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TECHNIQUES AND INSTRUMENTATION

Single-port hysterectomy with pelvic lymph node dissection in the porcine model: feasibility and validation of a novel robotic lightweight endoscope positioner

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Abstract The purpose of this study was to evaluate the feasibility and validity of a modified single-port robotic lightweight endoscope in the performance of single-port hysterectomy with pelvic lymph node dissection in the porcine model. Task completion times were recorded for each component of the procedure: port placement, docking of the surgical robot, operative time for the procedures. For each task, linear regression modeling was performed using SPSS to determine whether a correlation existed between task completion time and increasing surgeon experience. All robotic-assisted LESS procedures were performed successfully without the addition of laparoscopic ports or open conversion. Regression analysis demonstrated a strong correlation between the number of procedures and task completion time for robot docking and pelvic lymph node dissection, correlation coefficients 0.74 and 0.77, p=0.001, respectively. This study demonstrated the feasibility and effectiveness of a new, compact single-port robotic voice-activated endoscope at improving laparoscope guidance during the performance of single-port hysterectomy with pelvic lymph node dissection in the porcine model. Further work is needed to better define the ideal operative procedure for single-site surgery in oncology and integration of new single-port robotic platforms into clinical practice.

Keywords Robotic surgery · Single-port surgery · LESS · Single-port laparoscopy

Background

Innovations in minimally invasive surgical technology have allowed laparoscopic surgeons to perform increasingly complex surgeries through smaller incisions. An emerging area in minimally invasive surgery is single-port laparoscopy (SPL), or laparoendoscopic single-site surgery (LESS). SPL entails performing laparoscopic surgery utilizing a multi-channel port system, typically placed through a single umbilical skin incision. New technologies have improved the success and reproducibility of these single-access approaches, including the use of flexible laparoscopes, flexible instruments, and internal retractors. However, significant obstacles still exist mainly due to physical impediments of instrumentation.

Working within a confined space, typically the umbilicus, results in several shortcomings. These disadvantages include conflict of instruments sharing a common port, different or inferior retraction in the operative field, unstable flexible endoscopes, and surgeon fatigue and discomfort secondary to poor ergonomics. Recently, there has been interest in the application of robotic technology to these procedures [1–4]. Fusion of these concepts, single-site surgery and robotic technology is an area of active research and innovation in minimally invasive surgery. The purpose of this study was to evaluate the feasibility and validity of a modified single-port

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robotic lightweight endoscope (ViKY-XL) in the performance of single-port hysterectomy with pelvic lymph node dissection in the porcine model.

Material and methods

This pilot training study was performed at the Cleveland Clinic, c-SITE, Cleveland, OH, USA. All procedures performed in this training protocol have been approved by the Institutional Animal Care and Use Committee (IACUC) at the Cleveland Clinic, Protocol no. (2009–0086). Task completion times were recorded for each component of the procedure: port placement, docking of the surgical robot, operative time for the hysterectomy with BSO, and operative time for pelvic lymph node dissection. For each task linear regression modeling was performed using SPSS (version 19.0.0) to determine whether a correlation existed between task completion time and increasing surgeon experience.

Robotic lightweight endoscope positioner

The ViKY® System "Vision Control for endoscopY" (Endocontrol Medical, La Tronche, France) is a compact motorized endoscope driver designed to improve surgeon ergonomics (Fig. 1). The original model followed foot pedal commands, which moved the endoscope in the x, y, and z axes. Keeping the same architecture, but with a larger platform, the modified ViKY® XL system includes a compact motorized voice-activated (Bluetooth) endoscope manipulator specially designed for single-access surgery. The platform has a diameter of 182 mm and weighs 2.2 kg. The main ring of the system is fastened on one of the lateral operating room table rails through a height adjustment mechanism. Three degrees of freedom are integrated into the main ring of the system. Media File 1

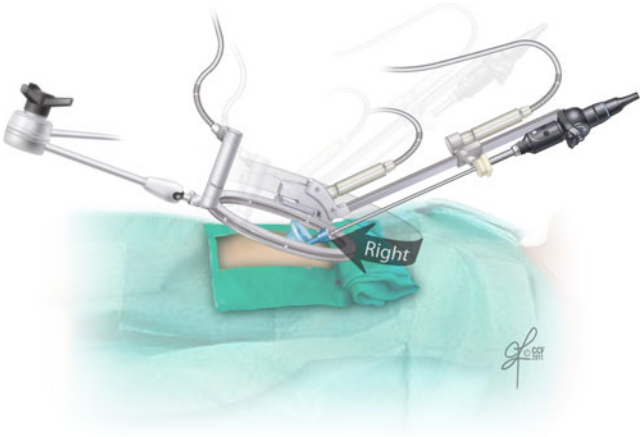

Fig. 1 Robotic endoscope driver moving camera toward field right

The study was performed on 12 healthy female pigs. Normal health status was determined preoperatively by physical examination, blood chemistry, and quarantine (according to the IACUC protocol). Food was withheld from the pigs for 24 h before surgery. All animals were provided water ad libitum. Pre-operative care, anesthesia, and euthanasia were overseen by a staff veterinarian. After induction, all pigs were positioned in dorsal lithotomy position for the surgical procedures. At the conclusion of the lab, the pigs remained under general anesthesia and were humanely euthanized.

Access was obtained using the Hasson technique through a 1.5–2.0 cm umbilical incision allowing insertion of the SILS™(Covidien, Mansfield, CT, USA) single-port robotic trocar system. The abdominal cavity was insufflated to an intra-abdominal pressure of 12 mmHg. The surgical table was tilted to a 35° Trendelenburg position to displace the abdominal viscera cranially. The urinary bladder was then drained directly to ease visualization of the pelvis.

The ViKY® System was docked into one of the lateral surgical table rails through a height/pivot adjustment mechanism. An Olympus 5-mm LTF-VH deflectable tip video laparoscope (Olympus Surgical and Industrial America Inc, Center Valley, PA, USA) was then coupled with the system. A Bluetooth ear-piece was utilized to aurally control the platform's 3 degrees of freedom (in/out, left/right, up/down) (Media File 1). Articulated Maryland graspers, curved scissors, and 5-mm Ligasure blunt tip vessel sealer were then used for lymph node dissections and hysterectomies/oophorectomies. The iliac artery and vein were first identified, the retroperitoneal space entered and developed in a caudal–cranial fashion. The lymphatic tissue was removed using the Maryland grasper and 5-mm Ligasure (Covidien, Mansfield, CT, USA).

Findings

All robotic-assisted LESS procedures were performed successfully without the addition of laparoscopic ports or open conversion. The lightweight/compact system allowed the surgeon to stand next to the surgical table in an ergonomic fashion without restricting the freedom of motion and limiting endoscope-instrument clashing.

Mean animal weight was 26.14 kg (23–29 kg). Mean task completion times are noted in Table 1. Figure 2 illustrates the trend in task completion times with increasing number of procedures, $p=0.001$. Regression analysis demonstrated a strong correlation between increasing surgeon experience and decreasing task completion time for robot docking and pelvic lymph node dissection, correlation coefficients 0.74 and 0.77, respectively (Figs. 3 and 4). No statistically significant improvement in task completion time was noted for port placement or hysterectomy with oophorectomy. No intraoperative complications were observed.

Table 1 Task completion time

Task	Mean completion time (range)
Port placement	4.75 min (3–7 min); SD, 1.22
Docking	7.25 min (4–13 min); SD, 2.93
Hysterectomy, oophorectomy	20.92 min (15–25 min); SD, 2.94
Pelvic node dissection	64.25 min (48–85 min); SD, 11.89

Discussion

This study demonstrated the feasibility and effectiveness of a new, compact single-port robotic voice-activated endoscope at improving laparoscope guidance during the performance of single-port hysterectomy with pelvic lymph node dissection in the porcine model. This robotic voice-activated endoscope driver contributed to a stable endoscopic image, and allowed significant improvement in operating times.

Ergonomics has a major influence on the acceptance and dissemination of new surgical technology. There are several inherent limitations of LESS when compared to laparoscopy and robotic techniques. These disadvantages include conflict between instruments, diminished triangulation, different or inferior retraction in the operative field, unstable flexible endoscopes, and surgeon fatigue and discomfort secondary to poor ergonomics. To alleviate inherent problems attributable to the single-site approach, several ad hoc novel flexible instruments and optics have been developed in the last few years.

Perhaps the most significant advantage of this robotic system when coupled with an articulated endoscope is improved visualization and stability of the surgical field as well as improved ergonomics, minimizing instrument conflict thereby potentiating greater precision and accuracy. Our results are consistent with a previous study by Crouzet et al. for reconstructive and extirpative urological surgery using the porcine model [5]. The authors concluded that with single-port access, the robotic endoscope allows more room for the surgeon compared to an assistant. This is also consistent with data published regarding the da Vinci SI for single-site surgery in urology. Using the current da Vinci SI via a single-site approach for radical prostatectomies in a preclinical setting, Desai et al. concluded that conflict of the robotic arms was worse compared to multiport cadaveric procedures, but closure/suturing was easier [6]. Consequently, White et al. reported early surgical outcomes on 20 patients who underwent robotic laparoendoscopic single-site radical prostatectomy (R-LESS RP) [7]. The authors concluded that R-LESS RP was technically feasible and reduces some of the difficulties encountered with conventional LESS.

The robotic platform as we know it today (da Vinci S and da VinciSI) is not ideal for robotic single-site surgery due to spatial constraints and a significant amount of exterior instrument collisions, but future versions of the device will surely provide integral elements to further the development of single-port gynecologic surgery [8]. Current research within our group has focused on the evaluation of novel single-port robotic platforms for procedures in gynecologic oncology [9, 10]. Preliminary data demonstrates that the performance of various oncology procedures using novel single-site robotic platforms is feasible, and more importantly, overcomes inherent limitations of LESS.

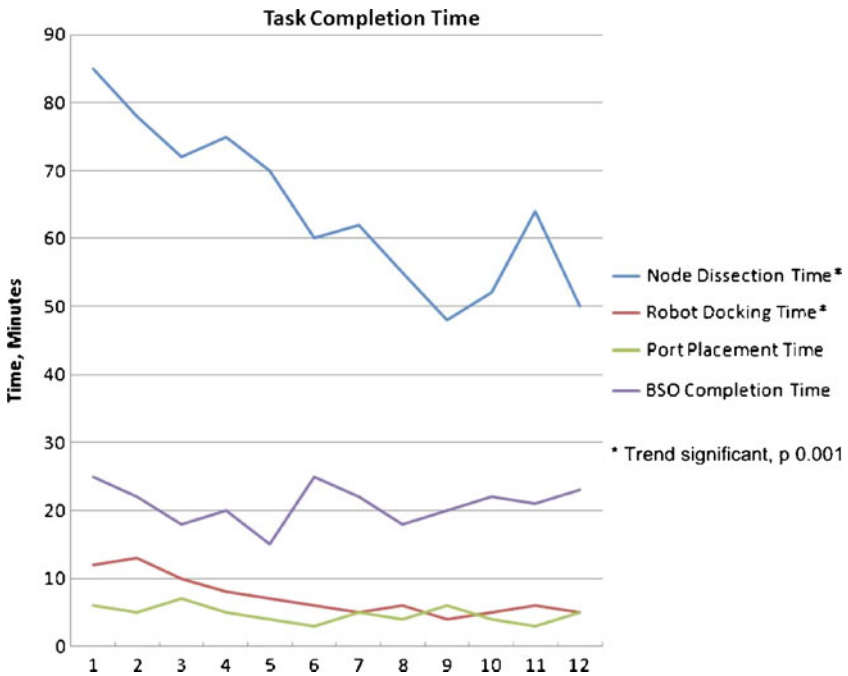

Fig. 2 Trends in task completion time

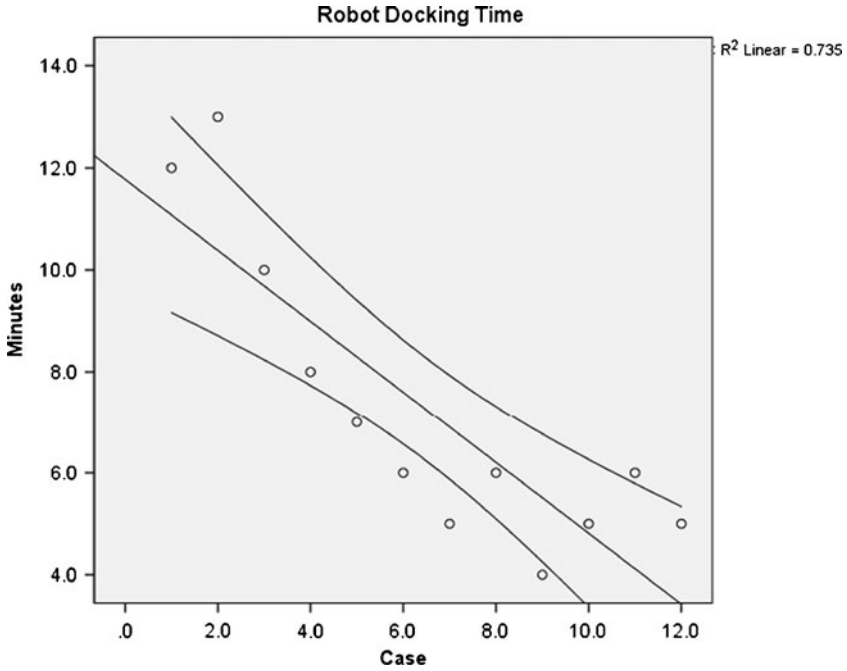

Fig. 3 Learning curve for robot setup

Conclusion

In conclusion, we report here the feasibility of a surgical robot with master–slave function for visual field control for single-port surgery. The novel advantage of the system when coupled with a flexible 5-mm endoscope is the control, and stability of the vision field for LESS. This is an advantage when performing ergonomically complex procedures such as node dissections during via a single-port approach. Further work is needed to better define the ideal operative procedure for single-site surgery in oncology and integration of new single-port robotic platforms into clinical practice.

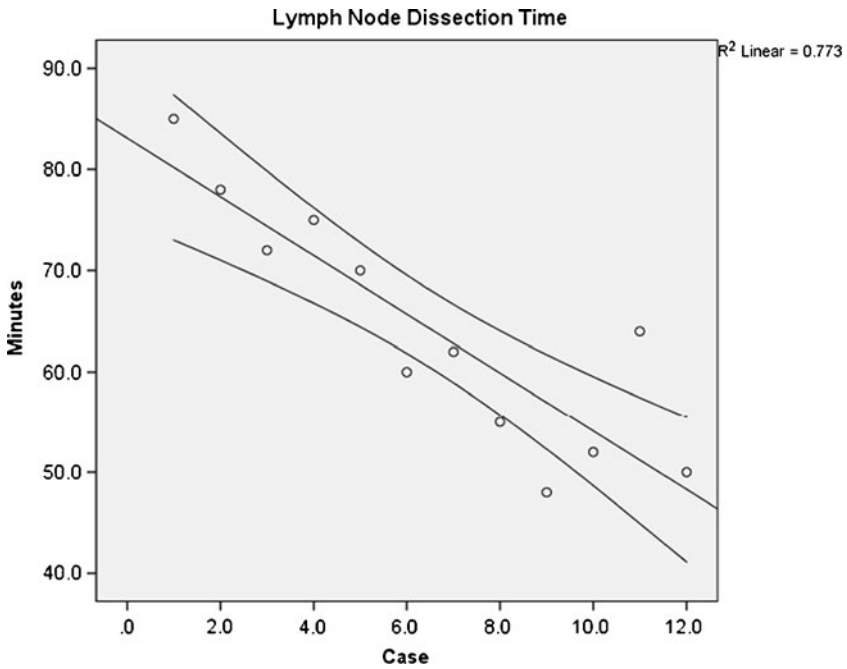

Fig. 4 Learning curve for lymph node dissection with ViKY

Declaration of interest The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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