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Short Report

Title: Tele-robotic distal gastrectomy with lymph node dissection on a cadaver

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ABSTRACT

The purpose of this study is to evaluate the performance of tele-robotic distal gastrectomy (tele-RDG) with lymph node dissection (LND) using a novel Japanese-made surgical robot hinotori™ (Medicaroid, Kobe, Japan) in a cadaver with a presumptive gastric cancer. The Cadaveric Anatomy and Surgical Training laboratory（CAST-Lab.）at Hokkaido University and Kushiro City General Hospital (KCGH) are connected by a guaranteed type line (1 Gbps), and the distance between the two facilities is 250 km. A patient cart was installed at CAST-Lab, and a surgeon cockpit was installed at KCGH. Tele-RDG with D2 LND was performed on an adult human cadaver. In all surgical processes, the communication environment was stable without image degradation, and the mean RTT was 40 ms (36.5-55 ms). For tele-RDG with D2 LND, the operation time was 199 min. without any technical problems. Tele-RDG using hinotori ™ was feasible and similar to local robotic RDG.

Keywords: Telesurgery, robotic surgery, gastrectomy, cadaver

Introduction

In recent years, the development of high-speed, high-capacity communication technologies using optical fiber and 5th generation mobile communication systems (5G), and new surgical robots have made remote surgery a reality[1]. The Japan Surgical Society (JSS) has published a series of studies to establish the minimum requirements for telesurgery, especially the telesurgical support needed to perform actual telesurgery using a novel Japanese-made surgical robot hinotori™ (Medicaroid, Kobe, Japan)[2,3]. The purpose of this study is to evaluate the surgical feasibility of tele-robotic distal gastrectomy (tele-RDG) with lymph node dissection (LND) using hinotori™ on a cadaver with presumptive gastric cancer in a clinical setting.

Material and Methods

The Cadaveric Anatomy and Surgical Training laboratory (CAST-Lab.) at Hokkaido University and Kushiro City General Hospital (KCGH), which are 250 km apart, were connected by a guaranteed type line (1G-bps) provided by NTT East (Nippon Telegraph and Telephone East Corporation, Tokyo, Japan) using Internet Protocol Security (IPSec) encryption. The operating unit was installed in the CAST-Lab. A surgeon cockpit was installed at KCGH, where the surgeon performed the tele-RDG with LND. Time (RTT; in milliseconds) where the round trip of communication was measured (Fig.1). The request was sent by a switch on the surgeon's cockpit side, and the response time from the switch on the operator's side was measured intraoperatively. The study was conducted using a Thiel-embalmed cadaver (male)

with an age at death of 80 years. The surgery was conducted by a physician certified in the robot proctoring qualification system of the Japan Society for Endoscopic Surgery (JSES), and the evaluators were skilled surgeons who were JSES technical certified physicians. We performed tele-RDG with D2 LND and intracorporeal Billroth I reconstruction in the cadaver (Fig. 2). The regions of lymph node dissection were defined according to the Japanese Classification of Gastric Carcinoma[4]. Details of this procedure have been described in our previous report on human patients[5]. Two assisting surgeons and one scrub nurse were assigned to CAST-Lab and one surgeon was assigned to KCGH to perform tele-RDG. We measured the operation time, Global Evaluative Assessment of Robotic Skills (GEARS)[6], Global Operative Assessment of Laparoscopic Skills (GOALS)[7], Robot Usability Score (RUS)[8], system Usability Scale (SUS)[9], and Piper Fatigue Scale-12 (PFS-12)[10]. GEARS and GOALS consist of each domain (depth perception, bimanual dexterity, efficiency, force sensitivity, autonomy, and robot control) and are scored on a 5-point scale to reliably quantify technical proficiency. The technical evaluation was conducted by two physicians certified in the endoscopic surgical skill qualification system of JSES[11].

Results

In all surgical processes, the communication environment was stable without image degradation, and the mean RTT was 40 ms. (36.5-55 ms). Tele-RDG with D2 LND was performed safely without organ injury. The operation time was 199 minutes, The overall score were GEARS:28 (depth perception:5,

bimanual dexterity:5, efficiency:4, force sensitivity 5, autonomy:5, robotic control:4), GOALS:23 (depth perception:5, bimanual dexterity:5, efficiency:4, tissue handling:4, autonomy:5), RUS:34 (physical comfort:4, hand controls:4, foot controls:4, 3D vision:5, annoyed or stressed:4, smooth:4, satisfaction:4, actuality:5), SUS:82.5（acceptability ranges: acceptable, grade scale: A, adjective ratings: excellent), and PFS-12:26 (behavioral:9, affective:6, sensory:6, cognitive:5).

Discussion

Our study revealed that tele-RDG with LND using the hinotori™ surgical robot system is feasible for local robotic surgery. To the best of our knowledge, this is the first report of a tele-RDG with LND envisioned for gastric cancer in a cadaver.

In 2001, Marescaux et al. reported the first successful completion of transatlantic robot-assisted cholecystectomy using a Zeus surgical robot (formerly Computer Motion, CA) in clinical practice[12]. One advantage of tele-robotic surgery (tele-RS) is that it reduces physical, emotional, and financial burdens by eliminating the need for patients and surgeons to travel. In areas where medical resources are scarce, the potential to contribute to the population through tele-RS is significant. In comparison to open or conventional laparoscopic surgery, RS having the medical staff away from the bedside potentially reduces not only contamination with body fluids and surgical gasses of the surgical area but also the number of directly exposed medical staff[13]. Tele-RS can play a pivotal role in surgical procedures performed during

the pandemic caused by the currently prevalent coronavirus disease.

In this study, the communication environment was stable, with an average RTT of 40 ms on a guaranteed line (1 Gbps), and all surgical procedures, including gastrectomy, lymph node dissection, and intracorporeal anastomosis, were performed without any problems caused by communication delay. Regarding transmission delay, we reported that operability decreases when the delay time perceived by the surgeon exceeds 100 ms in dynamic environments[14], and on hemostasis and cholecystectomy in animal experiments. In the future, we plan to validate delays in more sensitive tasks (e.g. lymphadenectomy and reconstruction) in dynamic environments.

Regarding the tele-RDG with D2 LND, the operation time was 199 min. and was performed without any organ injury nor technical trouble. Moreover, the technical evaluation score (GEARS:28, GOALS:23), usability score (RUS:34, SUS:82.5), and surgeon fatigue score (PFS-12:26) were similar to those of clinical RDG.

This study had several limitations. The current experiment was conducted by only one expert surgeon, and its introduction into clinical practice should be made with caution. Clinical trials are necessary before tele-RDG with LND can be introduced into clinical practice in the future.

Conclusion

Tele-RDG with LND using hinotori™ on cadavers was feasible and is similar to the local robotic

RDG for gastric cancer.

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Author contributions: All authors contributed to the conception and design of the study. Yuma Ebihara, Hironobu Takano, and Satoshi Hirano helped in the material preparation, data collection, and analysis.

The first draft of the manuscript was written by Yuma Ebihara and Satoshi Hirano, and all authors commented on the previous versions of the manuscript. All the authors have read and approved the final manuscript.

Ethics approval and consent to participate: Ethical Review Board for Life Science and Medical Research, Hokkaido University Hospital approved the cadaveric study, data collection and analysis (No. 022-0363). All managements of the cadaver study including the informed consent of body donation and opt-out of this research and were carried out in accordance with guidelines for cadaver dissection in education and research of clinical medicine by Japan Surgical Society and Japanese Association of Anatomists.

Consent to publish: All authors confirmed that consent to publish has been obtained.

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Figure legends:

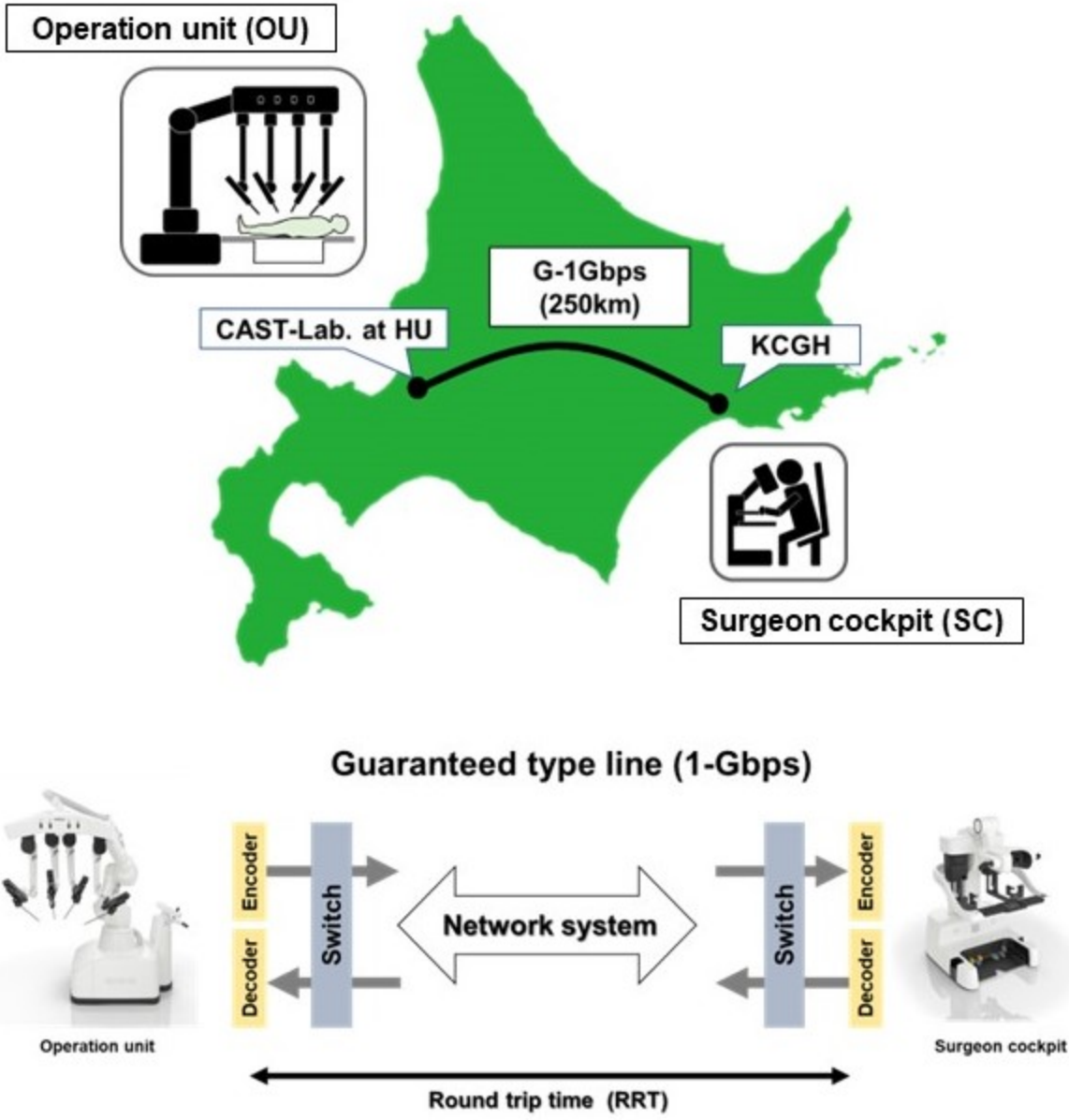
Fig.1

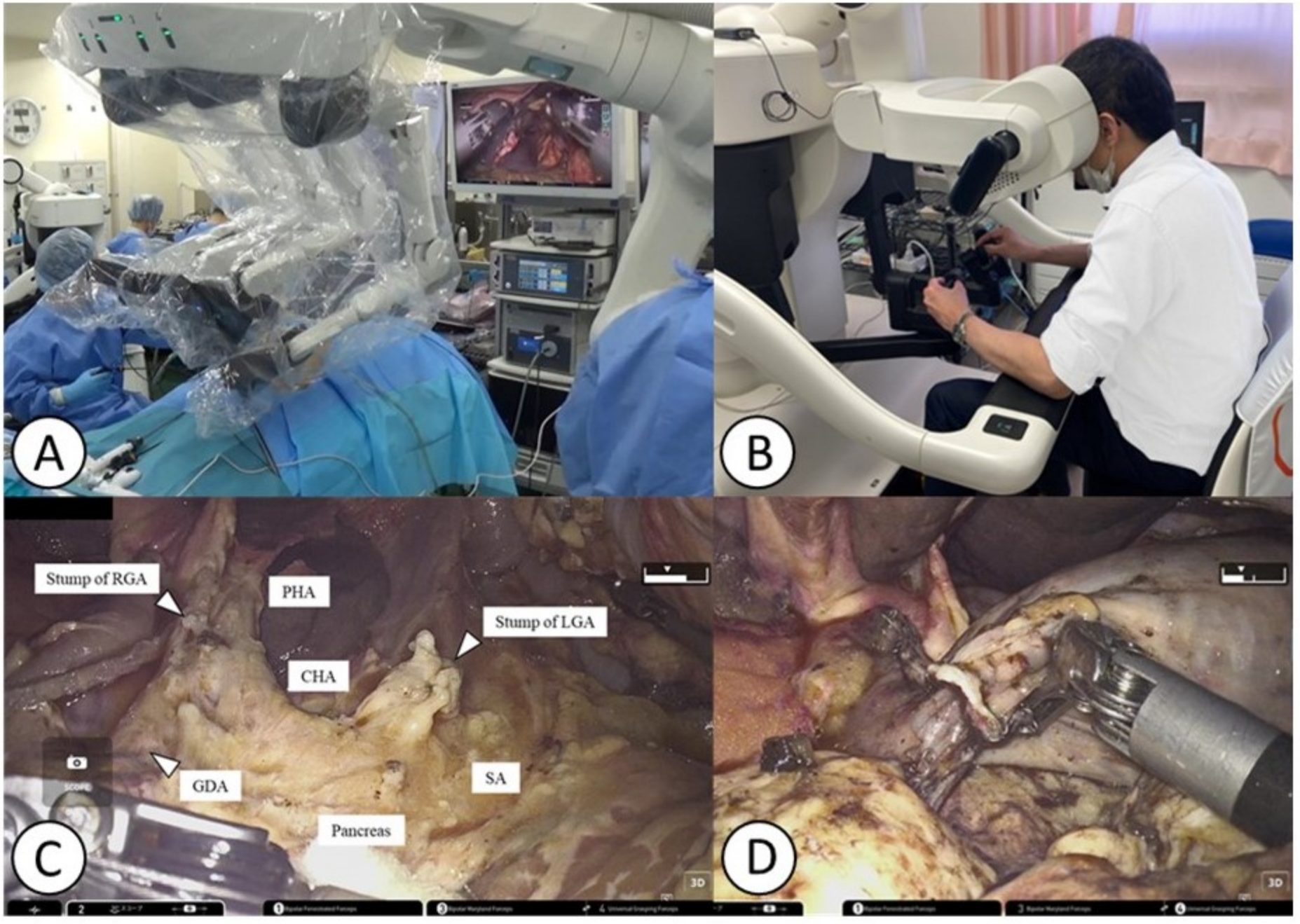
(Up) Operation unit (OU) at the clinical autopsy training center (CAST-Lab.) at Hokkaido University (HU) and surgeon cockpit (SC) in the remote site 250 km away (KCGH; Kushiro City General Hospital) where the surgeon performed tele-robotic distal gastrectomy with D2 lymph node dissection using a novel Japanese-made surgical robot hinotori™ (Medicaroid, Kobe, Japan) on a cadaver. (Down) OU at CAST-Lab and SC at KCGH were connected by a guaranteed type line (G-1Gbps) provided by NTT East (Nippon Telegraph and Telephone East Corporation, Tokyo, Japan) using Internet Protocol Security (IPSec) encryption. Round trip time (RTT) is composed of communication line delay.

Fig.2

A: Operation unit at the clinical autopsy training center at Hokkaido University. B: surgeon cockpit at Kushiro City General Hospital. C: Final view of the dissection of suprapancreatic lymph nodes. (CHA, common hepatic artery; GDA, gastroduodenal artery; LGA, left gastric artery; PHA, proper hepatic artery; SA, splenic artery; RGA, right gastric artery) D: Final view of the intracorporeal Billroth-I

reconstruction. (Duo, duodenum; St. stomach)


Operation unit (OU)
G-1Gbps
(250km)
CAST-Lab. at HU
KCGH
Surgeon cockpit (SC)
Guaranteed type line (1-Gbps)
Encoder
Decoder
Switch
Network system
Switch
Encoder
Decoder
Operation unit
Surgeon cockpit
Round trip time (RRT)


A
B
Stump of RGA
PHA
Stump of LGA
CHA
GDA
SA
Pancreas
C
D
3D
3D