



# 5G-Assisted Remote Guidance in Laparoscopic Simulation Training Based on 3D Printed Dry Lab Models

Weier Wang<sup>1,2</sup> · Zhifei Wang<sup>1</sup> · Haibo Gong<sup>3</sup> · Liming Jin<sup>1</sup> · Fangqiang Wei<sup>1</sup>

Received: 15 March 2022 / Accepted: 14 October 2022 / Published online: 24 October 2022  
© Association of Surgeons of India 2022

## Abstract

This is a pilot study to assess the utility of applying 5G-assisted remote guidance in laparoscopic simulation training. A single trainee of a junior surgeon was recruited to complete three steps of tasks including basic task 1, basic task 2, and model task, and the performance was recorded and evaluated. The operator completed each task three times. Except for basic task 1, all tasks were remotely guided by a more experienced surgeon using 5G technology. Tasks completion time and a 30-point objective structured assessment of technical skills (OSATS) score were utilized to assess the results of simulation training. All remote guidance processes were successfully completed without significant network latency. Through basic task 1, the operator quickly became familiar with the trained laparoscopic instruments. For basic task 2, OSATS scores increased from 16 to 24 points, and completion time decreased from 1500 to 986 s after training under 5G-assisted remote guidance. For model tasks, OSATS scores increased from 15 to 26 points, and completion time decreased from 1734 to 1142 s. This is a novel mode of laparoscopic simulation training to increase the convenience of training. Perhaps in the near future, surgeons can simulate difficult operations at home or in the office, and accurately grasp the possible situations that may occur in actual operations in advance.

**Keywords** 5G-assisted · Remote guidance · 3D printed · Laparoscopic training · Choledochojejunostomy · Simulation

## Introduction

The shortage of health care providers, especially surgeons, is one of the major challenges to achieving the goal of universal health coverage by 2030 [1, 2]. The training of surgeons is very important, especially to help them master some core skills, among which reconstruction of digestive tract is a

key technique in many laparoscopic operations. Improper operation or poor quality of reconstruction often leads to disastrous consequences. Therefore, it is necessary for novice surgeons to receive strict and standardized laparoscopic training before actual operation. At present, the world has been in a normal state of fighting against COVID-19 for a long time, which brings great challenges to the traditional surgical simulation training requiring personnel gathering.

The fifth generation wireless network (5G) is being gradually deployed globally. Its amazing performance such as high speed, low latency, and high broadband brings unprecedented communication experience and provides a reliable network medium for the development of telemedicine [3]. Telesurgery, remote diagnosis and remote consultation based on 5G have been gradually tried and achieved encouraging results [4–6]. Scholars have successfully conducted 12 spinal surgeries using the 5G network offering faster internet connectivity than 4G, with a mean network latency of 28 ms, and no adverse intraoperative events [7]. Other scholars have successfully performed 29 cases of robot-assisted laparoscopic radical nephrectomy, with a median round-trip delay of 26 ms and a median distance between the primary

---

This study has been presented at the 2021 SAGES Annual Meeting by Wei FQ.

✉ Fangqiang Wei  
wdfwfq@126.com

<sup>1</sup> Department of General Surgery, Cancer Center, Division of Hepatobiliary and Pancreatic Surgery, Zhejiang Provincial People's Hospital, Affiliated People's Hospital, Hangzhou Medical College, Zhejiang Province, Hangzhou 310014, China

<sup>2</sup> Emergency Department Trauma Center, College of Medicine, the First Affiliated Hospital, Zhejiang University, Zhejiang Province, Hangzhou 310003, China

<sup>3</sup> Ningbo Chuangdao 3D Medical Technology Co., Ltd., Zhejiang Province, 315336 Ningbo, China

hospital and the surgeon of 187 km [8]. Telesurgery seems to be accurate and feasible.

3D printing technology can present models that are highly similar to real organs in appearance and texture, and is gradually applied in preoperative planning, intraoperative guidance and teaching training [9, 10]. Previous studies have demonstrated that 3D printed dry lab models can help improve surgical skills, support the future surgical applications, and reduce procedure time after simulation training [11]. At present, the exploration of remote guidance in laparoscopic simulation training based on 3D printed dry lab models has not been reported. The integration of 5G technology and 3D printing technology seems to provide more convenient and real-time simulation training opportunities for trainees. This pilot study aims to introduce the experience of 5G technology combined with 3D printing technology in remote guidance of laparoscopic choledochojejunostomy training, and discuss its advantages and limitations, as well as its possible role in laparoscopic training.

## Methods

The 3D dry lab models have been described in detail in our previous report [12]. The models, made by Ningbo Chuangdao 3D Medical Technology (Cixi, China), show off very subtle designs. The 3D models of liver and extrahepatic biliary tract are printed based on data obtained from computed tomography (CT) scan of a patient with cancerous lesions. Commercially jejunum models were also purchased for dry lab training with choledochojejunostomy. A junior surgeon (chief or associate surgeon) with experience of around 50 cases of laparoscopic cholecystectomy was selected as the surgeon for training, but without experience in laparoscopic choledochojejunostomy. A surgeon experienced in minimally invasive hepatobiliary surgery was recruited as a remote instructor, and another experienced senior surgeon was invited as an independent referee. The training consists of three rounds of tasks, including basic task 1, basic task 2, and model task (Fig. 1). Performance was recorded and assessed by a modified objective structured assessment of technical skills (OSATS) [13, 14] score. The modified OSATS contains six aspects, with a maximum score of 30 points (Table S1). For basic task 1, which used laparoscopic instruments to clamp 14 beads on staggered piles, the operator completed three times alone. Then, the operator completed basic task 2 three times under 5G-assisted remote guidance, which was to suture the pre-cut latex gloves using laparoscopic instruments (continuous suture in the posterior layer and intermittent suture in the anterior layer). Similarly, the model task was to practice choledochojejunostomy under laparoscopy using the 3D printed dry lab model, which was completed three times under 5G-assisted remote guidance.

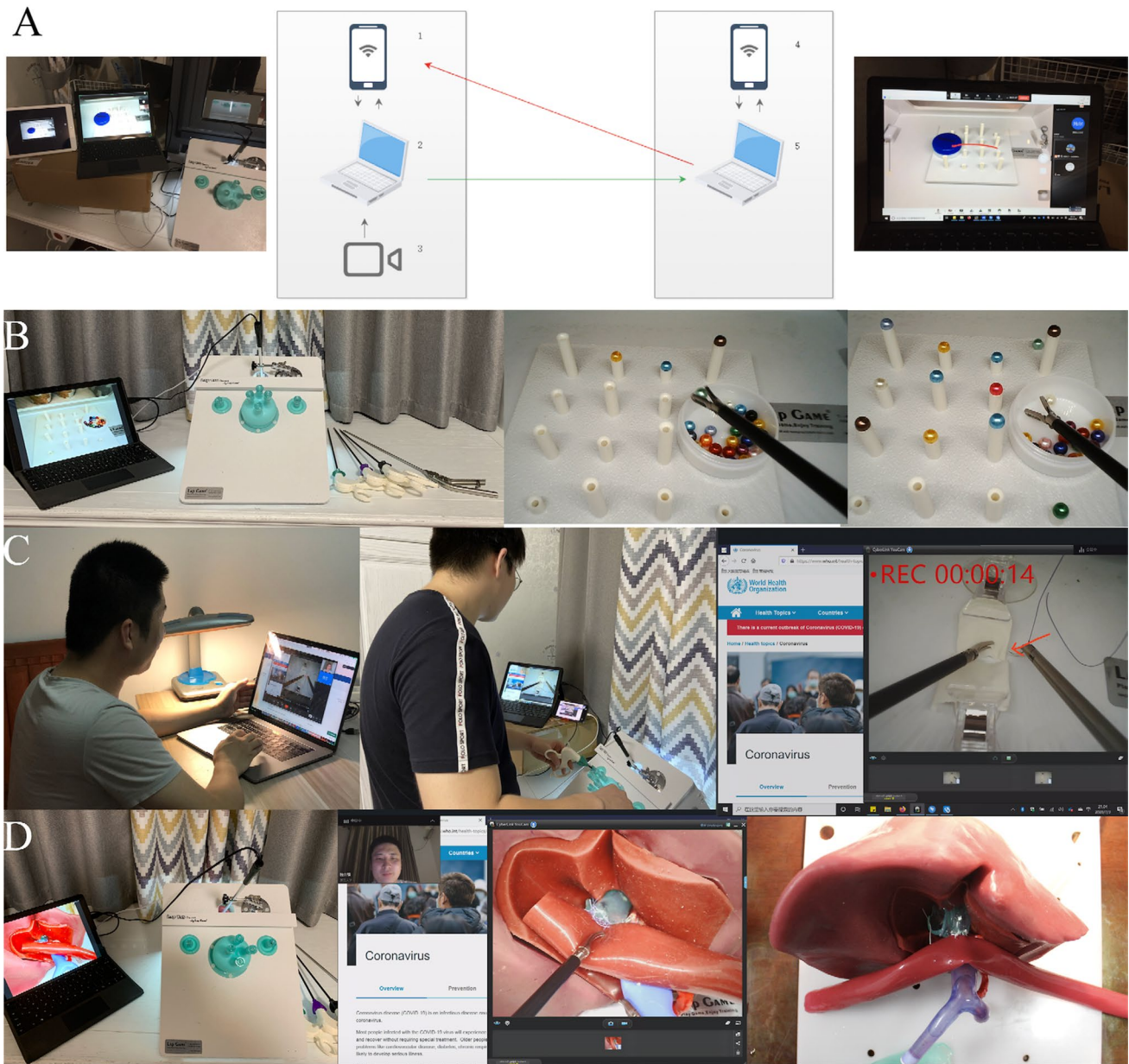
During the training, the operator and the instructor communicated in real-time through the platform established by the applications of Ding Talk version 5.1.15 and Tencent meeting version 1.5.0 using 5G connection. Both the operator and the instructor can see the same training images. The instructor drew on the laptop screen using ScreenBrush version 1.6.6, and the operator could see it on the screen (Fig. 1). The network settings are shown in Fig. 1. The operator and the instructor were at their respective homes, at a distance of 22 km. Both had 5G mobile phones to provide 5G network signals, and laptops to transmit images and sound. The training images were captured by the camera of the laparoscopic simulator and displayed on the operator's computer via YouCam version 5.0. The operator communicated with the instructor, who received sound and images from the operator's computer via DingTalk. The instructor could draw instructions on the computer screen through the ScreenBrush, and share the screen image to the operator's 5G mobile phone through the Tencent meeting using 5G.

## Results

The results of all tasks were presented in Table 1. The operator skillfully accomplished basic task 1 (Table 1). All remote guidance processes were successfully completed without significant network latency. For basic task 2, after three 5G-assisted remote guidance training sessions, completion time was shortened by 514 s, and OSATS scores were increased by 8 points. For model tasks, completion time and OSATS scores of the first training were 1734s and 15 points, respectively. However, after three training sessions, completion time reduced to 1142 s and the OSATS scores increased to 26 points.

## Discussion

The growth of laparoscopic surgeons often requires a steep learning curve. Face-to-face teaching and training courses are undoubtedly an excellent educational tool for laparoscopic surgery [15]. However, the development of this laparoscopic curriculum model is limited by cost, time, and geographical location. Especially in the current epidemic of the COVID-19, the gathering of personnel is not conducive to the control of the epidemic. However, the training of young surgeons is crucial to the sustainable development of medicine, and it is an inevitable way to achieve universal health care [1, 2, 16]. Therefore, there is an urgent need to develop a new training and continuing medical education model to train novice surgeons. In the absence of medical resources, the innovation of new technologies needs to follow the two principles of frugality and responsibility [1, 17,



**Fig. 1** Network settings and the training tasks. **A** Network and equipment for 5G-assisted remote guidance procedures. **B** The basic task 1 was to clamp 14 beads on staggered piles using laparoscopic instruments. **C** The basic task 2 was to suture the pre-cut latex gloves using

laparoscopic instruments. **D** The model task was to practice cholecystectomy using the 3D printed dry lab models using laparoscopic instruments

18]. Understanding the specific needs of training and clinical practice, and establishing a good cost-effectiveness training model are essential for wider dissemination and adoption.

The 5G technology has made a great breakthrough in the application of telesurgery and remote ultrasound, and is bringing great changes to the medical industry [7, 8, 19–21]. Telesurgery requires high-quality networks due to legal, ethics, and security restrictions, and private networks are often used [22, 23]. Although the requirements of network quality of remote guided simulation training are not as high as those

of remote surgery, the insufficient network speed and obvious delay will greatly reduce the experience of participants, thus reducing the quality of training, which is not conducive to promotion. In this study, the 5G public network was used, and participants did not feel significant delay.

Using 3D printed surgical models for laparoscopic surgery training can accurately restore the surgical steps, operating space, and organ texture. The combination of 5G technology and 3D printing technology integrates the accuracy and timeliness of surgery and training, and realizes the

**Table 1** The operators' all tasks results

Task	Operation process	Completing time (seconds)	OSATS score
Basic task 1	1st operation	144	21
	2nd operation	104	24
	3rd operation	74	26
Basic task 2	1st operation	1500	16
	2nd operation	1380	20
	3rd operation	986	24
Model task	1st operation	1734	15
	2nd operation	1382	21
	3rd operation	1142	26

perfect integration of precise surgery and real-time surgery [24]. This study innovatively combines 5G technology with 3D printing technology, and tries to apply it to laparoscopic simulation training. The operator can receive real-time guidance from the remote instructor, such as pin position and knot direction, and quickly become familiar with the operation skills of choledochojunostomy. To the best of our knowledge, this is the first attempt to employ this mode for laparoscopic simulation training.

Additionally, the difference between 5 and 4G is obvious in latency, 1 ms in 5G and 70 ms in 4G; For data transmission speed, it is 10 megabit/s in 4G and almost 100 times more in 5G. Therefore we can never get the same results with 4G and 5G. It is precisely because of a long latency that tele-mentoring was hampered with 4G. With ultralow latency and high speed, 5G can run an eMBB (enhance mobile broadband) which in turn runs artificial intelligence, virtual reality, big data, cloud computing, and telerobotics. This is what makes tele-mentoring a reality with 5G.

This study was only a preliminary exploration of the new model of laparoscopic training, and there were several limitations. First of all, only one operator participated in the training without establishing a control group to compare with trainees who did with regular or 4G-assisted remote guidance. It is sure that through 5G network, training will be more convenient and fast, and real-time contact will be established. Second, the 5G network is public, which increases the convenience of research, but it also lacks a unique network for this study. Third, the ideal test to verify the proficiency of surgeons should be the clinical results [25, 26] instead of simulation models. Another study [26] by our team has shown that the three-dimensional models could mimic a real surgical situation and can distinguish among surgeons of different levels of experiences. However, the effectiveness of this groundbreaking laparoscopic training model is lack of clinical results to verify in the current study. Fourth, at present, 5G technology is still in its infancy and has not yet achieved full coverage worldwide, especially

in underdeveloped regions. Fifth, realistic training models need to be further developed, and current 3D printed models are expensive. Overcoming these challenges requires the joint development of multiple disciplines, such as materials science and medicine. Finally, the platform we used was built by combining with existing applications, which was cumbersome to operate. Special applications need further development.

Although this is the first time to try a new model of laparoscopic simulation training, the prospect is obvious. Surgeons in primary hospitals, junior surgeons, and a larger number of potential trainees may get more convenient, real-time, and accurate simulation training opportunities through this training mode, which may promote the progress and development of medicine.

In the near future, 5G technology, 3D printing technology, virtual reality technology and augmented reality technology can be combined. Perhaps, surgeons can simulate difficult operations at home or in the office, and accurately grasp the possible situations that may occur in actual operations in advance.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s12262-022-03590-2>.

**Funding** The current study was supported by the fund of the Zhejiang Medical and Health Science and Technology Project No. 2021KY027 to Wei FQ. The fund of Public Welfare Technology Research Program/Social Development of Zhejiang Provincial Natural Science Foundation of China No. LGF21H030011 to Wei FQ; The Outstanding Young Personnel Research Fund of Zhejiang Provincial People's Hospital (No. ZRY2020B012) to Wei FQ. The fund of Zhejiang Medical and Health Science and Technology Project 2021KY473 and 2022KY029 to Jin LM.

## Declarations

**Ethics Approval** This study was approved by the ethics committee of Zhejiang Provincial People's Hospital and conformed to the ethical guidelines of the Declaration of Helsinki.

**Informed Consent** Written informed consent was acquired from the patient.

**Conflict of Interest** The authors declare no competing interests.

## References

1. Bolton WS, Aruparayil N, Quyn A, Scott J, Wood A, Bundu I et al (2019) Disseminating technology in global surgery. *Br J Surg* 106(2):e34–e43
2. Campbell J, Buchan J, Cometto G, David B, Dussault G, Fogstad H et al (2013) Human resources for health and universal health coverage: fostering equity and effective coverage. *Bull World Health Organ* 91(11):853–863
3. Dananjayan S, Raj GM (2021) 5G in healthcare: how fast will be the transformation? *Ir J Med Sci* 190(2):497–501

4. Zhou B, Wu Q, Zhao X, Zhang W, Wu W, Guo Z (2020) Construction of 5G all-wireless network and information system for cabin hospitals. *J Am Med Inform Assoc* 27(6):934–938
5. Zheng J, Wang Y, Zhang J, Guo W, Yang X, Luo L et al (2020) 5G ultra-remote robot-assisted laparoscopic surgery in China. *Surg Endosc* 34(11):5172–5180
6. Barba P, Stramiello J, Funk EK, Richter F, Yip MC, Orosco RK (2022) Remote telesurgery in humans: a systematic review. *Surg Endosc* 36(5):2771–2777
7. Tian W, Fan M, Zeng C, Liu Y, He D, Zhang Q (2020) Telerobotic spinal surgery based on 5G network: the first 12 cases. *Neurospine* 17(1):114–120
8. Li J, Yang X, Chu G, Feng W, Ding X, Yin X et al (2022) Application of improved robot-assisted laparoscopic telesurgery with 5G technology in urology. *Eur Urol S0302–2838(22):02469–02471*. <https://doi.org/10.1016/j.eururo.2022.06.018>
9. Witowski J, Budzyński A, Grochowska A, Ballard DH, Major P, Rubinkiewicz M et al (2020) Decision-making based on 3D printed models in laparoscopic liver resections with intraoperative ultrasound: a prospective observational study. *Eur Radiol* 30(3):1306–1312
10. Kong X, Nie L, Zhang H, Wang Z, Ye Q, Tang L et al (2016) Do 3D printing models improve anatomical teaching about hepatic segments to medical students? A randomized controlled study. *World J Surg* 40(8):1969–1976
11. Zhang Y, Xia J, Zhang J, Mao J, Chen H, Lin H et al (2022) Validity of a soft and flexible 3D-printed Nissen Fundoplication model in surgical training. *Int J Bioprint* 8(2):546
12. Wei F, Wang W, Gong H, Cao J, Chen J, Chen H et al (2021) Reusable modular 3D-printed dry lab training models to simulate minimally invasive choledochojunostomy. *J Gastrointest Surg* 25(7):1899–1901
13. Martin JA, Regehr G, Reznick R, MacRae H, Murnaghan J, Hutchison C et al (1997) Objective structured assessment of technical skill (OSATS) for surgical residents. *Br J Surg* 84(2):273–278
14. Birkmeyer JD, Finks JF, O'Reilly A, Oerline M, Carlin AM, Nunn AR et al (2013) Surgical skill and complication rates after bariatric surgery. *N Engl J Med* 369(15):1434–1442
15. Sereno S, Mutter D, Dallemagne B, Smith CD, Marescaux J (2007) Telementoring for minimally invasive surgical training by wireless robot. *Surg Innov* 14(3):184–191
16. Bolkan HA, van Duinen A, Waalewijn B, Elhassein M, Kamara TB, Deen GF et al (2017) Safety, productivity and predicted contribution of a surgical task-sharing programme in Sierra Leone. *Br J Surg* 104(10):1315–1326
17. Meara JG, Leather AJ, Hagander L, Alkire BC, Alonso N, Ameh, et al (2015) Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Lancet* 386(9993):569–624
18. Howitt P, Darzi A, Yang GZ, Ashrafian H, Atun R, Barlow J et al (2012) Technologies for global health. *Lancet* 380(9840):507–535
19. Ye R, Zhou X, Shao F, Xiong L, Hong J, Huang H, Weiwei T et al (2021) Feasibility of a 5G-based robot-assisted remote ultrasound system for cardiopulmonary assessment of patients with coronavirus disease 2019. *Chest* 159(1):270–281
20. Bajracharya A, Gale TJ, Stack CR, Turner P (2008) 3.5G based mobile remote monitoring system. *Conf Proc IEEE Eng Med Biol Soc* 2008:783–786
21. Lacy AM, Bravo R, Otero-Piñeiro AM, Pena R, De Lacy FB, Menchaca R et al (2019) 5G-assisted telementored surgery. *Br J Surg* 106(12):1576–1579
22. Park JW, Lee DH, Kim YW, Lee BH, Jo YH (2012) Lapabot: a compact telesurgical robot system for minimally invasive surgery: part II Telesurgery evaluation. *Minim Invasive Ther Allied Technol.* 21(3):195–200
23. Goto T, Miyahara T, Toyoda K, Okamoto J, Kakizawa Y, Koyama J et al (2009) Telesurgery of microscopic micromanipulator system “NeuroRobot” in neurosurgery: interhospital preliminary study. *J Brain Dis* 1:45–53
24. Wang W, Wei F, Gong H, Yu T, Chen J, Tang J et al (2020) Applied prospect of 5G technique in the field of 3D printing surgery. *Chin J Exp Surg* 37(4):597–599
25. Wei F, Xu M, Lai X, Zhang J, Yiengpruksawan A, Lu Y et al (2019) Three-dimensional printed dry lab training models to simulate robotic-assisted pancreaticojejunostomy. *ANZ J Surg* 89(12):1631–1635
26. Yu H, Yu T, Wang J, Wei F, Gong H, Dong H et al (2022) Validation of a three-dimensional printed dry lab pancreaticojejunostomy model in surgical assessment: a cross-sectional study. *BMJ Open* 12(2):e052295

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.