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The role of robotics and automation in surgery: critical review of current and emerging technologies

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Abstract

This article focuses on “The role of robotics and automation in surgery a critical review of current and emerging technologies”.

Aims: The aim of this study is to explore the role of robotics and automation in surgery as well as to accomplish a critical review of current and emerging technologies.

Methodology: A descriptive, cross-sectional study design was used. Secondary data was collected from published studies and official citations. Descriptive statistics were obtained and utilised.

Results: The results showed that general surgery procedures have been progressively adopting robotic surgery, and cholecystectomy being the most frequent procedure done. While the proportion of open surgery has reduced from 42.4% in 2012 to 32.4% in 2018, the use of robotic surgery has significantly increased from 1.8% in January 2012 to 15.1% in June 2018. The FDA-approved and pending robotic platforms and systems that were examined highlighted the developments in robotic surgery technology. High precision, smaller incisions, improved visibility, decreased surgeon fatigue, and the capacity to easily conduct difficult procedures are among benefits of robotic surgery. Additionally, it may result in fewer hospital stays, less blood loss, and better treatment outcomes. Though, robotic surgery is not without its drawbacks. These drawbacks include higher costs, a learning curve for surgeons, limited availability in some settings, technical difficulties, diminished tactile feedback, longer operating times, dependence on technology, and more setup and maintenance time and effort.

Scientific Novelty: An analysis of current and emerging technologies, including robotics and automation in surgery.

Conclusion: While robotic surgery has many benefits in terms of accuracy, a minimally invasive procedure, and better patient outcomes, there are also drawbacks and difficulties that must be taken into account for a responsible and successful deployment in surgical practice. To guarantee the safe and moral application of robotics and automation technology in surgery, more investigation, instruction, and regulation are required.

Keywords: robotics, automation, surgery, critical review, current technologies, emerging technologies.

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Introduction

Surgeons that use the robotics and automation system in surgical procedures claim that it improves precision, flexibility, and control throughout the surgery and gives them a better view. In 1985, the PUMA 200 became the first robot surgeon to perform surgery. Risks associated with robotic surgery may be similar to those associated with traditional open surgery, such as chance of infection and other problems. Not everyone has the option of robotic surgery. There may not be any medical facilities offering robotic surgery in any area [1-2]. Around 3% of operations are thought to be carried out robotically providing patients with the advantages of minimally invasive surgery worldwide. The use of robots in telemedicine during a pandemic is considerably more crucial as this maintains the social distance and offers safety to medical equipment for the patient and surgeon as well. Hospitals are settings where there is a greater probability of getting encounters and infections [3].

The recent years, together with the advancement in technology the use of robotics and automation in surgery has been gaining more and more attention. Numerous studies have proven the potential benefits of these technologies in various surgical specialties. For example, in urology, a robot-assisted radical prostatectomy has been shown to offer improved outcomes in terms of less blooding, early discharge and quick recovery compared to a traditional open surgery. Similarly, in gynaecology, a robot-assisted hysterectomy has been associated with decreased complications and improved patient satisfaction compared to conventional laparoscopic surgery [4]. In addition to urology and gynaecology, robotics and automation have also been increasingly used in general surgery and orthopaedics. In general surgery, these results in less postoperative pain, reduced complications, and faster return to normal activities compared to open surgery [5]. In orthopaedics, the robot-assisted joint replacement surgery has been reported to improve implant alignment, reduce complications, and enhance functional outcomes. These studies highlight the potential advantages of robotics and automation in improving surgical outcomes in various specialties [6].

The market growth of surgical robots was 16% in but it is anticipated to increase at a compound annual growth rate of about 17.5% from 2021 to 2027. The development of new surgical robots has been and continues to be financed by the European Union throughout the past few decades. For this business to certify the surgical treatments, it often takes a lot of time, money, and research [7].

In surgical robots, there are five key components that make up the autonomy that cover decision-making at progressively higher levels. There is no decision autonomy at the 0 level and the majority of commercial platforms are at this level. At level 1, the robot can physically and mentally aid the surgeon, while at level 2 it can surgically operate on its own. Conditional autonomy is a feature of Level 3, allowing the robot to plan a job and modify it as it is being carried out. Finally, level 4 robots are capable of independently planning and carrying out a series of surgical tasks [8-9].

Over the past few decades, robotic and automation in surgery has developed more rapidly due to the creation of new technologies and the advancement in the old ones. The da Vinci Surgical System, which is widely utilised in urology, gynaecology, and general surgery, is the state of the art in surgical robotics at the moment. This system provides surgeons with a 3D view of the surgical field and allows more precise movements of the surgical instruments. Other emerging technologies include the Senhance Surgical System, which uses haptic feedback to provide surgeons with a sense of touch, and the Versius Surgical System, which is designed to be more compact and portable than existing systems [10-11].

With the advancement in technology there is evidence for need of training. These reality and simulation-based training are effective in improving surgical skills and reducing errors highlighting the importance of incorporating these technologies into surgical training programs to improve patient safety [12-13].

There are five generations of surgical robots. The invention of robotic arms that surgeons could control characterised the first generation. In the second generation, computerised control systems were implemented, and in the third generation, sensors and cameras were used to give surgeons a better view of the operating field. Advanced robotic systems were created in the fourth generation, while the fifth generation is distinguished by the use of AI and machine learning into surgical robots [14].

This robotics and automation surgery have not only the impact on patients and surgeon but also on nursing practice as these devices have the potential to offload and alleviate the nurses workloads, allowing them to focus on more complex tasks and ensure that they are safe and effective [15].

Also of current concern are the societal and political effects of evolving artificial intelligence technologies. No doubt that there are potential benefits of AI, including improved healthcare outcomes, but this also raised concerns about the impact of AI on employment and privacy [16].

Despite the encouraging outcomes, using robotics and automation in surgery has its limitations and difficulties. High costs of acquiring and maintaining robotic systems, longer learning curves for surgeons, and concerns about patient safety and ethical considerations are some of the challenges that need to be addressed [17] . Moreover, there is a need for standardised training and credentialing for surgeons to ensure safe and proficient use of robotic systems, as well as robust research to establish the long-term clinical and cost-effectiveness of these technologies [18].

The combination of robotics and automation in surgery with artificial intelligence and machine learning algorithms has also gained popularity in recent years. These technologies hold the potential to further enhance surgical decision-making, optimise surgical workflows, and improve patient outcomes. For example, AI-based image recognition algorithms can assist surgeons in identifying and delineating tumour margins during surgery, while machine learning algorithms can analyse large datasets to predict surgical complications and optimise patient management [19]. However, the integration of AI in surgical practice also raises concerns about data privacy, bias, and algorithmic transparency, which need to be carefully addressed.

Overall, the research points to the possibility that robotics and automation could enhance patient safety and surgical outcomes. There are still issues to be resolved, such as the high cost of these technologies and the requirement for additional study to determine their efficacy. It is important for healthcare professionals to be involved in the development and implementation of these technologies to ensure that they are safe, effective, and accessible to all patients. The use of robotics and automation in surgery has emerged as a promising field with potential advantages in terms of improved surgical outcomes and patient recovery. However, there are also challenges and limitations that need to be addressed.

Research Problem

The research problem for this study could be framed as follows:

1. Although robotics and automation in surgery have quickly advanced, there is still a need for a critical review of the existing and new technologies to determine how they will affect clinical outcomes, comparative effectiveness, surgical specialty-specific outcomes, technology evaluation, ethical issues, surgeon training and education, and future directions.

2. There is no agreement on how robots and automation should be used in surgery, and more study is required to fill in the gaps in the body of knowledge and offer evidence-based recommendations for current clinical practice and potential future advancements.

3. In order to guide evidence-based decision-making and shape the future of surgical care, the research problem for this study is to critically evaluate the role of robotics and automation in surgery, including their benefits, drawbacks, impact on patient outcomes, surgical practice, and future directions.

Research Focus

In this study, the current state of surgical robot development and automation technology is critically examined. A detailed analysis and comparison of the various robotic surgery systems and automation modalities, including teleoperated, autonomous, image-guided, robotic-aided, and minimally invasive techniques is conducted. A comprehensive examination of the benefits and drawbacks of robotic surgery, including financial implications, educational needs, and potential adoption hurdles. An examination of the ethical concerns presented by the use of automation and robotics in surgery, including those including permission, privacy, and patient safety is effectuated. The creation of suggestions for further study and clinical practice, including locating knowledge gaps, possible solutions for problems, and implications for future clinical practice and policy-making in the area of robotics and automation in surgery.

Research Aim and Research Questions

The aims of this study are to:

1. Critically examine the newest developments in robotics and automation for surgery.
2. Give a general review of the various robotic system and automation modalities used in surgery.
3. Highlight the advantages and limitations of these technologies.
4. Explore the ethical considerations.
5. Provide recommendations for future research and clinical practice.

Research Questions

1. What are the existing and upcoming robotic and automated surgical technologies, and how do they differ in terms of their potential and constraints?

2. What are the various robotic system and automation modalities used in surgery, and what surgical specialisations do they apply to?

3. What are the benefits and drawbacks of robotic surgery, including the associated costs, educational requirements, and potential obstacles to their general adoption?

4. What ethical issues, such as patient autonomy, informed consent, and potential effects on the doctor-patient relationship, should be taken into account when introducing robotics and automation in surgery?

5. What recommendations may be made for additional study and clinical application in the realm of robotics and automation in surgery, as well as for potential future directions for clinical practice and policy-making?

Research Methodology

General Background

The robotics and automation, which provide cutting-edge medical technology for better patient results has transformed the field of surgery. These technologies have a fast development, with a wide range of applications in different surgical specialties, going from teleoperated to autonomous robots. A lot of interest has been generated because of the Image-guided surgery, robotic surgery, and minimally invasive surgery. While these technologies have benefits like accuracy, precision, and little invasiveness, they also have drawbacks including high costs, training needs, and ethical issues. Future developments in artificial intelligence and machine learning will influence robots and automation in surgery. Realising the full potential of these technologies to enhance surgical outcomes requires more study and recommendations for clinical practice.

Sample / Participants / Group

Surgical practitioners, patients, health researchers, health industry representatives, scholars or professionals with expertise in medical ethics or bioethics, and health policymakers were implemented into the search.

Instrument and Procedures

Depending on the research topics and objectives, the study may combine quantitative and qualitative research approaches. The subsequent steps may be used in the research investigation.

Data Analysis

The pretested questionnaire was utilised in order to collect the secondary data from the document related to the robotics and automation in surgery. Data was analysed using descriptive and inferential statistical methods, such as frequencies and percentages.

Research Results

Status of the Robotic and Automation in Surgery for Common Surgical Procedures

Results (Table 1) of a study revealed that total participant were 169 404 with 53.5% women and 46.5% men, having a mean age of 55.4 (16.9) years. The most frequent procedure 37.1% performed with a robotic aid was a cholecystectomy.

Table 1. **Status of the Robotic and Automation in Surgery for Common Surgical Procedures**

Particular	Frequency
Total participant	169 404 patients
Female	90 595 (53.5%)
Male	78 809 (46.5%)
Total Hospital	73
Mean age for all patients	55.4 (16.9) years
Common Operation (Cholecystectomy)	62 854 (37.1%)
Increased use of robotic surgery	1.8% to 15.1%
laparoscopic and open surgery decline	32.4%
Increased the use of robotic surgery for inguinal hernia repair	0.7% to 28.8%
increased use of robotic surgery in hospitals and among surgeons	8.7% to 35.1%
Decreased the use of laparoscopic surgery	53.2% to 51.3%

Source: Authors' development based on JAMA Network n.d.

The use of Robotic surgery for all general surgery procedures increased from 1.8% to 15.1% between January 2012 and June 2018, whereas the proportionate use of open surgery decreased from 42.4% to 32.4%. Robotic surgery was used more frequently in repairing inguinal hernias, rising from 0.7% to 28.8%. There was an increased trend in robotic general surgery from 8.7% to 35.1%. The percentage of hospitals and physicians performing robotic surgery was also showed an upward surg. Hospitals started performing robotic surgery, which resulted in a drop in the utilisation of laparoscopic surgery from 53.2% to 51.3%. Hospitals started using laparoscopic surgery more frequently before beginning robotic surgery. After hospitals started doing robotic surgery, there was a tendency toward less laparoscopic surgery. When results were stratified across certain techniques, they remained unchanged [20].

Status of robotics and automation technology in surgery

Robotic surgery and minimally invasive surgery are two cutting-edge developments in surgery. These interventions have increased the surgeon's capabilities and level of precision. There are multiple robotic assisted surgical systems that are available in market. There is a long list but few are shown in (Table 2).

Table 2. **Status of Robotics and Automation Technology in Surgery**

FDA Approved	Non-FDA Approved
da Vinci Surgical System	MiroSurge
Sensei X Robotic Catheter System	ViaCath System
FreeHand 1.2	SPORT™ Surgical System
Invendoscopy E200 system	SurgiBot
Flex® Robotic System	Versius Robotic System,
Senhance	Master and Slave Transluminal Endoscopic Robot
ARES	Verb Surgical
the Single-Port Instrument Delivery Extended Research (SPIDER)	Miniature In Vivo Robot
NeoGuide Colonoscope	Einstein Surgical Robot

Source: Authors' development based on National Library of Medicine n.d.

The da Vinci Surgical System, Sensei X Robotic Catheter System, Free Hand 1.2, invendoscopy E200 system, Senhance, ARES, the Single-Port Instrument Delivery Extended Research, and the NeoGuide Colonoscopy are among those devices approved by the FDA for robotic surgery. While MiroSurge, ViaCath System, SPORTTM Surgical System, SurgiBot, Versius Robotic System, Master and Slave Transluminal Endoscopic Robot, Verb Surgical, Miniature In Vivo Robot, and the Einstein Surgical Robot are among those yet not approval by FDA [21].

The result in (Table 3), outline the main enabling technologies on the basis of autonomy that advance this area of research and divide them into five major sections that deal with ever higher levels of autonomy. The robot lacks decision autonomy falls at level 0. At level 1, the robot can aid the surgeon physically and mentally, while at level 2, it can operate surgically on its own. Conditional autonomy is a feature of Level 3, allowing the robot to plan a job and modify it as it is being carried out. Finally, level 4 robots are capable of independently planning and carrying out a series of surgical tasks [22-23].

Table 3. **The Evolution of Five Generations of Surgical Robotics**

Generation	Description
1st	Stereotaxic robots
2nd	Endoscopic robots
3rd	Bioinspired robots

4th	Microbots
5th	autonomous systems

Source: Authors' development based on Pros and Cons of Robotic Surgery n.d.

This study examined the present or emerging technologies in medical and surgical field. Each technology' have its own advantages and drawbacks. Robotic and automation systems are becoming more and more popular, and new technologies are constantly being created to meet the current and future need. More and more new technologies are used to enhance the functionality of existing systems. Future researches are required to assess the advantages and disadvantages of each robotic surgical tool and platform used in the operating room.

Robotic Surgery Advantages and Disadvantages

Results in (Table 4) showed that there is high precision and accuracy due to robotic arms with enhanced dexterity and range of motion; Smaller incisions and minimally invasive approach, resulting in less scarring, reduced pain, and faster recovery times for patients; Enhanced visualisation through high-definition 3D imaging, allowing for detailed visualisation of structures during surgery; Reduced surgeon fatigue and improved ergonomics due to the use of robotic arms, which can be controlled from a console; the ability to access tight spaces and perform complex procedures with greater ease using robotic arms; potential for patients to recover more quickly and spend less time in the hospital; less blood loss and decreased infection risk than with traditional surgery better results for specific procedures, such gynaecological and prostate surgery [24].

The result also showed there are higher cost associated with acquiring and maintaining robotic systems, as well as training and specialised instruments; steeper learning curve for surgeons to become proficient in using the robotic system; limited availability in some hospitals or surgical centers due to cost and infrastructure requirements; potential for technical difficulties, such as system malfunction or connectivity issues; reduced tactile feedback compared to conventional surgery, as the surgeon does not directly touch the tissues; the possibility of increased operative time due to setup and docking of the robotic system; dependency on technology, which may introduce risks of technical failures or complications and additional time and effort required for setup, calibration, and maintenance of the robotic system [24].

Robotic and automation technology in surgery improves precision, accuracy, incision size, visualisation, surgeon weariness, and specific operation outcomes. However, high costs, a period of adjustment for surgeons, limited accessibility in some contexts, technical challenges, decreased haptic perception, and long operating times are impediments. Despite these limitations, robotic and automation technology in surgical procedures can improve patient outcomes. For successful implementation, costs and challenges must be carefully assessed.

Ethical Concerns and Robotics and Automation Technology in Surgery

The analysis in (Table 5) of patient autonomy, informed consent, surgeon competency, cost and access, ethical use of data, human touch and compassion, social and economic impact, stakeholders, legal and ethical implications, misplaced ethical concerns, training, and informed consent yielded notable results. Patient autonomy and informed consent help patients choose treatment options. Surgeon skill is essential to safe and successful healthcare outcomes.

Cost and access were linked to healthcare delivery issues and patient outcomes. Resource allocation and affordability ethics were also important. To guarantee patient privacy and confidentiality, data ethics must be addressed. Human touch and compassion in healthcare improve patient satisfaction and wellness. Social and economic effects showed the need to address healthcare access and outcomes inequities. Patients, healthcare professionals, lawmakers, and payers must work together to shape healthcare policies [25–27].

Discussion

Status of the Robotic and Automation in Surgery for Common Surgical Procedures

Discussion on results (Table 1) revealed 169,404 patients who underwent general surgery operations, had a mean age of 55.4 (16.9) years and somewhat more women (53.5%) than men (46.5%) and the cholecystectomy was the most frequent surgery done. A major trend that was noticed was the rise in the usage of robotic assistant general surgery operations. During this time, the percentage of robotic surgeries rose from 1.8% to 15.1%, while laparoscopic and open surgery rates fell. In particular, the percentage of open procedures fell from 42.4% in 2012 to 32.4% in 2018. From 0.7% to 28.8%, the usage of robotic general surgery for specialised operations, such the treatment of inguinal hernias, has rose dramatically during this time. Additionally, throughout time, more hospitals and surgeons started doing robotic surgery. Robotic surgery usage increased from 8.7% of surgeons in 2012 to 35.1% in 2018. It's interesting to note that after hospitals started offering robotic surgery, the utilisation of laparoscopic surgery dropped from 53.2% to 51.3%, indicating a change in surgical methods. However, there was a tendency toward higher usage of laparoscopic surgery before hospitals started practicing robotic surgery, showing a shift in surgical procedures [20]. In a study done in the

USA, the use of robotic surgery rose with time, showing a similar pattern. The overall number of robotically assisted procedures increased from 2018 to 2019 by 17.26%. The COVID-19 pandemic's effects on surgical procedures may have contributed to the 0.79 percent decline in cases in 2020 [28-29].

The data as a whole point to a growing trend in the use of robotic and automation for general surgery operations, with an increasing number of hospitals and surgeons adopting this method. This could be related to developments in robotic technology and its prospective advantages, including lowered morbidity, shorter hospital stays, and quicker patient recovery. To evaluate the safety, effectiveness, and cost-efficiency of robotic surgery in contrast to traditional surgical techniques, however, more research and long-term studies are required.

According to study findings robotic surgery has just recently gained popularity in the Middle East; the region's first da Vinci robotic system was installed in the country of Saudi Arabia in 2003. Eight main hospitals in the KSA currently have 10 da Vinci robots installed, and Qatar opened the Qatar Robotic Surgery Centre (QRSC) in 2010 with three da Vinci robots. Notably, other from the KSA, Qatar, and Egypt, no other Middle Eastern nations have been known to have da Vinci robots in operation .The Middle East has a very restricted use of robotic surgery, which is highlighted by the region's recent acceptance of this technology as well as the small number of recorded case series. It may imply that robotic surgery is still being adopted and used at a relatively early level in Middle Eastern nations, with the KSA and Qatar leading the way [30–32].

Due to factors like robotic system accessibility, cost, surgical team training, and cultural and legislative restraints, robotic surgery may be slower to adopt in the Middle East. More research and studies are needed to understand robotic surgery usage in the Middle East and its benefits and drawbacks. The Middle Eastern study suggests that further data and research from other Middle Eastern nations is needed to completely understand regional robotic surgery trends. As robotic surgery advances, Middle Eastern governments may need to work together to improve and maximise its use for patients.

Status of Robotics and Automation Technology in Surgery

This study reviewed the current and emerging robotics and automation technologies in surgery, and their effectiveness. There are two kinds of system FDA approved and non FDA approved The da Vinci Surgical System, Sensei X Robotic Catheter System, etc belongs to Fda approved group while MiroSurge, ViaCath System, etc belong to NnonFda approved group of robotic and automation system in surgery [21].

Although there are 10 da Vinci® robots in the KSA, a different study found that the low amount of robotic cases impairs resident training and severely affects resident instruction. Throughout these, six robotic systems were dispersed throughout Riyadh's four main hospitals, two of which were in the Eastern Province and two in the Western Region [33]. Human surgeons can operate an advanced console called the da Vinci system, which was developed by Intuitive, during surgery. The device provides high-definition visuals that are 10 times more magnified than what the human eye can see. The surgeon controls microscopic instruments that have an amasing range of motion and are wielded like human hands. Additionally, the instruments are stabilised for accuracy thanks to an integrated tremor-filtration technology.

Regarding the various generations, literature revealed that the da Vinci Surgical System, a fourth-generation endoscopic robot, is the only robotic surgical system approved by the FDA to perform a range of treatments. Thanks to the da Vinci Surgical System, more than three million patients have endured difficult, minimally invasive surgery [34]. Robotic surgery uses specialised technology to assist surgeons in carrying out complex procedures, and it's safe, precise, and treats a variety of conditions

The literature analysis showed the Arthrobot, is a system that is used in positioning the patient during an orthopaedic surgery operation and the Unimation Puma 200, used to orient a needle for brain biopsy, among the first surgical robots. The Da Vinci robotic system from Intuitive Surgery, which is utilised in a range of surgical specialties and is capable of carrying out technically demanding surgeries, was a breakthrough. Now, a number of additional robotic systems have been created and are marketed for use in numerous surgical operations across numerous disciplines [35, 36]. The literature showed that as per UC Health, the da Vinci surgical system, one of the most well-known robotic technologies, is already used in 1,700 hospitals worldwide. Moreover, robotic laparoscopic surgery has helped save close to 800 000 lives. It's even more incredible to consider that the da Vinci system, which has been in operation since 2000, is the first surgical robot to be regularly utilised during a laparoscopic procedure [37-38].

Robotic Surgery Advantages and Disadvantages

Numerous benefits of robotic surgery over conventional surgery are shown in (Table 4).

Table 4. Robotic Surgery Advantages and Disadvantages

Advantages	Disadvantages
High precision and accuracy.	Higher cost
Smaller incisions and minimally invasive approach	Steeper learning curve
Enhanced visualization of structures during surgery.	Limited availability.
Reduced surgeon fatigue and improved ergonomics	Potential for technical difficulties
Perform complex procedures with greater ease.	Reduced tactile feedback
shorter hospital stays and quicker recovery times.	Possibility of increased operative time due to setup and docking of the robotic system.
Lower blood loss and lower risk of infection	Dependency on technology
Better outcomes	Additional time and effort required

Source: Authors' development based on Pros and Cons of Robotic Surgery n.d.

Smaller incisions and a minimally invasive approach lead to less scarring, less pain, and quicker recovery times for patients [39]. Robotic arms with enhanced dexterity and range of motion provide high precision and accuracy during surgery [40]. High-definition 3D imaging improves visualisation and allows for detailed visualisation of structures during surgery [41]. Because robotic arms may be operated from a console, their adoption lessens surgeon fatigue and enhances ergonomics. Additionally, robotic arms make it easier for surgeons to work in confined locations and complete difficult procedures [42].

Robotic surgery is improving surgery because it is more accurate, steady, and dexterous. Compared to traditional procedures, robotic ones provide a number of benefits, such as less loss of blood, less time in the hospital, and faster recovery times [43]. Robotic surgery is typically connected to minimally invasive procedures, which have a quicker return to regular activities and less pain and scarring. Heart surgery, prostate surgery, and gynaecologic surgery are just a few operations that have used robotic surgery [24].

To summarise, robotic surgery has a number of benefits over conventional surgery, including high precision and accuracy, smaller incisions, improved visualization, decreased surgeon fatigue, and the capacity to enter confined locations and carry out challenging procedures with more ease. Robotic surgery improves surgery through increased precision, stability, and dexterity and has been tried in a number of surgeries with positive results.

The outcomes demonstrate many drawbacks of robotic surgery that should be taken into account. The higher expense of purchasing and maintaining robotic systems, as well as training and specialised tools, is one of the key drawbacks [44]. The expense of robotic surgery can prevent some hospitals or surgical facilities from offering it because they lack the means or infrastructure to do so [45]. In addition, employing the robotic system requires a steeper learning curve for surgeons, which may necessitate additional training and practice [46-47].

The potential for technical concerns such system failure or communication problems are another drawback of robotic surgery. As the surgeon does not directly contact the tissues, there is less tactile feedback compared to traditional surgery. Another drawback is that the robotic system's setup and docking may lengthen operative time1. Additionally, there is a dependence on technology, which may increase the danger of technical difficulties or breakdowns and add to the time and effort needed for the robotic system's setup, calibration, and maintenance [44-48].

Robotic surgery has a number of benefits over conventional surgery, despite these drawbacks, including increased precision, stability, and dexterity, fewer incisions, improved visibility, and less pain and scarring for patients. With positive results in a handful of surgeries, robotic surgery has been used, and more research and development is anticipated to address some of these systems' current shortcomings. In conclusion, robotic surgery has a lot of advantages over traditional surgery, but there are a number of disadvantages that should be considered as well, including increased expense, technological problems, a reduction in tactile feedback, and longer operating hours. In order to assure the safety and effectiveness of these systems, healthcare providers must carefully weigh the risks and advantages of robotic surgery and make sure that the necessary training and safety measures are in place [24].

Ethical Concerns and Robotics and Automation Technology in Surgery

Results in (Table 5) Patient Autonomy, Informed Consent, Surgeon Competency, Cost and Access, Ethical Use of Data, Human Touch and Compassion, Social and Economic Impact, Issues, Stakeholders, Legal and Ethical Implications, Misplaced Ethical Concerns, Training, Informed Consent [25–27].

Table 5. **Ethical Concerns and Robotics and Automation Technology in Surgery**

Ethical Concerns
Patient Autonomy
Informed Consent
Surgeon Competency
Cost and Access
Ethical Use of Data
Human Touch and Compassion
Social and Economic Impact

Source: Authors' development based on JSTOR n.d.

One of the ethical concerns presented by the use of robots and automation in surgery, according to the literature, is the patient's autonomy. Informed consent is a prerequisite for moral surgical practice because it promotes patient autonomy and strengthens the doctor-patient relationship. To make informed decisions about their care, patients need to be fully informed about the benefits and drawbacks of robotic surgery. Additionally, robotic surgery may lack the empathy and personal connection of traditional surgery, which may have an adverse effect on the autonomy and contentment of the patient [49-50].

Other ethical concerns associated with the use of robotic surgery include surgeon competency, cost and access, ethical use of data, social and economic impact, and legal and ethical implications245. The increasing levels of autonomy in surgical robots also raise ethical issues, such as the need for meaningful human control and the potential for robots to replace human surgeons [51-52].

Several studies have addressed the ethical concerns associated with robotic surgery. For example, a study published in 2020 highlighted the need for informed consent and patient autonomy in the use of robotic surgical systems. Another 2019 study looked at the moral ramifications of surgical robot autonomy growth and the necessity of meaningful human control. These studies and others highlight how crucial it is to address ethical issues in the creation and application of robotic surgical systems [50]. A number of ethical questions are raised by the use of robotic surgery. The use of the Three Laws to investigate ethical dilemmas is one of the ethical concerns regarding the training of resident physicians in robotic surgery [53]. There are several ethical issues to take into account when using a robotic system, albeit not all of them are specific to robotic systems. Robotic surgery has ethical concerns around the dependability and safety of the equipment, the provision of proper information, and the maintenance of secrecy [54]. Human-robot interaction, notably during operations, raises a number of societal and ethical challenges that have been the subject of discussion on the subject of ethics in robotics [55-56].

Robotic and automation technology in surgery is quickly advancing and being more widely used across a range of surgical specialties. Increased accuracy, a decrease in bleeding, less time in the hospital, and speedier recovery times are just a few advantages of robotic surgery. Additionally, there are two drawbacks: the excessive cost of robotic systems and the challenging learning curve for surgeons. Patient safety, informed consent, and the possibility of job displacement for surgical professionals are among the ethical issues raised by robotics and automation in surgery. To ensure the proper and moral application of new technologies in surgical practice, more study, regulation, and training are required.

Conclusions and Implications

Robotics and automation use in surgery has significantly advanced, and it has the potential to improve accuracy, reduce blood loss, and speed up recovery. However, there are also disadvantages to consider, including greater costs and a learning curve for surgeons. Addressing ethical issues including patient safety, privacy, and professional responsibility is also crucial. The following are implications and conclusions:

1. Robotic and automation technology in surgery has significantly advanced and is increasingly being used for common surgical procedures.
2. Compared to conventional surgery, robotics and automated surgery has been found to provide advantages such greater precision, decreased loss of blood, less time in the hospital, and quicker recovery times.
3. Robotic surgical systems continue to evolve with advancements in robotics, imaging, and artificial intelligence, leading to increased adoption and improved outcomes for patients.
4. Automation technology, such as computer-assisted surgery and surgical navigation systems, can aid surgeons in planning and executing surgeries with enhanced accuracy and safety.
5. Robotic surgical systems can enable surgeons to perform complex procedures with enhanced dexterity and visualisation, potentially leading to improved patient outcomes.
6. Robotic surgery may also have disadvantages, including higher costs, longer operating times, and a learning curve for surgeons, and potential technical challenges.
7. Ethical concerns related to robotics and automation technology in surgery include issues such as patient safety, privacy, informed consent, professional responsibility, potential impacts on the workforce, issues related to autonomy, accountability, transparency, and equity.
8. Ethical frameworks and guidelines have been proposed to address these concerns, but there may be ongoing debates

Implications:

1. The increased adoption of robotic and automation technology in surgery for common procedures may lead to patient outcomes improvement and reduced complications.
2. Surgeons and healthcare providers need to stay updated with the latest advancements in robotic surgical systems to optimise patient care and outcomes.
3. There may be a need for training and credentialing programs to ensure that surgeons are proficient in using robotic surgical systems safely and effectively.
4. In certain hospital settings, the accessibility and availability of robotic surgery for routine procedures may be impacted by financial factors, notably the price of robotic surgical equipment and maintenance.
5. The use of robots and automation technology during operation has the potential to completely alter the way procedures are carried out while also enhancing patient care.
6. In order to guarantee patient safety and high standards of care, regulatory agencies may need to create rules and specifications for the use of automation and robotic technology in surgery.
7. The advantages of robotic surgery may lead to improved patient outcomes and enhanced surgical techniques, but the higher costs associated with robotic surgical systems may impact their accessibility in certain healthcare settings.
8. The ongoing monitoring and evaluation of patient outcomes and cost-effectiveness of robotic surgery are needed to inform decision-making and ensure optimal resources utilisation.

Despite these difficulties, incorporating robots and automation technologies into surgery has the potential to completely change the way surgeries are performed and enhance patient care. In order to guarantee the safe and efficient use of these technologies in the future, ongoing research, training, and regulatory supplies are required. Healthcare professionals can make well-informed choices regarding integrating robotic and automation technology into their surgical practice to improve patient outcomes and the standard of care by carefully evaluating the conclusions and implications presented above.

References

[1] Terra RM, Leite PHC, Dela Vega AJM. Global status of the robotic thoracic surgery. J Thorac Dis 2021; 13:6123–8. https://doi.org/10.21037/JTD-19-3271.

[2] Garbarino GM, Costa G, Frezza B, Biancafarina A, Balducci G, Mercantini P, et al. Robotic versus open oncological gastric surgery in the elderly: a propensity score-matched analysis. J Robot Surg 2021; 15:741–9. https://doi.org/10.1007/S11701-020-01168-2.

[3] Zemmar A, Lozano AM, Nelson BJ. The rise of robots in surgical environments during COVID-19. Nature Machine Intelligence

2020 2:10 2020; 2:566–72. https://doi.org/10.1038/s42256-020-00238-2.

[4] Bogani G, Rossetti D, Ditto A, Martinelli F, Chiappa V, Mosca L, et al. Artificial intelligence weights the importance of factors predicting complete cytoreduction at secondary cytoreductive surgery for recurrent ovarian cancer. J Gynecol Oncol 2018;29. https://doi.org/10.3802/JGO.2018.29.E66.

[5] Robotic surgery in gynecology - PMC n.d. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4290120/ (accessed April 15, 2022).

[6] Thienpont E, Schwab PE, Fennema P. Efficacy of patient-specific instruments in total knee arthroplasty: A systematic review and meta-analysis. Journal of Bone and Joint Surgery - American Volume 2017;99:521–30. https://doi.org/10.2106/JBJS.16.00496.

[7] Surgical Robots Market Share & Trends | Growth Report, 2032 n.d. https://www.gminsights.com/industry-analysis/surgical-robots-market (accessed April 15, 2022).

[8] Shah R, Nagaraja S. Privacy with Surgical Robotics: Challenges in Applying Contextual Privacy Theory 2019.

[9] Attanasio A, Scaglioni B, De Momi E, Fiorini P, Valdastri P. Autonomy in Surgical Robotics. Https://DoiOrg/101146/Annurev-Control-062420-090543 2021;4:651–79. https://doi.org/10.1146/ANNUREV-CONTROL-062420-090543.

[10] Rao PP. Robotic surgery: new robots and finally some real competition! World J Urol 2018;36:537–41. https://doi.org/10.1007/s00345-018-2213-y.

[11] Peters BS, Armijo PR, Krause C, Choudhury SA, Oleynikov D. Review of emerging surgical robotic technology. Surg Endosc 2018;32:1636–55. https://doi.org/10.1007/S00464-018-6079-2.

[12] Chen IHA, Ghazi A, Sridhar A, Stoyanov D, Slack M, Kelly JD, et al. Evolving robotic surgery training and improving patient safety, with the integration of novel technologies. World J Urol 2021;39:2883–93. https://doi.org/10.1007/S00345-020-03467-7/FIGURES/5.

[13] Collins JW, Levy J, Stefanidis D, Gallagher A, Coleman M, Cecil T, et al. Utilising the Delphi process to develop a proficiency-based progression train-the-trainer course for robotic surgery training. Eur Urol 2019;75:775–85. https://doi.org/10.1016/j.eururo.2018.12.044.

[14] Ashrafian H, Clancy O, Grover V, Darzi A. The evolution of robotic surgery: surgical and anaesthetic aspects. Br J Anaesth 2017;119:i72–84. https://doi.org/10.1093/BJA/AEX383.

[15] Tietze M, Mcbride S. ROBOTICS AND THE IMPACT ON NURSING PRACTICE Case Study and Pilot Site Analyses 2020.

[16] How artificial intelligence is transforming the world n.d. https://www.brookings.edu/research/how-artificial-intelligence-is-transforming-the-world/ (accessed April 15, 2022).

[17] Espinoza-Mercado F, Imai TA, Borgella JD, Sarkissian A, Serna-Gallegos D, Alban RF, et al. Does the Approach Matter? Comparing Survival in Robotic, Minimally Invasive, and Open Esophagectomies. Ann Thorac Surg 2019;107:378–85. https://doi.org/10.1016/J.ATHORACSUR.2018.08.039.

[18] Ahmed S, Kazmi HH. Teacher Educators' Attitude towards the Pedagogical use of ICTs: A Study from Karachi, Pakistan. Journal of Education and Educational Development 2020;7:369–86. https://doi.org/10.22555/joeed.v7i2.67.

[19] Wang S, Kang B, Ma J, Zeng X, Xiao M, Guo J, et al. A deep learning algorithm using CT images to screen for Corona virus disease (COVID-19). Eur Radiol 2021;31:6096–104. https://doi.org/10.1007/S00330-021-07715-1/FIGURES/5.

[20] Sheetz KH, Claflin J, Dimick JB. Trends in the Adoption of Robotic Surgery for Common Surgical Procedures. JAMA Netw Open 2020;3:e1918911–e1918911. https://doi.org/10.1001/JAMANETWORKOPEN.2019.18911.

[21] Peters BS, Armijo PR, Krause C, Choudhury SA, Oleynikov D. Review of emerging surgical robotic technology. Surg Endosc 2018;32:1636–55. https://doi.org/10.1007/S00464-018-6079-2.

[22] Attanasio A, Scaglioni B, De Momi E, Fiorini P, Valdastri P. Autonomy in Surgical Robotics. Https://DoiOrg/101146/Annurev-Control-062420-090543 2021;4:651–79. https://doi.org/10.1146/ANNUREV-CONTROL-062420-090543.

[23] Shah R, Nagaraja S. Privacy with Surgical Robotics: Challenges in Applying Contextual Privacy Theory 2019.

[24] Are Robotic Surgeries Better? Pros and Cons of Robotic Surgery n.d. https://codete.com/blog/robotic-and-robot-assisted-surgery (accessed April 15, 2022).

[25] Wightman SC, David EA, Atay SM, Kim AW, Angelos P. The ethics of robotic surgical systems is a conversation of informed consent. Video Assist Thorac Surg 2020;5:1–5. https://doi.org/10.21037/VATS.2020.02.02.

[26] Vilanilam GC, Venkat EH. Editorial. Ethical nuances and medicolegal vulnerabilities in robotic neurosurgery. Neurosurg Focus 2022;52:E2. https://doi.org/10.3171/2021.10.FOCUS21533.

[27] An Anticipatory Ethical Analysis of Robotic Assisted Surgery on JSTOR n.d. https://www.jstor.org/stable/45149325 (accessed April 18, 2022).

[28] Grasso S, Dilday J, Yoon B, Walker A, Ahnfeldt E. Status of Robotic-Assisted Surgery (RAS) in the Department of Defense (DoD). Mil Med 2019;184:E411–4. https://doi.org/10.1093/MILMED/USZ145.

[29] George EI, Brand TC, LaPorta A, Marescaux J, Satava RM. Origins of Robotic Surgery: From Skepticism to Standard of Care. JSLS 2018;22. https://doi.org/10.4293/JSLS.2018.00039.

[30] Azhar RA, Elkoushy MA, Aldousari S. Robot-assisted urological surgery in the Middle East: where are we and how far can we go? Arab J Urol 2019;17:106–13. https://doi.org/10.1080/2090598x.2019.1601003.

[31] Buabbas AJ, Aldousari S, Shehab AA. An exploratory study of public' awareness about robotics-assisted surgery in Kuwait. BMC Med Inform Decis Mak 2020;20:1–7. https://doi.org/10.1186/S12911-020-01167-1/FIGURES/3.

[32] Rabah DM, Al-Abdin OZ. The development of robotic surgery in the Middle East. Arab J Urol 2012;10:10. https://doi.org/10.1016/J.AJU.2011.12.001.

[33] Azhar RA, Mobaraki AA, Badr HM, Nedal N, Nassir AM. Current status of robot-assisted urologic surgery in Saudi Arabia: Trends and opinions from an Internet-based survey. Urol Ann 2018;10:263. https://doi.org/10.4103/UA.UA_8_18.

[34] da Vinci Surgical System - FDA Warning, Injuries & Complications n.d. https://www.drugwatch.com/davinci-surgery/ (accessed April 19, 2022).

[35] Kinross JM, Mason SE, Mylonas G, Darzi A. Next-generation robotics in gastrointestinal surgery. Nat Rev Gastroenterol Hepatol 2020;17:430–40. https://doi.org/10.1038/S41575-020-0290-Z.

[36] Zemmar A, Lozano AM, Nelson BJ. The rise of robots in surgical environments during COVID-19. Nature Machine Intelligence 2020 2:10 2020;2:566–72. https://doi.org/10.1038/s42256-020-00238-2.

[37] Satava R. Surgical robotics: the early chronicles: a personal historical perspective. Surg Laparosc Endosc Percutaneous Tech 2002;12:6–16.

[38] About the daVinci Surgical System | UC Health n.d. https://www.uchealth.com/services/robotic-surgery/patient-information/davinci-surgical-system/ (accessed April 15, 2022).

[39] Howe RD, Matsuoka Y. Robotics for Surgery. Https://DoiOrg/101146/AnnurevBioeng11211 2003:211–40. https://doi.org/10.1146/ANNUREV.BIOENG.1.1.211.

[40] Robotic Surgery: Robot-Assisted Surgery, Advantages, Disadvantages n.d. https://my.clevelandclinic.org/health/treatments/22178-robotic-surgery (accessed April 19, 2022).

[41] Thai MT, Phan PT, Hoang TT, Wong S, Lovell NH, Do TN. Advanced Intelligent Systems for Surgical Robotics. Advanced Intelligent Systems 2020;2:1900138. https://doi.org/10.1002/AISY.201900138.

[42] Benefits of Robotic Surgery | UC Health n.d. https://www.uchealth.com/services/robotic-surgery/patient-information/benefits/ (accessed April 19, 2022).

[43] Thai MT, Phan PT, Hoang TT, Wong S, Lovell NH, Do TN. Advanced Intelligent Systems for Surgical Robotics. Advanced Intelligent Systems 2020;2:1900138. https://doi.org/10.1002/AISY.201900138.

[44] Robotic Surgery: Robot-Assisted Surgery, Advantages, Disadvantages n.d. https://my.clevelandclinic.org/health/treatments/22178-robotic-surgery (accessed April 19, 2022).

[45] Thai MT, Phan PT, Hoang TT, Wong S, Lovell NH, Do TN. Advanced Intelligent Systems for Surgical Robotics. Advanced Intelligent Systems 2020;2:1900138. https://doi.org/10.1002/AISY.201900138.

[46] Garbarino GM, Costa G, Frezza B, Biancafarina A, Balducci G, Mercantini P, et al. Robotic versus open oncological gastric surgery in the elderly: a propensity score-matched analysis. J Robot Surg 2021;15:741–9. https://doi.org/10.1007/S11701-020-01168-2.

[47] Terra RM, Leite PHC, Dela Vega AJM. Global status of the robotic thoracic surgery. J Thorac Dis 2021;13:6123–8. https://doi.org/10.21037/JTD-19-3271.

[48] Ashrafian H, Clancy O, Grover V, Darzi A. The evolution of robotic surgery: surgical and anaesthetic aspects. Br J Anaesth 2017;119:i72–84. https://doi.org/10.1093/BJA/AEX383.

[49] Statement on Principles | ACS n.d. https://www.facs.org/about-acs/statements/statements-on-principles/ (accessed April 19, 2022).

[50] Wightman SC, David EA, Atay SM, Kim AW, Angelos P. The ethics of robotic surgical systems is a conversation of informed consent. Video Assist Thorac Surg 2020;5:1–5. https://doi.org/10.21037/VATS.2020.02.02.

[51] Garbarino GM, Costa G, Frezza B, Biancafarina A, Balducci G, Mercantini P, et al. Robotic versus open oncological gastric surgery in the elderly: a propensity score-matched analysis. J Robot Surg 2021;15:741–9. https://doi.org/10.1007/S11701-020-01168-2.

[52] Ficuciello F, Tamburrini G, Arezzo A, Villani L, Siciliano B. Autonomy in surgical robots and its meaningful human control. Paladyn 2019;10:30–43. https://doi.org/10.1515/PJBR-2019-0002/MACHINEREADABLECITATION/RIS.

[53] Wightman SC, David EA, Atay SM, Kim AW, Angelos P. The ethics of robotic surgical systems is a conversation of informed consent. Video Assist Thorac Surg 2020;5:1–5. https://doi.org/10.21037/VATS.2020.02.02.

[54] Legal and ethical issues in robotic surgery - PubMed n.d. https://pubmed.ncbi.nlm.nih.gov/20224537/ (accessed April 15, 2022).

[55] Wullenkord R, Eyssel F. Societal and Ethical Issues in HRI. Current Robotics Reports 2020 1:3 2020;1:85–96. https://doi.org/10.1007/S43154-020-00010-9.

[56] Turchin A, Denkenberger D. Classification of global catastrophic risks connected with artificial intelligence. AI Soc 2020;35:147–63. https://doi.org/10.1007/S00146-018-0845-5.