Self-debriefing Model Based on an Integrated Video-Capture System: An Efficient Solution to Skill Degradation

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OBJECTIVE: Video-based teaching is considered highly effective in debriefing, especially in minimally invasive surgeries. In this study, the benefits of using a new integrated video recording system, were investigated and compared to those of the standard basic skills robotic training procedure.

DESIGN: Fifty residents from the 2nd and 3rd year medical faculty without any experience of robot usage or laparoscopy were randomized into 2 groups: group A——a natural self-training group without a trainer, and group B——a self-training group assisted by an integrated video recording system during training. The training was divided into four 2-hour sessions, with a 72-hour delay between each session. Two tasks were selected for testing on the dV-Trainer, a virtual reality based robotic simulator: Match board 2 and Thread the Rings 1. After each session, the practice video recorded by the system of group B was transferred to the residents' smartphones for self-debriefing. At the end of each session, the performance score was evaluated automatically by using the simulator to plot learning curves A and B.

RESULTS: Group A showed a significant drop in performance score due to skill decay caused by the 72-hour delay. Group B exhibited a regular stepwise rising learning curve. At the end of the training, group B showed a significantly higher performance score both in Match board 2 and Thread the Rings 1. The autoanalysis and capture function, which selects only the critical errors and most valuable parts, could facilitate time saving.

CONCLUSIONS: The use of an integrated video recording system makes the self-manipulated protocol with own smartphone feasible to improve training efficiency and overcome the skill decay during robotic surgical training. (J Surg Ed 76:362−369. © 2018 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: Robotic Surgery, Robotic Training, Simulation, Video Capture, Self-debriefing

COMPETENCIES: Patient Care, Practice-Based Learning and Improvement

INTRODUCTION

Video capturing is widely used in domains, such as in the training of athletes, as an excellent method to present procedures to other people or to oneself.[1,2] Video-based teaching has also been considered a classic[3] and popular[4-6] method during surgical procedures for debriefing, especially in minimally invasive surgeries, such as laparoscopic and robotic surgeries, benefiting the patient more than open access surgeries. In addition, capturing the operating field by simply using video duplication is considered an ideal platform.

However, this duplication of the operation field can only replay the endoscopic view and does not provide the comprehensive procedure in the same timeframe. Thus, an integrated recording and replaying system composed of multiple cameras and sensors was considered a solution, and proved beneficial for trainees in improving their training efficiency and decreasing the trainers' burden during robotic surgical training.[7]

Virtual simulation has proven efficient and necessary for acquisition competence in clinical robot-assisted

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surgery.[8-10] Thus, robot manufacturers recommend purchasing a console-integrated simulator, allowing surgeons to train themselves during sporadic periods when the robot is not clinically in use.

Remote mentoring and education has become a new trend and effective solution for the standardization of robotic skill training, as the training efficiency varies considerably according to the professionalism and competence of the trainers.[11-13] The following 2 barriers still exist for teleteaching with respect to robots and their simulators: ensuring training efficiency with a decrease in the local work for the trainer and effectively utilizing the new robotic surgeons' free time for debriefing until the formation of a professional habit.

To solve the aforementioned problems, we investigated the feasibility of a novel self-debriefing protocol based on an integrated video-recording system on a user's device. We speculate whether this method could help surgeons refresh their memory and improve the performance quality during robotic training.

MATERIALS AND METHODS

Simulator

The dV-Trainer (dVT) is a validated robotic simulator based on virtual reality technique for robotic training[8,9,14] with an automatic scoring system (M-scores) for evaluating the performance of an operator with respect to 7 categories (time to complete the exercise, economy of motion, instrument collisions, excessive instrument force, instrument out of view, master workspace range, and drops) and a proficiency-based score for global evaluation.

Exercises

The selection of exercises in this study was based on literature review[9] and our prior experience,[7] and included the pick-and-place (PP; for warm-up), Match Board 2 (MB; for test), and Thread-the-Rings 1 (TR; for test) exercises (Fig. 1).

The PP exercise was simple and aimed at familiarizing the user with dVT. The trainees practiced PP 3 times for warm up. The MB and TR were intermediately difficult exercises with a proper learning curve. Both the exercises required the use of both hands: MB had a larger moving range for instruments and TR was sensitive to excessive force.

FIGURE 1. Task selected (from left to right): pick-and-place (PP; for warm up), Match Board 2 (MB; for testing), and Thread-the-Rings 1(TR; for testing).

Recording and Replaying System

System 1: Integrated video system

The core of this system is a high-definition multimedia interface video card installed in a secondary monitoring computer dependent on the dVT simulator, the interface of which is based on Visual Studio 2010 open software (Microsoft Corporation, Redmond, WA).

Eight force-sensing resistors (FSR 408; Interlink Electronics Inc, Camarillo, California) were separated into 2 groups on the left and right sides of the armrest. Pressure signals were transmitted to the monitoring computer through a universal serial bus connection (Fig. 2).

System 2: Screen capture software

The Super Bukuai (Dream technology Inc, GuangZhou, CHN) was used to capture the integrated screen and restore it into a film in either of the following formats: windows media video or audio video interleaved; these could easily be replayed using media players on a smartphone.

Hardware Installation and Video Transfer

The secondary monitoring computer with high-definition multimedia interface video card (4 ports) was installed beside the dVT for the trainer. One video signal was a duplication of the operational view from the simulator. The other 2 signals were obtained from digital cameras installed in the console and in front of the pedals. Pressure signals were connect to this computer through a universal serial bus connection. Trainees' smartphones were connected to this secondary

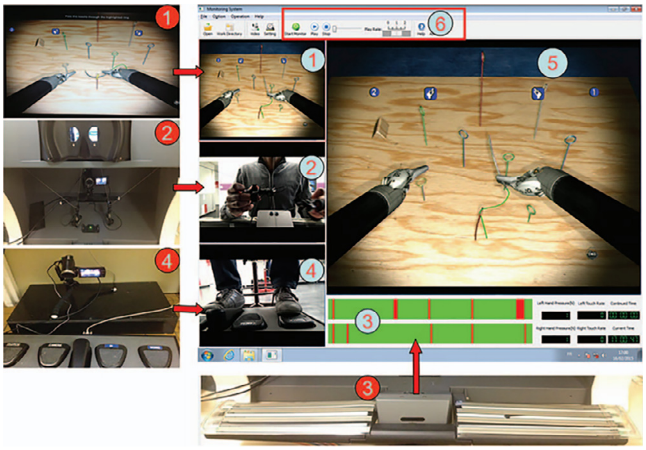

FIGURE 2. Interface of the new controller of events on the simulator and robot (CESIR).

monitoring computer with corresponding cables and recognized as hard disk for video transmission.

Organization

Fifty residents from the 2nd and 3rd year medical faculty of Wuhan University, with no experience in robotic surgery or simulators, were recruited and randomly assigned to group A and group B, respectively. They all signed an informed consent form. A standard film (one channel) was prepared to introduce the installation, combination of the 2 instruments, and utilization of the clutch pedal. After watching the film, the participants practiced PP 3 times for warm-up and immediately made their first attempt at MB; this score was noted as their initial level on dVT. The training procedure of every task was separated into 4 sessions, each of 2 hours; there was a 72-hour rest between each session and the switch from MB to TR (Figs. 3 and 4).

Group A received training similar to the most popular self-training method, without any coaching or any video debriefing, throughout the training procedure, including a pause period.

Group B was self-coached during the training procedure:

- They replayed the perfect film (4 channels integrated) prepared by the experts and self-debriefed on their own practice film (4 channels integrated) by directly using the monitoring and recording computer during the training session.
- At the end of each training session, their smartphones were connected to the monitoring and recording computer through the corresponding cables for data transfer. The perfect film and last 3 attempts were mandatory for selection, in addition to which the trainees could select any film with typical critical errors from all their practice attempts based on the evaluation of the automatic scoring system.
- During the pause period, they held a 1-hour self-debriefing with the perfect film and their own films once every 24 hour (totaling 3 hours in the pause period). The self-debriefing history could be traced from the record of recently played videos on the media players in the smartphone.

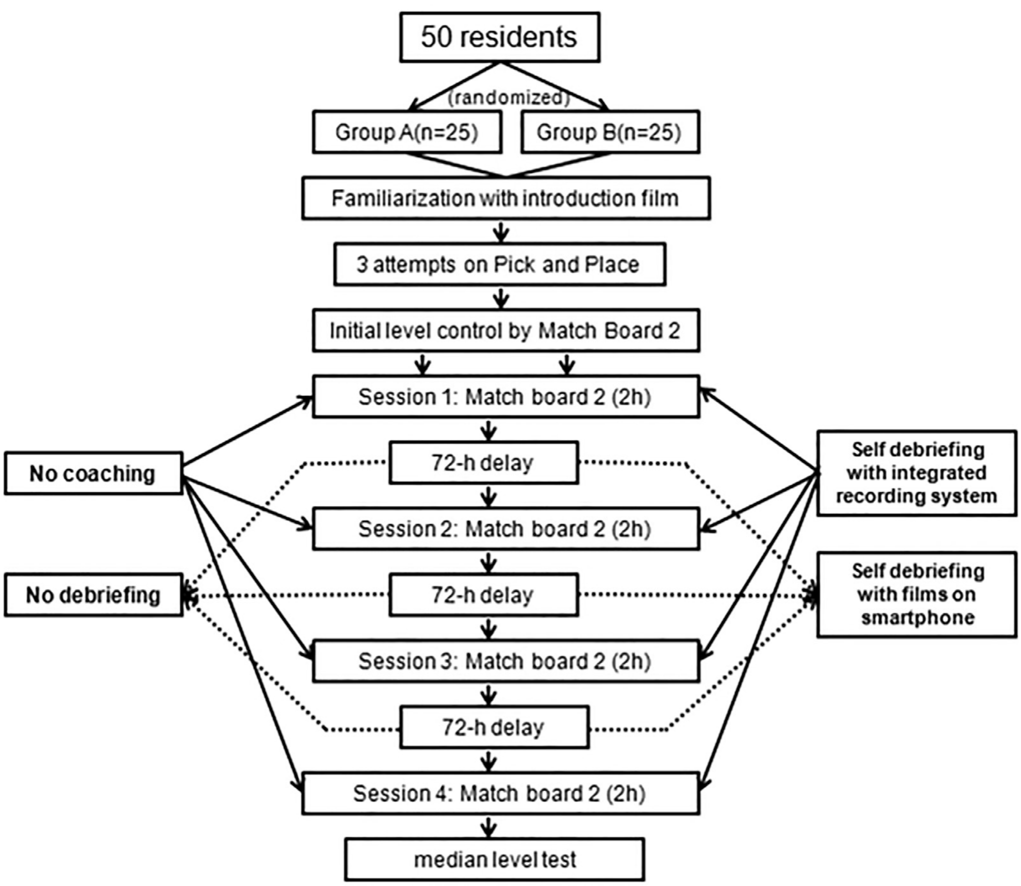

FIGURE 3. Study organization of MB.

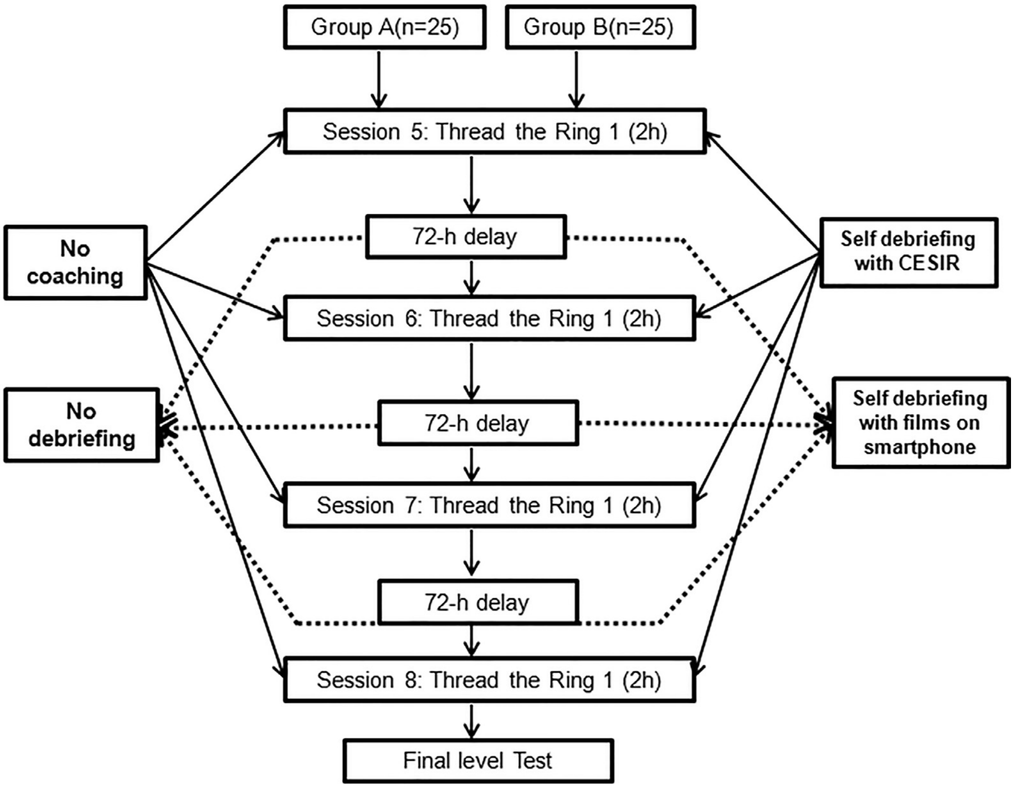

FIGURE 4. Study organization of Thread-the-Ring 1.

Data Collection

The first attempt at MB was noted as the baseline of each group. At the beginning and end of each session, the overall score evaluated automatically by the dVT was noted to plot the learning curves for A and B.

Statistical Analysis

A statistical analysis was performed using the SPSS software version 20 (SPSS, Inc, Chicago, Illinois). We were interested in comparing the overall score between the 2 groups, and the score of the last session and first attempt in a new session after interruption in the same group. Thus, we conducted a one-way analysis of variance or student's *t*-test. The Kolmogorov−Smirnov test was used for checking the distribution of the overall score, and if it did not correspond to a normal distribution, the Wilcoxon signed-rank test was used. The significance level (p) was set at 0.05.

RESULTS

Main Result

Group A consisted of 10 males and 15 females with an average age of 23.42 ± 2.22, and group B consisted of 13 males and 12 females with an average age of 23.74 ± 2.56. Group A and group B achieved a similar initial level based on the results of the control test.

Learning Curves of MB

The beginning and end of a session are denoted by Sxb and Sxe, respectively (where x = 1, 2,. . .). From the end of session 1 (S1e) to the end of session 4 (S4e) and after the execution of the self-training protocol by the recording and replaying system, group B achieved a significantly higher score than group A on MB ($p < 0.05$). Group A showed a significant difference in the overall score between the end of session 2 and beginning of session 3 (S2e−S3b; $p1 < 0.05$) and the end of session 3 and beginning of session 4 (S3e−S4b; $p2 < 0.05$) (Fig. 5).

Learning Curves of TR

From S5b to the final test, after the execution of the self-training protocol by the recording and replaying system, group B achieved a significantly higher score than group A on TR ($p < 0.05$). Group A showed a significant difference in the overall score between S5e & S6b ($p3 < 0.05$), S6e & S7b ($p4 < 0.05$), and between S7e & S8b ($p5 < 0.05$). Group B showed a significant difference in the overall score between S7e and S8b ($p6 < 0.05$) (Fig. 6).

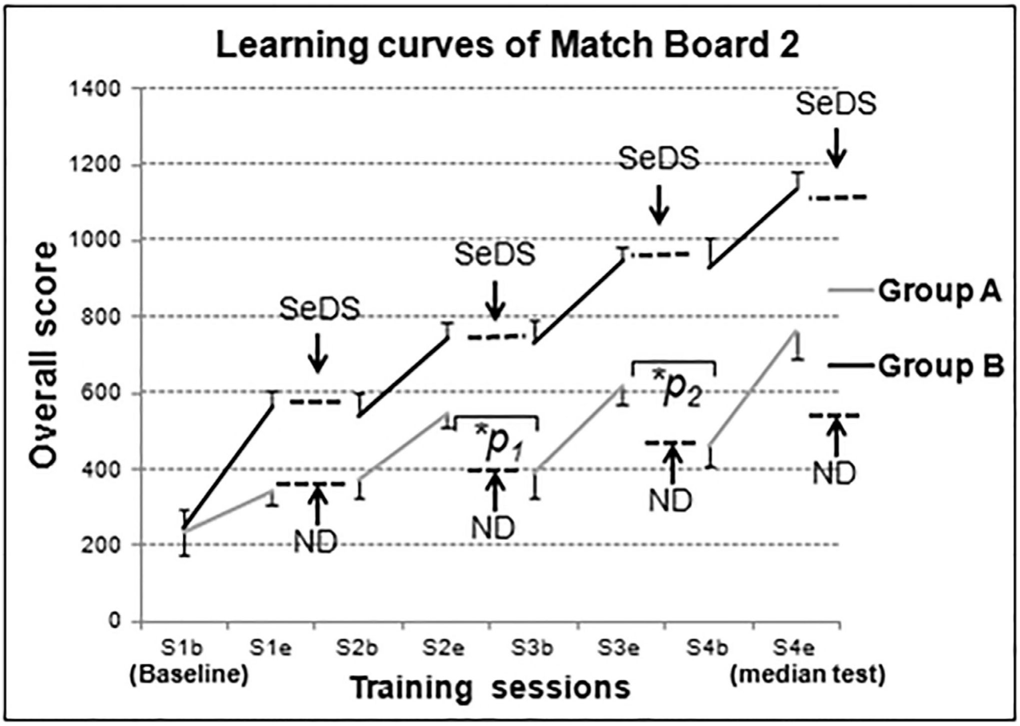

FIGURE 5. MB learning curves. There was a 72-hour delay between two training sessions. SeDS: self-debriefing by using smartphone, ND: No debriefing, $*p_1$: comparison of the overall score between S2e and S3b in group A, $*p_2$: comparison of the overall score between S3e and S4b in group A, p_1, $p_2 < 0.05$ by using one-way ANOVA.

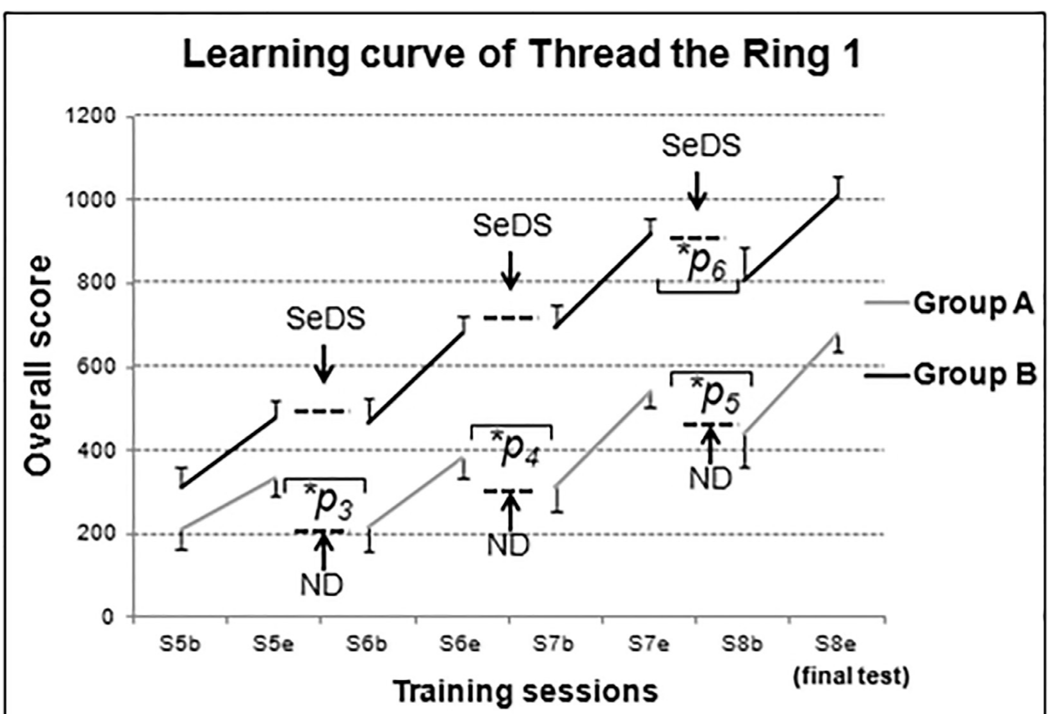

FIGURE 6. TR learning curves. There was a 72-hour delay between two training sessions. SeDS: self-debriefing by using a smartphone, ND: No debriefing. S5b: the beginning of the fifth training session, S5e: the end of the fifth training session, $*p_{3-5}$: comparison of the overall score between the end of a session and beginning of the following session in group A, $*p_6$: comparison of the overall score between S7e and S8b in group B, p_{3-6}, < 0.05 by using one-way ANOVA.

DISCUSSION

An acquired surgical skill will decay naturally after periods of nonuse. Spaced practice outperformed massed session for the retention of skill in several studies,[15,,16] but the optimal intersession interval were not clear.[17] In this study, the intersession interval was set at 72 hours, which simulate the novice robotic surgeons operating with robot twice a week at the beginning of carrier. The result of group A showed a natural self-training procedure common among the hospitals with simulator-equipped robotic consoles; sometimes, the trainees guided themselves in the absence of a professional trainer or the novice surgeons operated without an expert. In the free-training model, the natural-learning curve increased gradually but decreased during the progress from one session to the next.

Replaying videos was proved as an efficient method for during surgical training.[18,19] Its advantage is presented in the next two paragraphs for Group B.

First, the benefit of integrating cameras and sensors into an interface could provide more detailed information than with a single-view range-limited camera, as robotic surgery requires the coordination of the eyes, hands, and feet. It is important to relocate the forearm on the armrest to ensure movement precision and ergonomic comfort; this differs completely from a laparoscopic surgery.[20] When an operator is concentrating during a difficult case, they might focus on controlling the robot's joystick, ignoring the ergonomic position and pedal utilization. With the same error time-stamp on the integrated recording and replaying system, the operators could easily note the position of the hands and ergonomic error corresponding to the most important/dangerous parts when replaying the operation recording. Compared to the case of the perfect films, they could not only rapidly detect errors (what happened) but also recognized their corresponding hand movements and ergonomic position (how it happened).

Second, the "easy-to-use" function was significantly improved for this self-training model. A screen-capture function was added to the software, and the video files were output directly in audio video interleaved or windows media video format by pushing a button. The group was able to transfer the perfect film, collection of errors, and their practice sessions onto their smartphones after each training session. The debriefing could then be freely realized anywhere and at any time, and was not just limited to the training room during the training course. This "free-to-learn" function might be the most attractive feature of this self-debriefing training model, with a more free environment and flexible study time, and is helpful in eliciting the key skills and avoiding mistakes.[21,,22] The robot operating skill degradation was observed in group A, and was significant between sessions 2 & 3, 3 & 4, 5 & 6, 6 & 7, and 7 & 8 after a 72-hour interruption in both MB and TR (Figs. 5 and 6); however, in group B, the continuous self-debriefing model was efficient in refreshing the participants' memories.

In addition to the main results, we observed some interesting phenomena. In group A, no significant difference was observed between sessions 1 and 2, as they might be the real levels after simulator adaptation (Fig. 5). After 72 hours, without feedback, the performance quality decreased to these levels at the beginning of session 3. Then, the group had to restudy in solace, and the real level was improved until the beginning of session 4.

In addition, a drop in the overall score was observed from the end of session 7 to the beginning of session 8 in group B (Fig. 6). This difference was caused by an increase in excessive instrumental force. The self-briefing by using a smartphone could help them recall the key points during the operation but could not teach them force control through the video, as their muscle memory had not reached a professional level. A strict rule exists for pilots: when they quit flight service for a long time, to ensure safety, they must obtain a license on a simulator before flying an aircraft.[23,24] Although complications in the robotic surgery appear in the early period of the learning curve, a warm-up call might be needed during clinical activities.[16] A new robotic operator, who did not get the opportunity to practice on enough cases, or a robotic expert, who quits a robotic console for a long time (e.g., maternity leave, sick leave, or a long holiday) could self-debrief by using their earlier operation records or those of other experts for the preparation.[25]

Some researchers were able to detect muscle stress through an electromyograph,[26] and used a magnetic sensor[27] instead of a force sensor for motion analysis. The "open to integrate" characteristic permits the combination of cameras and different sensors for different research purposes. The "easy-to-use" and "free-to-learn" characteristics decrease the burden on a trainer and offer the trainees a free learning environment. The self-debriefing model based on integrated videos could become a standardized method for robotic surgical training without requiring the presence of a trainer. With the validation of the integrated video-capture system in the training session[7] and the self-debriefing model covering the pause period, both the hardware and software were ready for the telemonitoring and tele-education[28,29] of robotic surgery training.

LIMITATIONS

In reality, there was no data exchange between the simulator and recording system; we were required to replay the video from the beginning for the debriefing. The autoanalysis and capture function, which replays only the critical errors and the most valuable parts, could be helpful in saving time. The video was transferred to one's own device by using a physical cable connection. The cloud-based learning platform permits the trainees to download their films or self-debriefs online; this is suitable for imparting remote education of the robotic training curriculum.

CONCLUSIONS

As sporadic robotics training, which is currently being used, provides limited results because of skill degradation, we investigated the benefits of using an integrated video-recording system during and between basic robotic skill-training procedures. By using such a system, a self-debriefing protocol is feasible with the utilization of one's personal smartphone and valuable in ensuring the training efficiency and overcoming the skill decay. A self-training model could provide a new insight into basic robotic skills training.

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SUPPLEMENTARY INFORMATION

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