



OPEN Comparative outcomes of Toumai robotic and laparoscopic transabdominal preperitoneal inguinal hernia repair in a retrospective cohort

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To compare the clinical efficacy of the “Toumai” surgical robot and conventional laparoscopic inguinal hernia repair in order to inform surgical practice. A retrospective analysis was conducted on clinical data from 50 patients who underwent inguinal hernia repair at the Department of General Surgery, Gansu Provincial Hospital, between January 2022 and October 2023. Among them, 16 patients received robot-assisted repair (robotic group), and 34 underwent conventional laparoscopic repair (laparoscopic group), all via the transabdominal preperitoneal approach. Evaluation indicators included: (1) preoperative baseline characteristics; (2) intraoperative and postoperative outcomes; and (3) postoperative incision healing and adverse events. Outpatient follow-up and clinical re-examination were conducted 1 to 3 months after surgery to assess wound recovery and recurrence. Continuous variables were expressed as mean \pm standard deviation or median (M), and analyzed using the t-test; categorical data were compared using the chi-square test. There were no significant differences in baseline characteristics between the robot-assisted and laparoscopic groups, including sex ratio, age, weight, and hernia classification ($P > 0.05$). Intraoperatively and postoperatively, the robot group had a significantly longer operative time (104.19 ± 18.93 min vs. 90.17 ± 22.31 min), but demonstrated significantly less blood loss (6.94 ± 3.80 mL vs. 12.24 ± 9.31 mL), shorter hospital stay (3.18 ± 0.54 vs. 3.68 ± 0.81 days), lower pain scores (2.06 ± 0.93 vs. 3.03 ± 1.29), and reduced Subjective Mental Load Scale scores (18.12 ± 12.23 vs. 30.17 ± 11.46) compared to the laparoscopic group (all $P < 0.05$). No intraoperative complications were observed in either group. Follow-up results showed that postoperative recurrence occurred in 1 case in the robot group and 2 cases in the laparoscopic group. Poor incision healing occurred in 0 and 3 cases, and incision pain in 1 and 4 cases, respectively. In this retrospective cohort, Toumai robot-assisted repair was associated with lower estimated blood loss, lower postoperative pain scores, and shorter length of stay, but longer operative time, compared with laparoscopic repair.

Keywords Inguinal hernia repair, Toumai surgical robot, Robotic surgery, Laparoscopic surgery, Analysis of efficacy

Inguinal hernia is a relatively common surgical disease, which is caused by the protrusion of abdominal organs or tissues to the body surface through the defect and weak position of the inguinal area. With the advancement of science and technology, laparoscopic surgery has gradually become the preferred treatment for inguinal hernia.

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Laparoscopic inguinal hernia repair (LIHR) is currently the most widely used inguinal hernia treatment^{1,2}, in which transperitoneal preperitoneal hernia repair (TAPP) and total extraperitoneal hernia repair (TEP) occupy the dominant position of LIHR surgery³. LIHR has the advantages of mild postoperative pain, fast recovery, and good health economics benefits², and the proportion of LIHR in China is increasing year by year. However, traditional laparoscopic surgery has the disadvantages of poor three-dimensional spatial perception, mutual interference of instruments, and long-term surgery that is susceptible to external factors such as subtle tremor of the operator's hand^{4,5}. The robotic surgical system has a clear 3D high-definition lens that provides a more three-dimensional surgical field of view, as well as a convenient and flexible robotic arm with a more ergonomic design^{6,7}. The robot-assisted method can increase the range of movement of the instrument, and together with the three-dimensional and intuitive surgical field and operation space, it can effectively reduce the difficulties in traditional laparoscopic surgery and facilitate the implementation of related surgical steps^{8,9}. In 2000, the da Vinci surgical robot system (DVRS) was approved in the United States for surgical treatment, which is more in line with human needs and easy to operate than traditional laparoscopic surgery¹⁰. Robot-assisted inguinal hernia repair was carried out relatively late in clinical practice, and it was not until 2008 that Fumito et al. reported transperitoneal robotic inguinal repair¹¹, which filled the gap in this field. Therefore, in 2021, Gansu Provincial Hospital introduced the "Toumai" surgical robot system developed by China with independent intellectual property rights, and gradually carried out robot-assisted inguinal hernia repair since then, achieving good clinical application results. The purpose of this study was to compare the efficacy of the "Toumai" surgical robot with the traditional laparoscopic inguinal hernia repair, and to analyze the application prospect of the domestic "Toumai" surgical robot-assisted inguinal hernia repair.

Materials and methods

Inclusion and exclusion criteria

Inclusion criteria: (1) age from 18 to 85 years old; (2) Imaging examination to assist in diagnosis, if there is controversy, the "gold standard" is the main one; (3) robot-assisted or laparoscopic inguinal hernia repair; (4) Complete clinical data. Exclusion Criteria: (1) Pregnant and lactating patients; (2) Those who need emergency surgery; (3) Active bleeding and coagulation disorders; (4) Have severe respiratory and cardiovascular system diseases and cannot tolerate surgery; (5) Participated in clinical trials of drugs or devices in the past 1 month.

Clinical data

The clinical case data of 50 patients who underwent hernia repair in the first ward of general surgery (gastrointestinal) of Gansu Provincial Hospital from January 2022 to October 2023 were retrospectively collected, of which 16 cases were in the "Toumai" surgical robot-assisted group (robot group) and 34 cases were in the traditional laparoscopic group (laparoscopic group).

This study has been approved by the Gansu Provincial Hospital Ethics Committee 2024-025. This study complied with the requirements of the Declaration of Helsinki, and all enrolled patients had signed an informed consent form.

Surgical robotic system

In this study, robot-assisted procedures were performed using the Toumai surgical robotic system (Shanghai MicroPort Medical Robotics Co., Ltd.). The system comprises a surgeon console (master unit) and a patient-side cart (slave unit), which are connected via dedicated data cables to ensure high-speed and stable signal transmission, enabling real-time and coordinated surgical operations. Compared with the da Vinci system, the Toumai robotic platform features a modular design with localized manufacturing and a comparable configuration, offering similar dexterity and three-dimensional visualization capabilities. Recent clinical studies have demonstrated the feasibility and effectiveness of the Toumai robotic surgical system in complex surgeries such as pulmonary lobectomy and vascular tumor resections, suggesting its potential advantages in minimally invasive surgery^{12,13}. Our surgical team had prior experience operating this system, which facilitated smooth intraoperative workflow and ensured procedural consistency^{14,15}. The system structure is illustrated in Fig. 1.

During surgery, the surgeon operates via the master console, with control signals transmitted through data cables to the slave unit located beside the patient, where the commands are executed as actual surgical movements. Simultaneously, endoscopic images of the surgical field are transmitted back through the same data connection to the master console's display, forming a closed-loop feedback system for real-time interaction.

To ensure smooth operation, the robotic system underwent comprehensive calibration and maintenance four days prior to surgery. On the day of surgery, a professional clinical engineer continuously monitored the system status and connectivity throughout the procedure. Any non-human disturbances were promptly addressed, ensuring the stability and safety of the robotic-assisted operation.

Preoperative preparation and trocar layout

All enrolled patients underwent routine preoperative assessments, including cardiopulmonary function tests, complete blood count, and biochemical analyses. Appropriate nursing care and anesthesia were provided, along with standard perioperative management. All surgeons were proficient in operating the da Vinci robotic system and had completed certified training on the Toumai robotic surgical system, meeting the required competency standards.

Instrument Preparation: In the robotic-assisted group, Arm T2 was configured to allow intraoperative switching between a robotic monopolar cautery hook and robotic dissecting forceps, depending on surgical needs. Arm T3 was equipped with robotic bipolar forceps. In the laparoscopic group, Arm T2 allowed intraoperative switching between standard laparoscopic instruments, including a monopolar hook, dissecting forceps, and a needle holder. Arm T3 was used with dissecting forceps. Surgical details in this study were illustrated using



Fig. 1. Schematic diagram of the Toumai surgical robotic system (Pictures courtesy of Shanghai MicroPort Medical Robotics Co., Ltd.)

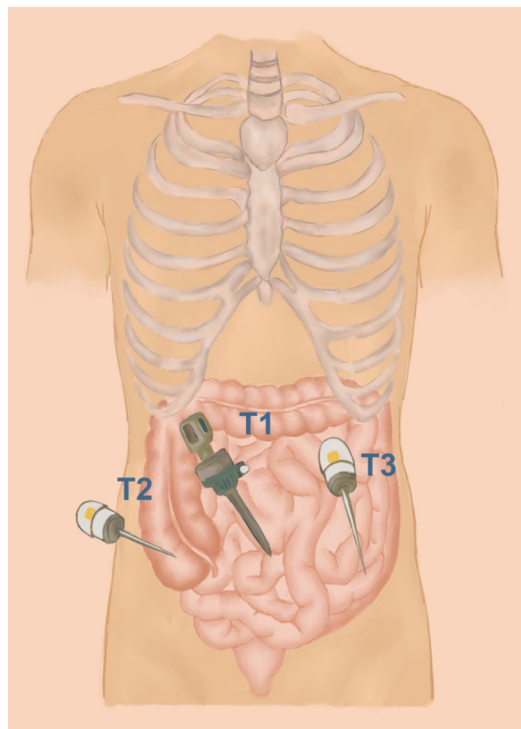


Fig. 2. Trocar layout for inguinal hernia repair. (A standardized trocar placement is used for the figure. When performed using the Toumai robotic system, all three trocars are identical in design and size.) This figure was created using Adobe Photoshop (Adobe Inc., San Jose, CA, USA).

left-sided inguinal hernia repair as a representative example. To ensure comparability, trocar placement was standardized in both the robotic-assisted and laparoscopic surgery groups.

As shown in Fig. 2, T1 served as the camera port and was placed supraumbilically with a 12-mm trocar. T2, the primary operating port, was positioned at the level of the umbilicus along the lateral edge of the right rectus abdominis, where a 12-mm trocar was inserted. T3, the auxiliary port, was located 2 cm below the umbilicus

along the lateral edge of the left rectus abdominis. A 12-mm trocar was used for the robotic-assisted group, while a 5-mm trocar was used for the laparoscopic group.

Surgical procedure

After general anesthesia was stabilized, the surgical field was disinfected in a routine manner. The patient was placed in the supine position with a 30° Trendelenburg tilt and 15° right tilt. An approximately 11.5-mm skin incision was made at the T1 site, through which a trocar was inserted to establish pneumoperitoneum with CO₂. Intra-abdominal pressure was dynamically monitored and maintained at 12 mmHg. A laparoscope was introduced, and the abdominal cavity was explored systematically. Subsequently, incisions were made at T2 and T3, and the corresponding trocars were inserted. Following these steps, inguinal hernia repair was performed. The surgical procedure was largely similar between the robotic-assisted and laparoscopic groups. The peritoneum in the inguinal region was incised, and the hernia sac was carefully dissected using a monopolar hook and dissecting forceps. The spermatic cord was gently mobilized and reduced into the abdominal cavity. The hernia sac was further dissected, and the retropubic (space of Retzius) area was exposed. The surgical field and surrounding areas were carefully inspected for active bleeding. A 3–0 barbed suture was used to close the internal ring. A hernia mesh was placed to cover the internal ring, ensuring adequate coverage. The mesh was carefully flattened and secured in place. The peritoneum was closed with a continuous barbed suture. After confirming the absence of active bleeding, all instruments were withdrawn. The abdominal cavity was deflated by applying pressure. The trocars were removed, and the incisions were closed in layers from deep to superficial. The procedure is illustrated in Fig. 3.

Evaluation indicators

Surgical observation indicators: operation time, intraoperative blood loss, intraoperative, postoperative complications, postoperative hospital stay. Postoperatively, the Pain Score and the Subjective Mental Load Scale (SME Scale) were completed¹⁶. Whether there was a record of a second operation within 24 h after surgery, and complications and adverse events found during the visit. All patients were followed up 1–3 months after surgery, and the healing of the incision and the degree of pain were recorded, which was jointly completed by the medical staff of the Department of General Surgery of our hospital.

Statistical methods

Statistical analysis was performed using SPSS version 26.0. Continuous variables following a normal distribution were expressed as mean ± standard deviation ($\bar{x} \pm s$), while non-normally distributed data were expressed as median (IQR). Between-group comparisons were performed using the independent-samples t test. Categorical variables were compared using the chi-square (χ^2) test. A P value < 0.05 was considered statistically significant.

Results

General baseline characteristics

There was no statistically significant preoperative clinical situation between the robot group and the laparoscopic group ($P > 0.05$), and there was a comparability, as shown in Table 1.

Analysis of surgical efficacy

From January 2022 to October 2023, 50 cases of inguinal hernia repair performed in the Department of General Surgery of Gansu Provincial Hospital were successfully completed. Compared with the laparoscopic group, the intraoperative blood loss, postoperative pain score, SME scale, and postoperative hospital stay in the robot group were lower than those in the laparoscopic group, but the operation time was longer ($P < 0.05$). There was no second operation in the two groups within 24 h, and no complications and adverse events were found during the visit, which was not statistically significant ($P > 0.05$). All the data are given in Table 2.

Comparison of postoperative recovery

The postoperative follow-up period was 3 months. In the robotic group, 1 patient (6.3%) experienced recurrence of a left-sided hernia 2 months after surgery. In the laparoscopic group, 2 patients (5.9%) experienced recurrences: one right-sided at 1 month and one left-sided at 3 months postoperatively.

Poor incision healing occurred in 0 cases (0.0%) in the robotic group and 3 cases (8.8%) in the laparoscopic group. Incision pain was reported in 1 case (6.3%) and 4 cases (11.8%), respectively. Overall, postoperative wound healing was better and pain milder in the robotic group. No postoperative adverse events occurred in either group. Detailed data are presented in Table 3.

Discussion

Inguinal hernia is one of the earliest diseases in general surgery to be used laparoscopic technique, and laparoscopic inguinal hernia repair has been widely recognized for its clinical practicability and safety, and has gradually replaced the mainstream position of traditional open surgery due to its advantages of less intraoperative bleeding and faster postoperative recovery¹⁷. Follow-up studies have found that robotic inguinal hernia repair has less intraoperative blood loss, less postoperative pain than traditional laparoscopy, and faster postoperative recovery¹⁸.

The results of this study showed that the operation time of the patients in the robot group was longer than that in the laparoscopic group, but the intraoperative blood loss, postoperative hospital stay, SME scale and pain score were lower than those in the laparoscopic group, and the difference was statistically significant ($P < 0.05$). The longer operation time of the robotic group is due to the fact that it takes a certain amount of time

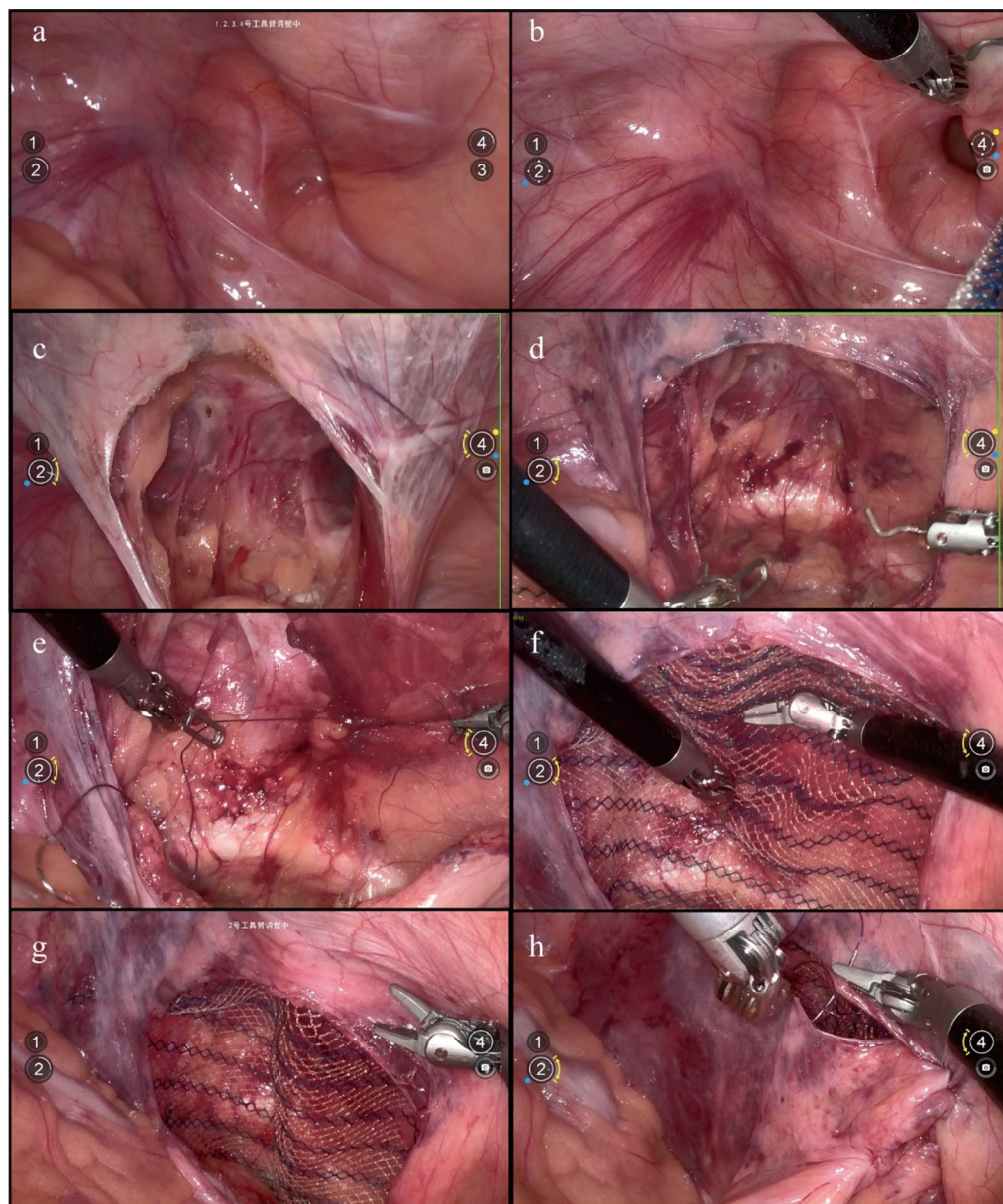


Fig. 3. Intraoperative picture of “Toumai” robotic surgical system assisted in lower inguinal hernia repair. (a) Establishment of CO₂ pneumoperitoneum. (b) Abdominal exploration. (c) Isolation of the hernia sac. (d) Removal of the abdominal wall by free spermatic cord and peeling off of the hernia sac. (e) Suturing and closing of the hernia ring. (f) Taking the patch to cover the inner opening of the hernia ring. (g) Suturing and fixing the mesh. (h) Continuous suturing of the peritoneum.

Variables	Age	Gender	Weight (kg)	Hernia classification	
		Male: female		Oblique hernia (left, right)	Straight hernia
Robot group (n = 16)	55.56 ± 11.37	15:1	63.94 ± 11.21	13(5,8)	3
Laparoscopic group (n = 34)	56.38 ± 16.36	29:5	65.03 ± 7.01	28(11,17)	6
χ^2/t	0.201	0.737	0.366	0.011	
P	0.841	0.391	0.716	0.991	

Table 1. Compares the preoperative clinical data of the two groups.

Variables	Intraoperative blood loss (mL)	Length of postoperative hospital stay (days)	Postoperative pain score	SME scale	Operative time (min)
Robot group (<i>n</i> = 16)	6.94 ± 3.80	3.18 ± 0.54	2.06 ± 0.93	18.12 ± 12.23	104.19 ± 18.93
Laparoscopic group (<i>n</i> = 34)	12.24 ± 9.31	3.68 ± 0.81	3.03 ± 1.29	30.17 ± 11.46	90.17 ± 22.31
t	2.744	2.543	2.98	3.324	2.286
P	0.008	0.015	0.005	0.002	0.027

Table 2. Comparison of the evaluation indicators between the two groups.

Variables	Postoperative recurrence	The incision heals poorly	Pain in the incision
Robot group (<i>n</i> = 16)	1 (6.3%)	0 (0.0%)	1 (6.3%)
Laparoscopic group (<i>n</i> = 34)	2 (5.9%)	3 (8.8%)	4 (11.8%)

Table 3. Comparison of postoperative recovery between the two groups.

to locate and connect the robotic surgical system in the preparation stage, and it also takes a lot of time to replace the surgical instruments in the middle of the process, but with the development of technology and the progress of the surgical team, this process may be greatly reduced. Robotic surgical systems are characterized by flexible joint manipulation, combined with reduced amplitude of motion and fibrillation filtration, which makes instrument movement more sensitive and less restricted in tight spaces¹⁹. For long-term surgery, considering the influence of the surgeon's physical strength and mental concentration, it may have a certain impact on the operation of laparoscopic surgery. However, robotic surgical systems further reduce the errors caused by human and instrument collisions, allowing laparoscopic procedures such as suturing and knotting⁶. Although the differences in blood loss and hospital stay may appear small, they can still be clinically meaningful—especially in high-risk patients or high-volume centers where small improvements per case can lead to significant cumulative benefits. Additionally, shorter hospitalization aligns with enhanced recovery after surgery protocols, improving recovery efficiency and patient outcomes.

The reduced postoperative pain and improved wound healing observed in the robotic group may be attributed to enhanced precision and stability of instrument movement, resulting in minimized tissue traction and thermal damage. Moreover, smaller and more stable incisions facilitated by the robotic arms could promote better healing with fewer complications. Recent studies have also demonstrated that robot-assisted surgery is associated with reduced intraoperative blood loss and shorter hospital stays²⁰. A small value on the SME scale indicates that Toumai robot-assisted surgery can reduce the difficulty of inguinal hernia repair. The recurrence rates of the robot group and the laparoscopic group were 6.3% and 5.9%, respectively. This shows that both robotic and traditional laparoscopic surgery have good postoperative recovery under strict adherence to aseptic operation and standardized surgical procedures.

According to the research results, the surgeon's overall experience of using the "Toumai" robotic surgical system is better than that of laparoscopy, in which the operation and visual performance of the doctor's console and the use of the patient's surgical platform are more convenient, the surgical field of vision is very clear, the stability of the instruments is mostly stable, and a few occasionally flutter but do not affect the sense of experience, and the operation flexibility is also better. Based on the evaluation of the surgeon's perception of the robotic surgical system, it has more advantages than traditional laparoscopy in the treatment of longer operation time and complex surgical fields. The three-dimensional visual experience, fine and accurate use experience, can very clearly expose the position of organs and blood vessels, play a good role in avoiding intraoperative errors, and facilitate the surgeon to carry out precise operations such as vascular separation and suturing the peritoneum. The shortening of the learning curve of robotic surgical systems has been helpful in performing inguinal hernia repair by surgeons who are less skilled in laparoscopy.

In summary, the experience of using the "Toumai" surgical robot-assisted and traditional laparoscopic inguinal hernia repair is as follows: (1) The highly flexible robotic arm of the "Toumai" surgical robot can minimally invasive, improve the accuracy of the operation, and reduce the fatigue of the surgeon, which is effective, feasible, and safe in clinical application, which has been proven in other surgeries¹². Compared with the traditional laparoscope, the instruments interfere with each other, the hand movement is wrong, and the fatigue caused by long-term surgery, the "Toumai" surgical robot will be improved. (2) Due to the built-in eyepiece, the Toumai surgical robot can provide a clear naked-eye 3D high-definition stereo vision experience¹³, which has a more intuitive visual range than the traditional laparoscope, which is convenient for the surgeon to operate in a small space. (3) The "Toumai" surgical robot has multiple flexible and mobile robotic arms, which can simplify the complex surgical process and reduce the errors caused by the mismatch of manpower coordination in laparoscopic operation. (4) Robot-assisted surgery, with intuitive robotic arm swing design and rotation angle, and several times magnified surgical field of view is also conducive to the treatment of some difficult situations during surgery²¹. Compared with laparoscopy, it has a shorter training and learning time for students, and is relatively friendly to beginners. At the same time, there are also some limitations of the "Toumai" surgical robot: (1) Although the cost of equipment repair and maintenance is relatively cheaper than that of imported robotic surgical assistance systems such as da Vinci, compared with traditional laparoscopy, the primary aspect that patients focus on is especially the high surgical cost²², which creates some resistance

to its large-scale popularization and promotion in primary hospitals. Traditional laparoscopic surgery is more affordable than surgical robots in terms of hospitalization costs, and may be the preferred treatment for patients, and traditional laparoscopic inguinal repair is still the main treatment for inguinal hernia at this stage. (2) The lack of force feedback is a common problem in robotic surgical systems that needs to be improved, and the same is true of the “Toumai” surgical robot system. Compared with the mobility and maneuverability established by tactile and visual double feedback in laparoscopic surgery, surgical robots need to be improved in this regard. Due to the lack of tactile feedback, the surgeon can only make visual judgments, which increases the risk of tissue damage, and physicians with rich experience in robotic surgical system operation can compensate for the lack of force feedback through experience after receiving training.

At present, there are few studies on robot-assisted inguinal hernia repair, especially involving the domestically developed “Toumai” surgical system. This study is limited by its small sample size, single-center setting, and retrospective design, which may affect the generalizability of the results. Although the outcomes are encouraging, further confirmation through large-scale, multicenter prospective studies is needed. In addition, the use of big data analysis would help validate these findings and better assess the long-term effectiveness and safety of the “Toumai” robot in broader clinical practice.

Conclusion

In summary, the “Toumai” surgical robot has less blood loss, faster postoperative recovery and less postoperative pain than laparoscopic surgery in inguinal hernia repair, but its operation time is relatively longer, which preliminarily verifies that the clinical application of “Toumai” surgical robot is safe and feasible. It is believed that the development of science and technology and the accumulation of clinicians’ operating experience can promote the improvement of the “Toumai” surgical robot system and benefit more patients.

Data availability

The datasets used and analysed during the current study available from the corresponding author on reasonable request.

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Author contributions

YW: Writing–review and editing, Formal Analysis, Data curation. CG: Writing–original draft, Writing–review and editing. MZ: Writing–original draft, Writing–review and editing. XG: Data curation, Writing–review and editing. GY: Data curation, Writing–review and editing. HS: Data curation, Writing–review and editing. PN: Funding acquisition, Formal Analysis, Writing–review and editing. YM: Funding acquisition, Writing–original draft, Writing–review and editing.

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Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

Approval was obtained from Gansu Provincial Hospital (2024-025). The study was performed in accordance with the ethical standards of the Declaration of Helsinki.

Informed consent

Informed consent was obtained from all individual participants included in the study. The patients consented that their data and photographs will be published.

Additional information

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