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RESEARCH

Establishment of a new practical telesurgical platform using the hinotori™ Surgical Robot System: a preclinical study

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Abstract

Aim The recent development of new surgical robots and network telecommunication technology has opened new avenues for robotic telesurgery. Although a few gastroenterological surgeries have been performed in the telesurgery setting, more technically demanding procedures including gastrectomy with D2 lymphadenectomy and intracorporeal anastomosis have never been reported. We examined the feasibility of telesurgical robotic gastrectomy using the hinotori™ Surgical Robot System in a preclinical setting.

Methods First, the suturing time in the dry model was measured in the virtual telesurgery setting to determine the latency time threshold. Second, a surgeon cockpit and a patient unit were installed at Okazaki Medical Center and Fujita Health University, respectively (approximately 30 km apart), and connected using a 10-Gbps leased optic-fiber network. After evaluating the feasibility in the dry gastrectomy model, robotic distal gastrectomies with D2 lymphadenectomy and intracorporeal B-I anastomosis were performed in two porcine models.

Results The virtual telesurgery study identified a latency time threshold of 125 ms. In the actual telesurgery setting, the latency time was 27 ms, including a 2-ms telecommunication network delay and a 25-ms local information process delay. After verifying the feasibility of the operative procedures using a gastrectomy model, two telesurgical gastrectomies were successfully completed without any unexpected events. No fluctuation was observed across the actual telesurgeries.

Conclusion Short-distance telesurgical robotic surgery for technically more demanding procedure may be safely conducted using the hinotori Surgical Robot System connected by high-speed optic-fiber communication.

Keywords Gastrectomy · Lymphadenectomy · Remote operations · Robotic surgical procedure

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Introduction

In 2001, Marescaux and colleagues reported the first successful completion of transatlantic robot-assisted cholecystectomy using the Zeus surgical robot (former Computer Motion, CA) in clinical practice [1]. They performed cholecystectomy from New York in six porcine models and one human located in Strasbourg, France, which are approximately 7000 km apart. Subsequently, Anvari and colleagues reported 21 successful procedures routinely performed using the Zeus surgical robot and Canadian telesurgical network [2, 3]. Thus far, a limited number of telesurgical procedures, including cholecystectomy, gastric banding, Nissen fundoplication, hemicolectomy, and anterior resection, have been performed in the gastroenterological field [2, 4, 5]. Despite its introduction in the early 2000s, telesurgery has not widely spread because of the limited telecommunication network technology, its high cost, and the fact that telesurgery has not been implemented in the da Vinci™ Surgical System (Intuitive Surgical Inc., CA), which is the most common surgical robot installed worldwide [6]. Recently, the development of new surgical robots and network telecommunication technology using optical fiber, and 5G has expanded the potential use of telesurgery [6–8].

As several studies demonstrated the advantage of robotic surgery over open or conventional laparoscopic approach, the Japanese government approved robotic surgery for three gastrointestinal cancers including gastric cancer under the national medical insurance coverage in 2018 [9]. Subsequently, robotic surgery has rapidly spread nationwide. It is mandated by the Japanese Society of Endoscopic Surgery to invite expert surgeons for new application of robotic approach, which causes excessive burden for the experts. The telesurgical platform, which enables training, mentoring, and proctoring of surgery, is expected to solve this issue.

In 2019, a new surgical robot named the hinotori™ Surgical Robot System was launched by Medicaroid Inc. (Kobe, Japan), Japan. This surgical robot has a surgeon cockpit with a manipulator and operation unit with four arms for instruments, including a camera scope. In addition, a telesurgery system was implemented in this surgical robot.

For patients with gastric cancer, R0 resection with lymphadenectomy is a mainstream curative treatment [10]. Minimally invasive surgery for gastric cancer has been utilized for a few decades, and recently, a robotic approach using the da Vinci Surgical System has rapidly gained popularity globally. However, this technique is technically demanding, and there is no report of telesurgical gastrectomy for gastric cancer.

Following these previous examples, this study aimed to establish a telesurgical system that enabled us to perform complex procedures including gastrectomy combined with D2 lymphadenectomy and intracorporeal anastomosis using the hinotori Surgical Robot System.

Methods

hinotori Surgical Robot System

We used a new Japanese surgical robot named the hinotori Surgical Robot System in this study. This surgical robot was developed by Medicaroid Inc., which was established in 2013 as a joint investment between Kawasaki Heavy Industries, Ltd. (Tokyo, Japan) and Sysmex Corporation. (Kobe, Japan), by focusing on "compactness," "safety," and "maneuverability," and it consists of an operation unit with four arms and a surgeon cockpit (Fig. 1a, b). This system became the first robotic-assisted surgery system created in Japan to gain Japanese regulatory approval in August 2020. In the urology field, the first human surgery with the system was successfully conducted in December 2020. As points differing from the da Vinci Surgical System, (1) each robotic arm has eight axes that enable more flexible arm movement and reduce the interference between the arms as well as between the arm and the patient body (Fig. 1c), (2) the software calibrates the trocar position (pivot position) without attaching the trocar (Fig. 1d), which can provide a large space around trocars and prevent the tissue damage of the abdominal wall by excessive traction, and (3) the surgeon cockpit has a flexibly positioned 3D viewer that can reduce the fatigue of the surgeon's neck and shoulder.

Virtual telesurgery setting

First, we conducted an experiment to identify the latency time threshold using the virtual telesurgery setting, which consisted of the hinotori Surgical Robot System and the latency generator (Fig. 2). Seven gastric surgeons certified by the Endoscopic Surgical Skill Qualification System created by the Japanese Society for Endoscopic Surgery [11] who had performed at least 20 robotic gastrectomies for gastric cancer (M. N., K. S., K. N., T. T., S. S., K. I, and I. U.) participated in this experiment. Under the virtual latency setting ranging from 25 to 625 ms, the time for suturing in the dry model was measured. In addition, to examine the latency time threshold in more detail, the suturing time was measured further, dividing the latency time into smaller segments around the threshold obtained in the above setting. The suturing technique was standardized as one surgical knot and two normal knots using a 12-cm 3–0 Vicryl™ suture (Ethicon, Inc., Johnson & Johnson Company, Somerville, NJ, USA). The suturing procedure was performed from the initial position consisting of the bilateral arms and needle in place to complete the knots (Fig. 3a). After suturing under each delay setting, surgeons

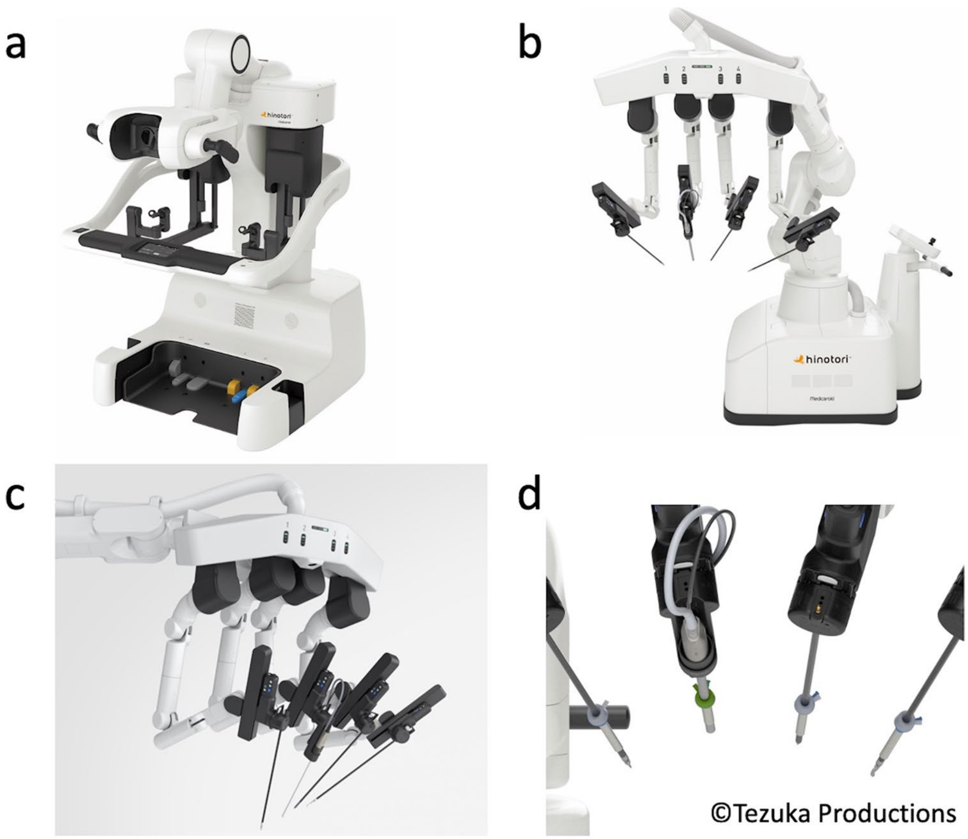

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Fig. 1 The hinotori Surgical Robot System. A surgical cockpit (**a**), an operation unit (**b**), four manipulating arms with eight axes without attaching the trocar (**c**, **d**)

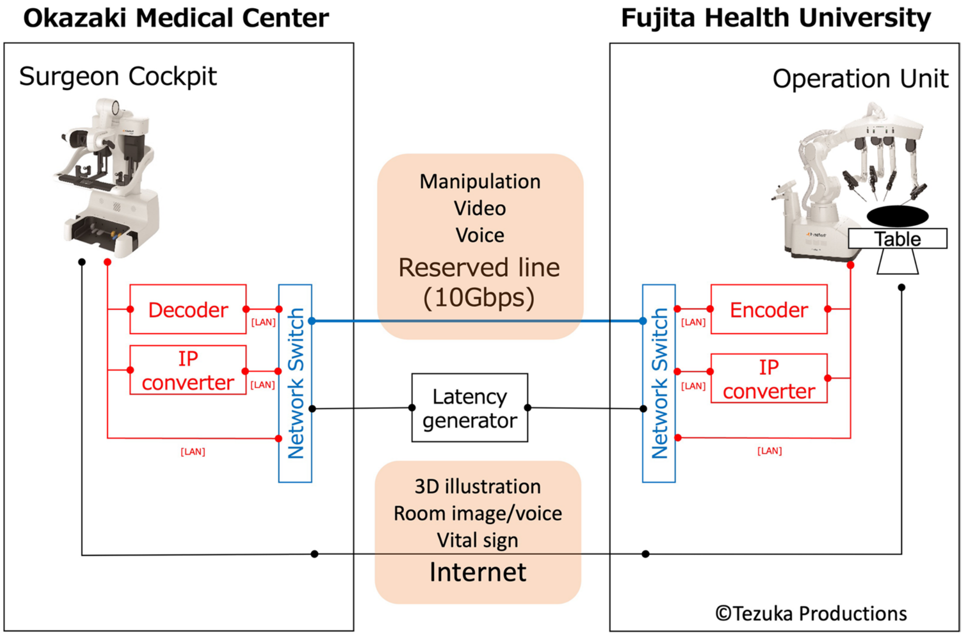

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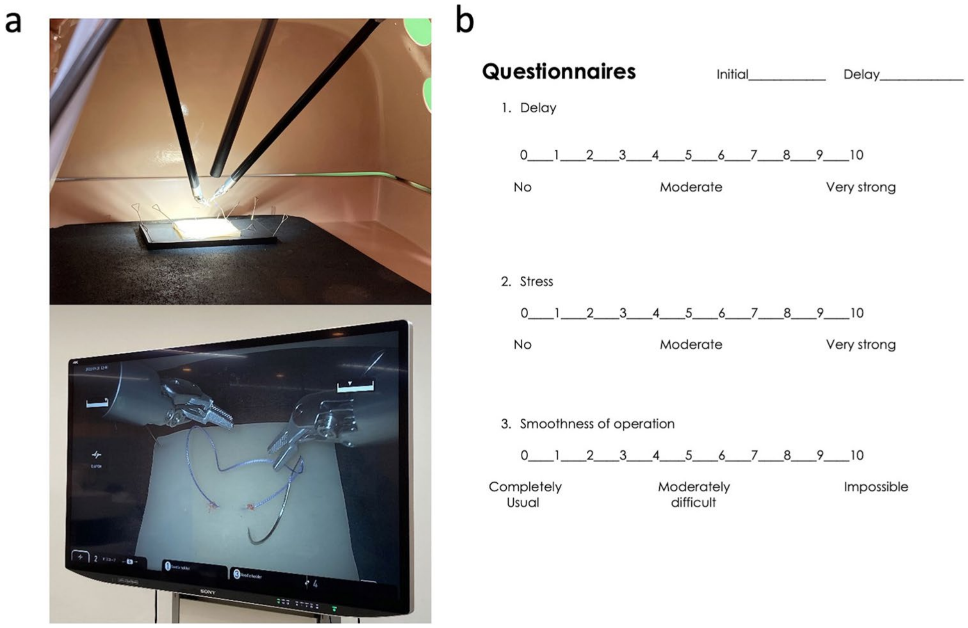
Fig. 2 The network map in the virtual telesurgical setting and actual telesurgical gastrectomy setting in porcine models. In the virtual setting, the delay generator was inserted between the network switches

answered the questionnaires to evaluate the procedure's feasibility with a score of 0–10 (Fig. 3b). Technical failures including incomplete suturing and deviation from the suturing point were subsequently evaluated. Each surgeon was blinded to the other surgeons' procedures.

Network connections

We leased a commercial fiber-optic network connected between Fujita Health University (Toyoake, Japan) and Okazaki Medical Center (Okazaki, Japan), which were



Questionnaires Initial__________ Delay__________

1. Delay

0___1___2___3___4___5___6___7___8___9___10

No Moderate Very strong

2. Stress

0___1___2___3___4___5___6___7___8___9___10

No Moderate Very strong

3. Smoothness of operation

0___1___2___3___4___5___6___7___8___9___10

Completely Usual Moderately difficult Impossible

Fig. 3 Suturing under the virtual telesurgery setting (**a**) and questionnaires after suturing in the virtual setting (**b**)

separated by approximately 30 km. A leased-line with 10 Gbps of bandwidth was provided by Chubu Telecommunications Co., Inc. (Nagoya, Japan) and dedicated for this study during the operation. The network system for this telesurgery consisted of this dedicated fiber-optic network and local devices, including the hinotori Surgical Robot System and information processors (Fig. 2). Video data was processed using H.265 codec. Latency time, including the telecommunication network delay caused by the delivery between the two locations (transmission path between network switches at each site; shown in blue color) and the local information process delay caused by compression or decompression of the video image and audio signal (transmission path between surgeon cockpit/operation unit and network switch at each site; shown in red color) were measured (Fig. 2). In addition, the fluctuation of latency time attributable to unstable network connections was also evaluated. The real-time image and voice in the operation room were shared with the remote meeting software (Teams™, Microsoft Corporation, WA, USA) using a standard internet connection. In addition, to inform the console surgeon of the arm position, the real-time three-dimensional illustration of the arm position was created at the operation unit side and sent to the console surgeon using a standard internet connection (Fig. 4a).

Telesurgical gastrectomy

Two gastric surgeons who had performed more than 100 robotic gastrectomies (I. U. and K. S.) participated in this study as console surgeons. As the first step of the actual telesurgery, each surgeon performed gastrectomy on a synthetic training model for gastrectomy [12] (Fasotec Co., Ltd., Chiba, Japan) (Fig. 4b). In each case, the dry gastrectomy model and surgical robot were located at Fujita Health University. By contrast, the console surgeons were located at Okazaki Medical Center. Using the aforementioned telesurgery setting and following the dry gastrectomy model, we performed robotic distal gastrectomy with D2 lymphadenectomy and intracorporeal Billroth-I anastomosis in two porcine models, the anatomical aspects of which are similar to those of humans (Fig. 4c, d). The details of this procedure in a human patient were described in our previous reports [13, 14]. Two females 41.7–42 kg, 10–13-week-old WL specific pathogen-free porcine (ZPP, ZEN-NOH, Tokyo, Japan) were purchased. All animals were kept in a controlled environment with a 12-h light/dark cycle and 20 ± 5 °C room. The animals were fasted for 12 h before anesthesia to control the vomiting, otherwise were able to eat and drink anytime. Midazolam 15 mg/head (SANDOZ, Bavaria, Germany), medetomidine 1.5 mg/head (Kyoritsu Seiyaku Corporation, Tokyo, Japan), butorphanol 7.5 mg/head (Meiji Seika Pharma Co., Ltd., Tokyo, Japan) was injected intramuscularly for premedication and were weighted. The animals were induced with isoflurane (Pfizer, NY, US) by mask and were intubated. The vital sign of porcine was captured and shared at both ends using a standard internet connection. First, five trocars, including one port for the assistant surgeon, were placed at the upper abdomen, and pneumoperitoneum was started. The operation unit was rolled in from the right side and set up the arm arrangement targeting to the left shoulder to prevent

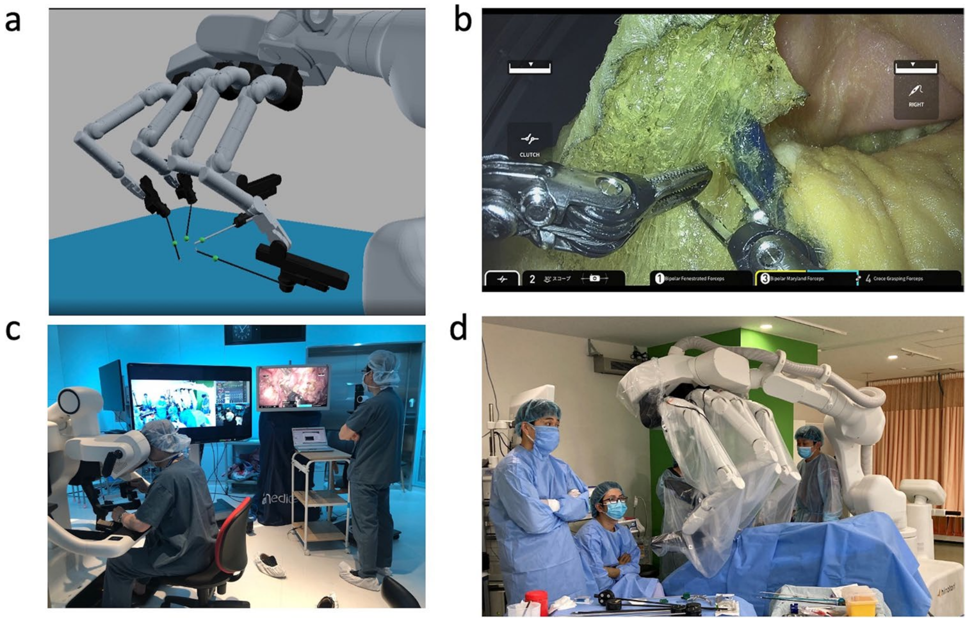


Fig. 4 The real-time three-dimensional illustration of the robotic arms (**a**), telesurgical gastrectomy using a gastrectomy model (**b**), and the operating surgeon (**c**) and the surgical robot (**d**) during telesurgical gastrectomy in a porcine model

extracorporeal collision between the robotic arms. Positioning of the forceps during procedures was determined based on the monitor quadrisection theory to avoid intracorporeal collisions [14]. Maryland Bipolar Forceps (Medicaroid Inc., Kobe, Japan) or monopolar curved scissors (Medicaroid Inc., Kobe Japan), which was connected to a AUTOCON™ II 400 Electrosurgical Unit (KARL STORZ、Tuttlingen, Germany), and Universal grasp (Medicaroid Inc., Kobe, Japan) were used with the operating surgeon's right hand (i.e., the third and fourth arms of the robot, respectively), whereas Croce grasping forceps or fenestrated bipolar forceps (Medicaroid Inc., Kobe, Japan) was used with his left hand (i.e., the first arm of the robot). Then, dissection of the D2 lymph nodes, including perigastric lymph nodes and lymph nodes along the celiac trunk, left gastric artery, common and proper hepatic arteries, proximal splenic artery, and portal vein, was performed. After transection of the proximal duodenum and proximal stomach, Billroth-I anastomosis using linear staplers was performed intracorporeally [15]. The console surgeons performed all procedures, excluding port placement, clipping of vessels, and transection of the stomach and the duodenum, using linear staplers. All procedures in porcine surgery were performed under the approval of the Institutional Animal Care and Use Committee at Fujita Health University (APU19076-MD3). The care and handling of the animals were in accordance with the policies promulgated by the Regulations for the Management of Laboratory Animals at Fujita Health University. Each animal was under the care of a veterinarian (T. H.) at all times. The porcine model was monitored during the general anesthesia and euthanized immediately after the completion of each procedure.

Statistical analysis

A latency time was expressed as a total round-trip delay in milliseconds. Continuous variables were expressed as the mean and standard deviation. One-way analysis of variance with a post hoc Bonferroni correction test was used to evaluate the continuous variables. $P < 0.05$ indicated statistical significance. All analyses were conducted using SPSS 28.0 (IBM Inc., Chicago, IL, USA).

Results

In the virtual telesurgery setting, the suturing time increased as the delay increased; 74.6 ± 20.0 s in the latency of 25 ms, 84.6 ± 21.3 s in 125 ms, 104.1 ± 24.4 s in 225 ms, 156.5 ± 38.6 s in 425 ms, and 215.1 ± 74.1 s in 625 ms. Although a longer time was found between 25 and 125 ms, the difference was not significant ($p = 0.247$), whereas significant differences in time were found in the other comparisons (Fig. 5a). Additional suturing time measurements under the latency time of 25, 50, 75, 100, and 125 ms did not show significant differences in time between any pairs of settings (see Fig. S1, Online Resource1). Every suturing was appropriately performed without any failures. The questionnaires revealed no apparent cut-off in the feeling of delay, stress, and smoothness of the procedure. In all questionnaires,

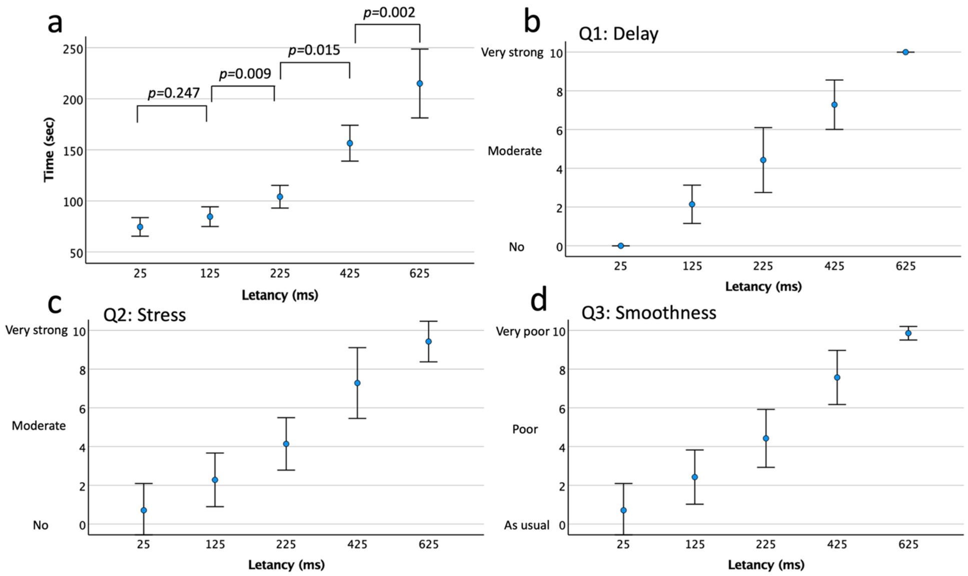


Fig. 5 The suturing time (**a**) and surgeons' answers (**b**–**d**) under each virtual delay setting

43%–57% of surgeons answered moderately delay/stress and poor smoothness (score ≥ 4) under a delay of 125 ms or less (Fig. 5b–d). This virtual telesurgery study suggested that the latency time threshold was less than 125 ms.

Then, in the actual telesurgical setting, we performed the gastrectomy in the dry gastrectomy model. The latency time in the dry model surgery was 27 ms, including 25 ms for information processing and 2 ms for data communication. Following this dry model surgery, we conducted telesurgical gastrectomy with lymphadenectomy and intracorporeal anastomosis in two porcine models in May 2021, and the procedures were successfully completed (Figs. 6 and 7). The intraabdominal procedures are presented in the attached video (Supplemental Video). There was no unexpected event, including trauma to adjacent structures such as the major arteries and pancreas during the operation. In each case, the actual latency time was also 27 ms, and almost no fluctuation was observed during the operation. The local information process delay comprised 25 of the 27 ms of delay. In the two cases, the total operation times from the skin incision were approximately 173 and 237 min, including console times of 160 and 225 min, respectively.

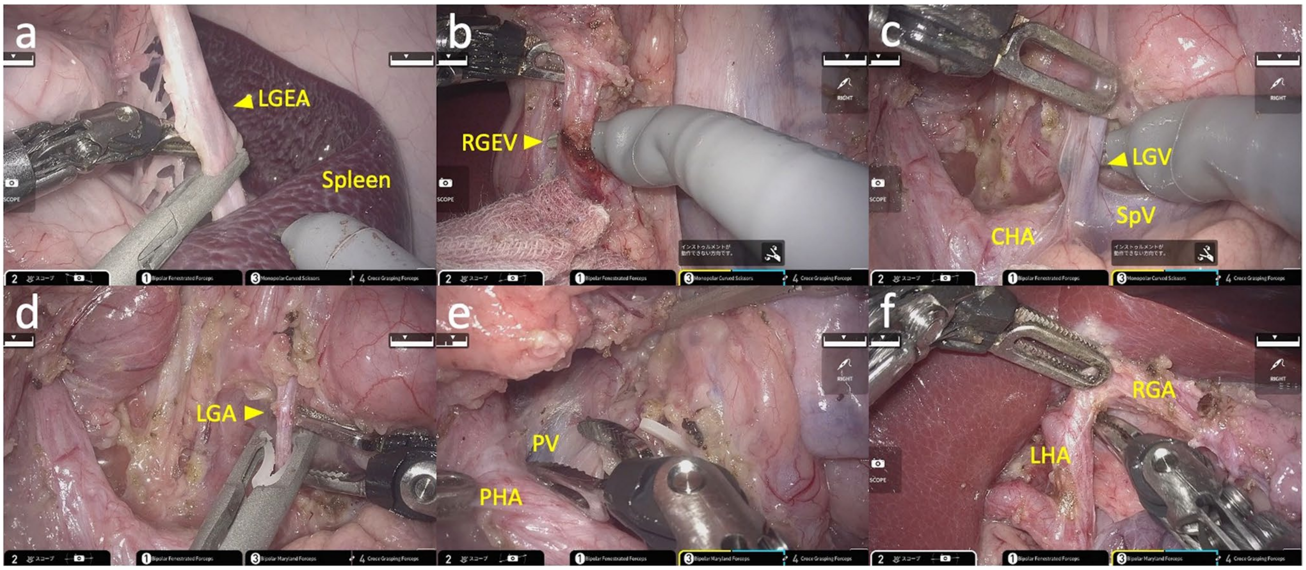


Fig. 6 D2 nodal dissection in the telesurgical gastrectomy in a porcine model. Division of the left gastroepiploic artery (LGEA) (**a**), division of the left gastroepiploic vein (RGEV) (**b**), dissection at the suprapancreatic area and left gastric vein (LGV) (**c**), division of the left gastric artery (**d**), nodal dissection along the proper hepatic artery (PHA) and portal vein (PV) (**e**), and dissection along the right gastric artery (RGA) (**f**). CHA, common hepatic artery; PV, portal vein; PHA, proper hepatic artery; LHA, left hepatic artery

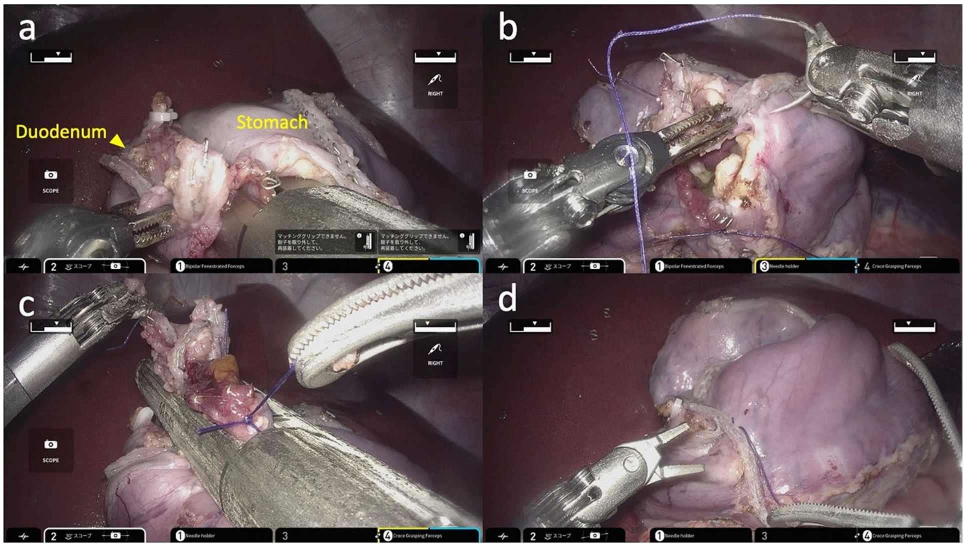


Fig. 7 Intracorporeal Billroth-I anastomosis using linear staplers (**a**–**d**)

Although the console surgeon and assistant surgeons at the patient side communicated smoothly on the leased line, live room image and voice using Teams™, vital signs of the porcine, and the real-time three-dimensional illustration, which were sent on a standard internet connection, reached the other side later.

Discussion

This study found that the latency time threshold was less than 125 ms in telesurgery. In addition, we successfully performed telesurgical porcine gastrectomy with D2 lymphadenectomy and intracorporeal anastomosis using the hinotori Surgical Robot System and a leased fiber-optic network. The actual latency time was 27 ms with no fluctuation. To our knowledge, this is the first report of such a procedure and the use of this new Japanese surgical robot in the gastroenterology field.

As reported in previous studies, the latency time is critical in telesurgery, and the acceptable upper limit has been reported as 100–450 ms limit [1, 16–18]. The threshold of the latency time in the virtual telesurgery study (125 ms) was within this range. In addition, the latency time of 27 ms in this study was much better than those reported previously [1, 16–18]. Although it may be difficult to shorten the telecommunication delay further because an optic-fiber is currently the fastest communication line, it is vital to reduce the delay in the information process, mainly composed of encoding and decoding the data. The information process delay of 25 ms in this study was shorter than that reported previously (70–126 ms) [1, 2, 8]. This difference could be attributable to the up-to-date information process system including encoder and decoder in the hinotori Surgical System, suggesting that this system is appropriate for telesurgery. Regarding the telecommunication delay, 1 ms with no fluctuation for one-way was superior to other networks reported previously [1, 2, 8]. The optic-fiber network is widely and commercially used across the nation in Japan. Therefore, we believe that we can theoretically secure a sufficiently short and stable network delay (nearly 2 ms for the round trip) under the optic-fiber network even if we perform remote surgery between places separated by longer distances. However, in this study, we sent supplemental data, including the live room image, vital signs, and the three-dimensional illustration, using a standard internet connection due to the technical limitation, which caused the delay compared to the primary data using the leased line. As these are essential information, the system is expected to be updated to send these data on the same line as the primary data.

This study revealed the feasibility and safety of short-distance telesurgical gastrectomy from a technical standpoint. Because of technical difficulties, the rate of surgical morbidity in laparoscopic gastrectomy was reported to be lower in high-volume academic centers than in low-volume community hospitals [9, 19], which may indicate the importance of not only telesurgery but also surgical training, including observation and mentoring in community hospitals. Our telesurgical system enables patients with gastric cancer to undergo high-quality robotic surgery at hospitals near their home. In addition, our telesurgical system can provide benefits to surgeons as well as patients. In minimally invasive surgery, including robotic surgery, in which all participants share the same operative screen, telestration with an audio system and augmented reality (AR) has been applied [20], and its usefulness in improving learning effects on surgical techniques was reported [21]. In addition, AR mentoring with three-dimensional instructions reportedly facilitated the surgical learning effects [22]. Also, telementoring in human laparoscopic colectomy with the fifth-generation wireless network has already been reported, and it was safely performed with 146 to 202 ms of latency [7]. The latency of our telesurgical platform is well below those values, which indicates our system is applicable for such telementoring. Furthermore, our system enables experts to join the actual surgery if needed as well as give advice, which could guarantee the operative safety, although ethical, legal, and financial issues should be reconciled [23].

Although two RCTs recently showed benefits in short-term outcomes of robotic gastrectomy over laparoscopic approach [24, 25] and we also reported the oncological benefit of robotic gastrectomy [26], the benefits of robotic gastrectomy over conventional laparoscopic approach are not established. Most studies considered the higher cost of surgical robots problematic [27]. Despite this situation, many companies have accelerated the development of surgical robots, indicating that massive surgical data obtained from robotic surgery attracts developers. The short-distance telesurgery system in the present study can efficiently collect such large data, which could be transformed into surgical intelligence using artificial intelligence, leading to advanced surgical training and subsequent improvements of surgical outcomes and cost-efficiency.

Since 2019, the pandemic caused by the SARS-CoV-2 virus has limited our free movement, and the importance of remote outpatient clinics and prescriptions has been emphasized [28]. Therefore, the development of this telemedicine system, which features a telesurgical system, has the potential to play an important role in the near future after the pandemic. Furthermore, considering cost-effectiveness and sustainability, this telemedicine system could provide better efficacy even in the short-distance setting, such as that in this study (30 km), than in long-distance settings such as transcontinental surgery.

This study had several limitations. First, 125 ms of threshold of the latency found in this study might be specific in this system and cannot be treated as a general value. It is needed to re-assess in other surgical robots and transmission system. Second, this was a preclinical study using a porcine model, and thus, validation in humans is needed. Third, we did not establish metrics because this was a pilot study. Further research under several patterns of distance and type of procedures is required.

In conclusion, this study found that the latency time threshold was less than 125 ms in telesurgery using the hinotori Surgical Robot System. Meanwhile, this study represents the first case of telesurgical gastrectomy with D2 lymphadenectomy and intracorporeal anastomosis in a porcine model and the first use of the hinotori Surgical System in the gastroenterology field. Our telesurgical platform using this surgical robot and a leased optic-fiber network is feasible and safe.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00423-022-02710-6.

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Authors' contributions Masaya Nakauchi, Koichi Suda, and Ichiro Uyama substantially contributed to the study conceptualization. Masaya Nakauchi, Koichi Suda, Tsuyoshi Tanaka, Susumu Shibasaki, Kazuki Inaba, Tatsuhiko Harada, Masanao Ohashi, Masayuki Ohigashi, Hiroaki Kitatsuji, Shingo Akimoto, Kenji Kikuchi, and Ichiro Uyama contributed to data acquisition. Masaya Nakauchi, Koichi Suda, Masanao Ohashi, and Ichiro Uyama contributed to data analysis and interpretation. Masaya Nakauchi drafted the original manuscript. All the authors reviewed the manuscript draft and revised it critically on intellectual content. All the authors approved the final version of the manuscript to be published.

Declarations

Competing interests Tsuyoshi Tanaka and Ichiro Uyama belong to an endowed chair by Medicaroid Inc. Koichi Suda was funded by Sysmex, Co. in relation to the Collaborative Laboratory for Research and Development in Advanced Surgical Intelligence, Fujita Health University. Koichi Suda has served on advisory boards for Medicaroid Inc. Ichiro Uyama has served on advisory boards for Intuitive Surgical Inc. and has received lecture fees from Intuitive Surgical Inc. and Medicaroid Inc. Masaya Nakauchi, Kenichi Nakamura, Susumu Shibasaki, Kazuki Inaba, Tatsuhiko Harada, Masanao Ohashi, Masayuki Ohigashi, Hiroaki Kitatsuji, Shingo Akimoto, and Kenji Kikuchi have no relevant or material financial interests to disclose.

Conflict of interest There is no funding support to be disclosed in this study. Tsuyoshi Tanaka and Ichiro Uyama belong to an endowed chair by Medicaroid Inc. Koichi Suda was funded by Sysmex, Co. in relation to the Collaborative Laboratory for Research and Development in Advanced Surgical Intelligence, Fujita Health University. Koichi Suda has served on advisory boards for Medicaroid Inc. Ichiro Uyama has served on advisory boards for Intuitive Surgical Inc. and has received lecture fees from Intuitive Surgical Inc. and Medicaroid Inc. Masaya Nakauchi, Kenichi Nakamura, Susumu Shibasaki, Kazuki Inaba, Tatsuhiko Harada, Masanao Ohashi, Masayuki Ohigashi, Hiroaki Kitatsuji, Shingo Akimoto, and Kenji Kikuchi have no relevant or material financial interests to disclose.

References

1. Marescaux J, Leroy J, Gagner M, Rubino F, Mutter D, Vix M, Butner SE, Smith MK (2001) Transatlantic robot-assisted telesurgery. Nature 413:379–380
2. Anvari M, McKinley C, Stein H (2005) Establishment of the world's first telerobotic remote surgical service: for provision of advanced laparoscopic surgery in a rural community. Ann Surg 241:460–464
3. Anvari M (2007) Remote telepresence surgery: the Canadian experience. Surg Endosc 21:537–541
4. Satcher RL, Bogler O, Hyle L, Lee A, Simmons A, Williams R, Hawk E, Matin S, Brewster AM (2014) Telemedicine and telesurgery in cancer care: inaugural conference at MD Anderson Cancer Center. J Surg Oncol 110:353–359
5. Gambadauro P, Torrejon R (2013) The "tele" factor in surgery today and tomorrow: implications for surgical training and education. Surg Today 43:115–122
6. Choi PJ, Oskouian RJ, Tubbs RS (2018) Telesurgery: past, present, and future. Cureus 10:e2716

7. Lacy AM, Bravo R, Otero-Pineiro AM, Pena R, De Lacy FB, Menchaca R, Balibrea JM (2019) 5G-assisted telementored surgery. Br J Surg 106:1576–1579
8. Morohashi H, Hakamada K, Kanno T, Kawashima K, Akasaka H, Ebihara Y, Oki E, Hirano S, Mori M (2021) Social implementation of a remote surgery system in Japan: a field experiment using a newly developed surgical robot via a commercial network. Surg Today. https://doi.org/10.1007/s00595-021-02384-5
9. Shibasaki S, Suda K, Obama K, Yoshida M, Uyama I (2020) Should robotic gastrectomy become a standard surgical treatment option for gastric cancer? Surg Today 50:955–965
10. Japanese Gastric Cancer A (2021) Japanese gastric cancer treatment guidelines 2018 (5th edition). Gastric Cancer 24:1–21
11. Mori T, Kimura T, Kitajima M (2010) Skill accreditation system for laparoscopic gastroenterologic surgeons in Japan. Minim Invasive Ther Allied Technol 19:18–23
12. Shibasaki S, Suda K, Kadoya S, Ishida Y, Nakauchi M, Nakamura K, Akimoto S, Tanaka T, Kikuchi K, Inaba K, Uyama I (2022) The safe performance of robotic gastrectomy by second-generation surgeons meeting the operating surgeon’s criteria in the Japan Society for Endoscopic Surgery guidelines. Asian J Endosc Surg 15:70–81
13. Uyama I, Kanaya S, Ishida Y, Inaba K, Suda K, Satoh S (2012) Novel integrated robotic approach for suprapancreatic D2 nodal dissection for treating gastric cancer: technique and initial experience. World J Surg 36:331–337
14. Suda K, Man IM, Ishida Y, Kawamura Y, Satoh S, Uyama I (2015) Potential advantages of robotic radical gastrectomy for gastric adenocarcinoma in comparison with conventional laparoscopic approach: a single institutional retrospective comparative cohort study. Surg Endosc 29:673–685
15. Man IM, Suda K, Kikuchi K, Tanaka T, Furuta S, Nakauchi M, Ishikawa K, Ishida Y, Uyama I (2015) Totally intracorporeal delta-shaped B-I anastomosis following laparoscopic distal gastrectomy using the Tri-Staple reloads on the manual Ultra handle: a prospective cohort study with historical controls. Surg Endosc 29:3304–3312
16. Sterbis JR, Hanly EJ, Herman BC, Marohn MR, Broderick TJ, Shih SP, Harnett B, Doarn C, Schenkman NS (2008) Transcontinental telesurgical nephrectomy using the da Vinci robot in a porcine model. Urology 71:971–973
17. Xu S, Perez M, Yang K, Perrenot C, Felblinger J, Hubert J (2014) Determination of the latency effects on surgical performance and the acceptable latency levels in telesurgery using the dV-Trainer((R)) simulator. Surg Endosc 28:2569–2576
18. Wirz R, Torres LG, Swaney PJ, Gilbert H, Alterovitz R, Webster RJ 3rd, Weaver KD, Russell PT 3rd (2015) An experimental feasibility study on robotic endonasal telesurgery. Neurosurgery 76:479–484
19. Kodera Y, Yoshida K, Kumamaru H, Kakeji Y, Hiki N, Etoh T, Honda M, Miyata H, Yamashita Y, Seto Y, Kitano S, Konno H (2019) Introducing laparoscopic total gastrectomy for gastric cancer in general practice: a retrospective cohort study based on a nationwide registry database in Japan. Gastric Cancer 22:202–213
20. Nickel F, Cizmic A, Chand M (2022) Telestration and augmented reality in minimally invasive surgery: an invaluable tool in the age of COVID-19 for remote proctoring and telementoring. JAMA Surg 157:169–170
21. Wild C, Lang F, Gerhauser AS, Schmidt MW, Kowalewski KF, Petersen J, Kenngott HG, Muller-Stich BP, Nickel F (2022) Telestration with augmented reality for visual presentation of intraoperative target structures in minimally invasive surgery: a randomized controlled study. Surg Endosc. https://doi.org/10.1007/s00464-022-09158-1,Mar9
22. Jarc AM, Shah SH, Adebar T, Hwang E, Aron M, Gill IS, Hung AJ (2016) Beyond 2D telestration: an evaluation of novel proctoring tools for robot-assisted minimally invasive surgery. J Robot Surg 10:103–109
23. Hung AJ, Chen J, Shah A, Gill IS (2018) Telementoring and telesurgery for minimally invasive procedures. J Urol 199:355–369
24. Ojima T, Nakamura M, Hayata K, Kitadani J, Katsuda M, Takeuchi A, Tominaga S, Nakai T, Nakamori M, Ohi M, Kusunoki M, Yamaue H (2021) Short-term outcomes of robotic gastrectomy vs laparoscopic gastrectomy for patients with gastric cancer: a randomized clinical trial. JAMA Surg. https://doi.org/10.1001/jamasurg.2021.3182,Sep2
25. Lu J, Zheng CH, Xu BB, Xie JW, Wang JB, Lin JX, Chen QY, Cao LL, Lin M, Tu RH, Huang ZN, Lin JL, Zheng HL, Huang CM, Li P (2021) Assessment of robotic versus laparoscopic distal gastrectomy for gastric cancer: a randomized controlled trial. Ann Surg 273:858–867
26. Nakauchi M, Suda K, Shibasaki S, Nakamura K, Kadoya S, Kikuchi K, Inaba K, Uyama I (2021) Prognostic factors of minimally invasive surgery for gastric cancer: does robotic gastrectomy bring oncological benefit? World J Gastroenterol 27:6659–6672
27. Kikuchi K, Suda K, Shibasaki S, Tanaka T, Uyama I (2021) Challenges in improving the minimal invasiveness of the surgical treatment for gastric cancer using robotic technology. Ann Gastroenterol Surg 5:604–613
28. Qian AS, Schiaffino MK, Nalawade V, Aziz L, Pacheco FV, Nguyen B, Vu P, Patel SP, Martinez ME, Murphy JD (2022) Disparities in telemedicine during COVID-19. Cancer Med. https://doi.org/10.1002/cam4.4518,Jan5