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ORIGINAL RESEARCH

The Impact of Remote Visualized Teaching on Clinical Competence Following Short-Term Bronchoscopy Training

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Objective: To evaluate the impact of remote visualized teaching (RVT) on trainees' confidence and clinical competence after short-term traditional simulation-based bronchoscopy training.

Methods: In this prospective self-controlled quasi-experimental study, two cohorts, with 24 trainees each, completed a one-day traditional bronchoscopy course and voluntarily joined a one-month RVT program. Confidence and clinical competence were evaluated before and after RVT using the Bronchoscopy Operator Confidence Scale (BOCS) and a modified Ontario Bronchoscopy Assessment Tool (OBAT), with scores analyzed using the Wilcoxon signed-rank test.

Results: 48 trainees from 43 hospitals (81.2% secondary-level) completed the RVT course. Median BOCS scores increased significantly from 60.0 (54.0–64.0) to 75.0 (72.0–81.0; $p<0.001$), with notable improvements in emergency response (2.00→3.50) and operational skills (2.75→3.50). Modified OBAT scores rose from 66.7 (60.7–74.4) to 79.7 (76.7–84.9; $p<0.001$), notably, there were significant improvements in the scores for operational skills, diagnostic abilities, and post-procedure management.

Conclusion: Remote visualized teaching significantly enhances trainees' confidence and clinical competence, serving as a valuable adjunct to traditional bronchoscopy education.

Keywords: bronchoscopy, training, remote visualized teaching, clinical competence

Introduction

Bedside bronchoscopy is a critical skill for ICU physicians, essential for airway management and pulmonary diagnostics. Due to its complexity and invasiveness, a significant period of training is required to attain proficiency in this procedure.[1–3] In the past, training primarily relied on a master-apprentice model, with trainees enhancing their bronchoscopy skills through clinical observation and one-on-one mentorship. However, this model is constrained by its limited scalability and efficiency, making it insufficient for meeting the evolving needs of modern medical education.[4–6] Currently, the predominant training method combines theoretical education with simulation-based training.[7–9] The application of high-fidelity electronic simulators, in particular, has demonstrated the potential to enhance operator proficiency, shorten procedure times, and mitigate the risks inherent in blind procedures.[5,10–12] Furthermore, systematic assessments of trainees have replaced the traditional standard of using the number of procedures performed as a measure of clinical competence.[13,14] Short-term simulator training helps trainees quickly acquire basic skills[11] and boosts their confidence,[7] However, simulation-based training fails to capture the complexity of real clinical scenarios, and it remains unavailable in resource-constrained settings, making remote teaching a promising solution.

During the COVID-19 pandemic, the need for social distancing, personal protective equipment, and other physical restrictions accelerated the rapid development of tele-medical education.[15–20] However, relying solely on video recordings for teaching has proven to be insufficient in achieving desired outcomes.[5,14] The widespread adoption of wireless connectivity and transmission technologies, such as Wi-Fi and Near Field Communication (NFC), has enabled real-time remote image

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transmission from bronchoscopy devices. A new bronchoscopy system equipped with dual-channel wireless video transmission technology can simultaneously display real-time endoscopic images and record the operator's actions, presenting them on corresponding software. This technology makes remote visual teaching and assessment possible, allowing instructors to interact with trainees through the device, creating a more realistic teaching environment. Additionally, the software can facilitate collaborative learning across multiple hospitals, increasing learning opportunities without being constrained by specific locations. This study adheres to the core principles of David Kolb's Experiential Learning Model,[13] utilizing bronchoscopy systems equipped with remote visualization technology for operator training, aims to evaluate whether RVT enhances clinical competence after short-term simulation training, addressing gaps in scalable medical education.

Materials and Methods

This study was reviewed and approved by the Clinical Research Ethics Committee in China-Japan Friendship Hospital (2022-KY-202-4). Informed consent was obtained from all participants prior to their inclusion in the study. The study process, participants' rights and obligations, as well as potential risks and benefits, were explained to the participants in detail. Participation was voluntary and confidential, with no associated costs or payments. All procedures performed in this study were in accordance with the ethical standards of the Declaration of Helsinki (2013).

This quasi-experimental study adopted a prospective self-controlled design. Remote training is conducted at a large tertiary hospital, where three instructors with over five years of bronchoscopy experience oversee teaching and assessment. The main instrument used in the study is the Remote Airway Management System (i-Workstation, produced by Insighters Medical Technology Co., Ltd., Shenzhen, China).

Due to the participant cap of 24 trainees per bronchoscopy training session, this study included two cohorts: Cohort A (June-December 2023) and Cohort B (January-June 2024), the training protocol and instructor team remained consistent across both cohorts to ensure standardization. Participants voluntarily completed a basic information questionnaire and were asked if they were willing to participate in the remote visual training program. The traditional training was a one-day offline course featuring lectures, hands-on practice with bronchoscopy simulators, and procedures like bronchoalveolar lavage using ex vivo pig lungs. After the short-term training, trainees who agreed to continue with the remote training were invited to complete the Bronchoscopy Operator Confidence Scale (BOCS) for bidirectional feedback between trainees and instructors (see Supplement 1), which was collected within one week. This scale was adapted and expanded from the Endobronchial Ultrasound Self-Assessment Tool (EBUS-SAT),[21] and underwent culturally adapted validation within the Chinese clinical context. The scale assesses operator confidence across six domains: theoretical knowledge and preparation, operational skills, emergency management, communication and teamwork, decision-making ability, and equipment user and maintenance. Each domain comprises 3–4 items, rated on a 5-point scale, with a total possible score of 100.

Building on the Ontario Bronchoscopy Assessment Tool (OBAT)[22] and considering the unique characteristics of bedside bronchoscopy in the ICU,[3] a validated modified version (see Supplement 2) was employed for remote assessment of the practical skills of trainees expected to participate in the remote visual training program. The assessment was completed within two weeks. Based on the patient case details selected by the trainees, the examination items, and the presence or absence of complications, the difficulty of the procedure was categorized into three levels: easy, moderate, and difficult, scored as 1, 2, and 3 points, respectively (see Supplement 2). The assessment form consists of 19 items, each rated on a 1–5 point scale. Points cannot be simultaneously assigned for both trans-glottic and artificial airway intubation, with a maximum total score of 90 points, which is then converted to a percentage for statistical analysis. Each assessment session was conducted by two instructors, and the average score was calculated. The evaluation focused on the trainees' operational skills and their ability to integrate knowledge.

After all trainees completed the remote assessment, a one-month RVT program commenced. The program was conducted twice a week, with each session lasting approximately two hours. The sessions included two main components: (1) a comprehensive explanation of the bronchoscopy process based on specific clinical cases, and (2) interactive discussions with trainees to address practical issues encountered during their practice. Between teaching sessions, trainees engaged in independent practice. Upon completion of the remote training, the trainees' confidence and practical skills were reassessed and compared with the previously recorded scores. The detailed research steps are illustrated in Figure 1.

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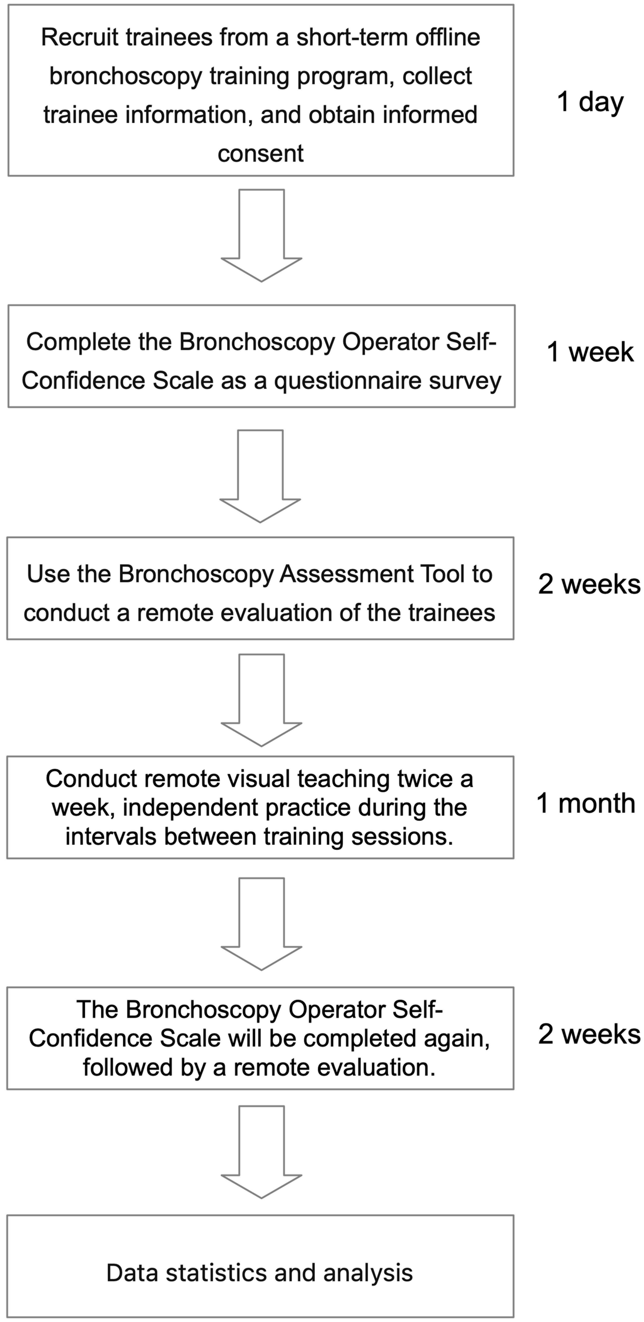

Figure 1 Research procedure for the study of The Impact of Remote Visual Teaching on Clinical Competence Following Short-Term Bronchoscopy Training.

Statistical analysis was performed using GraphPad PRISM software (version 10.3.1 for MacOS, GraphPad Software, San Diego, California). Continuous and ordinal data were expressed as the median with the interquartile range (IQR). Paired data were analyzed using the Wilcoxon signed-rank test, while unpaired data were compared using the Mann–Whitney *U*-test. A p-value < 0.05 was considered statistically significant.

Result

All 48 trainees from two cohorts completed the study (100% response rate), representing 43 hospitals (81.2% secondary-level). Participants, primarily critical care physicians (mean age 35 years, 56.3% female), and 85.4% of trainees had

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performed fewer than 30 independent procedures (without requiring a supervising physician for guidance or intervention). Baseline characteristics are detailed in Table 1.

Post-simulation training, the median BOCS score was 60.0 (54.0–64.0), rising to 75.0 (72.0–81.0) after remote visualized training (p<0.001). From the perspective of specific dimensions, remote training led to significant improvements in trainees' self-confidence across all levels. Before training, the lowest rated dimension was emergency response ability, with a median score of 2.00 (1.67–2.67), followed by operational skills, with a pre-training median score of 2.75 (2.31–3.00). Both dimensions showed significant improvements after remote training, with median scores rising to 3.50 (3.00–3.92) and 3.50 (3.25–4.00), respectively, with p-values < 0.001 (Table 2 and Figure 2).

During the two remote assessments of bronchoscopy, the majority of trainees chose easy cases. The proportion of easy cases before and after remote training was 58.3% and 64.6%, respectively. The proportion of moderate cases was 33.3% and 22.9%, respectively, while the proportion of difficult cases was 8.3% and 12.5%, respectively. There was no statistically significant difference in the distribution of cases between the two assessments (p = 0.70). The total scores of trainees before training were 66.7 (60.7–74.4), which significantly increased to 79.7 (76.7–84.9) after training (p < 0.001). Notably, there were significant improvements in the scores for operational skills, diagnostic abilities, and post-procedure management, with p-values all < 0.001. (See Table 2 and Figure 3 for details).

Table 1 Basic Information of Trainees Participating in Remote Visualized Bronchoscopy Training

Age, median (IQR)	35.0 (32.3–37.8)
Female, n (%)	27 (56.3%)
Work experience (years), median (IQR)	9 (7–11)
Source hospital and number of independent operations	
Tertiary, n (%)	9 (18.8%)
<10 times, n (%*)	2 (4.2%)
10–30 times, n (%*)	4 (8.3%)
>30 times, n (%*)	3 (6.3%)
Secondary, n (%)	39 (81.2%)
<10 times, n (%*)	17 (35.4%)
10–30 times, n (%*)	19 (39.6%)
>30 times, n (%*)	3 (6.3%)
Source department	
ICU, n (%)	28 (58.3%)
EICU, n (%)	14 (29.2%)
NICU, n (%)	3 (6.25%)
RICU, n (%)	3 (6.25%)

Note: *Values shown as percentage of total trainees.
Abbreviations: IQR, Interquartile Range; ICU, Intensive Care Unit; EICU, Emergency Intensive Care Unit; NICU, Neurologic Intensive Care Unit; RICU, Respiratory Intensive Care Unit.

Table 2 Comparison of Trainees' Self-Confidence Scores and Performance Scores Before and After Remote Visualized Training

		n	Before Remote Training	After Remote Training	W/U	p*
BOCS	Theory& preparation	48	3.50 (3.00, 3.75)	4.00 (3.75, 4.25)	1023	<0.001
	Procedural skills	48	2.75 (2.31, 3.00)	3.50 (3.25, 4.00)	1158	<0.001
	Emergency response	48	2.00 (1.67, 2.67)	3.50 (3.00, 3.92)	1163	<0.001
	Communication & collaboration	48	3.33 (3.33, 3.67)	4.00 (4.00, 4.33)	1152	<0.001
	Decision-making	48	3.00 (2.67, 3.67)	4.00 (3.67, 4.33)	1050	<0.001
	Equipment use and maintenance	48	3.00 (2.67, 3.33)	3.67 (3.67, 4.00)	1103	<0.001
	Total scores	48	60.0 (54.0, 64.0)	75.0 (72.0, 81.0)	1176	<0.001

(*Continued*)

Table 2 (Continued).

		n	Before Remote Training	After Remote Training	W/U	p*
MOBAT	Operational difficulty	48	1.00 (1.00, 2.00)	1.00 (1.00, 2.00)	1106 (U)	0.704
	Simple, n (%)		28 (58.3%)	31 (64.6%)		
	Medium, n (%)		16 (33.3%)	11 (22.9%)		
	Difficult, n (%)		4 (8.3%)	6 (12.5%)		
	Before operation	48	4.17 (3.83, 4.33)	4.17 (4.00, 4.46)	288	0.140
	Sedation and monitoring	48	3.75 (3.25, 4.00)	3.75 (3.50, 4.00)	334	0.083
	Procedural skills	48	3.17 (2.78, 3.50)	3.97 (3.78, 4.22)	1176	<0.001
	Diagnostic abilities	48	3.50 (3.00, 4.00)	4.00 (3.50, 4.50)	789	<0.001
	Post operation	48	3.25 (2.71, 3.50)	4.00 (3.83, 4.33)	1175	<0.001
	Total score out of 100	48	66.7 (60.7, 74.4)	79.7 (76.7, 84.9)	1176	<0.001

Note: *p-values<0.05 indicate statistically significant results.
Abbreviations: BOCS, Bronchoscopy Operator Confidence Scale; MOBAT, Modified Ontario Bronchoscopy Assessment Tool; W, Wilcoxon signed-rank test; U, Mann–Whitney *U*-test.

Discussion

The integration of remote visualized bronchoscopy systems into clinical training represents a paradigm shift in procedural education. This study pioneers the application of this technology for bronchoscopy skill development and provides the first empirical evidence of its impact on clinical competence.

There is currently no unified standard for bronchoscopy training. The mainstream approach remains structured training that combines theoretical teaching with simulation-based systems,[7,18,23] A short-term training program can quickly enhance trainees' knowledge of bronchoscopy-related anatomy and operational skills.[11,23–25] However, whether the advantages of this teaching model can transfer to clinical practice remains uncertain.[5,26] A study by Crawford[25] demonstrated that trainees using simulation systems correctly identified 71% of pulmonary segments, whereas only 50% of experienced clinicians proficient in bronchoscopy but without exposure to simulation systems were able to correctly identify all pulmonary segments. This suggests that simulation-based systems do not fully align with clinical practice, and their evaluation metrics have certain

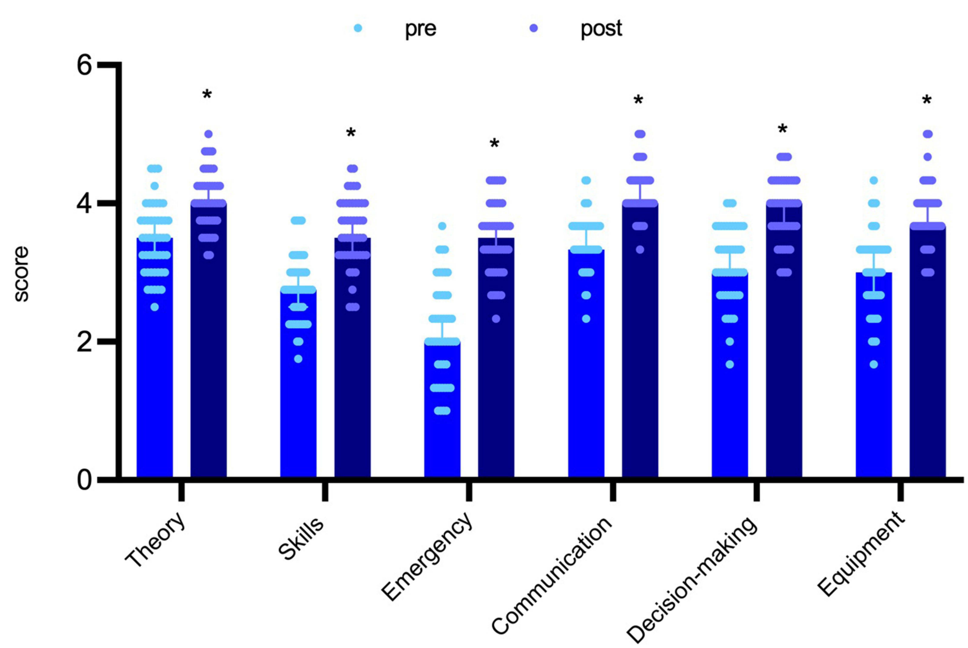

Figure 2 Bronchoscopy Operator Self-Confidence Scale before and after remote training. "Pre" represents before Remote Visualized Teaching, and "Post" represents after Remote Visualized Teaching. The bar chart shows the median of the average scores for each dimension, while the scatter plot represents the interquartile range of the scores. *There is a significant difference in scores before and after training. p<0.001.

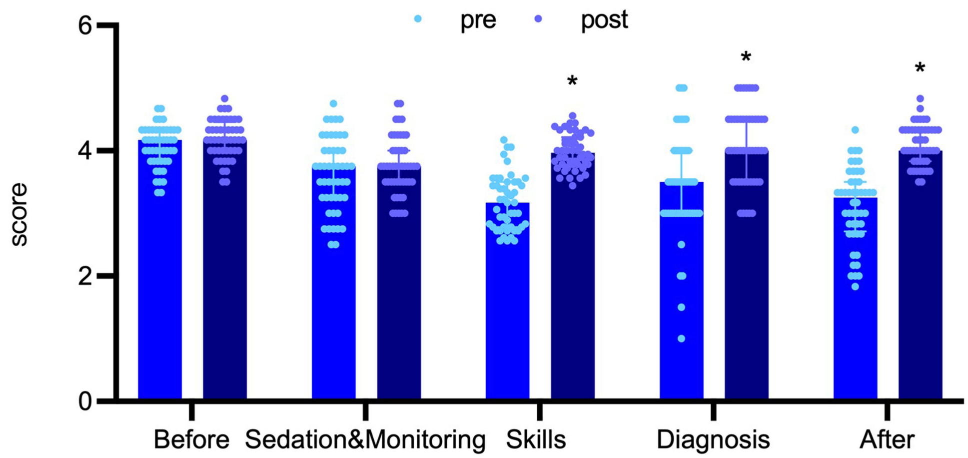

Figure 3 Trainees' Bronchoscopy Assessment Before and After Remote Training. "Pre" represents before Remote Visualized Teaching, and "Post" represents after Remote Visualized Teaching. The bar chart shows the changes in the median of the average scores for each dimension, while the scatter plot represents the interquartile range of the scores. *There is a significant difference in scores before and after training. $p<0.001$.

limitations. According to the results of this study, trainees still lacked confidence in their emergency response capabilities (median score: 2.0 out of 5) and operational skills (median score: 2.75 out of 5) after short-term traditional training, underscoring simulation's inability to replicate clinical complexity. The combination of short-term simulation training with RVT effectively addressed gaps in trainees' operational skills and ability to handle clinical situations.

Consistent with established pedagogical principles,[27] RVT capitalizes on experiential learning—a process where knowledge construction occurs through reflective engagement with clinical case experiences. The significant improvements in both BOCS (60.0→75.0, Δ25%, $p<0.001$) and modified OBAT scores (66.7→79.7, Δ19.5%, $p<0.001$) after RVT reflect dual impact on cognitive (knowledge integration, decision-making) and clinical competencies. Notably, the 75% increase in emergency response confidence—the most deficient pre-training domain—validates remote visualization training's capacity to simulate high-acuity scenarios unavailable in conventional simulators. This aligns with trainees' expressed need for guided clinical exposure post short-term simulation training.[26]

RVT also offers several additional benefits, including the ability to conduct training without face-to-face interaction, thereby reducing the risk of gatherings and hospital-acquired infections. As this study demonstrates, trainees from secondary hospitals—who constituted the majority of our cohort—exhibit a heightened need for sustained mentorship and continued practice beyond short-term intensive training due to deficits in educational and clinical case resources. RVT eliminates geographical and venue constraints, leading to reduced training costs while significantly enhancing trainees' clinical competency.

The limitations of this study are as follows. First, as a quasi-experimental study without a control group, causal inferences are limited. Future randomized trials comparing remote vs simulation training are needed. Second, the baseline levels of the trainees varied, and most trainees selected simple cases, which may have led to the assessment scale not fully capturing common issues among the trainees. Future studies should stratify by case complexity. Third, remote training requires a high level of self-discipline from trainees[28] and is influenced by the hardware conditions and the number of cases available at their local hospitals. As a result, the effectiveness of self-directed practice may vary among trainees. Fourth, Resource constraints (3 sets of system + 3 instructors per 24-trainee cohort) forced non-standardized assessment schedules. This temporal heterogeneity risks introducing performance measurement biases via two mechanisms: (1) differential skill decay/consolidation timelines, and (2) uncontrolled variations in clinical case exposure during intervals. Long-term skill retention beyond one month remains unverified.

Conclusion

The purpose of the training is to enhance clinical competence, remote visualized bronchoscopy training significantly enhanced confidence and clinical skills, can serve as a valuable supplement to traditional training methods. While effective as a post-simulation adjunct, further validation in multicenter trials is warranted to establish standardized implementation.

Author Contributions

Shupeng Wang, MD, Critical Care Physician. Responsible for applying for the research project, proposed a theoretical model for the integration of remote visual teaching and simulation training, responsible for research design, data analysis, and writing the initial draft of the paper. Dejing Song, BS, RT, Responsible for conducting remote teaching and assessment of bronchoscopy, as well as collecting experimental data. Xiaocong Sun, BS, RT, Responsible for conducting remote teaching and assessment of bronchoscopy, as well as collecting experimental data. Chen Li, MD, Critical Care Physician, Responsible for providing experimental equipment and coordinating training for 48 trainees. Hui Wang, MD, Critical Care Physician, Responsible for analyzing experimental data and statistical modeling. Junyu Ma, MD, Critical Care Physician, Assisted in the design of scales and the process of remote assessment. Wei Li, BS, RN, Supervised the academic rigor of experimental design and data analysis, and managed the funding. All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that the study was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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