



# Bronchoscopy simulation training in the post-pandemic world

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## ABSTRACT

Bronchoscopy is an important procedure to examine the airways. It is traditionally taught by having trainees perform it in humans. This carries risks, albeit rarely, and causes stress to trainees. The objective of this study was to review bronchoscopy simulators, as well as their use in and impact on medical education, presenting perspectives on the use of simulators in the post-pandemic world. This review was based on articles published in English in 2000-2021 and retrieved from any of the following **databases**: MEDLINE (PubMed), Embase, SciELO, and Google Scholar. Bronchoscopy simulators have improved markedly over time, allowing the teaching/learning process to take place in a risk-free environment. Bronchoscopy simulation training is an interesting option for the evaluation of the airways, especially in the coming years, with the COVID-19 pandemic highlighting the need for continuing medical education.

**Keywords:** Bronchoscopy; Learning; Teaching; Students; Coronavirus.

## INTRODUCTION

Bronchoscopy is an extremely important procedure performed by specialists such as pulmonologists, otolaryngologists, and surgeons. Appropriate training in performing bronchoscopy is essential because it is a complex procedure that requires mastery of cognitive and motor skills.<sup>(1)</sup> It is traditionally taught by the “see one, do one, teach one” approach, in which professionals in training perform the procedure directly in humans, under the guidance of experienced professionals.<sup>(1)</sup> This has long been an effective method for training bronchoscopists. However, complications may require repeated examinations, causing high levels of stress to learners.<sup>(2)</sup>

Technological advances have allowed the use of simulators, which have become an interesting alternative tool. Furthermore, the COVID-19 pandemic has posed numerous challenges. Given the reduction in the number of trainees in surgical procedures and the need to ration personal protective equipment (PPE), the use of simulators to train professionals in techniques such as bronchoscopy has become especially important.<sup>(3)</sup>

The objective of this study was to review the development of bronchoscopy simulators, as well as their use in and impact on medical education, presenting perspectives on the use of simulators in the post-pandemic world.

## STUDY SELECTION PROCESS

We searched the MEDLINE (PubMed), Embase, SciELO and Google Scholar databases for articles published in English between 2000 and 2021. Articles were initially

selected by title, then by abstract review prior to complete article review.

## BRONCHOSCOPY SIMULATORS

The first study on simulation in bronchoscopy was conducted in 1999 in a swine model.<sup>(1)</sup> In that same year, a virtual reality simulator was developed, namely the PreOp Endoscopic Simulator® (HT Medical Systems; Rockville, MD, USA). In 2001, a study was conducted on simulator effectiveness in bronchoscopy training.<sup>(4)</sup> The AccuTouch® simulator (Immersion Medical; Gaithersburg, MD, USA) was developed and validated during this period.<sup>(5)</sup>

Several tools are currently being used. Bronchoscopy training in animal models is known as a wet lab simulation. Some advantages of this method are the similarity of the anatomy and the possibility of using a real bronchoscope. The disadvantages include ethical issues in the use of animals for human training, the cost of raising them, and the potential damage to the bronchoscopy equipment.<sup>(1)</sup>

Low-fidelity simulation consists of the use of inanimate airway models—which do not simulate resistance to scope or breathing movements and which are not very realistic in anatomy—into which real bronchoscopes are inserted. There is a range of models, from simple, non-anatomical labyrinths to more modern simulators.<sup>(1,2)</sup> The non-anatomical labyrinth models provide training in the movement of the wrist and hands, and even bronchial tree models made of newsprint and vinyl glue are available. The most up-to-date models in this category, made of silicone and plastic-based materials,

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consist of a mannequin composed of a head, a larynx, a tracheobronchial tree, and a thorax, to which a panel is attached to visualize the procedure externally, like the Laerdal Airway Management Trainer® (Laerdal; Stavanger, Norway; Figure 1) and the Airway Larry® (Nasco; Fort Atkinson, WI, USA).<sup>(1)</sup> There is also the CLA Broncho Boy® model (CLA; Coburg, Germany), which has a detailed tracheobronchial tree at the level of the first segmental bronchi.<sup>(1)</sup>

Another class of low-fidelity simulators is produced by three-dimensional (3D) printers.<sup>(6)</sup> One study evaluated their performance in bronchoscopy training and found a significant improvement in examination speed and performance after training.<sup>(7)</sup> These are low-cost alternatives that allow the use of a real bronchoscope. However, the equipment can be damaged, and these systems do not provide much realism.

High-fidelity simulation is based on the use of computers for virtual projection of the airways, also known as virtual simulators. The first simulator is the PreOp Endoscopy Simulator® (HT Medical Systems; Rockville, MD, USA).<sup>(1)</sup> There is currently a new version of this simulator, designated the AccuTouch Endoscopy Simulator® (Figure 2) and consisting of a flexible scope and a computer with a monitor and software for simulating the procedure. The interface is a replica of the human face, with an access area in the nasal region for insertion of the scope. There is also hardware for detecting the movements performed by the machine operator, capable of simulating the mechanical resistance of a real examination, as well as coughing and the respiratory movements of the patient.<sup>(2)</sup> At the end of the examination, the equipment provides metrics related to the performance of the trainee, including procedure time, "red out" time, number of contacts with the bronchial walls, bronchial segments inspected, and use of the suction button, thus ensuring feedback.<sup>(2)</sup> In addition, it is possible to identify the anatomical structures explored because the device projects the location of the bronchoscope, injects aliquots of lidocaine, performs biopsies, and

reproduces multiple clinical scenarios. This simulator was used in most of the studies reviewed here, with positive results.

Other available models include the Gi-Bronch Mentor® (Symbionix USA Corp; Cleveland, OH, USA) and Orsim® (Airway Limited; Auckland, New Zealand).<sup>(1)</sup> These are simulators that reproduce extreme anatomical reality, ensuring learners an environment conducive to their learning. However, despite the complexity of the imaging system, even the most up-to-date models reproduce the tactile sensitivity of the examination in a rudimentary way, and tactile sensitivity is important when learning how to perform a bronchoscopy.

With the improvement of virtual simulators, it has become possible to train skills with a high degree of realism, allowing beginners to learn from their mistakes before having direct contact with patients. Therefore, students can improve their performance in challenging situations, such as gaining access to the pediatric airway and performing a bronchoscopy in patients with COVID-19.<sup>(8)</sup>

Since bronchoscopy is an aerosol-generating procedure, it is necessary to implement strategies to mitigate contamination risks during the procedure, such as an acrylic casing during intubation and the use of disposable curtains to create a tent around the patient.<sup>(8)</sup> Thus, training with simulators eliminates the risk of infection in a pandemic environment.

## VIRTUAL SIMULATORS IN THE EVALUATION OF BRONCHOSCOPISTS

Bronchoscopy teaching has not yet been standardized. At least 100 supervised procedures are recommended for the acquisition of basic competence.<sup>(9)</sup> However, this method has been questioned.

In a study conducted by Crawford & Colt,<sup>(9)</sup> pulmonology residents were asked to identify the bronchial segments using a virtual simulator. The bronchoscopists in training identified 71% of the



**Figure 1.** The Laerdal Airway Management Trainer® (Laerdal; Stavanger, Norway), a low-fidelity bronchoscopy simulator.



**Figure 2.** The AccuTouch Endoscopy Simulator® (Immersion Medical; Gaithersburg, MD, USA), a high-fidelity bronchoscopy simulator.

segments; 50% of the experienced bronchoscopists identified all segments; and beginners were not able to identify all necessary segments. This great variability indicated the need to review the assessment methods in the teaching of bronchoscopy.

Guidelines were updated, and it was recommended that the assessment of individual trainee improvement be performed with simulators. It was initially shown that the metrics provided by simulators allow the differentiation between beginners and experienced bronchoscopists.<sup>(4)</sup> However, it was later proposed that these metrics should not be used as the only assessment method, the accuracy of the software being questioned.<sup>(10)</sup>

In this context, two instruments were developed, namely the Bronchoscopy Skills and Tasks Assessment Tool (BSTAT) and the Bronchoscopy Step-by-Step Evaluation Tool (BSET).<sup>(11)</sup> The BSTAT provides a numerical score based on posture and knowledge of anatomy, as well as on tasks such as transbronchial biopsy and bronchoalveolar lavage. The BSET evaluates the handling of the bronchoscope at increasing levels of difficulty. A high correlation was found between the two instruments (0.86 for the BSTAT and 0.85 for the BSET), with clear differences between beginners and experts. However, there were no significant differences among intermediate-level trainees.<sup>(11)</sup>

In another study, based on video footage of trainees performing simulated bronchoscopy and evaluated by a checklist, it was possible to distinguish among

beginners, intermediate users, and experts.<sup>(10)</sup> In yet another study, an automatic motion analysis system was used in order to analyze scope movements.<sup>(12)</sup> Deviations were found to be greatest for beginners and smallest for experienced operators, the motion analysis system therefore being able to distinguish among beginners, intermediate operators, and experts.<sup>(12)</sup> Table 1 summarizes the studies examining the role of virtual simulators in the evaluation of bronchoscopists in training.

The use of virtual simulators in bronchoscopy has become an important option for evaluating professionals in training because virtual simulators allow the assessment of objective metrics and individual improvement in a risk-free environment. This becomes relevant in the context of the COVID-19 pandemic, with virtual simulators allowing the assessment of the performance of learners without any risk of exposure to the coronavirus.

### TRAINING ON VIRTUAL SIMULATORS

Virtual simulators allow the evaluation of bronchoscopy training by the equipment's own metrics. One study found evident improvement after training, both in dexterity, with fewer contacts with the bronchial walls ( $p = 0.022$ ), and in efficiency, with a higher percentage of analyzed bronchi ( $p = 0.029$ ).<sup>(4)</sup> Even a short introductory course with simulators showed significant improvement in resident

**Table 1.** Studies examining the role of virtual simulators in the evaluation of bronchoscopists in training.

Study	Objective	Population	Sample	Method	Result	Conclusion
Crawford et al. <sup>(9)</sup>	To evaluate specific technical skills by means of a virtual reality bronchoscopy simulator	Pulmonology residents	5	A prospective study evaluating the participants during identification of and insertion of the bronchoscope in five specific bronchial segments	Trainees identified 71% of the bronchi correctly. Of those who had performed more than 200 bronchoscopies, 50% explored all segments	Great variability was observed, suggesting that these abilities do not correlate with the years of training or the number of bronchoscopies performed
Colt et al. <sup>(4)</sup>	To evaluate whether training beginners on a bronchoscopy simulator would allow the acquisition of basic skills, in comparison with experienced physicians, who received traditional training	Pulmonology and intensive care residents	5	A prospective study comparing a group of beginners receiving bronchoscopy simulator training and a group of experienced physicians who had performed more than 200 bronchoscopies	Beginners were unable to identify all segments Beginners significantly improved their dexterity after training, equating or even surpassing the performance of experts	The evaluation metrics provided by the simulator were able to distinguish among novice, intermediate-level, and expert bronchoscopists, suggesting that clinical skills are correlated with the simulator environment
Davoudi et al. <sup>(11)</sup>	To evaluate bronchoscopy abilities by means of two novel instruments: the BSTAT and the BSET	Medical students, pulmonology residents, intensive care residents, intensivists, and thoracic surgeons	22	A prospective cohort study in which two independent evaluators simultaneously scored participants during simulation bronchoscopy	A high correlation (0.86 for the BSTAT and 0.85 for the BSET) was found for both methods There were clear differences between beginners and experts	Both tools showed high reliability and simultaneous validity in distinguishing beginners from experts It was not possible to discriminate significantly among intermediate trainees
Konge et al. <sup>(10)</sup>	To explore the validity of an evaluation method for bronchoscopy simulation training	Medical specialist, resident physicians, and medical students	42	A prospective study that filmed the participants while they performed six simulated bronchoscopies, with increasing difficulty Their performance was scored by two blind evaluators using a checklist	High interexaminer reliability was found The evaluation method differentiated among the three groups in terms of their performance ( $p < 0.001$ )	The evaluation procedure differentiated among beginners, intermediate trainees, and experts
Colella et al. <sup>(12)</sup>	To evaluate whether there is a correlation between scope movements and operator experience by means of an automatic motion analysis system	Resident physicians and medical students	29	A prospective cohort study using an automatic motion analysis system to measure total scope deviation during simulation bronchoscopy	The deviations were greatest for beginners and smallest for more experienced trainees	The motion analysis system can discriminate among different levels of experience

BSTAT: Bronchoscopy Skills and Tasks Assessment Tool; and BSET: Bronchoscopy Step-by-Step Evaluation Tool.

performance ( $p = 0.017$ ).<sup>(13)</sup> In another study, similar results were obtained, with a significant reduction in procedure time ( $p = 0.002$ ) and improvement in general performance ( $p = 0.002$ ).<sup>(14)</sup>

The effects of previous simulator training on performance in real patients have also been investigated. The use of simulated bronchoscopy has been found to increase the speed of skill acquisition, with improved BSTAT scores ( $p < 0.05$ ).<sup>(15)</sup> Ost et al. found similar results; specifically, a reduction in the time needed to perform the procedure ( $p = 0.001$ ) and an increased percentage of identified bronchi ( $p = 0.03$ ).<sup>(5)</sup> Even a short training session with a bronchoscopy simulator has been found to improve pediatric endotracheal intubation, with reduced time needed for intubation ( $p < 0.001$ ) and increased percentage of airway visualization ( $p = 0.004$ ).<sup>(16)</sup>

In a meta-analysis published in 2017,<sup>(17)</sup> virtual bronchoscopy simulator training was evaluated by examining original articles published between 2000 and 2016. Eight studies were included, and the authors concluded that bronchoscopy simulator training improves technical skills and that simulators can be an important learning tool.<sup>(17)</sup> In a systematic review,<sup>(18)</sup> the structure of simulation training in bronchoscopy and assessment of competence in bronchoscopy training were investigated. The review showed that simulation in bronchoscopy is effective, as well as showing that the training must be structured, that practice in pairs contributes to increasing the use of simulators, and that it is important to assess learners through validated tools.<sup>(18)</sup> Table 2 summarizes the studies evaluating the impact of virtual simulators on bronchoscopy training.

The effectiveness of simulator training is a fact of recognized relevance in the post-COVID-19 era because it assures continuing education regardless of the stage of the pandemic, which is still ongoing. Thus, more evidence on the effectiveness of simulation bronchoscopy training helps educators make decisions, highlighting the need for further studies on the subject.

### TEACHING METHODS IN BRONCHOSCOPY TRAINING

Given the relevance of bronchoscopy training on virtual simulators, new teaching methods have emerged in the past few years.

The effectiveness of bronchoscopy simulation training on a single day has been reported to be the same as that of training over one week ( $p > 0.36$ ), a finding that suggests that bronchoscopy simulation training can be conducted in a format that best suits trainees and training centers.<sup>(19)</sup>

Self-training can also be considered, wherein learners follow the manufacturer instructions to train themselves. One study showed a significant improvement in BSTAT scores after four self-driven training sessions on a virtual simulator ( $p < 0.0001$ ).<sup>(2)</sup> Veaudor et al.<sup>(14)</sup> obtained similar results with

self-training residents, who acquired basic skills similar to those of experienced bronchoscopists ( $p = 0.002$ ).

Evidence on the use of bronchoscopy simulators for training residents has increased. However, little is known about the impact of bronchoscopy simulation training on medical students, although some recent studies have investigated this issue.

One study found no difference in effectiveness between bronchoscopy simulation training of medical students in pairs and individually ( $p < 0.16$ ).<sup>(20)</sup> Training in pairs was considered more effective because the same resources used individually can be used in pairs.<sup>(20)</sup>

Intubation using fiberoptic bronchoscopy simulators has been evaluated in medical students, with no significant difference in technical skills between beginners and experts after training.<sup>(21)</sup> The modeling example, in which trainees observe the procedure performed by the instructor during bronchoscopy simulation training, has also been evaluated.<sup>(22)</sup> After training, the modeling example group was found to be significantly better than the control group ( $p < 0.0001$ ), a finding that demonstrates the effectiveness of this method.<sup>(22)</sup> Table 3 summarizes the studies examining bronchoscopy simulation training methods.

Thus, several studies have provided a well-established basis for the use of simulators in bronchoscopy training.

### BRONCHOSCOPY SIMULATION AND COVID-19

Medical education has been profoundly affected by COVID-19. The number of professionals allowed in the examination room had to be reduced, thus limiting the training of residents. In addition, because of the need to manage medications and beds, many procedures were suspended, thereby affecting the learning process.<sup>(23)</sup>

Bronchoscopy is a procedure that generates aerosols, leading to potential exposure to the virus. Furthermore, in cases of medical emergencies, such as foreign body removal, airway obstruction, or atelectasis caused by mucus plugging, there may not be enough time to perform COVID-19 diagnostic tests on the patient. Such situations impel bronchoscopists to perform the procedure quickly and efficiently, minimizing the time of exposure to the virus and, consequently, the probability of infection.<sup>(24,25)</sup>

Recent studies have evaluated the transmissibility of SARS-CoV-2 among bronchoscopists and found a low risk of transmission.<sup>(26,27)</sup> However, it should be noted that strict adherence to the guidelines recommended by the WHO and other organizations was reported, with most procedures being performed in negative pressure rooms, with all professionals wearing PPE, with neuromuscular blockade to prevent coughing, with bronchoscopy under apnea, with the use of disposable bronchoscopes, and with a reduced number of health professionals.<sup>(28)</sup> These situations require

**Table 2.** Studies evaluating the impact of virtual simulators on bronchoscopy training.

Study	Objective	Population	Sample	Method	Result	Conclusion
Colt et al. <sup>(4)</sup>	To evaluate whether training beginners on a bronchoscopy simulator would allow the acquisition of basic skills, in comparison with experienced physicians, who received traditional training	Pulmonology and intensive care residents	5	A prospective study comparing a group of beginners receiving bronchoscopy simulator training and a group of experienced physicians who had performed more than 200 bronchoscopies	After training, beginners significantly improved their dexterity, with fewer contacts with the bronchial wall ( $p = 0.022$ ), and precision, with more segments identified ( $p = 0.029$ ), equaling or even surpassing the performance of experts.	Virtual simulator training was effective.
Colt et al. <sup>(13)</sup>	To evaluate an introductory one-day bronchoscopy simulation training course.	Pulmonology and intensive care residents	24	A multicenter prospective study evaluating pre-test and post-test trainees on the simulator	After training, the mean scores for the technical skill tests on the simulator improved significantly, from 43% to 77% ( $p = 0.017$ ).	Virtual simulator training was effective.
Veaudor et al. <sup>(14)</sup>	To evaluate whether a self-driven training program on a high-fidelity simulator would allow beginner residents to acquire skills similar to those of experienced bronchoscopists	Pulmonology residents	34	A prospective cohort study comparing the performance of bronchoscopists trained on a high-fidelity simulator with that of experienced bronchoscopists	There was a significant reduction in mean procedure time ( $p = 0.002$ ) and an improvement in overall performance ( $p = 0.002$ ) among beginners, comparable to the general performance of experienced professionals.	The simulator was effective in bronchoscopy training.
Wahidi et al. <sup>(15)</sup>	To evaluate trainees performing bronchoscopy on real patients after receiving bronchoscopy simulator training.	Pulmonology residents	47	A multicenter prospective study comparing the performance of simulator-trained participants with that of participants who had received traditional training  The BSTAT was used	The incorporation of simulated bronchoscopy increased the speed of acquisition of bronchoscopy skills, and there was a statistically significant improvement in the mean BSTAT scores of trainees ( $p < 0.05$ )	The use of simulators prior to performing bronchoscopy on real patients allows the improvement of bronchoscopy skills
Ost et al. <sup>(5)</sup>	To validate a virtual bronchoscopy simulator	Pulmonology and intensive care residents	28	A multicenter prospective cohort study evaluating participants performing bronchoscopy on real patients after receiving simulator training or traditional training	The participants who underwent simulation training significantly improved their abilities after 20 simulations, with a reduction in time ( $p = 0.001$ ) and an increase in the number of bronchi inspected ( $p = 0.03$ )  In addition, they obtained better results on real patients than did those who received traditional training	Bronchoscopy simulation training allowed faster acquisition of bronchoscopy skills in comparison with traditional training

**Table 2.** Studies evaluating the impact of virtual simulators on bronchoscopy training. (Continued...)

Study	Objective	Population	Sample	Method	Result	Conclusion
Rowe et al. <sup>(16)</sup>	To evaluate the efficacy of a single short training session in pediatric endotracheal intubation on a bronchoscopy simulator	Pediatrics residents	20	A prospective study comparing the performance of residents on real patients before and after simulator training	After simulator training, there was a reduction in the time to complete intubation with a bronchoscope ( $p < 0.001$ ), in the number of contacts with the mucosa ( $p < 0.001$ ), and in the time spent to view the mucosa adequately ( $p < 0.001$ ), as well as an increase in the percentage of airway visualization ( $p = 0.004$ )	Even a single short simulator training session improved the ability to perform pediatric endotracheal intubation with a bronchoscope
Sokouti et al. <sup>(17)</sup>	To conduct a systematic review of studies on virtual reality bronchoscopy simulator training	Database searching (MEDLINE/ PubMed, Scopus, and Google Scholar)	-	A meta-analysis including original articles published between 2000 and 2016 and examining virtual reality bronchoscopy simulator training in rigid and flexible bronchoscopy	Eight studies of virtual reality bronchoscopy simulator training were retrieved	Bronchoscopy simulation training improved technical skills and should be considered an important learning tool
Nilsson et al. <sup>(18)</sup>	To conduct an extensive bibliographic review of bronchoscopy simulation training	Database searching in July of 2016	-	Systematic review of studies of bronchoscopy simulation training, covering training structure, evaluation of skills, and inexpensive alternatives	It was reported that bronchoscopy simulation training should be structured, that practicing in pairs is feasible and allows for more efficient use of the equipment, and that the performance of trainees should be evaluated by validated tools	Bronchoscopy simulation training is effective

BSTAT: Bronchoscopy Skills and Tasks Assessment Tool.

**Table 3.** Studies examining bronchoscopy simulation training methods.

Study	Objective	Population	Sample	Method	Result	Conclusion
Bjerrum et al. <sup>(19)</sup>	To compare the efficacy of bronchoscopy simulation training on a single day with that of training distributed over one week	Pulmonology residents	20	A randomized study evaluating bronchoscopy simulation training on a single day vs. over one week	No interaction was found between groups and test scores ( $p > 0.16$ ), except for the percentage of explored segments	Training can be conducted in a format that best fits the clinical practice of trainees and the availability of training centers
Veaudor et al. <sup>(14)</sup>	To evaluate the efficacy of self-driven bronchoscopy simulation training	Pulmonology residents	34	Pre-test, post-test, and retention test performance was evaluated after four weeks A prospective cohort study comparing the performance of beginner bronchoscopists receiving simulation training with that of experienced bronchoscopists	No major group effect was found for any of the evaluated measurements ( $p > 0.36$ ) There was a significant reduction in the mean procedure time and a significant improvement in overall performance ( $p = 0.002$ ) among beginners, comparable to the general performance of experienced professionals	Self-driven training on a bronchoscopy simulator was effective, allowing trainees to acquire basic skills similar to those of experienced bronchoscopists
Gopal et al. <sup>(2)</sup>	To evaluate the impact of bronchoscopy simulation training on the knowledge of anatomy and on the technical skills of medical students	Medical students	47	A prospective study in which two surgeons evaluated the performance of participants receiving bronchoscopy simulation training The BSTAT was used	After training, there was a significant increase in BSTAT scores ( $p < 0.0001$ ), visualization of bronchial anatomy ( $p < 0.0001$ ), and bronchoscopy navigational skills ( $p < 0.0001$ )	Self-driven bronchoscopy simulation training was effective in medical students
Bjerrum et al. <sup>(20)</sup>	To compare the effectiveness of bronchoscopy simulation training performed in pairs and individually	Medical students	36	A randomized study comparing bronchoscopy simulation training performed in pairs and individually, by means of a pre-test, a post-test, and a retention test three weeks later	The two groups showed significantly improved performance after simulation training ( $p < 0.001$ ) There was no difference in the efficacy of acquiring bronchoscopy skills between the two groups ( $p < 0.16$ )	Training in pairs can be considered more effective because the same resources used individually can be used in pairs
Latif et al. <sup>(21)</sup>	To establish the time and number of attempts required to train beginners in fiberoptic bronchoscopy and intubation using simulators	Medical students	15	A prospective study in which participants received guidance from an experienced instructor and then started supervised training on a virtual simulator They returned after two months for a new evaluation	After training, the trainees' technical skills were compared with those of experts. In the evaluation performed after two months, a longer time was needed to view the anatomy; however, when this performance was compared with the pre-test performance, retention of knowledge was observed	Training in fiberoptic bronchoscopy and intubation on simulators was effective, with knowledge retention

Continue...▶



**Table 3.** Studies examining bronchoscopy simulation training methods. (Continued...)

Study	Objective	Population	Sample	Method	Result	Conclusion
Bjerrum et al. <sup>(22)</sup>	To evaluate the effectiveness of integrating modeling examples into bronchoscopy simulation training	Medical students	48	A randomized study evaluating the effectiveness of integrating modeling examples into bronchoscopy simulation training, by means of a pre-test, a post-test, and a retention test after three weeks	Both groups showed significant improvement after training However, the modeling example group was significantly better than the control group ( $p < 0.0001$ )	The use of modeling examples in bronchoscopy simulation training was effective

BSTAT: Bronchoscopy Skills and Tasks Assessment Tool.

experienced professionals who are able to perform the procedure quickly.

Koehler et al. developed a simulation model to visualize aerosol, droplet generation, and surface contamination using a fluorescent solution during a bronchoscopy simulation.<sup>(29)</sup> The authors found evidence of aerosol generation, droplet dispersion, and surface contamination; however, the proper use of PPE and safety strategies mitigated contamination risks.<sup>(29)</sup>

The changes imposed by COVID-19 require prior preparation from professionals performing bronchoscopy. Simulation allows professionals to state their concerns, discuss perceptions about the safety and comfort of both the team and the patient, and practice technical modifications to the procedure. The benefits of simulations are more clearly noted in emergency bronchoscopy situations, when previous training sessions have been reported to provide better communication and operational planning.<sup>(24)</sup>

In the COVID-19 era, simulation laboratories have gained importance in health sectors.<sup>(3)</sup> Bronchoscopy simulation allows the improvement of basic skills such as knowledge of anatomy, 3D spatial orientation, and motor coordination without putting patients at risk, as well as ensuring the continuation of the learning process regardless of the state of the pandemic. Lower levels of stress result in more efficient learning, ensuring effective performance in real situations.<sup>(2)</sup>

### LIMITATIONS AND PERSPECTIVES

One of the difficulties in using virtual simulations is related to the cost. Low-fidelity simulator models cost between USD 2,000.00 and USD 3,000.00. The cost of developing and producing a simulator from 3D printing can range from USD 5.00 to USD 100.00.<sup>(6)</sup> On the other hand, virtual simulators can cost as much as USD 100,000.00. This problem can be solved by acquiring a single piece of equipment to be shared among different institutions.<sup>(9)</sup>

Another limitation is the absence or limited availability of pediatric simulators. Future simulators should incorporate multiple scenarios, allowing trainees to acquire decision-making ability and new skills, as well as basic proficiency.<sup>(17)</sup> However, because of the impact of the COVID-19 pandemic in 2020 and the uncertainty regarding how long the COVID-19 pandemic will last, simulation laboratories have become a necessity. Simulators guarantee the continuation of learning regardless of the state of the pandemic, providing training in daily clinical situations and in more difficult situations.

### FINAL CONSIDERATIONS

Simulators in bronchoscopy training are useful and interesting tools to complement the conventional method of training. They allow trainees to practice in a risk-free environment and allow mistakes to be

made. Bronchoscopy simulation training meets the growing medical needs to ensure an effective teaching/learning process while ensuring patient safety. In addition, the COVID-19 pandemic has highlighted the importance of continuing education in a safe environment regardless of the state of the pandemic, allowing materials and supplies to be used in order to fight the virus.

Further studies on bronchoscopy simulation are needed in order to make this promising teaching tool more accessible. Its increased use in training centers by physicians and students alike will encourage other

medical professionals to perform this procedure during and even after the COVID-19 pandemic.

### AUTHOR CONTRIBUTIONS

LMNV: literature review and drafting of the manuscript; PAMC and CCI: drafting of the manuscript and critical revision of the manuscript for important intellectual content; LMNV, PAMC, and CCI: final approval of the version to be published.

### CONFLICTS OF INTEREST

None declared.

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