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CASE REPORT

Total laparoscopy-assisted total gastrectomy with Da Vinci robotic system conducted by robotic enhanced neurocomputing joint intelligence gastrointestinal surgery hub (RENJI-GISH): a preliminary clinical study and case report

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Abstract

Background On August 7, 2024, the inaugural total laparoscopy-assisted total gastrectomy with the Da Vinci robotic system was performed in the department of gastrointestinal surgery of Renji Hospital, Shanghai Jiaotong University School of Medicine. The procedure, conducted by RENJI-GISH, employed the use of a Da Vinci robot system in conjunction with the Vision Pro and SonoScape medical electronic endoscopy system. This phenomenon has not been documented in the field of gastric cancer surgery The objective of this study is to investigate the safety, feasibility, and surgical effect of the first total laparoscopy-assisted total gastrectomy with the Da Vinci robotic system, conducted by the Robotic Enhanced Neurocomputing Joint Intelligence Gastrointestinal Surgery Hub (RENJI-GISH).

Case presentation A 71-year-old male patient was admitted to the hospital with a six-month history of nausea and vomiting. A gastric malignant tumor was identified through gastroscopic examination. The patient was diagnosed with cardiac adenocarcinoma by gastroscopy and pathology, and there were clear indications for surgical intervention, though no contraindications were identified. On August 7, 2024, the patient underwent a robot-assisted total laparoscopic gastrectomy under general anesthesia. During the surgical procedure, the Vision Pro and the electronic endoscopy system played a pivotal role in accurately identifying the location of the gastric lesions, confirming the resection margin of the tumor, and ensuring the safety of the anastomosis. The intraoperative blood

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loss was 20 ml, and the operative time was 180 min. On the third postoperative day, the patient passed flatus and was transitioned to a liquid diet on the fourth postoperative day. The patient was discharged on the seventh postoperative day, having not experienced any complications. The postoperative pathology report indicated that the lymph node dissection was complete (0/32), and no evidence of malignancy was identified in the upper and lower resection margins.

Conclusions This case study illustrates the safety and feasibility of total laparoscopy-assisted total gastrectomy with the Da Vinci robotic system, performed by the robotic enhanced neurocomputing joint intelligence gastrointestinal surgery hub (RENJI-GISH). Further investigation and experimentation are necessary to fully elucidate the potential of this approach.

Keywords Apple vision pro, Wearable space computing devices, Da Vinci surgical robot, Augmented reality, Mixed reality, Total gastrectomy, Robotic enhanced neurocomputing, Intelligent gastrointestinal surgery hub

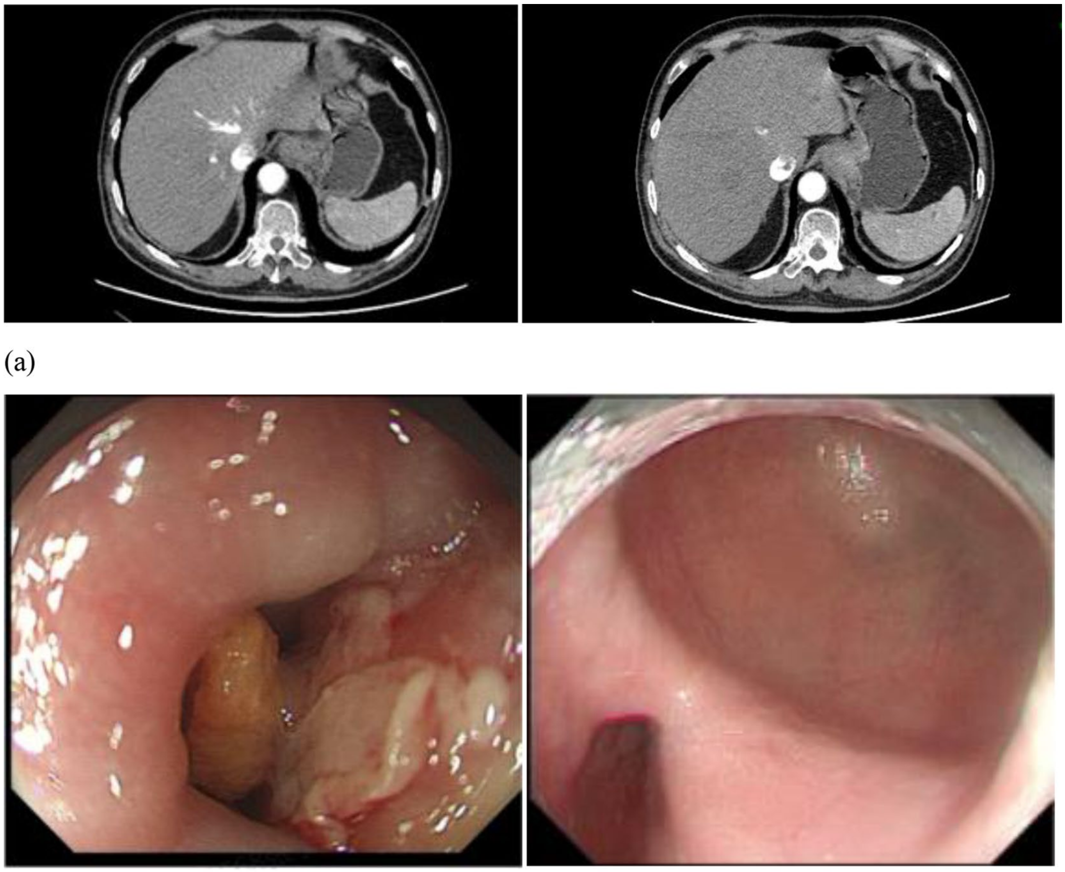
Background

In recent years, there has been a gradual application of augmented reality (AR) technology in the medical field, particularly in laparoscopic and robotic surgical systems that require display assistance. As surgical robots undergo iterative updates and augmented reality technology continues to advance, the advent of headset spatial computing devices has created new application scenarios for augmented reality technology. In liver surgery, artificial intelligence systems such as augmented reality are making surgical resection safer and more systematic, while improving oncological outcomes [1]. The integration of augmented reality technology and robot-assisted maneuvers is poised to become a pivotal aspect of surgical practice. Contemporary research is exploring the potential of image-overlay navigation techniques in laparoscopic procedures, including pancreatectomy and robotic liver resection. AR technologies are about to transform surgical practice, enhancing efficiency, precision, and potentially safety. These innovations are also on the verge of revolutionizing surgical education, equipping future surgeons with cutting-edge knowledge and skills [2]. In February 2024, the Apple Vision Pro, a headset spatial computing device, was launched in the United States. Three days later, Dr. Robert Masson from the United States utilized the Apple Vision Pro headset for minimally invasive spinal reconstruction surgery. Subsequently, numerous domestic and international surgical operations utilizing the Apple Vision Pro were documented. For instance, the Apple Vision Pro was employed by the thoracic surgery team at Peking University People's Hospital to perform the inaugural thoracoscopic radical resection of lung cancer [3]. Nevertheless, this phenomenon has not been documented in the field of gastric cancer surgery. In the context of gastrointestinal cancer surgery, the rapid and precise localization of the patient's lesion and the determination of a safe resection margin are of paramount importance. To conduct precise surgical procedures, it is essential to combine the innovative Apple Vision Pro's mixed realistic (MR) laparoscopic and endoscopic views with the Da Vinci robot system. This innovative combination ensures accuracy, reduces the incidence of surgery-related complications, and enhances recovery. Recently, the world's inaugural total laparoscopy-assisted total gastrectomy with the Da Vinci robotic system was performed in the department of gastrointestinal surgery at Renji Hospital, Shanghai Jiaotong University School of Medicine. The procedure was conducted by RENJI-GISH and utilized a Da Vinci robot system in conjunction with the Vision Pro and SonoScape medical electronic endoscopy system. This represents a significant advancement in the field of gastric cancer surgery, marking a notable achievement in the development of augmented reality technology.

Methods

Case presentation

A 71-year-old male patient was admitted to the hospital with a six-month history of nausea and vomiting. A computed tomography (CT) scan revealed a notable uneven thickening of the cardia wall with abnormal enhancement and the presence of multiple small lymph nodes in the lesser omentum (Fig. 1a). A gastroscopy revealed an occupying lesion in the cardia (Fig. 1b), a 3 cm diverticulum in the lower esophagus (Fig. 1b), and a type IIb lesion in the esophagus with contact bleeding. A gastroscopy revealed the presence of a malignant tumor in the gastric region. The biopsy results confirmed the presence of cardiac adenocarcinoma and high-grade intraepithelial neoplasia of the esophageal squamous epithelium. A positron emission tomography (PET) scan in conjunction with a computed tomography (CT) scan revealed a thickening of the cardia with increased fluorodeoxyglucose (FDG) metabolism, consistent with the presence of gastric cancer. A series of preoperative examinations were conducted to ascertain the absence of any contraindications. A risk assessment of the patient's preoperative physical condition was conducted, and a Da Vinci robot-assisted radical gastrectomy (total laparoscopy-assisted total gastrectomy with Da Vinci robotic system



(a)

(b)

Fig. 1 Preoperative examination. (**a**) The enhanced computed tomography (CT) images. (**b**) The gastroscopy images

supported by RENJI-GISH) was performed on August 7, 2024.

Augmented reality and mixed reality technology

Immersive technologies, including mixed reality and augmented reality, offer a novel means of interacting with three-dimensional data that differs significantly from the traditional computer desktop perception model. These technologies afford users the ability to spatially experience and interact with the virtual world in a manner that is not possible in the real world, and to freely explore virtual information. The emerging visualization presented by this interactive approach has the potential to serve as an auxiliary means of surgery in the current medical process [4]. In this study, the Apple Vision Pro (Apple, USA), an augmented reality device, was utilized as the headset spatial computing device. The device is composed of a headband, a display glass with a light shield on the front, and a charging cable.

Surgical system

The Da Vinci robotic surgical system (IntuitiveFosun Inc., Shanghai) utilized in this study is comprised of three primary components: the surgeon console, the patient cart, and the display device. The system is capable of performing complex surgical procedures through minimally invasive techniques. The Da Vinci surgical system is a robot comprising four mechanical arms, which are entirely controlled by the surgeon. The system translates the surgeon's manual movements into instrumental movements that operate within the patient's body, which is more delicate, as if the surgeon's eyes and hands were able to reach the patient's abdominal cavity. The medical electronic endoscopy system (Sonoscape Medical Corp., China) utilized in this study is a self-developed high-definition electronic endoscope with superior image quality and a multi-core heterogeneous system, which has been implemented to achieve sensitive and precise brightness control and intelligent dimming. These innovative technologies facilitate precise diagnosis and meet the requirements of Chinese medical institutions to implement high-definition endoscopic diagnosis and treatment. In this study, Apple Vision Pro integrates the robotic surgical system and electronic endoscopy system into a unified system of mixed reality technology via wire input. The endoscopic and 3D images captured by the endoscope are transmitted to the screen as electronic signals, which are then transformed into visual signals for the surgeon. The full integration of neurocomputing is a crucial element. Moreover, the platform has demonstrated its resilience through a series of stress tests conducted in complex environments. The surgical robot and electronic endoscopy image signals are input to the spatial computing equipment with minimal delay. Prior to the commencement of operations, personnel responsible for debugging and testing have ensured that the intelligent gastrointestinal surgery platform is fully functional and ready for use. All surgical instruments were tested after installation to determine that there is no perspective delay. This surgical system utilizes HUAWEI WiFi6 wireless technology to ensure reduced latency. The screen in the Vision Pro headset also needed to be adjusted to the center of the field of view, adjusting the size and clarity of the image to ensure that the anatomical details in the book were seen. Regular calibration of equipment is essential, including adjusting focus, white balance, and other endoscopic parameters, as well as calibrating Vision Pro display parameters and troubleshooting hardware hazards. Intraoperatively, if the delay exceeds a certain threshold (e.g., 300ms), an alarm is triggered to alert the surgeon.

Conclusions

Surgical scene presentation

The surgical scene and the surgeons are divided into three sections by the surgeon console, electronic endoscopy system, and patient cart, which are linked together by Apple Vision Pro, the central mediator. The surgeon console and patient cart are operated by the main surgeon. The first assistant and the gastroscopist were equipped with a headset spatial computing device, Apple Vision Pro, which enabled them to clearly view the images of the endoscope and laparoscope. The main surgeon doesn't need to wear Vision Pro headset and what the main surgeon has to do is to use the naked-eye 3D display system on the surgeon console to perform surgical operations. We are trying to abandon the use of traditional surgeon console in an effort to bring the surgical image directly to the attending surgeon through the headset device so that the main surgeon would be comfortable and flexible. Meanwhile, the respective assistants and operators performed their designated tasks. The first assistant exposed the surgical field and provided assistance to the principal operator, while the gastroscopist operated the gastroscope catheter and exposed the tumor location. A concise depiction of the surgical scene is presented in the subsequent figure (Fig. 2).

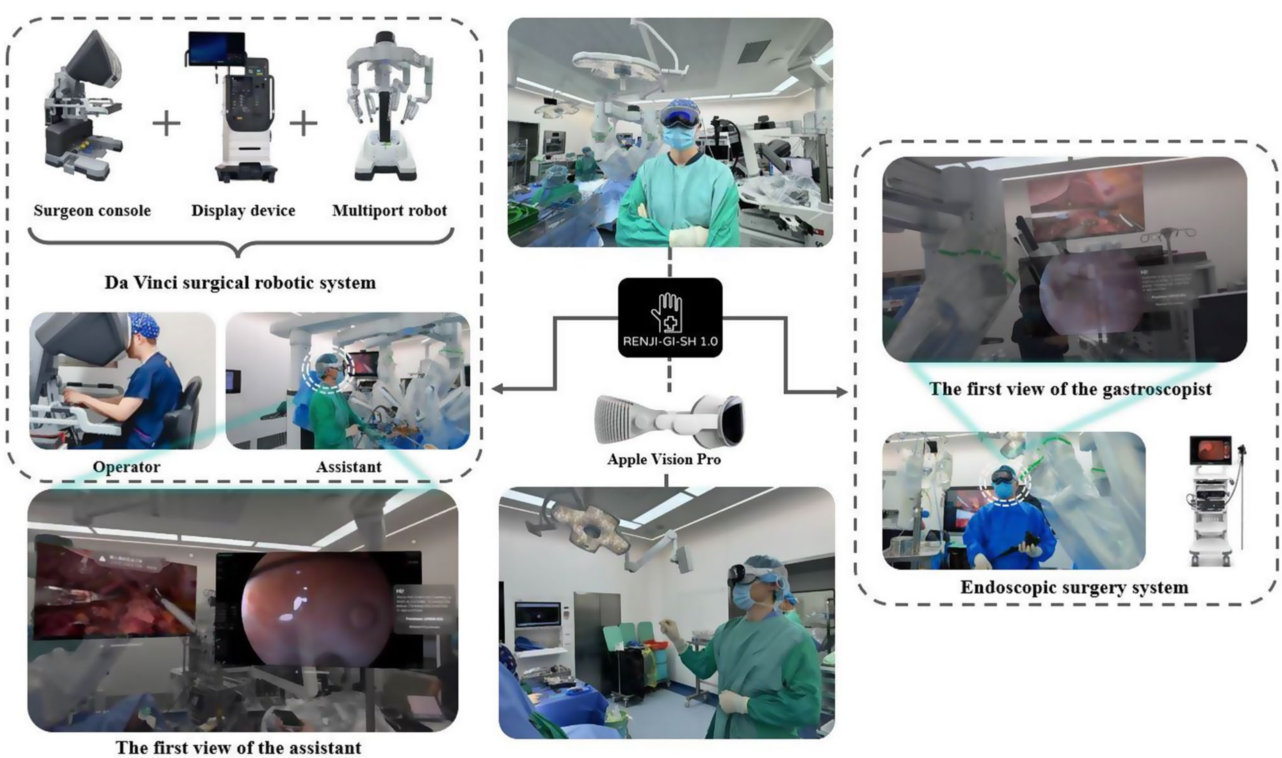


Fig. 2 Surgical scene supported by RENJI-GISH

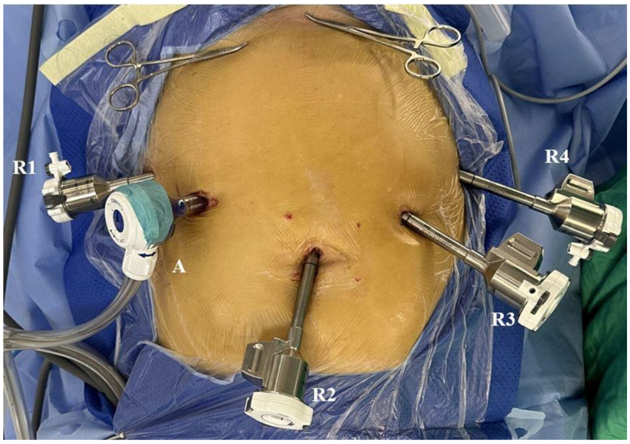


Fig. 3 Trocar layout

Surgical techniques

Upon confirming the suitability of the equipment, the surgical team proceeded with administering general anesthesia to the patient. The patient was positioned supine in a splitting leg posture, with the upper abdominal area sterilized in accordance with standard protocols. The upper abdominal incision was made using the five-hole method, with the puncture cannula inserted (Fig. 3). A pneumoperitoneum was established, with a pressure of 12 mmHg (equivalent to 0.133 kPa). The bedside mechanical arm was then connected, and the lens, ultrasonic scalpel, bipolar electric coagulation forceps, and non-invasive grasping forceps were inserted in the appropriate sequence. Subsequently, the surgeon initiated the robotic surgical procedure.

The surgical steps, were as follows: (I) Dissociation of the gastrocolic ligament, division and ligation of the right gastric omental vessels, followed by dissection of No.6 lymph nodes. (II) Division and ligation of the lesser omentum and the right gastric vessels, followed by dissection of No.5 lymph nodes and No.12 lymph nodes. (III) Division of the duodenum that is 3 cm from the pylorus using a linear stapler inserted through the assistant trocar. (IV) Division and ligation of the left gastric omental vessels and the short gastric vessels, followed by dissection of No.2 lymph nodes and No.4sb lymph nodes. (V) No.8 lymph nodes were dissected and No. 7 lymph nodes were dissected, followed by the division and ligation of the left gastric vessels at the root. (VI) The lower segment of the esophagus was dissociated, the No.1 lymph nodes was dissected, and the vagus nerve on both sides was divided. (VII) Tumor localization and resection margin were determined by the gastroscopist wearing Apple Vision Pro (Fig. 4), the esophagus was divided and the specimen was removed after applying purse string instrument 3 cm above the cardia. (VIII) Division of the jejunum 15 cm from the ligament of Treitz, followed by incisions in the proximal and distal jejunum 50 cm below the esophagojejunostomy and an end-to-side jejunojejunostomy by the manual anastomosis. (IX) The robot arm was installed, and the esophagojejunal anastomosis was performed manually. (X) 2 drainage tubes were placed behind the anastomosis from the right side of the abdomen through the duodenal stump, and 1 drainage tube was placed behind the anastomosis from the left side of the abdomen through the splenic fossa.

The surgical procedure was conducted in a smooth and consistent manner, as observed by the surgeon, the assistant, and the gastroscopist. There was no discernible delay or stuttering in the operation.

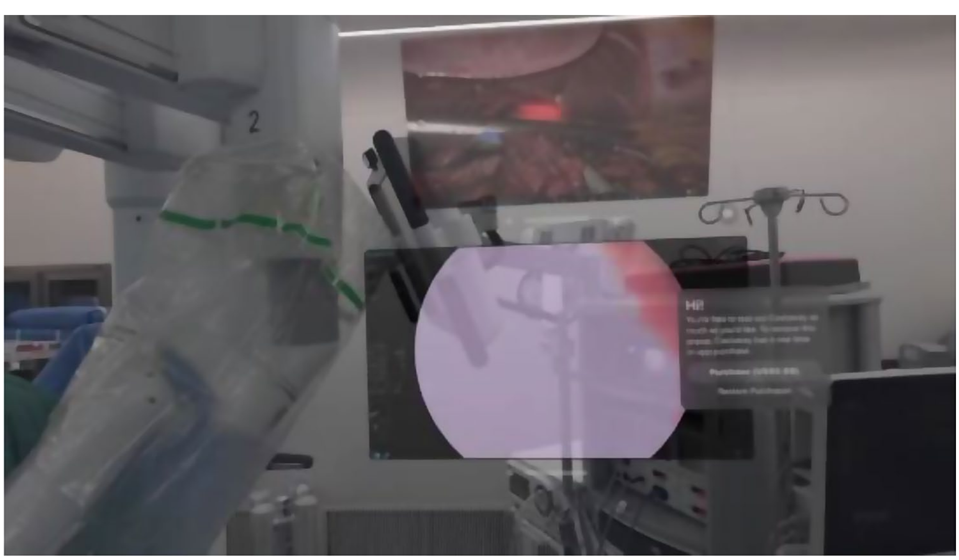


Fig. 4 The first view of combined images of the double-endoscopy joint positioning picture

Fig. 5 The postoperative incision

Perioperative outcomes

The findings are presented as follows. The study successfully completed a total laparoscopy-assisted total gastrectomy with the assistance of the Da Vinci robotic system, in accordance with the protocols set forth by the RENJI-GISH protocol. The intraoperative blood loss was 20 ml, and the operative time was 180 min. The patient's first bowel movement occurred on postoperative day 3, and oral intake of water commenced on postoperative day 4. On day 4, the patient transitioned to a liquid diet. Furthermore, the patient was discharged from the hospital on postoperative day 7, having not experienced any postoperative complications. The postoperative pathology report indicated the presence of tubular adenocarcinoma of the cardia, with evidence of invasion beyond the serosa and involvement of the lower esophageal segment. The lymph nodes were completely dissected and detected, and no evidence of malignancy was identified in the upper and lower resection margins. The four incisions measured 1 cm each, while one incision measured 4 cm, as illustrated in the figure below (Fig. 5).

Discussion

The advent of modern technological innovation has brought about notable changes to the surgical process of gastrointestinal tumors, and these changes will further serve to propel the medical field into the future. In the field of gastrointestinal cancer surgery, the integration of augmented reality technology, mixed reality technology, an electronic endoscopy system and cutting-edge surgical robots represents a significant advance in the application of cutting-edge technologies in clinical diagnosis and treatment. This marks a new trend in surgical innovation. The construction of the robotic enhanced neurocomputing joint intelligence gastrointestinal surgery hub (RENJI-GISH) version 1.0 provides a seamless connection between the most cutting-edge scientific and technological achievements and the forefront of diagnosis and treatment. This facilitates the standardization, modularization, innovation and branding of minimally invasive gastrointestinal surgery, and provides patients with more accurate and safe treatment.

In the absence of a discernible boundary, the localization of gastrointestinal tumors may prove challenging. It is imperative that the tumors be exposed by endoscopy. Furthermore, accurately determining the esophageal resection margin represents a significant challenge in the surgical management of malignant tumors involving the gastroesophageal junction [5]. Consequently, intraoperative gastroscopy is frequently necessary to ascertain the resection margin in conventional robotic surgery due to the absence of direct tactile feedback. In comparison to the conventional Da Vinci robot, the technology under investigation addressed the issue of the surgeon's inability to simultaneously observe the internal (gastroscopic) and external (laparoscopic) aspects of the gastrointestinal tract within the same field of view. This was achieved by integrating a high-definition double scope, which facilitated communication, and provided each member of the surgical team with a high-definition, low-latency, multi-position, and undifferentiated surgical scene. The shortcomings of glasses-free 3D displays, namely their diminutive size, suitability for single-person viewing, and inability to be moved, have been addressed. In this operation, the tumor margin, the stapler cutting position in the abdominal cavity, and the Da Vinci robotic arm's esophagogastric fundus traction is presented under the same field of view, allowing each member of the surgical team to observe and interact with the tumor margin and the surgical instruments in real-time. This enhanced situational awareness and enabled seamless collaboration, ensuring the accuracy and safety of the operation while optimizing its efficiency. Furthermore, the operation demonstrated a reduction in adverse reactions and potential tumor safety issues associated with patient anesthesia. The objective of ensuring the clean resection of gastroesophageal junction tumors is best achieved by improving accuracy, which in turn reduces the necessity for the resection of normal tissue and affords greater protection to gastroesophageal function. Furthermore, the surgeon is able to modify the dimensions, location, and proximity of the laparoscopic surgical field and endoscopic field of view independently, thus ensuring optimal observation and operation fields for the surgeon while preventing touch pollution, enhancing surgical quality, and adhering to aseptic principles. The electronic endoscopy system utilized in Fig. 2 is equipped with a full HD sensor, which is capable of providing a 1080P image. The combination of a 4LED light source, spectral imaging technology, and photoelectric composite staining imaging technology facilitates the rapid positioning of lesions, enables subtle observation, and allows for early cancer screening. The AI diagnostic technology integrated into the system is capable of detecting early cancer lesions that are often overlooked, thereby reducing the learning curve for surgeons in endoscopic procedures and unlocking the full potential of perioperative endoscopy.

The performance of laparoscopic total gastrectomy with the Da Vinci robot by RENJI-GISH presents a significant challenge. It is an invaluable test of the surgeon's proficiency in robotic operations, their ability to meet endoscopic operational requirements, their capacity for mutual coordination and stability between surgical equipment. The success of the operation is contingent upon the professional knowledge, skills, and experience of the surgical team. The Da Vinci surgical robot arm utilized in this procedure exhibits precise wrist movements and a significantly expanded range of motion and flexibility compared to that of the human hand. Furthermore, it can filter out hand jitter and improve accuracy, thereby facilitating the performance of numerous challenging or unsafe surgical operations [6]. The surgeon involved in this study has performed over 500 robotic surgical procedures, while the gastroscopist has extensive experience in endoscopy. Moreover, the surgical team is equipped with the necessary expertise to effectively respond to emergency situations. Furthermore, the surgical procedure in this study was modularized under the multi-screen prompt of Vision Pro in the same picture, which reduced the traction stimulation of the gastrointestinal tract and the frequency of lens movement, thus ensuring the fluency and standardization of the surgery. In practice, there is no any perceptive lag or variable latency among the visual fields of those main surgeon, endoscopist and first assistant. They could work closely together during the procedure and neither felt any delay. Before performing robotic operation, our team will test and exam all the surgical instruments to ensure there were no perceptive delays. Our team ensured that there were no delays mainly through HUAWEI WiFi6 wireless technology to ensure reduced latency and we need to make sure there's no delay before the operation.

The integration of three-dimensional image input in augmented reality technology represents a significant challenge. Some limitations are as follows. The clinical conversion of medical augmented reality (AR) remains in its infancy [7]. Wired connections, such as high-quality HDMI or fiber optic transmission lines, provide a more stable signal than wireless connections, which can be subject to delay and interference. But the use of wired input in this surgery system will restrict the surgeon's range of motion, diminish comfort, and increase the probability of contravening the principle of sterility. So the wireless image input we conducted in this surgical system is essential to evaluate the potential impact of network latency on the surgeon's ability to perform precise operations and collaborate intraoperatively. For instance, in the operating room, the presence of multiple electronic devices operating on the same 2.4 GHz band, such as wireless monitoring equipment, can interfere with the Vision Pro's reception of endoscopic image signals, potentially leading to delays or asynchronization in image transmission. It is imperative that the study addresses the issues of network security and network stability. In the event of a network issue, communication between the surgical team may be disrupted, necessitating a suspension of the operation and the removal or debugging of the headset. Otherwise, the patient may sustain injury due to maloperation. It is this author's opinion that the implementation of encrypted networks and 5G lines, coupled with the introduction of a new generation of firewalls, is essential to prevent cyberattacks and guarantee the long-term stability of wireless input. Furthermore, the surgeon must perform the requisite gestures within the visual range when debugging the headset, which may entail the risk of inadvertently contacting obstacles and contravening the principle of sterility. However, as shown in Fig. 2, the operating areas of our hands are all in the sterile zone, and as long as aseptic principles are strictly observed, operative region will not become infected. And our patient had no complications from infection. In addition, there is a real learning curve problem, doctors need to know how to properly wear and adjust the head-mounted display device so that it accurately adapts to personal visual habits, ensures the perfect integration of presented virtual information and real vision, and prevents visual bias from interfering with surgical judgment. This process can take hours or even days of repeated practice. Doctors also need to learn how to manipulate complex interactive devices and use gamepads or gesture recognition to flexibly access, scale, and rotate medical image models in mixed reality spaces. Apple vision pro interface is user-friendly and AR applications are becoming more and more widespread, so the AR learning curve won't take so long.

In addition to focusing on robotic surgery combined with AR and endoscopy, we also need to focus on patient prognosis. However, because this study is a case report, the number of cases was insufficient, and cases from other centers were rare, it was not feasible to compare the surgical outcomes and patient prognosis between conventional robotic surgery and robotic surgery combined with AR. A review of studies showed that patients with robotic-assisted distal gastrectomy (RDG) started eating solid food sooner, stayed in the hospital less, and their bowels recovered faster. There were no big differences in blood loss, complications, or lymph node removal, and the safety and thoroughness of the surgery were similar [8]. In the future, we will conduct studies to compare them. Our center will also explore the localization of gastric antrum lesions in order to perform radical surgery for distal gastric cancer and observe the anastomosis for stenosis, edema, and other complications in the postoperative period.

This study will focus on the future direction of augmented reality (AR) and mixed reality (MR) technology. Applications related to clinical medicine, such as those providing anatomical image guidance, access to medical records, image reporting systems, laboratory indicators, anesthesia-related data, surgical instrument parameters, and patient body parameters, can also be integrated into the Vision Pro display interface in real time via the screen. The technology enables surgeons to obtain pertinent information during operations, facilitate comprehensive understanding of anatomical variations, assist in intraoperative decision-making and treatment, and reduce the incidence of surgical complications. In addition to applying this surgical innovation to the identification of gastroesophageal negative margins, it can also be used to accurately locate and locally resection of early gastric cancer, better preserving the function of the stomach. This can also be applied to observe if there is anastomotic stenosis and oedema after gastrectomy. The combination of robotics and Vision Pro allows the first assistant to better assist in the completion of surgery, such as sharing a 3D view with the main surgeon and the surgical view is not obscured by obstacles such as robotic arms. We firmly believe that in the future, the size of the surgeon console will be reduced, and the main surgeon will be able to carry out surgery by wearing a headset and equipped with an operating rod. In years to come, our center will study how different surgical procedures and reconstructive techniques affect the results of the study. With the development of 5G networks, wireless connections will replace wired connections with minimal latency, and the principle of sterility will be further ensured. Our center will also study how the study's findings apply to other types of surgery, such as combined endoscopic-robotic technique assisted distal gastrectomy (Billroth I, Billroth II, Roux-en-Y) and colorectal cancer.

In this study, the surgical effect is satisfactory when compared with the previous traditional robot-assisted total gastrectomy. This is the case in terms of the operation cooperation of the surgical team, the picture clarity of the wearable space computing device, the intraoperative blood loss, operation time, lymph node dissection, and complications. The world's inaugural totally laparoscopic total gastrectomy, supported by robotic enhanced neurocomputing joint intelligence gastrointestinal surgery hub (RENJI-GISH), established a robust foundation for prospective advancements in gastrointestinal cancer surgery. Additionally, it validated the safety, feasibility, and novel benefits of this study in surgical efficacy.

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Author contributions
Conception and design: ZZ, JG, XX, YZ. Principal investigators of the study: ZL, JG, LB, YG. Revision of the study design and protocol: ZZ, XX, ZY, JG, BN. Study coordination: ZZ, XX, JG, HZ, AM. Acquisition of data and patient recruitment: ZL, XX, JG, SW, BY, HZ, AM. Statistical analysis: ZL, PZ, XS. Obtaining funding and supervision: ZZ. Drafting the manuscript: ZL, ZZ, XX. Revision and adaptation: All authors. All authors read the final manuscript and approved the submitted version.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The study has been approved by the Ethics Committee of Renji Hospital, Shanghai Jiaotong University School of Medicine. This study will be conducted in accordance with the Declaration of Helsinki and all patients will not be enrolled until the protocol and informed consent have been approved.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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