# Surgical Video Projection onto a Mannequin: An Educational Tool for Simulation Practice of Perioperative Anesthetic Management

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Simulation practice is known to be effective in anesthesiology education. In our simulation practice of general anesthesia for open cholecystectomy at the Tohoku University simulation center, we projected a surgical video onto a mannequin's abdomen. In this observational study, we investigated whether video-linked simulation practice improved students' performance. We retrospectively compared the general anesthesia simulation practice scores of fifth-year medical students in a video-linked or conventional group. In the simulation practice, we evaluated the performance of each group in three sections: perioperative analgesia, intraoperative bleeding, and arrhythmia caused by abdominal irrigation. The primary endpoint was the total score of the simulation practice. The secondary endpoints were their scores on each section. We also investigated the amount of bleeding that caused an initial action and the amount of bleeding when they began to transfuse. The video group had significantly higher total scores than the conventional group (7.5 [5-10] vs. 5.5 [4-8], $p = 0.00956$). For the perioperative analgesia and arrhythmia sections, students in the video group responded appropriately to surgical pain. In the intraoperative bleeding section, students in both groups scored similarly. The amount of bleeding that caused initial action was significantly lower in the video group (200 mL [200-300]) than in the conventional group (400 mL [200-500]) ($p = 0.00056$). Simulation practice with surgical video projection improved student performance. By projecting surgical videos, students could practice in a more realistic environment similar to an actual case.

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## Introduction

Simulation-based medical education (SBME) is widely used in medical education for undergraduate students and residents (Motola et al. 2013; Alsuwaidi et al. 2021). The high-fidelity human patient simulator (HPS), one of the standard systems of SBME, commonly involves the use of life-like mannequins and sophisticated scenarios featuring anatomy, physiology, and clinical situations (Meyers et al. 2020). HPS monitors respond to oxygen, anesthetic gases, ventilation, and medication. Most institutions have adopted HPS for medical education and evaluation of technical and non-technical skills, teamwork, team leader roles, situation awareness, and decision-making in low-stress conditions (Yunoki and Sakai 2018). Simulation training is also suitable for learning about perioperative critical situations and patient safety in low-resource settings (Everett et al. 2017; Marynen et al. 2020; Gao et al. 2021). Effective tools, such as cognitive aids that improve trainees' performance have also been investigated (Gleich et al. 2019).

At our institution, fifth-year medical students undergo anesthetic training for 5 days every week with 2-4 students per group. On the final day, perioperative management with high-fidelity HPS is evaluated. Students have to man-

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age anesthesia for an open cholecystectomy with the occurrence of 1,000 mL of intraoperative bleeding and arrhythmia. The evaluation consists of greeting a patient, inducing and maintaining anesthesia, airway management, hemodynamic management, extubation, and emergence. Students assume the role of the anesthesia team leader, and situational awareness and decision-making are assessed. They have to understand the patient's condition and surgical progress based on changes in vital signs and the instructor's supplemental explanation of the surgical situation. During conventional training, students only observe the vital monitor during surgery and hemorrhage and often struggle to appropriately manage intraoperative analgesia and bleeding, whereas induction of anesthesia and airway management pose few problems. Even life-like mannequins do not obtain surgical wounds or lose blood.

We believe that visual information regarding the progress of surgery may improve students' performance. Tan et al. (2008) and Schwid et al. (2001) reported that screen-based simulation could have better educational outcomes than conventional education on specific treatment for medical crises and management of anesthetic emergencies for clinical anesthesia residents. The latest high-resolution projector can present videos of various materials and colors. Thus, we projected a surgical video onto the abdomen of the HPS mannequin to provide an accurate picture of the surgical procedure and bleeding. We hypothesized that video-linked HPS practice sessions would allow students to demonstrate their abilities better than conventional HPS practice sessions.

This study aimed to investigate the efficacy of surgical video projection in establishing a visual environment suitable for SBME in an anesthesiology program. This study retrospectively compared students' performances between video-linked simulation and conventional simulation practice sessions.

## Methods

This retrospective observational study evaluated medical students' performance in anesthetic simulation practice. Ethics approval for this study was obtained from the Ethics Committee of the Tohoku University Graduate School of Medicine (2022-1-221), and the study was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The requirement for informed consent was waived owing to the retrospective study design.

Fifth-year medical students were randomly divided into small groups (2-4 students per group). Each group was scheduled for 5 days of clinical clerkship of anesthesiology (Table 1), and the simulator examination was performed on the final day. Our faculty did not give the students any lectures or suggestions directly related to the answers to the simulator examination. Data from groups between March 2019 and August 2021 were included in the analysis. Simulation practice was performed without video projection in the conventional group from March 2019 to March 2020. From June 2020 to August 2021, simulation practice with surgical video projection was performed for the video group.

The patient in the scenario was a 40-year-old man (height: 177 cm, weight: 85 kg) undergoing scheduled open cholecystectomy. He was suspected of having intra-abdominal adhesions due to an appendectomy 5 years prior. All examination data were normal, and the American Society of Anesthesiologists physical status classification was class 1. The above information was disclosed to the students immediately before simulator practice.

The simulation room contained a patient mannequin, items, and drugs for general anesthesia, anesthesia machines, and monitors. An evaluator (E.O. and M.Y.) and technical operators who controlled the HPS were behind a one-way mirror. The evaluator communicated verbally as a surgeon or nurse using a microphone. The faculty explained the standard monitors, such as the electrocardiogram, non-invasive blood pressure, invasive blood pressure, pulse oximeter, and the possibility of infusion, transfusion, and vasopressor administration. In the conventional group, the mannequin was laid on a surgical table without any change. In the video-linked group, a surgical video of cholecystectomy was projected on the mannequin's abdomen using a high-resolution projector (EV-100, EPSON Co., Tokyo, Japan) at the start of the open cholecystectomy (Fig. 1). The video contains a skin incision, intraoperative bleeding, abdominal irrigation, and skin sutures.

We evaluated the performance of each group in three sections: perioperative analgesia, intraoperative bleeding, and arrhythmia caused by abdominal irrigation (Table 2). We scored their performance in each section using Google Forms. A score of 1 point was given for a correct response and 0 points for a failure to respond.

In the perioperative analgesia section, students were evaluated for adequate analgesia in three tasks: analgesia before surgery by an opioid dosage adjustment or epidural analgesia, intraoperative analgesia by an opioid dosage adjustment or epidural analgesia, and postoperative analgesia by continuous intravenous or epidural analgesia. If preoperative analgesia was inadequate, the operator manually

Table 1. Schedule of clinical clerkship for anesthesiology in the fifth year.

| | Contents |
|---|---|
| First day | Orientation, anesthesia training with patients |
| | Phantom training of epidural and spinal blocks |
| Second day | Intensive care unit |
| Third day | Round of pain clinic and palliative care |
| | Understanding anesthesia machine |
| Fourth day | Anesthesia training with patients |
| Fifth day | Simulation practice and debriefing |
| | Review of the clinical clerkship |

elevated the systemic blood pressure and heart rate to 140 mmHg and 100 bpm, respectively. If preoperative analgesia was adequate, the systemic blood pressure and heart rate were elevated during the intraperitoneal manipulation phase.

Each group was assessed for their response to elevated blood pressure and heart rate and how analgesia was performed. We also evaluated their understanding of the need for continuous post-operative analgesia.

In the section on intraoperative bleeding, the evaluator announced the amount of bleeding every 100 mL and decreased the blood pressure gradually until the student performed a transfusion or the volume of blood loss reached 1,000 mL. Students were expected to assess arterial blood gas analysis (BGA) and treat hypotension by administering extracellular fluids and vasopressors. The evaluator assessed 10 tasks regarding students' performance in dealing with intraoperative bleeding in the following scenarios: 1) increased infusion rate, 2) further increase in infusion rate, 3) administering colloid infusion, 4) recording BGA, 5) recording BGA more than twice, 6) inserting vascular access, 7) inserting vascular access with 20-gauge or thicker catheter, 8) administering vasopressor drug, 9) continuous infusion of phenylephrine or noradrenaline, and 10) ability to avoid transfusion of red cell concentrate (RCC). We also recorded the amount of bleeding that they initially responded to, and when the students began RCC transfusion.

In the section on intraoperative arrhythmia, premature ventricular contraction occurred during subdiaphragmatic irrigation, in which the suction tube touched the patient's heart through the diaphragm. The evaluator assessed whether each group could resolve the cause of the arrhythmia.

The primary endpoint was the total score of medical

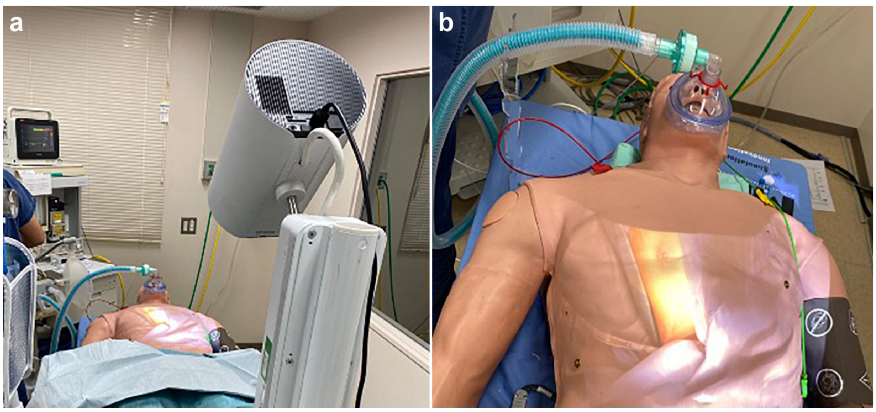


Fig. 1. Surgical video projection.
Video of open cholecystectomy is projected onto the mannequin. (a) Projector is placed at the mannequin's feet. (b) Surgical video is visible.

Table 2. Simulation practice checklist.

| Section | Task | Score | Section Score |
|---|---|---|---|
| Perioperative analgesia | Preoperative analgesia | 1 | 3 |
| | Intraoperative analgesia | 1 | |
| | Postoperative analgesia | 1 | |
| Intraoperative bleeding | Increased infusion rate | 1 | 10 |
| | Further increased infusion rate | 1 | |
| | Colloid infusion | 1 | |
| | Blood gas analysis | 1 | |
| | Blood gas analysis more than twice | 1 | |
| | Vascular access | 1 | |
| | Vascular access with intravenous catheter thicker than 20 gauge | 1 | |
| | Administered vasopressor | 1 | |
| | Continuous infusion of vasopressor | 1 | |
| | Avoid RCC transfusion | 1 | |
| Intraoperative arrhythmia | Realize the reason of arrhythmia | 1 | 1 |
| Total score | | 14 | |

RCC, red cell concentrate.

Table 3. Scores and analysis of simulation training in the video and conventional groups.

| | | | Video group (n = 50) | Conventional group (n = 48) | *P*-value |
|---|---|---|---|---|---|
| Perioperative analgesia | Preoperative analgesia | n (%) | 15 (30.0) | 12 (25.0) | 0.654 |
| | Intraoperative analgesia | | 43 (86.0) | 29 (60.4) | 0.00573 |
| | Continuous infusion for postoperative analgesia | | 20 (40.0) | 10 (20.8) | 0.0495 |
| Intraoperative bleeding | Increased infusion rate | n (%) | 49 (98.0) | 46 (95.8) | |
| | Further increased infusion rate | | 44 (86.6) | 27 (56.3) | |
| | Colloid infusion | | 18 (41.8) | 23 (47.9) | |
| | Blood gas analysis | | 29 (62.7) | 21 (43.8) | |
| | Blood gas analysis more than twice | | 14 (28.4) | 8 (16.7) | |
| | Vascular access | | 36 (58.2) | 21 (43.8) | |
| | Vascular access with intravenous catheter thicker than 20 gauge | | 22 (50.8) | 15 (31.3) | |
| | Administered vasopressor | | 44 (50.4) | 38 (33.0) | |
| | Continuous infusion of vasopressor | | 10 (13.9) | 5 (4.4) | |
| | Avoid RCC transfusion | | 20 (26.1) | 23 (20.0) | |
| | The amount of bleeding when the groups began to RCC transfusion | mL (median [IQR]) | 700 [600-900] | 800 [700-900] | 0.653 |
| | Total score of management of bleeding | points (median [IQR]) | 6 [3.25-7.0] | 4.5 [3.0-6.25] | 0.0952 |
| | Initial amount of bleeding that the groups responded to | mL (median [IQR]) | 200 [200-300] | 400 [200-500] | 0.00056 |
| Intraoperative arrhythmia | Realize the reason of arrhythmia | n (%) | 15 (30) | 5 (10.4) | 0.0231 |
| Total score of practice | | points (median [IQR]) | 8 [5-10] | 5.5 [4-8] | 0.001 |

IQR, interquartile range; RCC, red cell concentrate.

students' performance. The secondary endpoints were the performance on each section, the amount of bleeding that caused their initial action, and when they began to transfuse.

*Statistical Analysis*

All statistical analyses were performed using EZR Version 1.61 (Saitama Medical Centre, Jichi Medical University, Saitama, Japan) (Kanda 2013). All reported *p*-values were two-sided. Significance was defined as $p < 0.05$. The comparison of the scores between video-linked and conventional simulation practices was examined using the Mann–Whitney U test. The comparison of the amount of bleeding that caused their initial action, and the amount of bleeding when RCC transfusion was initiated were also examined using the Mann–Whitney U test. The performance of each task was compared using Fisher's exact test. Data were presented as mean (standard deviation [SD]) or median [interquartile range], as appropriate.

## Results

We collected the simulation practice scores for 98 groups (48 conventional and 50 video groups). Table 3 shows the number and proportion of groups that obtained scores for each task. The total score of the video group was significantly higher than that of the conventional group (7.5 [5-10] vs. 5.5 [4-8], $p = 0.00956$, Table 3).

In the section on perioperative analgesia, there was no significant difference between the two groups that used adequate analgesics before surgery (30.0% vs. 25.0%, $p = 0.654$). However, the video group could appropriately administer analgesics against elevation of blood pressure caused by surgical invasion compared with the conventional group (86.0% vs. 60.4%, $p = 0.0057$). The video group could also recognize the need for continuous administration of analgesics as postoperative analgesia (40.0% vs. 20.8%, $p = 0.0496$).

In the section on intraoperative bleeding, no significant differences in section scores were found between the two groups: the video group 6.0 [3.25-7.0] vs. the conventional group 4.5 [3.0-6.25], $p = 0.0952$. The initial amount of bleeding that the groups responded to was significantly lower in the video group (200 [200-300] vs. 400 [200-500] mL, $p = 0.00056$, Table 3). Both groups scored similarly for performing blood transfusion (60.0% vs. 52.1%, $p = 0.542$). The volume of blood loss at the start of blood transfusion was also similar (700 [600-900] vs. 800 [700-900] mL, $p = 0.653$).

In the intraoperative arrhythmia section, students in the video group could better identify the reason for arrhythmia as stimulation of subdiaphragmatic irrigation (15.0% vs. 5.0%, $p = 0232$).

## Discussion

This retrospective investigation demonstrated that video-linked simulation practice significantly improved students' performance during perioperative anesthetic management. To our knowledge, simulation practice using surgical video projection onto mannequins has not yet been reported. The surgical video helped students immerse in perioperative management and understand by visual information that surgical progress is strongly associated with perioperative hemodynamic changes and pain management. Therefore, students in the video-linked group were better able to deal with perioperative management of open cholecystectomy.

Simulation practice with HPS can provide almost all components of medical education, including knowledge, technical skills, clinical judgment, decision-making, team training, and communication ability (Melloul et al. 2016). In the field of anesthesia, SBME is known to be an enjoyable and valuable educational tool for undergraduates (Morgan and Cleave-Hogg 2000) and is constituted of mannequin-available content, such as basic knowledge. Skills include airway management, cardiopulmonary resuscitation, evaluation of vital sign monitors, judgment of necessity for anesthetics, and communication during an emergency. Our scenario featured anesthesia for open cholecystectomy using the above components. In our study, students in the conventional group relied on cues from the faculty and the vital monitors, while there was no signaling from the mannequin. On the contrary, projecting surgical video has the advantages of reproducing the clinical situation and sharing information within the team. Most anesthesiologists perform perioperative management based on multiple types of information, including surgical progress, vital signs, blood loss, and urine output. By incorporating "Seeing is believing," video-linked simulation practice could impressively train students to make decisions in similar clinical situations. Furthermore, by sharing video information within the group, students became more aware of the surgical situation and discussed bleeding. Several groups asked the surgeons whether they could stop bleeding. Thus, video-linked HPS practice encourages team conversations, including with anesthesiologists and surgeons. Additionally, it could contribute to multifaceted decision-making and develop teamwork by enhancing the ability to communicate.

The importance of pain education and treatment has been recognized; however, a sophisticated curriculum has not yet been developed. Lectures can introduce essential knowledge such as physiology, anatomy, types of pain, medication, and nerve blocks. Clinical clerkships teach the degree of pain, appropriate treatment, and care. Simulation practice allows medical students to judge pain treatment accurately. Upper abdominal laparotomy, as in our case, was accompanied by severe pain and required continuous postoperative administration of analgesics. Most of the students would not correctly plan a perioperative analgesic protocol. In our study, the video-linked groups could provide immediate analgesia against increasing blood pressure due to the surgical procedure and perform continuous administration of epidural analgesia or intravenous fentanyl for postoperative analgesia. The results of this study showed that surgical video projection facilitates students' awareness of appropriate analgesia for highly invasive surgical procedures, which causes a circulatory response of the sympathetic nerve. In contrast, the number of groups that received a score on the task for postoperative pain was only 20 (40.0%), even in the video group. In the debriefing session, we explained the necessity of continuous analgesia by showing the surgical video to the students. This is expected to help students understand the recent increasing guidelines for postoperative analgesia or enhanced recovery after surgery (Chou et al. 2016; Melloul et al. 2016; Feray et al. 2022).

In the section on intraoperative bleeding, we evaluated what the students thought and how they would respond to sudden bleeding. The patient in our scenario had no complications such as anemia, hemorrhagic diathesis, or cardiac disease. In such case, most anesthesiologists deal with bleeding up to 1,000 mL, while maintaining intravascular volume, using vasopressor, checking blood analysis, and determining indications for transfusion. Therefore, we required students to maintain hemodynamics with extracellular infusion, administer vasopressin drugs, and analyze blood gas, and avoid blood transfusion as much as possible. In our study, surgical video projection did not improve the students' scores in the section on intraoperative bleeding; however, the video group responded earlier to bleeding than the conventional group. The curriculum and lecture content were the same for the two groups. Therefore, the ability to deal with intraoperative bleeding might be similar between the two groups. However, the projection of the bleeding in the surgical video encouraged students to respond earlier and share their knowledge with each other in preparation for a massive hemorrhage. Video projection might promote students to change their behavior.

In the section on intraoperative arrhythmia, students in video-linked groups realized that irrigation near the diaphragm caused arrhythmia. When a change in vital signs is detected, most anesthesiologists check the surgical situation and search for the cause of the change. A surgical video projection might allow trainees to understand and develop clinically relevant attitudes and behaviors against sudden fatal cardiac changes according to the guidelines (Dalia et al. 2019).

The aim of our simulation practice was to bridge the gap between medical knowledge learned through lectures in a classroom and essential practice in clinical situations. Simulation practices are related to the third level of Miller's pyramid, "SHOW HOW," published in 1990 (Miller 1990). In our scenario, using surgical video, students could understand the hemodynamic changes caused by the surgical procedure and intraoperative bleeding. They dealt with problems without the advice of a supervising physician and confirmed changes in vital signs due to their actions. Therefore, our simulations are practical training focusing on "DO" levels of Miller's pyramid. Simulation practice encourages students to use their knowledge to make decisions based on various types of visual information. Replication of the actual clinical environment is essential for establishing realistic and immersive simulation practice (Kim and Lee 2021). We demonstrated that HPS with video projection allowed students to realize situations in which they should put their knowledge into practice. One of the next steps, the eye-tracking system, will help assess and advise medical students about thinking compared to an expert's visual perception (Tanoubi et al. 2021).

This study has several limitations. First, time-related bias should be considered. This study was a retrospective investigation, and video-linked simulation practice has been performed since 2020 as an improved version of conventional practice. Changes in teaching skills may have affected the simulation practice scores. Second, the difference in anesthesia experience before HPS practice is related to the score of this study. Similar experiences of the scenario in clinical clerkship could have helped to obtain a higher score. Third, the scoring for this simulation practice has not yet been standardized and established. Whether this evaluation item objectively assesses student performance and variations among supervisors should be considered. The validity of the scoring needs to be verified among multiple faculty members by referring to the Core Curriculum.

In conclusion, our retrospective study demonstrated that surgical video projection onto the HPS mannequin could improve students' performance in the simulation practice of perioperative management. Impressive visual information supports decision-making and communication within the group. Further investigation is needed to establish more effective and practical simulation education.

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## Author Contributions

Eiko Onishi: Data curation, funding acquisition, writing - original draft, and writing - review & editing. Toshihiro Wagatsuma: Conceptualization, methodology, writing - review and editing. Shizuha Yabuki: Data curation, investigation. Yutaro Arata: Software. Masanori Yamauchi: Supervision, writing - review and editing. All the authors read and approved the final version of the manuscript.

## Conflict of Interest

The authors declare no conflict of interest.

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