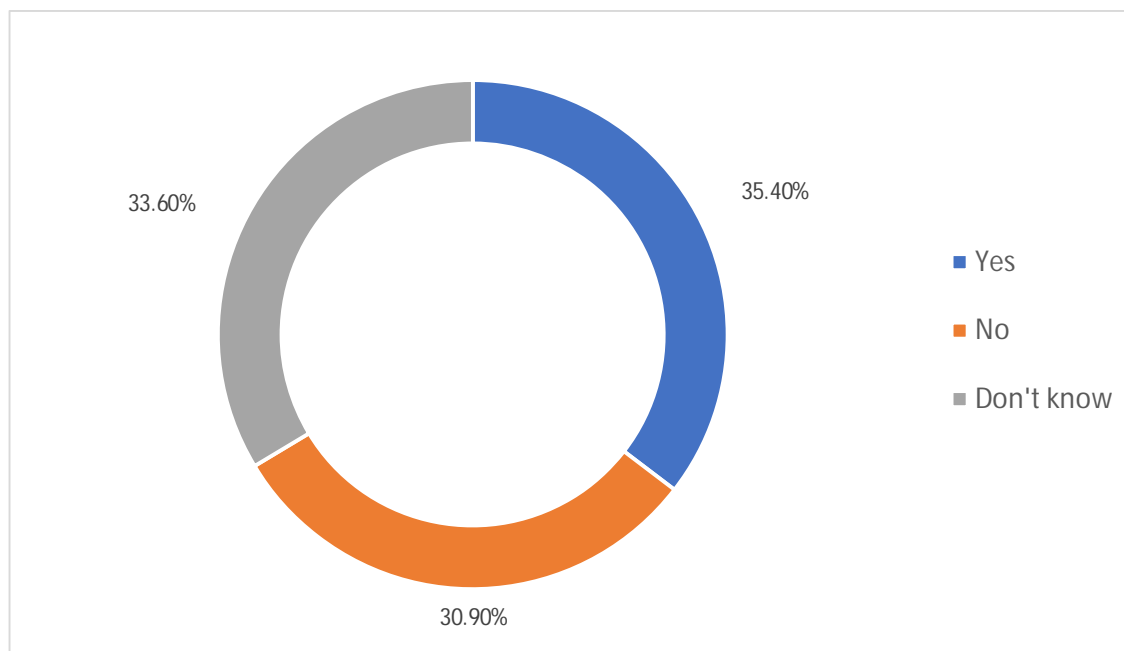


Fig. 1 Respondent's reviews on whether RAS can be a viable surgical option

- 2) *Comparison of respondent's reviews on RAS and conventional surgical methods:* People's perception regarding the pros and cons of RAS in contrast to conventional methods was also surveyed. It was found that 30.6% of people believed that RAS would stop working in the middle of the operation. 15.5% of people feared that RAS could be erroneous and cause serious complications while 14.5% believed that it would lead to fewer complications. 34.4% were of the viewpoint that RAS is faster than conventional methods while 6.5% assumed that it would take a longer time. 40.9% of people supported RAS in terms of precision. 9.9% of people were in favour that RAS would cause less pain. In contrast, 1.7% of people had the opinion that RAS would give rise to more pain. A bar graph delineating the people's reviews is shown below (Fig. 2). [8]

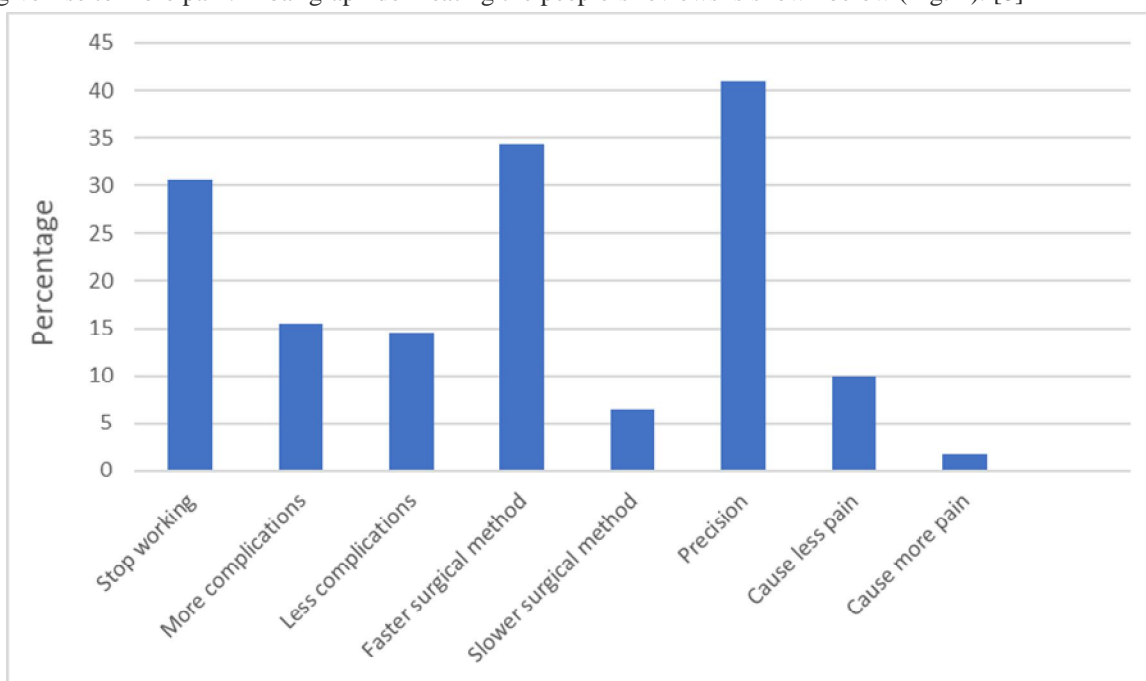


Fig. 2 Comparison of respondent's reviews on RAS and conventional surgical methods

B. Comparison of RAS with Conventional Surgical Methods

A comparison of open, laparoscopic and robotic gastrectomy was conducted on 241, 511 and 173 patients respectively. It was found that robotic gastrectomy had the highest surgical success rate of 96% with its counterparts having success rates of 90% and 90.8%.

[9]

- 1) *IRDG vs CLDG*: Another survey was performed to collate the surgical outcomes of Integrated Robotic Distal Gastrectomy (IRDG) and Conventional Laparoscopic Distal Gastrectomy (CLDG). It was observed that IRDG caused less blood loss (30.7 ml) as compared to CLDG (73.3 ml). Further in IRDG, a higher number of lymph nodes were retrieved (50.4) as compared to CLDG (41.9). There were lower readmission rates in IRDG (2.0%) as compared to CLDG (15.7%). IRDG had a 98.0% success rate in contrast to 82.4% observed in CLDG. The only downside of IRDG was that it took a longer operation time (159.5 min) in comparison with CLDG (131.7 min). From these facts, it can be inferred that robotic based gastrectomy has potential benefits over conventional methods for patients with early gastric cancer and it holds the capability to replace them in future.[10]
- 2) *RAS vs Open Surgery for liver transplant*: An article from the Manipal Hospital, Bangalore elucidated the benefits obtained from robotic surgery in terms of precision. Liver transplantation using robotic surgery was performed on a patient with a critical condition. A liver transplant is performed due to cirrhosis [11], which is the scarring of the liver tissues. The scar's length should be as small as possible to avoid complications. Open surgery causes a long scar on the liver tissue, increasing the risk of complications. Therefore, robotic surgery was adopted for performing a liver transplant. A successful robot aided transplant was completed by the surgeons of the Manipal Hospital. It was found that the scar's length obtained due to robotic surgery was merely 10 cm as opposed to 35 cm which would have been generated by open surgery. [7]
- 3) *Adopting Robotic Gastrectomy for the elderly*: To examine if robotic gastrectomy is suitable for older people, both the young and older people underwent robotic surgeries. Also, surgical results of elderly people who went through laparoscopic and robotic surgeries were compared. In both cases, it was found that there was not a lot of variation in the outcomes. Hence it is concluded that robotic gastrectomy is a secure and viable way to treat gastric cancer among senior citizens. [12]
- 4) *Analysing the cost-effectiveness of the robot-assisted surgical methods*: One of the major drawbacks causing hindrance in the widespread implementation of surgical robots is the huge cost associated with it. The return on investment derived from the surgical robots takes a lot of time and therefore small healthcare centres prohibit its use to perform operations. A cost analysis was made by comparing the cost of a variety of surgeries using surgical robots and laparoscopic methods. For every surgery, the cost of RAS was higher than the conventional methods. A graph comparing the cost of various surgeries using RAS and Laparoscopic methods is shown below (Fig. 3). [2]

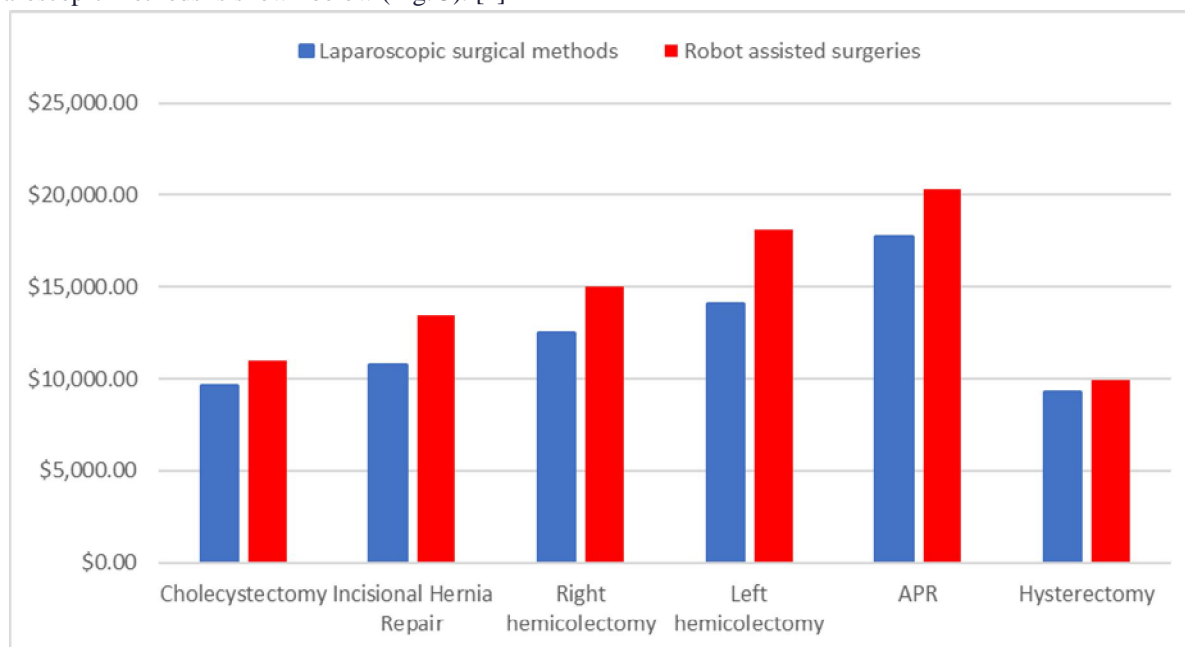


Fig. 3 Cost Analysis of Various Medical Procedures Performed Using Laparoscopic Surgeries vs Robot-Assisted Surgeries

Robot-assisted surgeries can be made cost-effective by increasing the number of patients who undergo these procedures. In this way, the cost recovery would be easy and the prices of the robotic surgeries would become comparable to laparoscopic surgeries. With increasing competition in the field of robotic surgeries, the costs of RAS are likely to decrease by many folds in the future.

- 5) *Casualties associated with robot-assisted surgeries:* There have been few cases where robotic surgeries have been responsible for casualties and injuries. Research work carried out at the University of Illinois at Urbana-Champaign, Massachusetts Institute of Technology and Chicago's Rush University Medical Centre stated that 144 people have died and 1,391 people have been wounded due to Robotic surgery from Jan 2000-Dec 2013.
 - a) In one of the cases published by the FDA regarding malfunctioning of RAS, a patient underwent a hernia operation with RAS. The operation was successful but later it was discovered that RAS had caused damage to the patient's intestine, creating a hole in it causing the unfortunate demise of the patient.
 - b) In another case, a patient underwent gallbladder removal surgery using a robotic arm. The robotic arm severely damaged the patient's liver, causing it to bleed.

One of the major reasons leading to such detrimental incidents is the freezing of the robot's moving parts performing surgery. This results from the abrasion of moving parts due to their frequent movements. Another reason ascribed for such malfunctioning during surgeries is the hindrance caused by one moving part on other parts inside the organ causing them damage. Some other factors attributed to faulty outcomes are irregular power supply to robots, a low-grade video feed of the part being operated, electric sparks causing wounds on the skin and tissues and wear tear of the robot's parts. A pie chart depicting the reasons responsible for casualties involved in robotic surgeries is shown below (Fig. 4). [13]

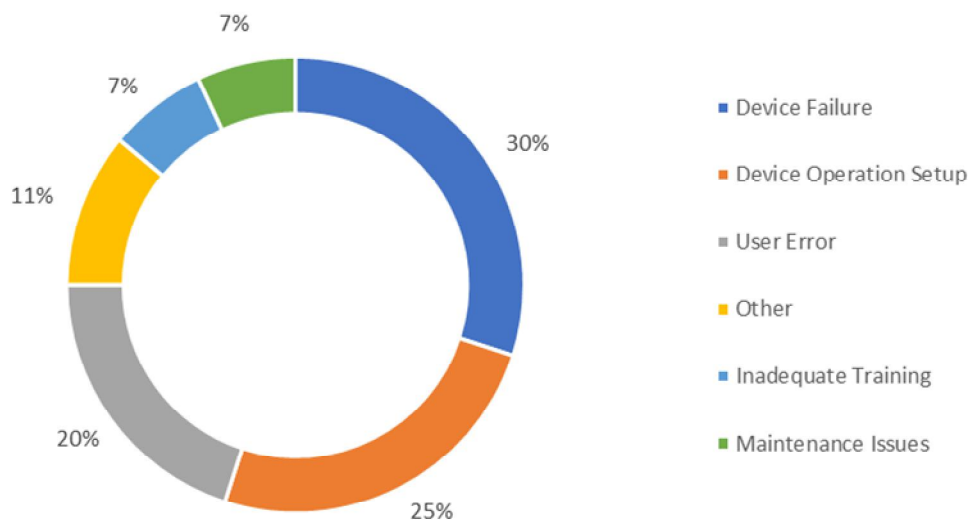


Fig. 4 Reasons responsible for casualties involved in robotic surgeries

To overcome such fatalities and malfunctioning, few solutions have been suggested in "da Vinci Robotic Surgery Complications". It emphasized the need to prepare a proper curriculum to educate the operators regarding proper handling, maintenance, fault identification and taking safety measures. Certification for the same should be made mandatory for the surgeons and hospital staff. [14]

V. USING ROBOTS FOR REHABILITATION

Rehabilitation is the process of restoring the normal health of the patient who underwent a surgical procedure. It involves the use of various therapies and training exercises. The process of rehabilitation comprises of four major steps:

- 1) First, the patients are evaluated for their extent of disablement.
- 2) Second, the therapist must decide the exercise plan.
- 3) Third, the exercise plan is implemented on the maimed part which requires a repeated practice of specific movements.
- 4) Finally, the patient is reassessed and accordingly the exercise plan is revised.

Earlier, the process of rehabilitation was continuously monitored by the doctors to help their patients heal quickly. But with advancements in medical sciences, various robots are now being used to help patients recuperate rapidly. The use of advanced robots for rehabilitation makes it possible to treat many patients simultaneously. Robots evaluate the level of impairment precisely and then provide targeted exercise. This makes the rehabilitation process more comfortable. The recovery time of the patient is also very less using robotic rehabilitation.

The most common robots used in rehabilitation are as follows: -

A. End Effector Robotic Device

End effector robotic device is used for rehabilitation of upper limbs and gait training. It consists of a manipulandum connected to the robotic arm which provides specific movements to the impaired part. The performance is measured by sensors and appropriate changes are made according to feedback provided by the system. They can be used for various body sizes with some small changes. [15]

B. Exoskeletal Robotic Device

Exoskeletal devices are directly attached to the period limb and have to be modified according to limb size. Force applied at each limb point is different thus high motion accuracy is achieved after the treatment. The only drawback of using exoskeletal robots is their complex design and the high cost associated with it. [15]

VI. ROBOTS DURING COVID-19 PANDEMIC

The coronavirus outbreak engendered the need for rapid and contactless methods to disinfect hospitals. Acquiring the virus from hospitals has been one of the major reasons behind the rise of Covid-19 cases. It poses a great risk to the hospital staff and doctors. It was found that 17.6% of covid 19 infections were acquired from hospitals in England. This created an urgent need to disinfect hospital floors. To save the doctors and staff from acquiring the disease, disinfection robots are being deployed in hospitals. The robot cleans the floor by emitting powerful UV radiations for a certain period of time and disinfects the place. A report released by UVD Company, which is one of the leading manufacturers of UV disinfection robots stated that they sold over 100 robots during the pandemic [16]. The efficacy of disinfectant robots to extirpate bacteria level is 80% as corroborated by Odense University Hospital in 2018. [17]

During this pandemic time, robots have been used for diagnosing Covid-19 cases. By automating the diagnosing process, the exposure of nurses and doctors to affected patients can be significantly reduced. Robots have been able to reduce the swab sampling time by 50% and the sampling rate has increased to 95%. The robotic systems designed for diagnosing can measure symptoms such as temperature and cough.

The rapid spread of Covid-19 has engendered the need to increase the number of testing. Hence, robots are being employed to expedite the testing process. A cobot named Yumi has been developed in Italy to speed up serological testing. It is capable of analysing samples with a speed of 450 samples/hour. Hence by using robots, the process of disinfection, diagnosis and testing can be improvised which in turn can be helpful to reduce Covid-19 cases by a significant number. [18]

VII. CONCLUSION

This paper presented a comprehensive analysis of the recent developments in medical surgeries. Several case studies were taken into account to analyse the impacts of using advanced robots in medical surgeries. Substantial growth has been observed in the implementation of robot-assisted surgeries.

The data collected from the various studies indicated RAS to be a viable replacement over conventional surgical methods. The surgeries performed using robotic assistance had higher success rates and lesser recovery time. Robot-assisted surgical methods provide doctors with high-resolution images of the tissues involved in the surgery. This helps doctors to devise a precise operation strategy. The only downside of using RAS currently is that it increases the cost of operation by manifolds. But with the increasing demands of RAS in medical science, the cost of surgeries is likely to drop in the upcoming years. Apart from assisting in surgeries, robots have also proved helpful in diagnosing, providing medical support, nursing, disinfecting hospital rooms and helping patients with their rehabilitation. Hence it is a reasonable assumption that deploying robots in healthcare will benefit our current treatment procedures and will increase human life expectancy.

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