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Basic Bronchoscopy Competence Achieved by a Nationwide One-day Simulation-based Training

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Background: In 2020, a mandatory, nationwide 1-day bronchoscopy simulation-based training (SBT) course was implemented for novice pulmonology residents in the Netherlands. This pretest–posttest study was the first to evaluate the effectiveness of such a nationwide course in improving residents' simulated basic bronchoscopy skills.

Methods: After passing a theoretical test, residents followed a 1-day SBT course, available in 7 centers, where they practiced their bronchoscopy skills step-by-step on a virtual reality simulator under pulmonologist supervision. Residents practiced scope handling efficiency (task 1) and navigational skills combined with lung anatomy knowledge (task 2). Task 1 outcome measures were navigational skill simulator metrics: percentage of time at midlumen, percentage of time with scope-wall contact, procedure time (PT), number of wall contacts and number of wall contacts per minute of PT. Task 2 outcome measures were PT, observational assessment scores of a validated tool with a 5-point scale (1 representing the worst and 5 the best competence) and blinded dexterity assessments.

Results: The study included 100 residents. All outcome measures of task 1 improved significantly ($P<0.001$), except for the number of wall contacts per minute of PT (4.3 [IQR 3.0 to 6.2] pre vs. 3.5 [IQR 2.6 to 5.3] post, $P=0.07$). For task 2, PT was reduced by 54% (10.3 ± 2.7 minutes pre vs. 4.7 ± 0.9 minutes post, $P<0.001$) with an improvement in overall-competence scores (2.0 [IQR 1.0 to 2.0] pre vs. 4.0 [IQR 4.0 to 5.0] post, $P<0.001$) and all dexterity parameters ($P<0.001$).

Conclusion: Nationwide implementation of a SBT course led to rapid improvement of residents' basic bronchoscopy skills while halving PT.

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Flexible bronchoscopy is a crucial diagnostic and therapeutic tool for various pulmonary diseases, such as lung cancer.[1] The procedure is safe, although it is important to note that complications, while rare, can be life-threatening.[2] To minimize patient burden and ensure their safety, pulmonologists should be adequately trained. Traditionally, bronchoscopy training took, and in some training centers still takes place, through the "apprenticeship method," where a novice resident would start performing a bronchoscopy on patients under supervision of an experienced pulmonologist without any simulation-based training (SBT). This training method is associated with increased patient discomfort, longer procedure time (PT) and higher complication rates compared with patients undergoing bronchoscopy by a more experienced bronchoscopist.[3–5] Over the past 2 decades, there has been an increase in the use of simulation to teach bronchoscopy skills and competence to trainees. This increased uptake has also led to several studies evaluating bronchoscopy SBT courses, with the majority demonstrating effectiveness of SBT to teach bronchoscopy skills to novice trainees, according to a previous review.[6] Despite favorable outcomes, most studies in this review were low-powered, were conducted in a single-center setting and/or included participants that were nonrepresentative for the pulmonologist population (eg, medical students), which could have led to biased results.[7] Furthermore, as far as we know the effectiveness of the implementation of a bronchoscopy SBT course on a nationwide scale has not been studied yet. In light of the perceived benefits of SBT, the Dutch Association of Chest Physicians (NVALT) implemented a mandatory nationwide 1-day flexible bronchoscopy SBT course for first-year pulmonology residents in 2020. This initiative presented an opportunity to investigate the effectiveness of a nationwide bronchoscopy SBT course for residents on basic bronchoscopy skills. With this study, we aimed to enhance our understanding of the effectiveness of a flexible bronchoscopy SBT program that was implemented on a nationwide scale.

METHODS

Course Development and Implementation

The SBT course was developed collaboratively by pulmonologists/simulation experts from 6 simulation centers, the research team, and 2 international renowned colleagues with expertize in medical SBT. A series of online and on-site meetings were conducted to establish consensus on course content and assessment methods. Based on this input and a cognitive task analysis,[8] it was decided to focus the training on teaching residents *basic* bronchoscopy competence, implicating that at the end of the course residents should be able to navigate through the bronchial tree with proper scope handling (dexterity) *and* should be able to adequately enter and identify all airway segments, the cornerstones of bronchoscopy.[9] The assessment procedure was designed to evaluate trainee competence aligned with these training objectives. In addition, all researchers and trainers agreed that a maximum of two residents could attend each training day, aiming for an optimal interaction and a safe learning environment. The training sessions were led by either 1 pulmonologist, 1 pulmonologist who could be assisted by a simulation expert, or 2 pulmonologists, depending on the training center. Several pilots were conducted to determine the feasibility of the course program and to calibrate the assessors' evaluation of the simulated bronchoscopies, and subsequently, an additional center joined the simulation initiative network.

Participants

All first-year Dutch pulmonology residents were obliged to follow the 1-day training course, although residents who had performed more than 50 clinical bronchoscopies before the start of the training were excluded from the study. Data collection took place from May 2021 until May 2023. Ethical approval for this study was obtained from the ethical review committee of the University of Twente. Before the training, residents received verbal information and an information letter, followed by the opportunity to provide informed consent for participation. The training course was standardized for all trainees, irrespective of their participation in the study. The only distinction was that data of consenting trainees would be collected and analyzed anonymously. Both the verbal information and the information explicitly stated that participating in the study would not affect a trainee's chances of passing the training. This study was carried out in accordance with the Declaration of Helsinki.[10]

The simulator utilized for the training course by every center was the virtual reality GI-BRONCH Mentor flexible bronchoscopy simulator (MentorLearn software version 2.5.5.63, Surgical Science, Göteborg, Sweden). Within this training program, the *Essential Bronchoscopy* and *Diagnostic Bronchoscopy* modules were employed. The *Essential Bronchoscopy* module comprised several tasks, with residents practicing solely the *Basic scope manipulation* task and *Lung anatomy and bronchial segments* task, referred to as, respectively, task 1 and task 2 to enhance clarity. The *Diagnostic Bronchoscopy* module included various patient cases, allowing residents to select randomly the cases they wished to practice.

The Training Course

Before participating in the course, residents were required to read study material related to bronchoscopy[11–14] and pass a theoretical exam evaluating their knowledge of bronchial anatomy, indications, contraindications, and complications. This examination was developed by a team of experienced pulmonologists, and all questions underwent relevance assessment by 5 international experts through a Delphi procedure. The main goal of this exam was to ensure residents had adequate bronchial anatomy knowledge, so that insufficient knowledge would not hinder them in completing the training.

Figure 1 shows the course structure. The individual pretest and posttest assessment consisted of task 1 and task 2, aimed at assessing residents' simulated basic bronchoscopy competence. Task 1 involved following a ball through a digital maze. Residents were allowed to do a practice run first (however, only in the pretest session), followed by 5 actual runs, randomly selected from 8 trajectories. Performance metrics recorded after each run included PT, % of time at mid-lumen, % of time with scope-wall contact and the total number of wall contacts. Task 2 required residents to navigate to and name all airway segments, 10 in the right lung and 8 in the left lung, systematically from 1 to 10.

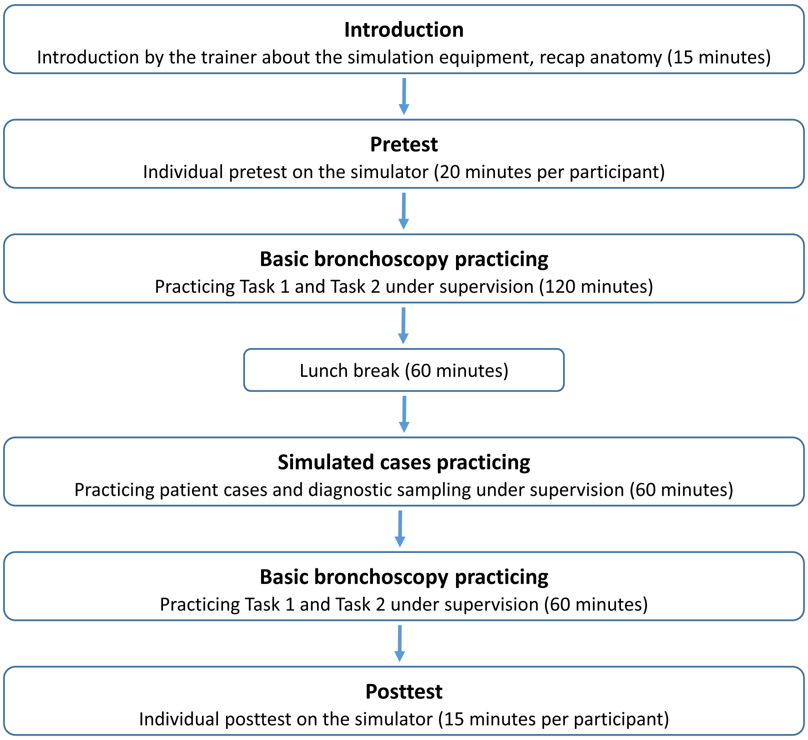

FIGURE 1. Overview of the training program.

Adequate navigation to a segment was confirmed by the appearance of a green circle around question mark within the segment on the screen. Subsequently, residents had to state the anatomical name and corresponding segmental number, after which the trainer selected the name on the screen. For this anatomy task, assessment was conducted using a previously validated bronchoscopy assessment tool[15] adapted to the simulation procedure. We decided not to use the Bronchoscopy Skills and Task Assessment Tool (BSTAT)[16] because it includes parameters for assessing the ability to describe mucosal abnormalities and perform interventions such as bronchoalveolar lavage or brushing, which were beyond the scope of our training program. Our basic bronchoscopy assessment tool (BBAT) comprised 10 parameters, yielding an overall-competence score on a scale of 1 to 5, where 1 represented the worst and 5 the best competence (Supplemental Digital Content 1, http://links.lww.com/LBR/A336). A final score of 3 or higher was required for trainees to pass the training course. Since this tool relied on direct observation and some parameters can thus be subject to bias, video recordings of residents' performances during this task were made for subsequent dexterity assessment by a blinded expert rater and comparison to the unblinded BBAT ratings at a later stage (see below for a detailed description for this dexterity assessment). During all practice sessions following the pretest, the trainees were continuously supervised by the trainer(s), receiving procedural information in the form of how-to instructions and corrective feedback.

Outcome Measures

For task 1, outcome measures were average values of each of the four simulator metrics (PT, % of time at mid-lumen, % of time with scope-wall contact and the number of wall contacts). In addition, considering that longer procedure durations may result in increased wall contacts, the number of wall contacts per minute of PT was calculated and included as an extra outcome measure for this task. Regarding task 2, outcome measures were (1) PT, (2) overall-competence scores of the BBAT (Supplemental Digital Content 1, http://links.lww.com/LBR/A336), and (3) blinded expert ratings of residents' dexterity in the video recordings, for which a separate assessment tool was developed. A detailed description of the various parameters of this assessment tool is provided below.

Bronchoscopy Dexterity Assessment Tool: Blinded Assessment

To collect additional validity evidence for the BBAT, a bronchoscopy dexterity assessment tool (BDAT) suitable for blinded evaluation was developed (see Supplemental Digital Content 2, http://links.lww.com/LBR/A337). The video recordings exclusively captured the bronchoscope and the participant's arms and hands (a screenshot of a video recording is shown in Supplemental Digital Content 3, http://links.lww.com/LBR/A338). The BDAT encompassed 4 parameters, "movements in horizontal plane" (1), "scope bending" (2), "deliberate wrist movements" (3), and "hand thumb position" (4) resulting in a composite "total score". The tool also included an overall assessment parameter: "fluency" (5). The inclusion of these parameters was based on the literature[14,17,18] and expert opinion. Essentially, correct navigation of the bronchoscope involves movements only being limited to a vertical plane coupled with rotation, flexion and deflexion of the tip. Movements in the horizontal plane (1) and scope bending (2) are deemed redundant, as they do not facilitate proper movement of the tip of the bronchoscope. The operator should only make deliberate

TABLE 1. Participant Demographics

Demographic category	Demographic	Participants, N
Gender	Male	33
	Female	67
Bronchoscopy experience	None	33
	1-10	44
	11-50	23
Gaming experience	None	82
	< 1 h per month	2
	1-10 h per month	9
	≥ 10 h per month	7
Simulation experience	None	70
	< 30 min	17
	≥ 30	13
Training center	Amsterdam	20
	Eindhoven	16
	Enschede	4
	Groningen	11
	Leiden	18
	Maastricht	17
	Nijmegen	14

wrist movements (leading to rotation of the scope) necessary for adequate scope navigation (3) with the thumb continuously placed on the steering lever to initiate tip flexion or deflexion (4). In addition, the entire procedure should ideally be performed fluently (5). Fluency in this regard might be seen as an overall global judgment of the operator's dexterity.

Statistics

The data were analyzed using SPSS, version 26. Paired *t* tests were employed to compare the normally distributed values: % of time at mid-lumen and % of time with scope-wall contact for the first task, and PT for the second task. For the non-normally distributed values, the Wilcoxon-signed rank test was utilized. In addition, a Bonferroni corrected significance threshold was calculated,[19] resulting in a corrected threshold of $\alpha = 0.025$ for the % of time at mid-lumen and % of time with scope-wall contact in the first task and $\alpha = 0.0167$ for the number of wall contacts, PT and the number of wall contacts per minute of PT in the first task. For PT and BBAT overall-competence scores of the second task, the corrected significance threshold was $\alpha = 0.025$. Finally, for the BDAT ratings, the resulting threshold was $\alpha = 0.01$. Effect sizes were calculated using Cohen's *d*, with values of 0.2, 0.5, and 0.8 indicating small, moderate, and large effect sizes, respectively. Spearman ρ was used to measure correlation between the movement in horizontal plane parameters of the unblinded BBAT and blinded BDAT, given their non-normal distribution. Spearman ρ values of 0, 0.1 to 0.3, 0.4 to 0.6, 0.7 to 0.9, and 1, respectively, indicate zero, weak, moderate, strong, and perfect correlation.[20]

RESULTS

The data collection process continued until 100 participants were included. Median age of participants was 31 years, with the 25th and 75th percentiles ranging from 29 to 33 years. Their demographics are described in Table 1. The majority (n = 77, 77%) had performed 10 or fewer bronchoscopies before participating in the training. Most participants had not previously practiced on a simulator (n = 70, 70%). The number of participants in the different centers was balanced, except for Enschede, where only 4 residents participated in the study.

Pretest and posttest results for all outcome measures of task 1 are described in Table 2. A significant difference between the posttest and pretest was observed for all outcome measures, except for the number of wall contacts per minute of PT. The effect sizes, ranging from −0.4 to −0.7 for the significantly differing outcome measures, indicate moderate to large effects of the training course on basic scope navigation skills.

Figure 2A and B shows pretest and posttest outcomes for task 2. Only 3 residents failed (ie, they had an overall-competence score lower than 3). A significant improvement was observed for both time (10.3 ± 2.7 min pre vs. 4.7 ± 0.9 post, $P < 0.001$, 95% CI of the difference = −5.1 to −6.0, paired samples *t*-test) and BBAT overall-competence scores (2.0 [IQR 1.0 to 2.0] pre vs. 4.0 [IQR 4.0 to 5.0] post, 95% CI of the difference = 2.0-2.0, $P < 0.001$, Wilcoxon-signed rank test). Effect sizes were, respectively, −2.3 and 0.9, indicating a large effect of the training course on both time and basic bronchoscopy skills.

Blinded Expert Ratings of Dexterity

Pretest and posttest results for all parameters of Task 2 that were rated by the blinded expert with the BDAT are shown in Table 3. All outcome measures improved significantly. The effect sizes, ranging from 0.5 to 0.8, indicate moderate to large effects of the training course on parameters associated with dexterity. Following the evaluation of the first 62 residents, an interim analysis was conducted. This revealed a moderate Spearman rank correlation coefficient between the unblinded on-site BBAT and the blinded BDAT ratings of movements in the horizontal plane for both the pretest and posttest dexterity

TABLE 2. Task 1 Simulator Metrics

Outcome measure	Pretest, mean ± SD/pretest median [25th-75th percentile]	Posttest mean ± SD/posttest median [25th-75th percentile]	*P* (95% CI of difference)	Cohen's *d*
Total time (s)	38.1 [29.8-46.7]	31.1 [24.1-39.2]	< 0.001* (−10.6 to −5.1)	−0.6
Percentage of time at mid-lumen	58.5 ± 8.6	62.2 ± 7.8	< 0.001* (2.0–5.3)	0.4
Percentage of time with scope-wall contact	10.7 ± 5.3	8.3 ± 4.6	< 0.001* (−3.5 to −1.4)	−0.5
No. wall contacts	2.6 [2.0-3.8]	2.0 [1.4-2.6]	< 0.001* (−1.2 to −0.7)	−0.7
No. wall contacts per minute procedure time	4.3 [3.0-6.2]	3.5 [2.6-5.3]	0.07 (−0.9 to −0.07)	−0.2

Paired samples *t* test for normally distributed outcome measures, Wilcoxon-signed rank test for nonnormally distributed outcome measures.
*Statistically significant difference.

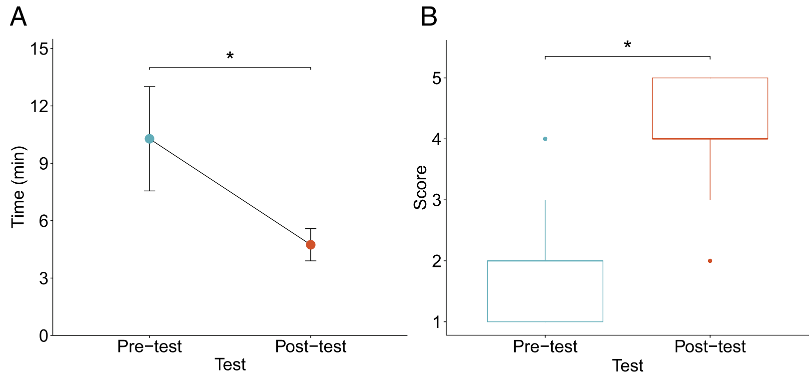

FIGURE 2. Pretest and posttest task 2 procedure time (A) and overall-competence scores on the basic bronchoscopy assessment tool (BBAT) on a scale of 1 to 5 (B). Paired samples *t* test for procedure time and Wilcoxon-signed rank test for overall-competence scores. *$P < 0.001$.

ratings, respectively $\rho = 0.6$, $P < 0.001$ and $\rho = 0.4$, $P = 0.002$. Based on these interim results, it was decided to discontinue the blinded ratings as further adding more blinded, very time-consuming evaluations, most probably would not change the final results or conclusions.

DISCUSSION

This article presented the first evidence of the effectiveness of a 1-day SBT course in improving basic bronchoscopy competence when implemented on a nationwide scale. With this course, residents significantly improved their basic bronchoscopic competence to a large extent. In a basic navigation task, nearly all simulator metrics improved significantly. More importantly, in a realistic anatomical task, PT was reduced by half, accompanied by a significant enhancement in basic bronchoscopic competence from a median level of 2 (novice) to a median level of 4 (competent). This enhancement was evidenced by the improvement of all participants' BBAT overall-competence scores and blinded expert ratings of the first 62 participants' dexterity. Notably, the vast majority of effect sizes for the outcome measures of this task were ≥ 0.8, suggesting a strong impact of the SBT course on residents' skills in an anatomically realistic simulated environment.

This study used various methods to assess residents' bronchoscopy competence, enhancing result robustness. Simulator-generated metrics were used for task 1, offering objective measurements that have been shown to correlate with bronchoscopist skill levels.[21] However, this task involves following a ball through a digital maze while keeping the scope centralized, which may reflect dexterity in general, but may, on the other hand, not be directly relevant to clinical bronchoscopy skills. Previous research also showed that novices could quickly learn how to achieve high scores on task 1.[17] Furthermore, our study demonstrated a lack of improvement in the number of wall contacts per minute of PT in task 1, potentially indicating its limited validity. Despite these limitations, incorporating task 1 in training programs can still be valuable, as it serves as an additional exercise to familiarize residents with basic scope navigation in the initial phase of their training and introduces some variety in the program. Nevertheless, for basic bronchoscopy assessment purposes, we believe task 1 has limited value, as it does not evaluate anatomy knowledge competence, navigational skills in an anatomical environment and dexterity, which were our key training objectives. These major objectives, necessary for achieving basic bronchoscopic skills, were assessed in task 2 with a validated bronchoscopy assessment tool adapted to a simulation setting. This BBAT however relies on direct observation, which introduces the possibility of bias for some parameters. Although the anatomical parameters are measured rather objectively (ie, raters can easily tell if a resident named a segment correctly or was able to enter it), the qualitative ratings of the tool's dexterity parameters might be susceptible to some degree of subjectivity. Therefore, video recordings were used to circumvent this subjectivity for the dexterity parameters to enable blinded assessment with the BDAT.[22,23] Moreover, the moderate

TABLE 3. Task 2 Dexterity Parameters Median [25th percentile-75th percentile], Rated by a Blinded Expert (n = 62 Residents)

Outcome measure	Pretest median [25th-75th percentile]	Posttest median [25^{th} – 75^{th} percentile]	*P* (95% CI of the difference)	Cohen's *d*
Hand thumb position (max 5)	2 [1-3]	2 [2-4]	< 0.001* (0.0-0.5)	0.5
Movements in horizontal plane (max 5)	2 [1-3]	4 [3-4]	< 0.001* (1.0-1.5)	0.8
Bending (max 5)	2 [2-3]	4 [3.75-5]	< 0.001* (1.5-2.0)	0.6
Deliberate wrist movements (max 5)	2 [2-3]	4 [3-4]	< 0.001* (1.0-1.5)	0.8
Total score (max 20)	9 [8-12]	15 [12-16]	< 0.001* (4.0-5.0)	0.8
Level of fluency (max 5)	2 [1-3]	4 [3-4]	< 0.001* (1.5-2.0)	0.8

Parameters were rated on a scale of 1 to 5, where a higher score indicated better dexterity on each parameter.
*Statistically significant difference.

correlation between the unblinded and blinded ratings of the "movements in horizontal plane" dexterity parameters indirectly supports the validity of the unblinded ratings.

A recent systematic review on the effectiveness of bronchoscopy SBT concluded that SBT probably is an effective training method for teaching basic bronchoscopy skills to novice trainees.[6] However, the vast majority of the included studies were single-center and included less than 30 participants. The success of these small-scale, highly controlled simulation interventions observed in previous research may not necessarily translate to success when implemented on a larger scale, also because transferring successful programs to real-life settings is complex.[24,25] Previous research has also shown that an implementation gap in other SBT fields still exists.[26] Despite these concerns, our study shows that even a nationwide implementation of this bronchoscopy SBT program is feasible and effective in achieving basic bronchoscopy competence in novice residents.

Strengths and Limitations

Major strengths of this study include the careful design of the training program, involving medical education, simulation, and pulmonology experts. Second, data were obtained in a nationwide training setting, encompassing 7 different training centers. Third, the number of participants was high, more than in any previous bronchoscopy simulation study, contributing to the robustness of the results. Finally, the validity of our findings regarding dexterity was confirmed by blinded ratings, which was omitted in most previous studies.

This study has also several limitations. First, we employed a pretest–posttest design, which, although commonly used, may be considered less robust than other designs because a pretest can influence the results of the posttest. However, ethical considerations and the mandatory nature of our training course precluded alternative designs. On the other hand, recent preliminary data showed no effect of the pretest on posttest results. Second, our study did not measure long-term retention following the training course, although a study is currently underway to assess this. Third, although the study focused on novice residents, a small number of participants had some bronchoscopy experience, potentially introducing some heterogeneity in the measured baseline skill levels. Fourth, although the dexterity assessment with the BDAT highlighted improvements in scope handling and provided validity evidence for the BBAT, it is important to note that this tool requires further validation before it can be used in other studies. Fifth, another limitation of our study is that we did not employ the widely used BSTAT for reasons discussed in the methods section, making it challenging to compare our results with those of other studies. Finally, we did not measure outcomes in a patient setting, highlighting a need for future bronchoscopy simulation studies to evaluate trainees' skills in a patient setting following SBT.

CONCLUSIONS

This study demonstrated that a 1-day nationwide bronchoscopy simulation-based training course significantly improved pulmonology residents' basic bronchoscopic competence in an anatomically realistic simulated task to a large extent, whereas procedure time was halved. Therefore, bronchoscopy simulation-based training has now, for the first time, been proven to be a highly effective training method when implemented on a nationwide scale.

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