



# Retrospective study of online ligation student practice incorporating flipped learning into e-learning

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## Abstract

**Purpose** Flipped learning has been applied in various fields, including medical professional education. E-learning is compatible with flipped learning; however, it is considered to be unsuitable for providing training on surgical techniques. In this study, we retrospectively examined the ligation performance of online students who underwent training with flipped learning incorporated into e-learning.

**Methods** We conducted a retrospective study of the ligation practices of online students at the Department of General Surgery from March 2020 to June 2021. The subjects included 134 fourth- and fifth-year medical students from Gunma University School of Medicine. We conducted mid-term checks on the 8th day of practice and an examination on the 19th day. Two instructors independently evaluated and calculated scores using the original Global Rating Scale of Gunma University. We also conducted a questionnaire survey on the ligation practice of online students.

**Results** The total average score of the three tasks was 12.4 for Instructor 1 and 12.0 for Instructor 2. All students had a passing score. The questionnaire survey showed that 70% of the students were trained in ligation at the time of the first evaluation.

**Conclusions** Our online training materials and training methods enabled the acquisition of ligation skills by students who had not previously received ligation training.

**Keywords** Ligation student practice · E-learning · Flipped learning

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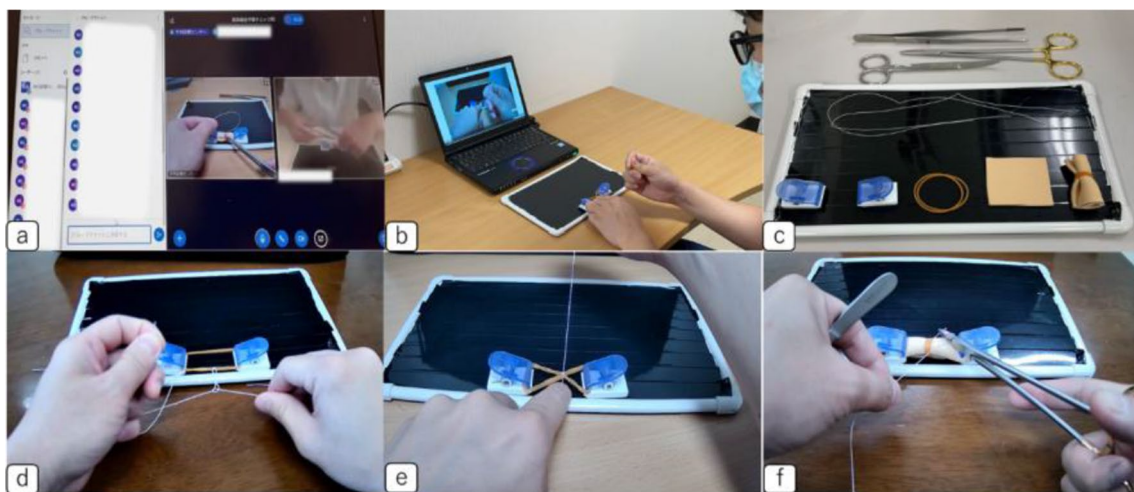
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## Introduction

Teaching approaches using flipped learning have been applied in various fields, including medical professional education. Such approaches have been shown to bring about significant improvement in learning in comparison to traditional teaching methods applied in professional health education [1]. Flipped learning is compatible with e-learning, which has recently been applied in medical education [1]. E-learning can be anywhere at any time and is considered to be a good match for flipped learning. However, it is difficult to teach students by e-learning alone, because most manual training is conducted face-to-face. At the Department of General Surgery, Gunma University Hospital (hereinafter referred to as “the Department of General Surgery”), ligation practice has only been provided with face-to-face instruction. We thought that face-to-face and personal instruction would be the best way for individual students to learn these techniques, because students show individual differences in learning progress and status. However, the time available for direct instruction is limited. During the year, nine groups of 13–15 students per group participated in 28 days of student practice in the Department of General Surgery, and they received 2–3 h of instruction and training on the first day and the day of evaluation after 28 days of practice; the time was limited due to a decrease in the number of available surgeons for teaching and an increase in the surgeons’ workload. One disadvantage of face-to-face practice was

that some students could not observe the practical skills from the instructor’s viewpoint. In addition, in the previous system, self-learning showed various limitations, including the lack of appropriate learning materials that could be used in the absence of an instructor, equipment, and places that are only available in hospitals, and limited practice hours. Furthermore, it was also impacted by the outbreak of coronavirus infection 2019 (COVID-19), which was confirmed in Wuhan, China, in December 2019 and which then rapidly spread throughout the world [2]. In Japan, the COVID-19 outbreak started in January 2020, and three densities (hermetic, dense, and close) were avoided and it became necessary to maintain social distance [3]. In addition, various in-person events were canceled and medical students were prohibited from visiting wards, meeting with patients, attending in-person training and lectures, and performing face-to-face ligation practice.

Since it is essential for medical students to learn basic surgical techniques [4], we asked whether it would be possible to provide training on ligation with flipped learning, even when face-to-face training was not available. The Department of General Surgery started online ligation practice using e-learning with flipped learning using online training materials in March 2020, at the start of the COVID-19 epidemic. The G-Conference system, a web application provided by the Education and Research Center for Mathematical Data Science at Gunma University, was used for learning, mid-term checks, and examinations, all of which were conducted exclusively online



**Fig. 1** The G-Conference system, methods, tools, and tasks. **a** We used the original online lecture system of Gunma University called the G-Conference system. **b** During self-training, students can watch videos of the online training materials. **c** With the exception of surgical instruments (e.g., needle holders and forceps), the training tools used in this study were inexpensive items, such as rubber bands, mag-

netic clips, and a white board. **d** Task 1 was to determine whether the two-handed ligation of one rubber band could be performed smoothly. **e** Task 2 was to determine whether two rubber bands could be ligated with two hands without loosening. **f** Task 3 was to determine whether instrumental ligation could be performed smoothly

(Fig. 1a). The G-Conference system differs from existing online video systems as it can be operated using only a web browser, create user-only lecture rooms using access codes, and record lectures for review. The online training materials uploaded to the G-Conference system included videos from the instructor's viewpoint and videos of failure countermeasures. Therefore, the cycle of learning, reviewing, and practicing became feasible, and flipped learning was achieved in an e-learning environment. In addition, since the training tools were distributed to the students, they were able to e-learn and train with flipped learning “on their own time,” “at their own place”, and “at their own pace” (Fig. 1b).

From April 2021, mid-term checks were conducted during training to enable flipped learning throughout practice. In this study, we report on the efforts and results of the ligation practice of online students at the Department of General Surgery, who underwent using e-learning that incorporated flipped learning in online training materials.

## Materials and methods

This was a retrospective study of the ligation practice of online students at the Department of General Surgery. The subjects included 134 fourth- and fifth-year medical students (male,  $n = 89$ ; female,  $n = 45$ ) from Gunma University School of Medicine, who received training at the Surgery Centre from March 2020 to June 2021. The two instructors for ligation practice had the following certifications: Board Certified Surgeon by the Japan Surgical Society, Board Certified Surgeon in Gastroenterology by The Japanese Society of Gastroenterological Surgery, and Endoscopic surgical skill qualification system: qualified surgeon by the Japan Society for Endoscopic Surgery.

## Training materials

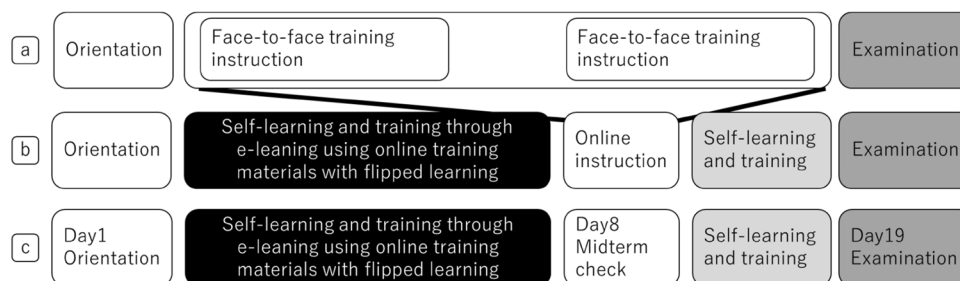
We used the G-Conference system and online materials (videos) for training. The online materials were created with the following four points in mind: (1) the training videos and assignments were created with actual surgery in mind, (2) videos were created, so that all students could learn equally from the viewpoint of the instructor's techniques, (3) the training for tasks were created by breaking the task down into elements, and (4) students could respond on their own when they encountered difficulties in training. The training tools distributed to the students are shown in Fig. 1c. With the exception of surgical instruments (e.g., needle holders and forceps), we used inexpensive items such as white boards, rubber bands, and magnetic clips.

## Tasks

Three tasks were included in the training: Task 1, to learn smooth ligation and basic two-handed ligation (Fig. 1d); Task 2, to learn how to ligate blood vessels without loosening them (Fig. 1e); and Task 3, to learn instrumental ligation that can be applied to endoscopic surgery (Fig. 1f). The contents of the three tasks—training methods broken down by element, tips on the tasks, and how to respond to failure—were incorporated into online training materials to enable flipped learning with e-learning (Fig. 2a, b).

## Practice schedule

Although the duration of student practice at the Department of General Surgery was 28 days, the examination for this task was conducted on the 19th day. On the first day of practice, we instructed students on how to learn using e-learning methods, and to study and train “on their own time”, “at their own place,” and “at their own pace”. From April 2021, a mid-term check on the 8th day of practice



**Fig. 2** Schematic illustration of the features of the present online training program. **a** In traditional student practice, students receive 2–3 h of face-to-face instruction in ligation training. It was difficult for them to train on their own, as there were no learning materials for self-training. **b** In our method, the students undergo self-learning and training through e-learning using online training materials with flipped

learning. These materials include a method for dealing with failures, which facilitates flipped learning by the students alone. **c** This is our current plan of practice. There was no mid-term check from March 2020 to March 2021. It was introduced in April 2021. The mid-term check was conducted online on the 8th day of training, and the instruction time was shortened to approximately 1 h

was introduced. One of the two instructors conducted the mid-term check. In the mid-term check, the students presented the tasks for which they had been training, and the instructor answered the students' questions and instructed them to revise their practical skills. One advantage of using the online system was that 14 students could simultaneously learn the content in the time that it would take to instruct one student. On the 19th day of practice, the two instructors independently evaluated the students (Fig. 2c). The entire course was conducted online using the G-Conference system.

## Evaluation of examination

We evaluated the examinations using Gunma University's original Global Rating Scale, created based on the Global Rating Scale [5], which has been shown to have good inter-rater reliability (Table 1). For each task, the instructors gave a score of either 1 (0–20% proficiency), 2 (20–50% proficiency), 3 (50–80% proficiency), 4 (80–90% proficiency), or 5 (90–100% proficiency). The passing score for each task was set at 3 points, which is more than half of the total score of 5 points for each task. The passing

**Table 1** Gunma University's original Global Rating Scale

[Task 1] Assessing the smoothness of two-handed ligation

- 1: Unable to perform two-handed ligation (proficiency level 0–20%)
- 2: Between 1 and 3 (proficiency level: 20–50%)
- 3: Able to perform two-handed ligation, but changing hands is not smooth and rubber bands are pulled (proficiency level 50–80%)
- 4: Between 3 and 5 (proficiency level 80–90%)
- 5: Able to ligate with both hands, change hands smoothly, and rubber bands are not pulled (proficiency level 90–100%)

[Task 2] Two-handed ligation evaluation of looseness

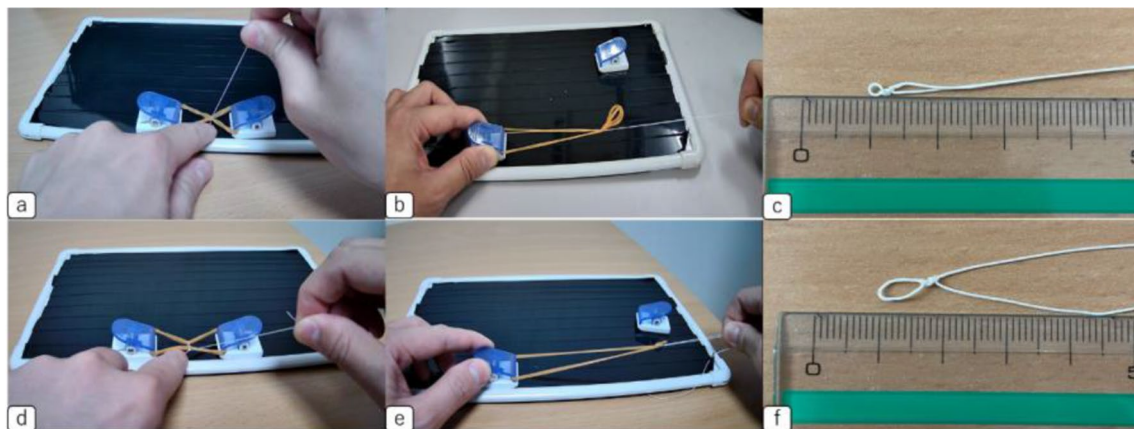
- 1: The ligation is loose, and the rubber bands are not tightened (proficiency level 0–20%)
- 2: Between 1 and 3 (proficiency level: 20–50%)
- 3: The first ligation is loose but can be tightened by the second ligation (proficiency 50–80%)
- 4: Between 3 and 5 (proficiency 80–90%)
- 5: Able to change hands smoothly without loosening after the first ligation. Able to change rubber bands without being pulled (proficiency level 90–100%)

[Task 3] Evaluation of instrumental ligation

- 1: Unable to perform instrumental ligation (proficiency level 0–20%)
- 2: Between 1 and 3 (proficiency level 20–50%)
- 3: Able to perform instrumental ligation, but the right-hand forceps is mainly used to form the loop, and the short tail is too long to catch (proficiency level 50–80%)
- 4: Between 3 and 5 (proficiency level 80–90%)
- 5: Instrumental ligation is performed, and loop formation is performed with the left hand; short tail is of appropriate length (approximately 2 cm) and catching is smooth (proficiency level 90–100%)

[Total passing score]

- 3–6: Very poor (retest), 7–8: poor (retest), 9–11: good (pass), 12–14: great (pass), 15: perfect (pass)



**Fig. 3** Task 2 could be evaluated as if it were an actual surgery. **a** The students tighten the rubber band firmly in task 2 and can ligate without loosening. **b** The ligated thread does not come out of the rubber band when it is pulled. **c** The loops of successful ligation are small

(approximately 1 mm). **d** Alternatively, if the ligation becomes loose. **e** The ligated thread will slip out of the rubber band when it is pulled. **f** The loops of failed ligation are large (approximately 6 mm)



score of the three combined tasks was set at  $\geq 9$  out of 15 points. For example, Task 2 was evaluated as if it were an actual surgery. When the students tightened the rubber band firmly and could ligate without loosening (Fig. 3a), the ligated thread did not come out of the rubber band when it was pulled (Fig. 3b). The loops of successful ligation were small (approximately 1 mm) (Fig. 3c). Alternatively, if the ligation was loose (Fig. 3d), the ligated thread slipped out of the rubber band when it was pulled (Fig. 3e). In failed ligation, the loops were large (approximately 6 mm) (Fig. 3f).

### Questionnaire survey

We conducted a questionnaire survey after the online ligation practice, since this was the first attempt at practice using this method. One hundred and thirty-four students who participated in the student training were surveyed, and 103 students responded. The survey assessed whether the student had previously received training on ligation, the total time of ligation training, and how satisfied they were with the online ligation practice. Satisfaction with online ligation practice was evaluated using a 5-point Likert scale (1, very dissatisfied; 2, slightly dissatisfied; 3, neutral; 4, satisfied; and 5, very satisfied).

This study was approved by the Ethics Committee of Gunma University Hospital (registration number: HS2020-252) and was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments. We verbally explained the study and questionnaire survey to the students and obtained their consent. We also disclosed the information and provided the opportunity to opt out of the study. We performed statistical analyses using JMP Statistical Discovery TM (ver. 15.2., SAS Institute Japan Ltd., Tokyo, Japan). Welch's *t* test was used to determine whether the final exam score increased before or after the mid-term check, and to compare scores between experienced and inexperienced students. *p* Values of  $< 0.05$  were considered statistically significant.

**Table 2** The results of the evaluation of each task

Students <i>n</i> = 134	Average (min– max)	Instructor 1	Instructor 2	Total average
Task 1 score		4.4 (3–5)	4.0 (2–5)	4.2 (2–5)
Task 2 score		4.1 (2–5)	4.1 (2–5)	4.1 (2–5)
Task 3 score		4.0 (2–5)	3.9 (3–5)	4.0(2–5)
Total score		12.4 (9–15)	12.0 (9–15)	12.2 (9–15)

## Results

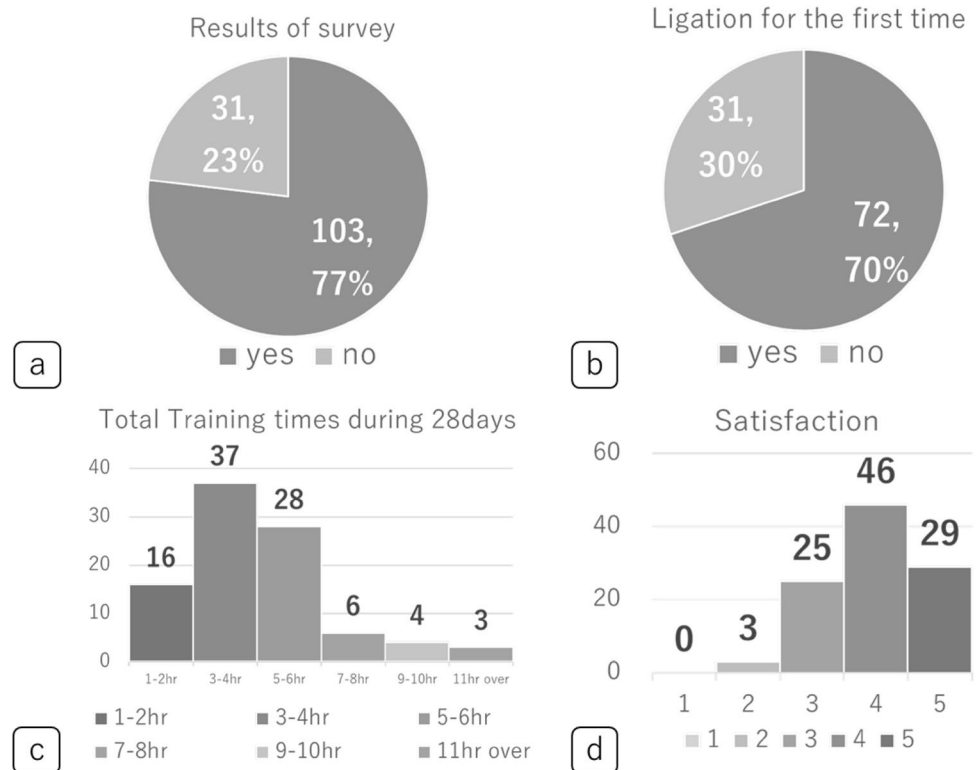
Both instructors independently assessed each task for the 134 students. Table 2 shows the evaluation of each task. The total average score of the three tasks was 12.4 (range, 9–15) for Instructor 1, 12.0 (range, 9–15) for Instructor 2, and 12.2 (range, 9–15) for both instructors. All students obtained a passing score of  $\geq 9$ . We compared the results before and after the mid-term check. There were no significant differences in the scores of Instructor 1, Instructor 2, or in their combined score. The mean scores and significant differences (Welch's *t* test) before and after the introduction of the mid-term check were as follows: Instructor 1: before check, 12.3 (9–15); after check, 12.8 (10–15),  $p = 0.178$ ; Instructor 2: before check, 12.0 (9–15); after check, 12.3 (10–15),  $p = 0.167$ ; Combined score: before check, 12.1 (9–15); after check, 12.5 (10.5–14.5),  $p = 0.113$ . However, the lowest score was 9 before the introduction of the mid-term check, while the lowest score was 10 after the introduction of the mid-term check, indicating a slight increase in the lowest score.

We also conducted a questionnaire survey of the ligation practice of online students (Fig. 4). Of the 134 students, 103 (77%) responded to the survey. Of the 103 students who responded, 72 (70%) reported that this was the first time they had learned about ligation. We compared the students without ligation training to those who had received ligation training in other departments; there were no differences in the scores for each instructor or in the total scores (Table 3). In terms of the total training time during the 28 days of practice, most students trained for 3–4 h. The scores of the satisfaction survey (using a 5-point Likert scale), which assessed satisfaction regarding online tubal ligation practice, were as follows: 1 ( $n = 0$ ; 0%), 2, ( $n = 2$ ; 3%); 3 ( $n = 25$ ; 24%); 4 ( $n = 46$ ; 45%); and 5 ( $n = 29$ ; 28%). It is noteworthy that 75 (73%) students indicated a high degree of satisfaction.

## Discussion

In the early 1990s, Eric Mazur proposed a peer teaching method of flipping a class, which is said to be the beginning of flipped learning [6]. In 2007, Baker et al. [7] conducted flipped learning using online tools, and found that it allowed students to manage their own learning time, which led to increased motivation to learn [8]. However, it is difficult for trainees to learn and perform surgical procedures using e-learning alone [9], and surgical procedures are taught face-to-face. In this study, we conducted ligation training using e-learning with flipped learning with

**Fig. 4** Results of the questionnaire survey. We conducted a questionnaire survey of 134 students who underwent online ligation training. Among these, 103 (77%) completed the questionnaire (a). Among the 103 students, 72 (70%) reported that this was the first time they had learned about tubal ligation (b). In terms of total training time during the 28 days of practice, most students trained for 3–4 h (c). In the satisfaction survey, most students gave a score of 4 or 5 (on a 5-point Likert scale), indicating a high level of satisfaction with the online ligation training program (d)



**Table 3** The results of experienced and unexperienced students

	Unexperienced students <i>n</i> = 72	Experienced students <i>n</i> = 31	<i>P</i> Value (Welch's <i>t</i> test)
Instructor 1	12.4	12.4	0.862
Instructor 2	12.0	12.0	0.911
Total average	12.2	12.2	0.868

online training materials, since face-to-face training was unexpectedly canceled due to the COVID-19 pandemic.

Although more than 70% of the students were undergoing ligation training for the first time, all of them exceeded achieved passing scores in the three tasks, and showed good results despite the fact that the learning, training, mid-term check, and examination were conducted entirely online. The main reason for this was that we included countermeasures in the online training material after analyzing the accumulated videos of the students and clarifying the causes of their inability to perform well, which made flipped learning possible through e-learning. When students failed to practice what they learned, countermeasures were introduced; thus, flipped learning was possible through e-learning without an instructor. Other factors that were considered to have contributed to the good results were as follows: (1) the training videos and assignments were created with actual surgery in mind, (2) videos were created, so that all students could

learn equally from the viewpoint of the instructor's technique, and (3) the training for each task was broken down into elements and the online training materials were not simple technique videos. Kikuchi et al. [10] reported the usefulness of breaking down methodological elements in their training for ultrasound-guided vascular access, and by breaking down the training method of the task into smaller elements, students could be trained in a step-by-step manner and master the technique. Training tools were distributed to each student for the duration of the practice period; therefore, they could train “on their own time”, “at their own place”, and “at their own pace”. The likely reason as to why there were no significant differences in the scores between experienced and inexperienced students was that the questionnaire survey only assessed whether the students had received ligation training in other departments. The students who answered “yes” to the questionnaire survey were classified as experienced; however, it did not clarify whether they had been trained in the same ligation method.

From April 2021, we introduced a mid-term check, which was associated with a one-point increase in the lowest score, but which was not associated with a significant increase in the examination score. This suggests that the educational effect of our online training materials was very high. However, the instructor thought that many students might have improved their understanding of ligation concepts with the introduction of the mid-term check. Therefore, although the interim check did not have a significant impact on the scores

in this study, we considered it to be an essential educational communication tool.

Michael et al. [11] reported that web-based surgical training was as effective as in-person surgical training. One of the advantages of online training and instruction is the ability to learn the content of the procedure from the instructor's viewpoint, regardless of the number of students, which is difficult to do offline. However, we believe that our method has an additional advantage. In Michael et al.'s method, the content of the training covered in conventional face-to-face training was provided directly online; thus, the surgeons who were instructing the students had to spend their time and effort teaching from scratch. Conversely, with our method, only a short time and a small amount of effort were required for the surgeon to teach the online training materials, and the surgeon only had to instruct the students during the mid-term check. We believe that this method can solve the problem of insufficient manpower and difficulty in adjusting time due to the decrease in the number of surgeons and increased workload in relation to surgery, daily treatments, and research.

Nevertheless, the present study was associated with some limitations. The creation of online training materials requires considerable effort and e-learning cannot be performed without an Internet environment [11]. Furthermore, we could not compare our previous face-to-face practice with this online practice, because the evaluation methods were not the same; although instructors who had experienced both face-to-face and online ligation training felt that students learned ligation better in the online training program.

Our online ligation practice with e-learning incorporating flipped learning within the online training materials allowed students to train and learn ligation “on their own time,” “at their own place,” and “at their own pace”, and is characterized by shortened teaching time regardless of the fact that one instructor can teach many students simultaneously. As a result, even at a time when the COVID-19 epidemic has caused—in our country and others—regular learning sessions to be replaced with online education [12, 13], students were able to learn ligation at a distance without congregating in large groups and were able to apply infection prevention measures. A delay in graduation from medical school may lead to disastrous consequences in the event of the COVID-19 pandemic [14–16]; however, we believe that this method is useful, because it allows students to learn ligation while preventing the spread of infection. Even after the COVID-19 epidemic is over, we consider that this method will be useful and appropriate for evolving times and hope to develop various flipped e-learning educational programs, such as needle suture training and surgical skill training, for surgical residents.

Ligation practice was conducted using e-learning with flipped learning with online training materials. This enabled students to perform this practice “on their own time”, “at

their own place”, and “at their own pace”. Even students who were trained in ligation for the first time were able to acquire skills through this method.

## Declarations

**Conflict of interest** The authors declare no conflicts of interest in association with the present study.

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