Comparative Effectiveness of Low- and High-Fidelity Bronchoscopy Simulation for Training in Conventional Transbronchial Needle Aspiration and User Preferences

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Key Words
Bronchoscopy · Simulation · Education · Conventional transbronchial needle aspiration

Abstract
Background: Conventional transbronchial needle aspiration (TBNA) can be learned using high-fidelity virtual-reality platforms and low-fidelity models comprised of molded silicone or excised animal airways. Objectives: The purpose of this study was to determine perceptions and preferences of learners and instructors regarding the comparative effectiveness of low-fidelity and high-fidelity bronchoscopy simulation for training in TBNA. Methods: During the 2008 annual CHEST conference, a prospective randomized crossover design was used to train study participants in three methods of conventional TBNA using low- and high-fidelity models. Likert style questions were administered to learners and instructors in order to elicit preferences and opinions regarding educational effectiveness of the models. Results: Learners felt that the models were equally enjoyable (13–13) and enthusiasm generating (low 17-high 15). There was preference for low-fidelity in terms of realism (23–17), ease of learning (20–6), and learning all three TBNA methods (31–7 for hub-against-wall, 31–6 for jabbing, 29–6 for piggyback). Low-fidelity was preferred as an ideal model overall (19–11). Instructors thought that low-fidelity was more useful in teaching TBNA (9–0 for all three methods). Instructors perceived the low-fidelity model overall as an ideal tool for learning TBNA (8–0) and a more effective teaching instrument (8–0). Conclusion: Based on learner and instructor perceptions, a low-fidelity model is superior to a high-fidelity platform for training in three methods of conventional TBNA.

Background and Purpose

Conventional transbronchial needle aspiration (TBNA) is a bronchoscopic diagnostic technique that lends itself well to the focused acquisition of technical skill and experiential knowledge, including elements pertaining to patient and equipment safety. Simulator mod-
els to teach TBNA include expensive high-fidelity platforms using three-dimensional virtual anatomy and force feedback technology [1] or low-fidelity models comprised of molded silicone or excised animal airways [2].

Simulated environments create opportunities where tasks can be practiced repeatedly with minimal interference, risks to patients are eliminated, and training scenarios can be tailored to individual learners’ needs [3–5]. Both low- and high-fidelity simulation have been shown to enhance physician competence in procedural skills [4–7], including bronchoscopy [8], while saving time and improving the learning curve [9–10]. Skills thus acquired transfer effectively to the patients’ bedside [11–14], and physicians who are trained using simulators perform significantly better than controls in their clinical encounters [15–17]. Simulator training with objective assessment and feedback identifies and reduces errors, and provides opportunities for remedial intervention [18–21]. In addition, the use of simulator platforms and inanimate models to train novices prior to patient contact has been proven to promote patient comfort and safety [17, 22].

While in many procedural fields investigators have explored the comparative educational efficacy, usability and user satisfaction of low- and high-fidelity simulation [23–30], a comparative study of the educational effectiveness of low- and high-fidelity models in the realm of minimally invasive bronchoscopic procedures has not been reported. The purpose of this study, therefore, was to determine the perceptions and preferences of learners and instructors regarding the comparative effectiveness of low- and high-fidelity bronchoscopy simulation for training in conventional TBNA. This study was designed to test the hypothesis that despite greater enthusiasm among instructors and learners for a high-cost, virtual-reality high-fidelity simulator, as compared to an affordable, low-fidelity airway model, the actual perceptions of either group would not be different regarding realism, ease of use, ability to learn patient and equipment safety measures, and ability to learn the technical skills necessary for performing three different methods of conventional TBNA.

Methods

This study was conducted during the 2008 ACCP-sponsored simulation center educational intervention in Philadelphia, Pa., USA. At the beginning of each of six 2-hour sessions using 9 faculty instructors, learners (who were not aware of the High-Low-Fidelity Comparative TBNA Training Study when signing up for the TBNA simulation center training session) were approached for enrollment in the study. Institutional Board Review and signed written informed consent were not required by the American College of Chest Physicians for performance of this study. Learners who did not wish to enroll participated in the educational session without taking part in the study.

Those who chose to participate were asked to complete a short pre-course Likert scale questionnaire prior to the simulator-based education. This questionnaire inquired about age, gender, geographic locale, primary specialty, setting of practice, bronchoscopy experience and self-assessed skill level, prior TBNA skill level, importance of practice and interest, along with prior simulation experience. Participants were then trained in conventional TBNA on both the low- and high-fidelity platforms (45 min at each station) using a randomized, cross-over study protocol.

Models and Sessions

The low-fidelity model consists of a rubber trachea (Sawbones, Pacific Research laboratories USA model No. 1815) attached to a laryngotracheal airway (demonstration model No. 252500, Laerdal, Wappingers Falls, N.Y., USA) mounted on a polyvinylchloride rectangular base (fig. 1a).

In teams of two, participants were taught to perform TBNA at the subcarina (station 7) and right and left lower paratracheal regions (stations 4R and 4L). Using the jab, hub-against-wall, and piggyback methods for conventional TBNA, learners were able to perforate the airway wall at the designated sites and, with the correct angle, develop a ‘feel’ for the needle going ‘through cartilage’ or ‘between cartilage’, and view the penetration angle by watching the needle protrude outside the airway model. One member from each team performed the TBNA and communicated appropriate commands in correct order, while the other team member served as the bronchoscopy assistant, inserting the needle sheath which was then advanced to the target area by the operator, aspirating and stopping aspiration, and withdrawing the needle, upon command. Each learner was thus trained as both operator and assistant.

The high-fidelity model used was the Immersion AccuTouch® System (Immersion Medical, San Jose, Calif., USA) with its bronchoscopy simulation module set to a basic TBNA scenario (fig. 1b). This model consists of a proxy bronchoscope, a robotic interface device, a monitor, and simulation software. The proxy bronchoscope is manually inserted into the simulator through the nostril of a plastic face model. The robotic interface device tracks the motions of the proxy, reproducing the forces felt during bronchoscopy, while the monitor displays computer-generated images of the airway as the user navigates through the virtual anatomy. The virtual patient breathes, coughs, bleeds, and exhibits changes in vital signs. A proxy ‘TBNA needle’ is inserted through the working channel, as would be done in real bronchoscopy, whereby the learner can simulate the different steps of TBNA. Commands such as ‘needle out’ and ‘needle in’, however, are executed by pressing a pedal [1, 3].

During the high-fidelity session, participants were similarly paired in teams of two, and trained to perform TBNA in similar fashion. Because the TBNA commands (‘advance needle’, ‘needle out’, ‘suction’ and so on) are actually enacted by the press of a pedal, the ‘needle’ itself was not operated by the assistant member of each team. While simulated needle movements are visible on the display panel, there is no tactile feedback of the needle perforating the airway wall or striking cartilage.
Surveys
At the end of each session, each learner was asked to complete a Likert survey. Some questions on the survey pertained to preferences (strong, somewhat, or neutral) for the high-fidelity versus low-fidelity model. Learners were asked to rate their preferences based on ease of learning, realism, fun of learning, generation of enthusiasm for learning, utility for learning each method of TBNA (jab, hub-against-wall, and piggyback) and learning how to ensure patient and instrument safety. The learners were also asked which model was ideal for learning TBNA and to rate their overall learning experience regardless of their preference for one model.

At the end of the six sessions, the 9 faculty members were also asked to complete a Likert survey. The faculty were essentially asked to respond to the same questions, ‘from the learner’s and instructor’s perspective’, based on the composite experiences gained from observing learners over several sessions rather than at the end of each session. This methodology was based on the psychometric theory that observation of behaviors watched over a temporal continuum tend to be more reliable than adding up multiple snapshot observations from a single experience, and hence the larger the number of observations which form the composite estimate, the more reliable this estimate becomes [31, 32]. The only question that was unique to the faculty was ‘If both models were to be used side by side to teach TBNA, which order (high-fidelity first or low-fidelity first) would be the ideal order?’ All results were collected and tabulated anonymously. Descriptive ordinal graphs were constructed for each Likert question, and median values determined.

Results
Forty-four of 48 participants were enrolled in the study, completed the surveys, and were included in the data analysis (fig. 2, 3).

Demographic Analysis
The majority (27/44) of participants were younger than 40, with another 12/44 between 40 and 54; 64% were male. A large majority (30/44) practiced in the US and Canada, with another 5 from Europe and 4 from the Middle East. Most (38/44) were pulmonary or pulmonary/critical care specialists, and two-thirds (29/44) worked in a private practice or mixed setting. Others (15) worked in academia or the industry. Almost three-quarters (31/44) had 5 years or less bronchoscopy experience, with most of these (20/31) having less than 3 years. While a majority self-rated their general flexible bronchoscopy skills as intermediate, experienced, or expert (31/44), almost all (42/44) considered their TBNA expertise as intermediate or lower, with 31 rating themselves as novice or beginner at TBNA. A large majority (36/44) believed TBNA to constitute an important component of their future practice, and most (28/44) expressed a high degree of interest in learning TBNA. Most (26/44) participants had no or very little prior simulation experience, while of the 34 that had
Fig. 2. a–j Survey results reflecting learners' perceptions and preferences. HF = High fidelity; LF = low fidelity; M = median.
any experience, the predominant impression was neutral (13/34).

Survey Results

Learners (fig. 2a–j) found their experiences using the low-fidelity model equally enjoyable to their experiences using the high-fidelity model (13–13), showing almost equal enthusiasm for each of the models (low 17–high 15). They showed some preference for the low-fidelity model in terms of realism (23–17) and more so for ease of learning (20–6). The learners showed strong preferences for the low-fidelity model for learning all three TBNA methods (31–7 for hub-against-wall, 31–6 for jabbing, and 29–6 for piggyback). They felt that the high-fidelity model was more useful for learning how to assure patient safety (27–12) while the low-fidelity model was preferred for learning how to protect the bronchoscope (25–10). As an overall ideal model, there was a preference for the low-fidelity model (19–11). The learning experience as a whole was rated positive by 42 of 44 participants.

Most instructors (fig. 3a–j) felt that the learners had more fun with the high-fidelity simulator (5–2), yet most thought that the low-fidelity model generated more learning enthusiasm (6–0) and was easier to practice with (5–1). The instructors unanimously thought that the low-fidelity model was more useful in teaching all methods of conventional TBNA (9–0 for all three methods). There was also a strong preference among instructors for the low-fidelity model to teach patient safety (6–1) and equipment protection (7–0). Instructors perceived the low-fidelity model overall as an ideal tool for learning TBNA (8–0) and a more effective teaching instrument (8–0). When asked in what order the two models should be used to teach TBNA to novices, if used sequentially, 6 instructors preferred using the low-fidelity model first, while 3 preferred the high-fidelity model.

Discussion

In this prospective study, we tested the hypothesis that despite greater enthusiasm among learners and teachers for a high-cost, virtual-reality high-fidelity simulation model as compared to an affordable, low-fidelity airway model, no differences would be demonstrated in user perceptions regarding realism, ease of use, ability to learn patient and equipment safety measures, and ability to learn the technical skills for performing three methods of conventional TBNA. To our surprise, the results of this study indicate that the learners actually found the models equal with regard to fun and generation of enthusiasm, and there was an observed preference for the low-fidelity model when it came to realism and ease of learning. A strong preference for the low-fidelity model was noted with regard to learning the three methods of conventional TBNA. Investigators in other fields have similarly not observed an educational advantage in the usage of the often more expensive high-fidelity virtual-reality simulation platform [25, 27, 30, 33–35], although some have reported superiority in user-satisfaction-related measures such as learner enthusiasm, and ability to integrate basic discreet tasks into more complex operations [24, 36].

In examining the learner and instructor preferences, we noted only two areas of difference: (1) learners found the models equally fun and enjoyable to learn with while the instructors thought learners were having more fun with the high-fidelity model, and (2) learners thought the high-fidelity model was better to learn patient safety protection, but instructors felt the low-fidelity model was more suited for this goal. While we cannot explain the reasons for these differing opinions with any degree of certainty, we may try to speculate. In the first case, instructors probably had the same preexisting bias as the investigators in elaborating the study hypothesis, imagining that a high-fidelity model would be more fun due to its novelty and higher degree of sophistication. But, from a learner-centric perspective, it appears that the learning platform does not make a difference in eliciting fun and enthusiasm in learners. In the second case, instructors were keenly aware of the importance of needle manipulation in the airway, and could see how the low-fidelity model was more advantageous for teaching patient safety protection while maneuvering the needle in the airway. In part, this may also be because the low-fidelity model requires the use of a real videobronchoscope and a real, rather than proxy, sheathed needle. The learners exposed to a virtual-reality high-fidelity platform, however, might have assumed that factors such as simulated cough, bleeding, and vital signs were crucial to patient safety protection.

The impact of platform fidelity has been researched in many fields, most significantly the engineering and aviation industries [37–39]. In medicine, especially the proce-
Fig. 3. a–j Survey results reflecting instructors’ perceptions and preferences. HF = High fidelity; LF = low fidelity; M = median.
dural fields, investigators have succeeded in elucidating some of the advantages and disadvantages of low- and high-fidelity platforms [23–36]. Low-fidelity models, if well-designed and judiciously employed, tend to offer affordable, easily available, portable and easily reusable tools for simulated practice, with minimal risk to users. They are not always enthusiastically accepted by trainees as suitable patient replacements [36]. Another disadvantage is that more complex procedures must often be broken down to basic tasks in order to be teachable on these platforms. In some models, a longer set-up time may be an added inconvenience. Several studies suggest that they are ideally suited for task-based teaching of novices and beginners, and for practicing specific discreet elements of a particular complex skill [34, 36]. One significant advantage of these low-fidelity models, such as the one designed by us and used in the present study, is that they allow for practice using the real instruments (such as rigid and flexible endoscopes, catheters or wires), hence exposing the learners to the sensation of pressure conveyed directly through the instruments [40].

In the case of high-fidelity, and particularly virtual-reality simulators, the high degree of realism, ease of set-up, the ability to incorporate several different learning modules within a single platform, as well as interactivity and data capture capacity can all be significant advantages [24, 29, 36]. Cost (usually more than USD 100,000) is often a major disadvantage; others include need for maintenance, software upgrades and downtime, and imperfect haptics, force feedback and three-dimensional user interfaces [35, 36]. Many investigators have therefore concluded that the virtual-reality high-fidelity simulators are well suited for training in complex procedures after learners have mastered the more basic and discreet task elements [34, 41].

In our study, the majority of learners (most of whom considered themselves beyond beginner in basic bronchoscopy skills) were primarily interested in learning the three methods of conventional TBNA. As these techniques are very task specific, and have a significant reliance on tactile feedback, we speculate that learners found the low-fidelity model particularly useful due to this model’s greater tactile feedback capabilities during needle insertion [35].

A limitation of this study was that the randomized cross-over design in a small number of subjects precluded the use of statistical measures that are amenable to determination of statistical significance. However, the near-unanimous preference among both learners and instructors, which was demonstrated for the low-fidelity model for learning and teaching all three methods of TBNA was clearly an endorsement of the effectiveness of this model for training in TBNA (31–7, 31–6 and 29–6 for learners, and 9–0 for all methods for instructors). Multicentric or multinational studies using a greater number of learners and instructors are being proposed to obtain even stronger results showing statistical significance, and also to further elucidate the advantages and drawbacks of the various simulation platforms used in training interventional pulmonary procedures, and the potential benefits of their combined usage.

In conclusion, both low- and high-fidelity simulators offer trainees direct experience in the manipulation of a bronchoscope, use of accessory instrumentation, and an opportunity to acquire procedure-specific communication skills while avoiding risk and discomfort for the patient. Ideally, the two models can be used side by side, sequentially, each enhancing the learners’ experience because of their respective strengths. The user preferences, overall, for the low-fidelity TBNA training model used in this study, however, prompt us to agree with Grober et al. [34], Matsumoto et al. [33] and Crofts et al. [41], who have concluded that a low-fidelity model may be better suited to provide learners with a basic foundation of skills and an appreciation for the key constructs of a procedural task.

Acknowledgements

We thank the American College of Chest Physicians, Ed Rendell, Steve Wood RRT, Larry Cherrison RRT, all simulation center participants as well as instructors, Drs. Eric Edell, David Feller-Kopman, Carla Lamb, Septimiu Murgu, Scott Shoffer, and Gerard Silvestri for their kind participation and support. We are grateful to Dr. Sanaz Hashemi for her help in the literature search and graphic design of the images. This study was in part funded by a C*REST® Research Grant.

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