Role of Robotics in Endovascular Surgery: Improving Outcomes in Vascular Interventions

Muhammad Raheel

Department of Business and Management, University of Greenwich, London, UK.

Abstract

Humans have been fascinated by robots for thousands of years, yet the first time a robot was employed in medical was just around 35 years ago. Since then, urology, general surgical specialties, and gynecology have seen a rise in the use of robot-assisted treatments. When it was originally presented in 2002, robot-assisted vascular surgery was believed to address the drawbacks of laparoscopy. It did not, however, become very popular, and only a small number of centers throughout the world currently use it. On the other hand, albeit still in their infancy, robot-assisted endovascular treatments have emerged as a viable substitute for current methods. For vascular and endovascular surgeons, the advancements in robotic technology encourage improved surgical performance and lower workplace risks. Using the search keywords "robotic," "robot assisted," "vascular surgery," and "aortic" for surgical operations or "robotic," "robot assisted," and "endovascular" for endovascular procedures, a thorough literature evaluation was conducted. Included were full-text publications released from 2000 to March 2021. The results, benefits, drawbacks, and viewpoints of the latest advancements in robot-assisted vascular and endovascular surgical procedures are included in this paper.

Keywords

Robotics (RR), Endovascular Surgery (ES), Vascular Interventions (VI)

Disclosure: The authors have no conflicts of interest to declare.

Received: 28 May 2024 Accepted: 25 October 2024 Citation: *Vascular & Endovascular Review* 2024;7: e05. DOI: https://doi.org/10.15420/ver.2024.07.02.05

Correspondence: Muhammad Raheel, Department of Business and Management, University of Greenwich, London, UK. Email: muhammad.raheel.greenwich@outlook.com

In medical sciences, medical robots are utilized. In those robots, surgical robots are essential. The location of these robots is mostly tele manipulators. These elements will use the activators of surgeons from one side to control effectors from the other side. A large number of updates can be seen in the field of robotics, which makes it possible for robots to perform lab tests without any interference from human abilities. Robotics also make it possible to remove the danger of plaque from the arteries with great ease. These are also involved in the biopsies of tissue. Cancerous cells can also be removed with the proper functioning of robots. It is expected that, with time, it will become possible to deliver the required medicines with the help of robotics. Patients suffering from minor issues can also be treated with antibiotics with great care. Robots will also discuss their problems with patients[1]. The surgery in which robots are involved makes it possible for doctors to do various types of complicated surgeries with great accuracy and precision. They perform this procedure with very keen, flexible behavior that involves traditional procedures. The interference of tiny incisions makes the performance of surgery very easy. However, it can also be seen that this is also involved in open surgeries. All those devices in which robots are involved are only permissible for minor injuries that face bacteria for a minimal time and area. All those elements should be found in an environment where surgery is performed with the help of robots that can assist in healing processing effectively. Robotic surgery is considered an improved process regarding precision, but it is deemed inaccurate as robots do not do the surgery; experts in their field direct it[2]. These qualified surgeons use those devices during the surgery process, which are based on robots. The da Vinci system at the movement of the surgeon's hands for a genuine time translates the movement of the console—the rotation and bending of the instruments when they perform this surgery. The tool, which isn't shaped just like a human's wrist, shows movement just like the hand of a human. The difference comes in the area where the robotic hand covers movement, as it covers more than an actual human hand. The first robot used in surgery was PUMA 560, which was utilized in 1985 for the first time. It was known as stereotaxic surgery. Computer tomography is used in this procedure to instruct the robot correctly[3]. A needle is inserted into the brain by the robot for biopsy. This procedure is methylated as a victim of error as during the needle placement process, tremoring of hands leads to wrong treatment. With time, robots are expected to prove the right hand for surgeons in medicine. Robots can perform tasks that are very simple and regular very quickly when the operation or surgery of the patient is going on[4]. Robots who perform such little side tasks can focus their work with total concentration, enabling them to make worthy decisions. Microrobots are the elements that are usually given the task of movement via blood vessels and transfer the therapy at their required site. In therapies, radiation and medication are the critical factors that are usually delivered and placed inside the blood vessels. The patient swallows endoscopic capsules to investigate the digestive system[5]. These capsules will collect the information and send the information about the events in the digestive system to the operator so that the operator can observe the whole thing happening and decide what should be done next for better performance. In the interventions of peripheral vascular type, interventional cardiology treatments involve a hollow tube, which isn't flexible, so that those blood vessels can also be accessed in the outside area of the heart. These procedures are usually applied to open the blocked blood vessels and remove blood clots from the blood vessels[6]. These techniques are also beneficial in ring bloomer high pressure. The primary purpose of vascular surgery is to protect all those very functional and beneficial tissues. These tissues can be the brain, limb, gut, kidneys, or many other organs. Robotic technologies, appearing in the present time, are high-speed and are used by surgeons during their surgeries to improve their performance[7]. These robots can facilitate and enhance the working of every minor surgery. All those interventions assisted by robots have been explored recently, and their place in vascular surgery has been found so that enhancement can be seen in the abilities of laparoscopic vascular and endovascular types. The research was done wholly systematically to recognize the published studies that clinics did, and these studies were utterly related to the application of robots in vascular interventions. Seventeen studies focusing on the applications of robotics for clinical use in laparoscopic surgery for endovascular and vascular procedures were identified[8]. They were either case studies, retrospective patient series, or prospective studies that reported laparoscopic endovascular and vascular procedures to people with the robotic technique. No comparative evidence was found clinically to assess the benefits of vascular procedures performed by robots. Laparoscopic aortic surgery performed by robots has been described in numerous studies as having satisfying payoffs. In addition, the use of robotics as the sole option to repair abdominal aortic aneurysms and the expansion of its application to renal artery and splenic aneurysm repair have been reported[9]. Endovascular catheters with a robotic steerable mechanism could offer advantages over conventional catheterization techniques. The promising payoff from heart interventions and preclinical research has encouraged their use in vascular surgery. Although applications that have been successful in the endovascular treatment of abdominal aortic aneurysms and Lower extremity arterial problems have been documented, the published experiences with the endovascular robot are sporadic[10].

Research Objective

The main aim of this research is to determine the current level of applications and how much clinical robots are utilized in vascular surgery. This research can also help understand the need for this advancement. The ease brought by these tools can be felt easily after reading this content, which is completely based on the research on robotics benefits.

LITERATURE REVIEW

Researchers claim that advancement in technology has increased the trend of using robotics in health sectors. For implanting Cather for endovascular surgery, the use of robotics systems is becoming prominent. The diversity in types as well as the functioning of Cather makes their evaluation process difficult. the modified robotics Cather shows improved performance than ordinary Cather[11]. The process of surgical operations has been improved through the process of endovascular surgery. the new innovative technology used in surgery is robotically developed Cather. The robotics Cather monitors the whole process of insertion of Cather in the patient's body[12]. Studies claim that traditional surgical methods have been replaced with modern methods because of lack of ability of the traditional method to fulfill the need of modern health services.

With innovative vascular surgery technology the number of death rates due to endovascular surgery is reducing[13]. Scholars predict that people affected with carotid artery disease develop plaque in their blood vessels that disturbs the flow of blood. the disturbance in the normal flow of blood through vessels increases stroke risk in patients. To avoid stroke conditions robotics-based carried stents are implanted in patients' bodies [14]. Studies reveal that vascular surgical operations performed with the assistance of robotics system makes the surgical procedure safer for the patient. but some surgical institutes have not fully accepted the use of robotics systems in surgical operations. To overcome this challenge different training programs are provided in surgical institutes to make the use of robots in surgical operations understandable[15] Studies suggest that vascular diseases are prominently categorized into two main categories. The first is cerebrovascular disease and the second is cardiovascular disease. Both diseases are life-threatening for the patient and require immediate treatment or surgery Endovascular interventional surgery is a surgical procedure adopted for these two major vascular diseases. This interventional therapy has shown improvement when robot technology is implanted in its working[16]. Studies suggest that using robotics systems is a feasible approach. Studies reveal that when cardiac vascular disease patient was treated using robotic-assisted technology they showed positive outcomes However, the process of implementation of robotics systems in the field of neuro-endovascular is still under study [17]. Study reveals that radiology is a technology-based system used during the surgical operational procedure.to advance the approach of radiology it is combined with robotics. Robotics radiology is the field made by combining two individual approaches for improving the overall efficacy of surgical processes[18]. Scholars conclude that soft Cather has been developed using a robotic approach. these soft Cather are involved in VIS. Despite robotic Cather's wide use, they still have some limitations.one major limitation is that robotic Cather shows poor stability. To solve this problem the newly developing robotic catheter is stabilized with special equipment [19]. Studies reveal that standard technology used in the surgical field has been replaced with neuro-radiological robotics systems. this system is an improved version of the radiological robotics system. Also, surgical procedures are very time-consuming.to make surgical procedures accurate and fast neuro-radiological robotics systems are preferred by surgeons [20].

The safety feature this robotics operational technique offers makes it use suitable for various surgical operations[21]. Studies predict that surgeons' interest in using robotic systems in surgical operations is increasing. the main reason behind is the accuracy they achieve in performing surgical procedure. The surgical interventions that are used in surgical operations lack proper surgical navigating system. To solve this issue the advanced robot-assisted technology is combined with MRI systems. MRI improves the navigation process during surgical practices[22]. Studies reveal that cardiovascular disease and cerebrovascular disease occur separately in people. But in some cases, the patients get affected by cardio-cerebrovascular disease. this disease is more severe the individual diseases. The treatment therapy required for cardio-cerebrovascular disease is vascular intervention for performing the surgery doctors are continuously exposed to harmful conditions. To avoid direct exposure to such radiation doctors or surgeons use robots to perform surgery. the robots are provided with guidelines to perform a specific surgery and then they perform their task with great accuracy[23]. Studies concluded that the first-ever endovascular robotic system showed improved results when applied to humans. The successful use of robotics systems on human has increased their commercial importance[24]. Studies elaborate that using robotics for surgical interventional processes is increasing at a large scale Most health institutes use robotics systems to carry out their surgical procedures Moreover the communication of AI with imagining technology has resulted in massive scale advancement of surgery-based processes[25]. AAA is a serious disease that requires immediate surgical treatment. endovascular aortic repair is the interventional surgery approach that uses robotics system to make it use effective for operational purposes. When a robotics system is adopted along with a surgical interventional process then it results in the automation of surgery[26]. Scholars explain that the only purpose of surgeons to use vascular interventional surgical programs is to minimize the surgery-associated risk. The vascular intervention provides great benefits as it has no side effects and ensures speedy recovery of the patient.to navigate the robotic tasks guiltiness is provided to robots using a deep learning algorithmic approach[27]. Scholars' studies conclude that neurovascular diseases are treated through robotics surgical intervention. CorPath GRX robotic system is involved in the treatment process for cerebral aneurysm. studies evaluate that CorPath GRX robotics is safer to use and shows great efficiency [28]. Studies reveal that manual operative strategies used in the past were ineffective. But in the modern age of technology, the ineffective strategies have been replaced with the robotics approach to make the endovascular repair process more reliable and safer. Also, the robotic approach for aortic repair is applicable in humans as the first line of treatment because of its novel applications[29]. The big problem faced by surgeons during operation is getting exposed to unwanted radiation. this exposure is dangerous for the surgeon and leads to complex health problems.to make surgeons safe from exposure to radiation robotic surgical operational techniques are gaining importance. The position of the robotic system is controlled by the surgeon and thus these robots come in contact with radiation and surgeons remain safe from harmful radiation[30]. Studies conclude that when AI and robotic systems are used together, it results in great benefits. In the IR field, combining these two approaches yields great interventional applications for the treatment of different diseases. AI-based algorithms like deep learning and CNN improve the overall working robotics-based surgical operational therapies[31].

Science and technology have made such tremendous innovations in each field of life that now humans are replaced by robots in each organization of service for humanity. As we know, the term robotics is related to the construction, proper operation, and use of robots in different fields of life. Now, robots are used in the medical field for other purposes, such as laboratory work, management department, and surgery department. Nowadays, robots are used in endovascular surgery to achieve desired outcomes differently. Following are the critical implications of the role of Robotics in Endovascular Surgery for improving outcomes in vascular interventions:

Improved Precision and Accuracy, Reduced Radiation Exposure, Enhanced Navigation and Visualization, Reduced Time for Procedure

Different types of error can occur depending e on human intelligence because of human error or random error. It is due to negligence, inexperience, or lack of interest of human beings in that particular task. In the same way, it has been proved that when human resources perform endovascular Surgery, there is a risk of error or less desired outcomes. However, the medical field has been revolutionized by robotics in endovascular surgery. The most important implication of robotics in endovascular Surgery is this surgical procedure's improved precision and accuracy. Many factors contribute to the enhanced precision and accuracy of robotics. One of these factors is that these robotics are automatic, so they are less prone to error or abnormality. The other factor is that there is no fatigue factor or less interest in work in the case of these robotics. This way, prolonged Surgery can also be performed more precisely and accurately. The other factor is that they have special sensors that can provide real-time results. In the case of any abnormality in a surgical procedure, these robotics can effectively cope. No factor of experience can be considered in the case of robotics in endovascular Surgery. As we know, when endovascular surgery has to be performed by a human being, there is a need for the professional to have a lot of experience, but in the case of robotics, there is no need for such a factor. The other important implication of the role of robotics in endovascular surgery in improving outcomes is the aspect of less radiation exposure. There is a prolonged procedure for Endovascular disease diagnosis, including ultrasound waves and X-rays. X-ray cases, during Surgery, there is a need for radiation to visualize the internal organs of the body. Although these radiations are helpful for diagnostic purposes, feeding the dose of these radiations may also harm the human body. These radiations can cause mutations in the body, which causes cancer in the body. However, when robotics is utilized in endovascular Surgery, there is less need for radiation, which is another aspect of robotics' role. The other important implication of the role of robotics in endovascular Surgery is the aspect of Enhanced visualization and integration. As has been described earlier, there is a need to visualize the body's internal organs for a better endovascular surgical process. Proper navigation is also needed to prove the surgical method is effective. We can achieve these desired outcomes by using robotics in endovascular surgery. The other important implication of using robotics in endovascular Surgery to improve outcomes is the reduced procedure time. We know that the method of endovascular Surgery is quite prolonged and can be delayed if it relies on human resources for Surgery. In contrast, when robotics are used in Endovascular Surgery, the period of Surgery is reduced, and there are more chances of swift recovery after Surgery in patients. All of these implications of the role of Robotics in Endovascular Surgery are evidence of the importance and innovations of robotics in the medical field.

Reduced Complications, Enhanced Physician Experience, Increased Efficiency, and Faster Recovery Time

In manual endovascular surgery, many complications need to be confronted after surgery. As we know, not only is Surgery essential, but the post-period of Surgery is also mandatory for better recovery. Because of human intelligence, there is a risk of human error, which can cause different complications in the post-surgery period of patients. These complications may increase the cost of treatment and will also make treatment difficult and complex.

On the contrary, in robotics, there is less risk of compilations, so there is no need for extra cost during the post-surgery. The other important implication of the role of robotics in endovascular Surgery is the enhanced physician experience. Although robotics in endovascular Surgery is automatic, it needs human assistance at some points. Secondly, experienced physicians can better handle robotics in endovascular Surgery than inexperienced physicians. Using robotics in endovascular Surgery is the most helpful way to train inexperienced physicians so that they may get experience and work well in their respective healthcare sectors.

The other important implication of the role of robotics in endovascular Surgery is the aspect of increased efficiency. Usually, better efficiency in healthcare depends upon better and swift workflow from these sectors. This workflow can be enhanced by replacing human and Manual work with automated and robotic work. These automated systems will work in less time with better accuracy, and such enhanced workflow will improve efficiency in healthcare sectors. This increased efficiency of healthcare sectors will help reduce disease rates in particular populations. The other important implication of robotics in endovascular surgery is the fast recovery of these patients. In Manual Endovascular Surgery, extended cuts and painful stitches will delay recovery in these patients. However, when robotics, shortcuts, and invisible stitches perform Surgery, it will improve the recovery of these patients (Figure 1).

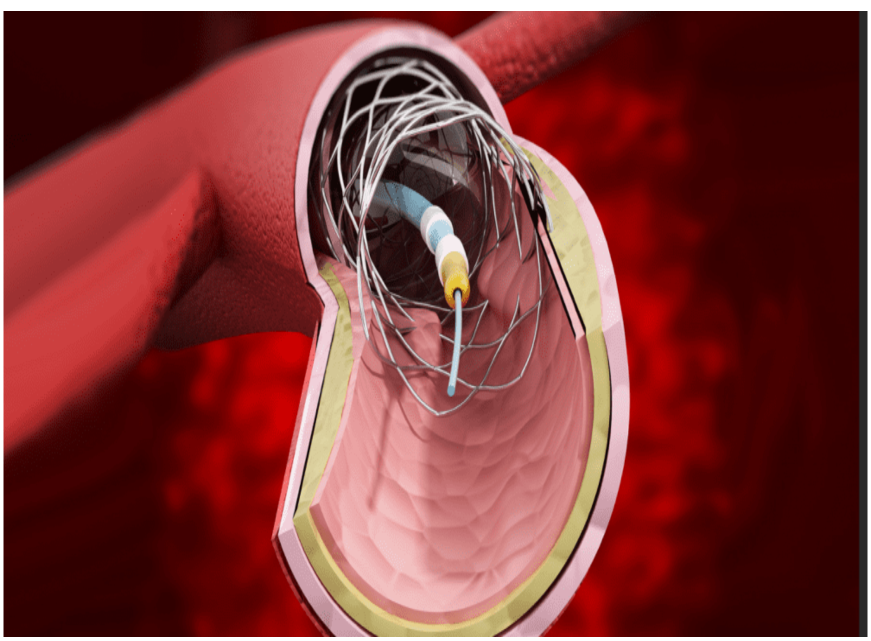

Figure 1: Vascular interventions

DESCRIPTIVE STATISTICAL ANALYSIS

Table 1: Result of Descriptive statistical analysis

Name	No.	Mean	Median	Scale Min	Scale Max	Standard Deviation	Excess Kurtosis	Skewness	Cramér-Von Mises P Value
RR1	1	1.560	1.000	1.000	3.000	0.668	-0.432	0.811	0.000
RR2	2	1.480	1.000	1.000	3.000	0.608	-0.133	0.905	0.000
RR3	3	1.580	2.000	1.000	3.000	0.635	-0.507	0.654	0.000
ES1	4	1.460	1.000	1.000	3.000	0.639	0.149	1.103	0.000
ES2	5	1.560	1.000	1.000	3.000	0.637	-0.442	0.723	0.000
ES3	6	1.700	2.000	1.000	4.000	0.755	0.271	0.863	0.000
ES4	7	1.640	2.000	1.000	3.000	0.656	-0.641	0.553	0.000
VI1	8	1.580	2.000	1.000	3.000	0.603	-0.574	0.528	0.000
VI2	9	1.540	1.000	1.000	3.000	0.639	-0.361	0.794	0.000
VI3	10	1.440	1.000	1.000	3.000	0.605	0.191	1.075	0.000
VI4	11	1.880	2.000	1.000	4.000	0.791	0.295	0.723	0.000

The result shown in table 1 demonstrate that descriptive statistical analysis result describes the mean values, the median rates, the minimum value, the maximum value also that it explains the standard deviation rate of each variable included dependent and independent. The RR stand for robostic level its shows that the mean value is 1.560, 1.480, 1.580 result represent that its standard deviation rate is 66%, 60% and 63% deviate from mean value.

The ES1,2,3 and 4 represent that mean value is 1.460, 1.560 and 1.700 also that its shows 1.640 all of them are consider as positive average value of mean. The standard deviation rate is 63%, 75% respectively. According to the result overall minimum value is 1.000 the maximum value is 3.000 the median rate is 2.00 respectively. The VI stand for vascular interventions result demonstrate that its mean value is 1.580, 1.540, 1.440 and 1.880 the standard deviation rate is 79%, 60%, 63% deviate from mean. The overall probability rate is 0.00 shows 100% significant level between them.

Applications in Endovascular Surgery

A new method in endovascular surgery is the use of remote-controlled steerable catheter navigation and arterial system catheterisation. The clinical application of robotic endovascular catheters has been shown in two published studies. It has been shown that a male patient with gangrenous toe ulceration was successfully treated endovascularly for peripheral artery disease using the Niobe magnetic navigation system.

A robotic-assisted endovascular aneurysm repair was performed on a 78-year-old man with a 5.9-cm infrarenal AAA from our unit after testing in in vitro silicon models and animal investigations. The robotic catheter was utilised to enter the aneurysm sac and reach the bifurcated stent graft's contralateral limb. In order to evaluate the viability of utilising the robotic system in vivo and ascertain its safety and effectiveness in clinical cases of fenestrated stent grafting, our institution is now conducting a clinical trial that has been approved by the Regional Ethics Committee.

Supporting Evidence for the Use of Robotic Endovascular Catheters

The first use of computerised robotically-controlled catheter devices was in cardiac mapping and ablation for arrhythmia therapy. The feasibility and safety of transseptal puncture and navigation into heart chambers were established by early studies in animal models; no intracardiac damage linked to catheter manipulation was seen. The robotic catheter system's accuracy in ablation and its capacity to manoeuvre inside the heart were assessed in different animal research in comparison to traditional ablation catheters.41 This study showed that using the robotically operated system resulted in shorter navigation times and more accurate aiming. Promising outcomes were linked to the Sensei robotic catheter system's transfer to human use. In addition to reducing radiation exposure, the initial experience with remote guidance for catheter ablation for the treatment of various cardiac arrhythmias showed that it was safe and clinically effective. Additionally, outcomes were shown that were comparable to those of traditional cardiac ablation techniques. Another study used an anthropomorphic pulsatile phantom model to compare steerable robotic catheter technology with conventional endovascular catheters in fenestrated stent grafting. The results showed that robotic cannulation techniques significantly reduced procedure times and improved stability at the catheter tip. Overall, employing robotic technology, four-vessel cannulation durations were lowered from 12 to 20 minutes using traditional catheters to less than 5 minutes. Despite the operators' limited exposure to this new technology, an improvement in operator performance was also demonstrated. The below model shown in figure 2 represents the smart PLS Algorithm model in between RR, ES and VI result demonstrate that RR represent the 0.123, 0.959 and -0.176 its shows some positive and some negative value. The RR shows that 35% positive and significant link with ES. The ES also present that -0.334 negative but its 33% significant relation between them. the RR represent that -0.162 its shows negative but its 16% significant value with VI.

SMART PLS ALGORITHM MODEL

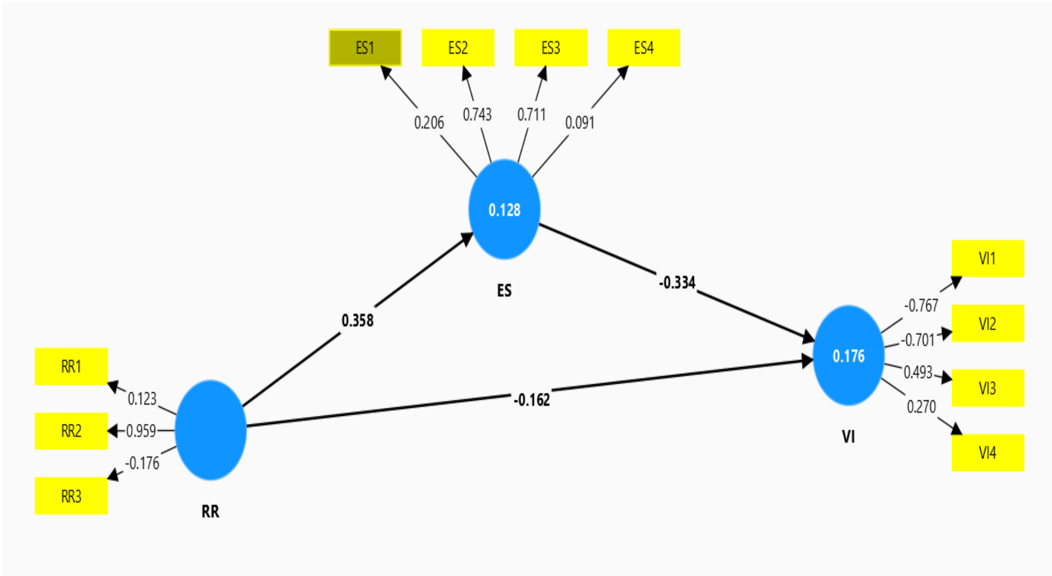

Figure 2: Smart PLS Algorithm Model

CORRELATION COEFFICIENT

Table 2: Result of Correlation coefficient

	RR1	RR2	RR3	ES1	ES2	ES3	ES4	VI1	VI2	VI3	VI4
RR1	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RR2	-0.071	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RR3	-0.106	0.056	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ES1	-0.135	0.049	-0.017	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ES2	-0.079	0.132	-0.160	0.300	1.000	0.000	0.000	0.000	0.000	0.000	0.000
ES3	0.016	0.401	0.113	0.162	0.100	1.000	0.000	0.000	0.000	0.000	0.000
ES4	0.004	0.032	0.069	-0.177	0.004	-0.137	1.000	0.000	0.000	0.000	0.000
VI1	0.038	0.223	0.062	-0.070	0.248	0.163	0.022	1.000	0.000	0.000	0.000
VI2	0.182	-0.049	-0.230	0.077	0.436	0.087	0.034	0.329	1.000	0.000	0.000
VI3	-0.065	-0.302	0.116	0.201	-0.017	-0.105	-0.105	-0.096	-0.045	1.000	0.000
VI4	-0.176	-0.171	-0.060	0.109	-0.065	0.141	-0.276	-0.148	0.089	0.277	1.000

The result shown in table 2 demonstrates that correlation coefficient analysis in between endovascular surgery improving outcomes in vascular interventions. The overall result shows some positive and some negative correlation between them. The da Vinci system has now been used in a variety of specialties, including gynecology, colorectal surgery, and urology. Robot-assisted laparoscopic aorto-bifemoral bypass surgery was the first application of this technique in vascular surgery in 2002.

Robot-assisted endovascular procedures have only lately emerged as a viable substitute for current endovascular techniques, although the viability of robotic vascular surgery has been proven over the years in a number of laparoscopic vascular reconstructions, primarily of the aortoiliac and visceral arteries. Da Vinci Surgical Systems conducted over 1,243,000 robotic surgeries globally in 2020. Despite the challenges posed by the COVID-19 pandemic, this is an increase above the 1,229,000 and 1,038,000 procedures performed in 2019 and 2018, respectively. Because it lacks the autonomous components of a robot and is totally reliant on human input, the da Vinci system—like the majority of surgical robots—is essentially a tele manipulator.

A patient-side cart with three or four interactive arms and the surgeon's console for remote manipulation make up this master-slave system. There are a number of technological advancements over traditional laparoscopy, including better ergonomics, motion scaling, wrist motion flexibility, tremor filtering, and greater visualization due to the 3-dimensional interface. The development of "virtual fixtures," which use software to establish "no-go" regions and keep robotic devices from accessing and harming delicate tissues like blood arteries, is an intriguing future advancement. This technique was first developed for the purpose of enabling surgeons to do telesurgery.

DISCUSSION

Robot-assisted laparoscopic aortic surgery has been reported in very few cases, although recent outcomes seem promising. There was just one research that compared robotic and laparoscopic vascular operations and showed benefits in terms of the time required to accomplish the aortic anastomosis. One would anticipate that as staff members get more experience with this technology, setup times will reduce even if the overall procedure duration rose. The use of endovascular robotic catheters is still relatively new, and more cases must be conducted before firm results can be drawn. Potential benefits of robotic-assisted technology over traditional vascular operations have been shown by a review and study of the literature. The findings of preclinical and clinical research are encouraging, despite the lack of evidence currently supporting the incorporation of robotic technology into routine clinical practice. By expanding human capacities, robotics may improve surgery. The exact real-time motions of the robotic devices within a patient's body may be translated from the actions of a surgeon using these technologies. By using hardware and software filters that remove physiological tremor, the robot can wield tools more steadily and correctly. Furthermore, the surgeon employs a master control manipulator to deliver orders to the robotic instruments carrying out the endovascular intervention or surgery while seated at the console distant from the patient. These technologies also provide better eyesight. Surgeons may now execute vascular anastomoses and identify and dissect anatomic structures because to the availability of high-definition, three-dimensional images with depth perception and adjustable magnification. Restoring natural hand-eye coordination is another benefit; robotic-assisted laparoscopic procedures reduce the fulcrum effect, making instrument handling more natural. It is assumed that robotics may be useful in overcoming the lengthy learning curve associated with traditional laparoscopic equipment while conducting vascular anastomoses because of the advantages offered by modern laparoscopic robotic technology and its uses in vascular surgery. One may hypothesize that robotic manipulation requires less skill maintenance and practice than traditional laparoscopic surgery. Other writers, however, have discovered that robotic aid does not reduce the learning curve or enhance laparoscopic competence. However, the enhanced dexterity and visualisation provided by robotic surgery are crucial for overcoming the challenges associated with traditional laparoscopic vascular surgery. The significance of training and experience with the robotic instruments has not been sufficiently examined, and learning curves, training programs, and evaluation methods have not yet been devised. Using standardised and repeatable training techniques, an experimental animal model has been created for the clinical deployment of the da Vinci robotic system in vascular and visceral surgery. It was proved that this training program shortened and optimised the learning curve while enabling the evaluation of surgical performance. Additionally, the transfer of training in robotic-assisted microsurgical vascular anastomosis was assessed in another study. The technical viability of conducting a robotically aided microvascular anastomosis was attained by both highly skilled surgeons and surgical trainees, who also showed that they could equally learn the robotically assisted operation.

CONCLUSION

After an overview of these critical implications of robotics' role in Endovascular Surgery for improving outcomes, we can conclude that robotics has tremendous applications in medical and other fields of life. This aspect will also gain much importance shortly. By expanding human capacities, robotics may improve surgery. A robotic system can let surgeons do tasks that are not feasible in traditional surgery by reducing bodily tremor, improving eyesight, and scaling their movements into micromotions. Many laparoscopic vascular reconstructions, including those of the abdominal aorta, visceral arteries, and iliac arteries, have used robotic surgery. However, only a few numbers of centres throughout the world carried out the majority of these operations, and only the most active centres have published extensive series. The presence of a large, established endovascular field is one of the reasons it has not been generally accepted in the vascular community. It may, however, nevertheless offer a minimally invasive surgical option in situations when endovascular therapy is ineffective or in complicated aortic disease treatment as hybrid operations. In contrast, a revolution is taking place in endovascular surgery. Even in difficult anatomical scenarios, the effectiveness of endovascular robots has been demonstrated in PAD, CAS, FEVAR, transfemoral renal, and mesenteric treatments. Robotic peripheral vascular procedures have been demonstrated in clinical trials to be safe, practical, and to lower risks for both patients and operators, including radiation exposure. To completely incorporate that exciting new technology into the clinical context, more technological developments are required, such as improvements in haptic feedback and steerability, as well as interoperability with current devices. This technology's potential applications include remote operations like stroke thrombectomies. The viability and safety of robot-assisted endovascular operations have only been shown in a few observational studies or case reports from a few centres throughout the world. A paucity of controlled randomised studies prevents a reliable assessment of its long-term advantages over traditional endovascular methods. But the expenses are the primary problem. Although robotic surgery is more costly than traditional treatments, endovascular robotics offers significant health advantages to both patients and staff.

REFERENCES

1. S. A. Menaker, S. S. Shah, B. M. Snelling, S. Sur, R. M. Starke, and E. C. Peterson, "Current applications and future perspectives of robotics in cerebrovascular and endovascular neurosurgery," *Journal of neurointerventional surgery,* vol. 10, no. 1, pp. 78-82, 2018.
2. P. Legeza, G. W. Britz, T. Loh, and A. Lumsden, "Current utilization and future directions of robotic-assisted endovascular surgery," *Expert Review of Medical Devices,* vol. 17, no. 9, pp. 919-927, 2020.
3. S. Au, K. Ko, J. Tsang, and Y. C. Chan, "Robotic endovascular surgery," *Asian Cardiovascular and Thoracic Annals,* vol. 22, no. 1, pp. 110-114, 2014.
4. H. Shen, C. Wang, L. Xie, S. Zhou, L. Gu, and H. Xie, "A novel robotic system for vascular intervention: principles, performances, and applications," *International journal of computer assisted radiology and surgery,* vol. 14, pp. 671-683, 2019.

5. J. C. Lin, "The role of robotic surgical system in the management of vascular disease," *Annals of Vascular Surgery,* vol. 27, no. 7, pp. 976-983, 2013.
6. B. D. Martinez and C. S. Wiegand, "Robotics in vascular surgery," *The American journal of surgery,* vol. 188, no. 4, pp. 57-62, 2004.
7. S. Gunduz, H. Albadawi, and R. Oklu, "Robotic devices for minimally invasive endovascular interventions: a new dawn for interventional radiology," *Advanced Intelligent Systems,* vol. 3, no. 2, p. 2000181, 2021.
8. A. Püschel, C. Schafmayer, and J. Groß, "Robot-assisted techniques in vascular and endovascular surgery," *Langenbeck's archives of surgery,* vol. 407, no. 5, pp. 1789-1795, 2022.
9. L. Cruddas, G. Martin, and C. Riga, "Robotic endovascular surgery: current and future practice," in *Seminars in Vascular Surgery*, 2021, vol. 34, no. 4: Elsevier, pp. 233-240.
10. G. A. Antoniou, C. V. Riga, E. K. Mayer, N. J. Cheshire, and C. D. Bicknell, "Clinical applications of robotic technology in vascular and endovascular surgery," *Journal of vascular surgery,* vol. 53, no. 2, pp. 493-499, 2011.
11. N. V. Belikov, I. V. Khaydukova, I. E. Poludkin, and A. S. Borde, "Evolution and current state of robotic catheters for endovascular surgery: A comprehensive review," *Engineering Science and Technology, an International Journal,* vol. 57, p. 101789, 2024.
12. L. Cruddas, G. Martin, and C. Riga, "Robotics and Endovascular Surgery: Current Status," in *Mastering Endovascular Techniques: Tips and Tricks in Endovascular Surgery*: Springer, 2024, pp. 111-125.
13. W. Duan *et al.*, "Technical and clinical progress on robot-assisted endovascular interventions: A review," *Micromachines,* vol. 14, no. 1, p. 197, 2023.
14. P. M. Łajczak, K. Jóźwik, and Z. Nawrat, "Mechanical marvels: robots in carotid artery stenting-a systematic review of effectiveness in neuroendovascular interventions," *Artificial Intelligence Surgery,* vol. 4, no. 2, pp. 48-58, 2024.
15. B. C. Lengyel, P. Chinnadurai, S. J. Corr, A. B. Lumsden, and C. S. Bavare, "Robot-assisted vascular surgery: literature review, clinical applications, and future perspectives," *Journal of Robotic Surgery,* vol. 18, no. 1, pp. 1-15, 2024.
16. N. Li, Y. Wang, H. Zhao, and H. Ding, "Robotic Systems Design in Endovascular Treatment," *IEEE Transactions on Medical Robotics and Bionics,* 2024.
17. J. D. Morrison *et al.*, "Feasibility of robotic neuroendovascular surgery," *Interventional Neuroradiology,* p. 15910199221097898, 2023.
18. G. Najafi, K. Kreiser, M. E. Abdelaziz, and M. S. Hamady, "Current state of robotics in interventional radiology," *CardioVascular and Interventional Radiology,* vol. 46, no. 5, pp. 549-561, 2023.
19. C. C. Nguyen *et al.*, "Development of a soft robotic catheter for vascular intervention surgery," *Sensors and Actuators A: Physical,* vol. 357, p. 114380, 2023.
20. H. Young, "Evaluating the efficacy of a marine reserve in enhancing the population growth and size of endangered fish species," *FishTaxa,* vol. 27, pp. 25-35, 2023.
21. S. Ning *et al.*, "Robotic interventional neuroradiology: progress, challenges, and future prospects," in *Seminars in neurology*, 2023: Thieme Medical Publishers, Inc.
22. J. Bijlsma, D. Kundrat, and G. Dagnino, "MR-based navigation for robot-assisted endovascular procedures," *International Journal of Intelligent Robotics and Applications,* pp. 1-12, 2024.
23. S. Cao *et al.*, "A Reciprocating Delivery Device-based Endovascular Intervention Robot with Multi-manipulators Collaboration," *IEEE Transactions on Instrumentation and Measurement,* 2023.
24. W. Guo *et al.*, "A Novel Endovascular Robotic System for Treatment of Lower Extremity Peripheral Arterial Disease: First-in-Human Experience," *Journal of Endovascular Therapy,* p. 15266028231182027, 2023.
25. C. Lanza *et al.*, "Robotics in interventional radiology: review of current and future applications," *Technology in Cancer Research & Treatment,* vol. 22, p. 15330338231152084, 2023.
26. Q. Lu, "First-in-Human Automated Endovascular Aortic Repair With the Novel Endovascular Surgical Robot," 2023.
27. Z. Mei *et al.*, "Transferring Virtual Surgical Skills to Reality: AI Agents Mastering Surgical Decision-Making in Vascular Interventional Robotics," *IEEE/ASME Transactions on Mechatronics,* 2024.
28. V. M. Pereira *et al.*, "Evaluation of effectiveness and safety of the CorPath GRX robotic system in endovascular embolization procedures of cerebral aneurysms," *Journal of neurointerventional surgery,* vol. 16, no. 4, pp. 405-411, 2024.
29. C. Song *et al.*, "A novel endovascular robotic-assisted system for endovascular aortic repair: first-in-human evaluation of practicability and safety," *European Radiology,* vol. 33, no. 11, pp. 7408-7418, 2023.
30. S. Wang, Z. Liu, Y. Cao, L. Zhang, and L. Xie, "Improved precise guidewire delivery of a cardiovascular interventional surgery robot based on admittance control," *International Journal of Computer Assisted Radiology and Surgery,* vol. 19, no. 2, pp. 209-221, 2024.
31. J. Zhang, J. Fang, Y. Xu, and G. Si, "How AI and Robotics Will Advance Interventional Radiology: Narrative Review and Future Perspectives," *Diagnostics,* vol. 14, no. 13, p. 1393, 2024.