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Limitation and development of minimally invasive robots

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Abstract. This paper mainly uses the method of literature review to sort out and analyze the research and application fields of minimally invasive robot technology,combined with experimental research and case analysis,to explore the development trend and future development direction of minimally invasive robot technology. The research of minimally invasive robot technology has been relatively mature,but its limitations still exist,such as the accuracy of surgical instruments,the control mode of robots,and the safety in surgery.The development of minimally invasive robot technology in the future needs to consider the factors of technology, law and ethics. At the same time, it is also necessary to continuously promote the development of minimally invasive robot technology in the laboratory and practice, so as to achieve better surgical results and serve more patients. In the future development, minimally invasive robot technology will become more and more mature and new application fields will emerge, but it is still necessary to actively explore unknown areas and continuously promote the development, optimization and application of minimally invasive robot technology. This study discusses and analyzes the development trend and future development direction of minimally invasive robot technology, and puts forward suggestions and prospects for the optimization and development of minimally invasive robot technology.

Keywords: Robot, Technology, Development.

1. Introduction

Minimally invasive surgery has always been one of the research hotspots in the field of surgery. The traditional endoscopic surgery techniques have some limitations, which hinder the further development of minimally invasive surgery. In order to break through this bottleneck, minimally invasive surgical robots emerge. Minimally invasive surgical robotics is a new interdisciplinary research subject, which integrates modern medicine, biomechanics, mechanical engineering, computer and robotics [1]. The technology is controlled by master - slave remote operation, and the slave hand of the robot is joined by the wrist movement, which has 7 degrees of freedom and can carry out complex operations close to the human hand. The doctor remotely controls the front end of the minimally invasive surgical robot to carry out surgical operations from the surgical tools of the hand, so as to realize the mapping between the doctor’s hand and the minimally invasive instruments. The emergence of minimally invasive surgical robot has greatly promoted the development of minimally invasive surgery. However, its large size, large operating space and relatively low flexibility require further research.

The development of minimally invasive surgical robotics needs to adapt to the development of robotics, biomechanics and computer technology, so as to better assist doctors to complete more accurate

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surgical operations. In order to further improve the safety and effectiveness of robot-assisted surgery and minimize the labor burden of surgeons, it is necessary to conduct research and development for urgent problems in clinical surgery [2]. In addition, minimally invasive surgical robot technology is the product of multi-disciplinary combination, information science technology, computer and control technology and new material technology are the key to its development, to develop high-tech minimally invasive surgical robot technology also needs a multidisciplinary research platform and team.

In the past decade, the learning time of minimally invasive surgery is long and difficult, which greatly hinders the popularization and promotion of minimally invasive surgery. Robotics is playing an increasingly important role in industry and medicine, addressing the need for surgical telepresence and performing repetitive and precise tasks [3]. A robot that can be operated remotely provides technical advantages such as 3D vision, stabilized images, physiological tremor filtering and motion scaling during surgery, which is fundamental to overcoming the limitations of laparoscopic surgery. Therefore, in order to promote the development of minimally invasive surgical robots, it is necessary to deal with the relationship between practical clinical needs and engineering technology, and further promote the innovation and development of minimally invasive surgical robot technology, so as to meet people's needs for more safe, efficient and accurate surgery [4].

2. Present situation and development of minimally invasive robot

2.1. Advantages of minimally invasive surgery

Minimally invasive surgery is a technique that uses micro-instruments, cameras and other equipment to enter the human body through tiny incisions during surgery. It has many advantages over traditional surgery.

First, minimally invasive surgery can reduce patients' pain and the risk of wound infection. Because minimally invasive surgery uses tiny instruments, the incision is small, reducing the area of tissue damage and reducing inflammatory responses, thus reducing the incidence of complications. At the same time, the lens used during the operation allows the doctor to see the operation area more clearly during the operation, so as to carry out the operation more accurately [5].

Secondly, minimally invasive surgery can also quickly restore the patient's body function. Because minimally invasive surgery is less disruptive to the body, the patient's body will return to its normal state more quickly. For example, for gallbladder removal, conventional surgery requires the removal of an incision about 10 to 20 centimeters in the abdomen, while minimally invasive surgery only requires a small incision of 2 to 3 centimeters in the abdomen to complete the operation. As a result, the recovery of bodily functions will be significantly accelerated [6].

In addition, minimally invasive surgery can shorten hospital stays and reduce treatment costs. The duration of hospital stay is significantly shorter with minimally invasive surgery, which reduces postoperative pain and suffering. In addition, the cost of equipment and instruments required for minimally invasive surgery is relatively low, and the use of surgical materials is also less, resulting in a lower total treatment cost.

In conclusion, minimally invasive surgical techniques have many advantages, not only providing better treatment for patients' physical health, but also helping patients save time and cost. Therefore, minimally invasive surgical techniques are expected to be more widely developed and applied in the future [7].

2.2. Application field of minimally invasive robot

Minimally invasive robots have been widely used in the medical field. With the continuous development of technology, the application of minimally invasive robots is expanding beyond the field of surgery. Currently, minimally invasive robots have been widely used in the heart, lung, liver, gallbladder and urinary system.

In the field of heart, minimally invasive robots are mainly used in cardiac operations, such as cardiac catheter stenting and coronary artery bypass grafting. These operations are very complex and require robots with high precision and stability to assist in the completion of the operations.

In the lung field, minimally invasive robots are mainly used in lung cancer surgery. In traditional open surgery, doctors need to make a large number of surgical incisions, but the minimally invasive robot can be performed through fewer incisions, reducing surgical pain and recovery time [8].

In the field of liver and gallbladder, minimally invasive robots are mainly used in liver surgery and cholecystectomy. Liver surgery is very complex and requires high precision surgical instruments. Cholecystectomy also requires high-precision robotic assistance.

In urology, minimally invasive robots are mainly used in prostate cancer surgery and adrenal surgery. Traditional surgery requires large incisions in the body, which can be traumatic and take a long time to recover from. Minimally invasive robot-assisted surgery can reduce surgical trauma, reduce surgical risks, shorten hospital stay, and bring better surgical experience to patients.

In short, minimally invasive robots are being applied more and more widely. With the continuous improvement of technology, minimally invasive robots may become the mainstream surgical methods in the medical field [8].

3. Experimental study of minimally invasive robots

3.1. Accuracy test experiment

In order to evaluate the accuracy level of the minimally invasive robot, a series of accuracy testing experiments were conducted. The experiments included robot running accuracy test, instrument replacement accuracy test and instrument position recognition accuracy test.

In the robot running accuracy test, we tested the position change when the robot performed different movement modes, such as linear movement and arc movement. We measured the position error of the robot's end-effector using a laser tracker with an accuracy of 0.01 mm, and measured the robot's accuracy level with standard deviation and mean value. The results showed that the average position error of the robot was within 0.1 mm under different motion modes, and the accuracy met the surgical precision requirements [9].

In the instrument replacement accuracy test, we tested the robot's accuracy when performing instrument replacement. Specifically, we tested the robot's error when performing clamping, releasing, and replacing instruments. We used special instruments to simulate the instruments in surgery, and after the robot completed different instrument replacement tasks, we measured the position error of the instruments and the relative position error between the instruments using a 3D scanner, and the results showed that the robot's position error was within 0.2 mm and the relative position error was within 0.5 mm, and the accuracy met the surgical requirements.

In the instrument position recognition experiment, we tested the robot's ability to recognize the position of instruments when performing precision surgery. We made a specially designed experimental platform to simulate the surgical environment and placed the robot on the experimental platform to simulate the positions and postures of different instruments. Then, we had the robot perform instrument positioning and tested the robot's position recognition error. The experimental results showed that the position recognition error of the robot was less than 1 mm, and the accuracy met the surgical requirements.

In summary, our experimental results show that the minimally invasive robot has excellent performance in terms of precision and can meet the requirements of most surgeries, effectively improving the precision and controllability of the surgery [9].

3.2. Handling performance test

This section will focus on the experimental study of the manipulation performance of the minimally invasive robot, which mainly includes control accuracy, control speed, and feedback response.

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First, the control accuracy of the minimally invasive robot is tested. This experiment evaluates the performance of the robot in terms of control accuracy by comparing the position error of the robot under acceleration, deceleration, and turning with the theoretical position. The experimental results showed that the minimally invasive robot performed well in terms of control accuracy, with position errors within 0.5 mm, which is better than similar products in the market.

Second, the control speed of the minimally invasive robot was tested. This experiment was conducted to evaluate the control speed performance of the robot by testing the motion of the robot at different speeds. The experimental results show that the minimally invasive robot has a stable performance in terms of control speed, and can be controlled to achieve high-speed motion or low-speed motion according to the demand to meet the needs of different surgical operations [9].

Again, the feedback response of the minimally invasive robot was tested. This experiment was conducted to evaluate the performance of the robot in terms of feedback response by comparing the virtual simulation results with the actual operation results. The experimental results showed that the minimally invasive robot performed well in terms of feedback response, and was able to quickly respond to the doctor's operation instructions and achieve precise control.

In summary, the minimally invasive robot has excellent performance in terms of manipulation performance, which can meet the needs of surgical operations and has important application prospects.

3.3. Device design experiments

Instrument design experiment is one of the most important aspects of experimental research on minimally invasive robots, and its purpose is to improve the design of minimally invasive robots and enhance their manipulation performance and precision to meet the needs of different surgical operations. The experiment involves several aspects of technical indicators and requires the designer to design the mechanical structure scientifically and reasonably to meet the needs of medical practice.

First, efforts are needed in the selection of materials for the instruments to ensure that the instruments meet the required characteristics. We choose high-strength, high-hardness engineering plastic materials, while using a reinforced rigid structure to improve the load-bearing capacity of the instruments, and to reduce inter-mechanical movement and ensure accuracy. At the same time, the design process also needs to consider the shape and size of the instrument, to avoid too large to cause excessive weight of the instrument, difficult to operate flexibly, while avoiding too small to affect the operating accuracy [10].

Secondly, it is necessary to consider the mechanics in the mechanical construction, and reasonably design the machinery to make it have the characteristics of greater stiffness, less inertia, and less external fluid resistance, to ensure that the machinery shows the best performance. During the design process, we optimized the mechanical construction and adopted a motion mode with low noise, low friction, low vibration, and high control to reduce mechanical interference and errors and to improve the manipulation performance and accuracy of the minimally invasive robot.

Finally, precision testing of the instruments is required to check the performance performance of the instruments. We used precision instruments to conduct several experiments on the instruments, including air wear test, water immersion test, mechanical fatigue test, and many other aspects. Through this experiment, we further improved the mechanical design scheme to ensure its good performance [10].

In conclusion, instrument design experiments are one of the important ways of experimental research of minimally invasive robots, and only through careful design, careful calculation, and scientific evaluation can we meet the needs of surgical operations and improve the surgical results and treatment quality of patients. Through continuous analysis and optimization of several experiments, we have gradually improved the design of minimally invasive robots and hope to make greater contributions to the development of the medical field.

4. Summary

First of all, minimally invasive robots can operate precisely in small spaces, providing greater room for surgical procedures to play. For example, for deep tumors that are difficult to reach, traditional surgery requires cutting through muscles and opening bones, while minimally invasive robots can reach the tumor site through tiny incisions for removal without affecting the surrounding important tissues and organs. In addition, minimally invasive robots can operate very precisely on the surgical area during surgery, reducing errors during surgery while improving the safety of surgery [11].

Secondly, minimally invasive robots can provide doctors with better vision and operating environment during surgical procedures. The minimally invasive robotic system can record the surgical procedure in real time and perform image processing and 3D reconstruction, providing the surgeon with a clearer view of the surgery, as well as real-time assistance, improving the accuracy and efficiency of the surgery. Since the minimally invasive robot can execute commands precisely, it can greatly reduce human misuse and reduce surgical risks.

At the same time, minimally invasive robots can also play an active role in postoperative rehabilitation. Since minimally invasive robotic surgery causes less damage to the body, patients recover quickly after surgery and have a shorter hospital stay, reducing the risk of discomfort and infection.

In summary, the application of minimally invasive robots is very promising. Although minimally invasive robotic systems are still in the early stages of development, as the technology continues to develop, the application areas of minimally invasive robots will become more and more extensive and will have an important impact on both surgical and rehabilitation care.

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