High-Fidelity Patient Simulation Mannequins to Facilitate Aerodigestive Endoscopy Training

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Objective: To evaluate the perceived value of aerodigestive endoscopy training using high-fidelity simulation.

Design: Self-reported survey.

Setting: Pediatric tertiary care hospital.

Participants: Consecutive sample of otolaryngology residents and 1 fellow during the 2006-2007 academic year.

Interventions: Foreign body aspiration and ingestion were simulated in a high-fidelity, computer-assisted infant simulation mannequin. Avoidance of complications and successful removal required teamwork and responsiveness to the mannequin’s physiologic characteristics in addition to dexterity with instruments.

Main Outcome Measures: Postcourse 5-point Likert scale and subjective evaluation of perceived realism reported by participants.

Results: Participant response was generally positive. Ratings were highest for training cognitive and psychomotor endoscopy skills, preventing and managing complications, and facilitating team process. Overall realism and appropriate “feel” showed opportunity for improvement.

Conclusion: Pediatric otolaryngology trainees perceive that high-fidelity patient simulation facilitates acquisition of aerodigestive endoscopy skills, especially in training cognitive and psychomotor endoscopy skills, preventing and managing complications, and facilitating team process.


MEDICAL EDUCATION IS undergoing a revolution with increased emphasis on trainees demonstrating competence in interpersonal and procedural skills and systems-based interactions. Advances in mechanical, electronic, imaging, virtual, and other technologies provide an evolving variety of educational strategies that use simulation to provide opportunities for learners to evaluate and manage normal and abnormal medical conditions and to teach systems-based function and transdisciplinary skills. High-risk but uncommon events, as well as skills that an individual or group may find challenging, can be practiced as needed. Concurrently, caregiver, institutional, and public concerns about medical errors can be addressed using simulation and other innovative educational processes to maximize educational experiences while minimizing patient risk.

This study evaluates the perceived value of high-fidelity simulation used by otolaryngology trainees in aerodigestive endoscopy training. High-fidelity simulation mannequins are life-size human models with standard monitors and computer control panels. They are controlled by a combination of built-in programming and responses, custom programming, and responses effected in real time by a facilitator. Mannequins demonstrate chest-wall motion during “breathing,” a variety of cardiac and breath sounds, some palpable pulses, and limited verbal and other audible conditions and responses. Using a combination of electronic, mechanical, and physical capabilities, the simulators can “sense” and respond to airway manipulation, including endotracheal intubation, right main bronchus intubation, and occlusion of the airway by inappropriate neck and mandible position. The simulators can also respond to the administration of oxygen, medications, and external defibrillation. Simulators can interfere with the learner’s ability to intubate or ventilate by developing tongue edema, laryngospasm, and increased pulmonary resistance. They can also demonstrate hypoxia, bradycardia, and a variety of other arrhythmias.

The mannequins “respond” to interventions, so the participants must pay atten-
tion to the mannequin just as they would a real patient, rather than waiting for descriptive but abstract information provided by a teacher. Participants, either singly or in teams, begin with a feeling of “role-playing,” but this is quickly overcome by a sense of realism.

**METHODS**

Following institutional review board approval of the study, participants completed a self-reported survey after using high-fidelity simulation to train equipment selection, assembly, and use; patient preparation; recognition and management of complications; and team leadership skills during endoscopic evaluation and treatment of a simulated infant (SimBaby; Laerdal Medical, Stavanger, Norway) with foreign body (FB) aspiration and FB ingestion (Figure 1 and Figure 2). Postcourse participants completed an anonymous survey with a 5-point Likert scale and subjective evaluations of perceived realism. Residents were coached to achieve competence; scores reflected the learner’s assessment of the model and the exercise. The setting was a pediatric tertiary care hospital.

Study participants were a consecutive sample of 8 otolaryngology residents (1 resident in postgraduate year 2 and 1 resident in postgraduate year 4 participated at a time, rotating in 3-month blocks) and 1 pediatric otolaryngology fellow (participating during the first 3-month block of his fellowship) during the 2006-2007 academic year.

The high-fidelity, computer-assisted infant mannequin’s capabilities were demonstrated to the residents, and the primary learning objectives of the exercise, as described in the introductory paragraphs, were articulated. Foreign body aspiration was simulated in a mannequin by placing an FB in the left main bronchus (Figure 3) and programming left-lung obstruction to ventilation; poor left chest-wall motion; audible stridor; and audible, progressively decreasing pulse oximeter saturation unless supplemental oxygen and ventilation were accomplished. Airway manipulation without adequate teamwork would trigger laryngospasm (ie, the mannequin’s glottis would mechanically close, preventing both distal instrumentation and ventilation [Figure 4]). Foreign body ingestion was simulated by placing a coin in the esophageal introitus. Critical skills practiced were the selection and assembly of appropriate endoscopy equipment, coordination of airway management with the “anesthesiologist,” removal of the FBs, and leadership communication skills within a team. Simulation exercises were repeated until trained to competence. Participants worked in teams of 2 (a junior and a senior resident) or 3 (plus a fellow) and took turns performing endoscopy and role-playing the anesthesiologist and/or the nurse. The faculty member was present for the entire session and functioned as both the “content expert” providing information, instruction, and correction as needed and as the “facilitator” controlling selected mannequin actions and responses. Sessions...
generally took 1.5 to 2 hours; residents were allowed to practice as many times as they wished, and exercises were continued until competence and resident satisfaction were achieved.

RESULTS

Participant evaluations were generally positive. The mean (SD) ratings were highest for training cognitive and psychomotor endoscopy skills (4.89 [0.33]), preventing and managing complications (4.67 [0.50]), and team process (4.78 [0.44]) (Figure 5). Overall realism (3.78 [0.67]) and appropriate “feel” (4.00 [0.87]) showed room for improvement. Subjective comments suggested that this exercise facilitated instrumentation dexterity and sequencing; limitations cited were unrealistic feel and lack of penalty for injury (Table 1). The exercise seemed to provide excellent psychological fidelity.

COMMENT

Simulation is a technique, not a technology, used to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner. Aerodigestive endoscopy requires a complex and sometimes delicate balance of cognitive, psychomotor, and teamwork skills; clinical opportunities may be unpredictable and unevenly distributed. The use of simulation in surgical education allows opportunities for practice and exploration based on the needs of the learner, exploration without direct risk to patients, immediate feedback and objective documentation, and activated adult learning.

The broad field of simulation-enhanced learning is defined by the Agency for Healthcare Research and Quality as “a strategy—not a technology—to mirror, anticipate, or amplify real situations with guided experiences in a fully interactive way” and includes a variety of physical, electronic, and animate models representing normal and abnormal anatomic and physiologic conditions, diseases, and situations. Teachers may use a single modality or assemble multiple learning modalities in hybrid combinations to achieve specific educational objectives addressing the needs of single or transdisciplinary learners.

For very unique otolaryngology skills, otology, sinus surgery, and flexible bronchoscopy simulators are being developed both in academic and commercial settings, and ongoing studies address the validity of these devices and strategies. In this study, I used a commercially available, relatively inexpensive high-fidelity mannequin that was not specifically designed for these teaching objectives.

The mannequin was programmed to demonstrate changing physical findings correlating with evolving medical circumstances, so that the participants had to repeatedly evaluate the mannequin’s condition rather than rely on cues provided by an instructor. For example, blockage and subsequent lack of ventilation of the left lung were evidenced by the lack of chest rise only on the left side of the chest, laryngospasm was demonstrated by mechanical closure of the glottis, and oxygen desaturation was represented by standard decreasing oxygen saturation information on the monitor (ie, decreasing oxygen saturation value visible on the display, and audible decrease in the pulse oximetry tone), as well as activation of a blue light within the oral cavity. For the purposes of

![Figure 4. Demonstration of mannequin vocal folds. A, Normal position; B, mechanically closed during laryngospasm.](image1)

![Figure 5. Likert scale ratings from participants’ evaluations (5 is best rating).](image2)
the learning objectives in this study, the facial and oral anatomy and jaw thrust mechanism of the mannequin are excellent; laryngeal anatomy is less accurate but remains representative, and tracheobronchial and esophageal anatomy is relatively primitive.

Better simulators, including a ready assortment of pathologic airway abnormalities, would be useful. It is likely that development of more accurate anatomic fidelity is in progress and will be incrementally improved with mannequin upgrades in the near future. The needed development of a cohort of pathologic airway abnormalities is important but more technically challenging and expensive for the manufacturers. As a specific example, managing tracheotomies is often intimidating for health care providers (physicians, nurse practitioners, and nurses), and sophisticated models are not yet available. The physical feasibility of placing a tracheotomy in the SimBaby has been demonstrated in a pilot study by the anatomically correct placement of a tracheotomy into a mannequin laryngotracheal complex (lent to me by the manufacturer) without damage to the laryngeal mechanics. One mechanism to support enhanced fidelity would be to obtain funding to develop a nonproprietary archive representing a spectrum of both normal and abnormal anatomy.

This preliminary report suggests that otolaryngology trainees are receptive to using simulation with high-fidelity mannequins to enhance their training. Study limitations include the small sample size, potential selection bias, subjective evaluation, and difficulty differentiating the contribution of high-fidelity simulation from the scenario-based exercise itself.

In conclusion, pediatric otolaryngology trainees perceive that high-fidelity patient simulation facilitates acquisition of aerodigestive endoscopy skills, especially in training cognitive and psychomotor endoscopy skills, preventing and managing complications, and facilitating the team process. The use of an “off-the-shelf” technology

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**Table 1. Subjective Responses Addressing Mannequin Assets and Limitations**

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<tr>
<th>Asset or Limitation</th>
<th>Response</th>
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<tr>
<td>Observed strength of the mannequin</td>
<td>Vital signs, realistic features; excellent in teaching the required steps for bronchoscopy and esophagoscopy; multiple areas for intervention or assessment (eg, radial pulse, fontanel); allows you to familiarize yourself with the sequence and instrumentation; real-time vital signs, accurate anatomy; “consequence-free” endoscopy training; wonderful endoscopic practice; ability to alter chest rise, vital sign stability vs instability; laryngospasm; realistic experience, wide range of exercises, dynamic airway or trachea feels like plastic; not many [deficiencies], but obviously, does not “feel” lifelike; becomes dry, injury without penalty; lack of tactile similarity to real patients, particularly for the laryngoscope portion; none; unable to pass foreign body distally into esophagus; no arytenoids (2 respondents)</td>
</tr>
<tr>
<td>Observed deficiencies of the mannequin</td>
<td>Lack of pharynx and sometimes difficulty in visualization is not present; airway or trachea feels like plastic; not many [deficiencies], but obviously, does not “feel” lifelike; becomes dry, injury without penalty; lack of tactile similarity to real patients, particularly for the laryngoscope portion; none; unable to pass foreign body distally into esophagus; no arytenoids (2 respondents)</td>
</tr>
<tr>
<td>Suggestions for improvement in the teaching exercise</td>
<td>None (3 respondents); tracheotomy option</td>
</tr>
<tr>
<td>Other comments</td>
<td>Using equipment from actual bronchoscopy cart and having to select desired lengths and sizes helps familiarize very well; it’s a great teaching and practice tool; great teaching tool! (2 respondents); very good overall, especially good to familiarize with instruments and procedures; very helpful; definitely feel comfortable with rigid bronchoscopy or esophagoscopy; excellent review of airway endoscopy/ esophagoscopy in casual setting</td>
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**Table 2. Brief Descriptions of Selected Simulation Technology**

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<tr>
<th>Simulation Terminology</th>
<th>Description</th>
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<tr>
<td>Standardized patients</td>
<td>Actors or trained patients</td>
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<tr>
<td>Task trainer</td>
<td>Device used to teach specific procedure or skill; may be used alone if that skill is the entire learning objective, or in combination with other devices to achieve a more complex learning objective. Target skills may be relatively simple or require multiple coordinated or additive components. Complexity ranges from simple physical models to models with sophisticated electronic tracking and feedback.</td>
</tr>
<tr>
<td>Virtual models</td>
<td>Computer-generated illusions of reality, carried out chiefly in an electronic medium. Incorporating tactile or “force” feedback.</td>
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<tr>
<td>“Serious capabilities”</td>
<td>An avatar interacts with a patient and the patient’s other health care providers and health care setting in a virtual environment.</td>
</tr>
<tr>
<td>Massively multiplayer online role-playing games</td>
<td>Multiple, simultaneous interactive health care providers (avatars) in a virtual environment.</td>
</tr>
<tr>
<td>High-fidelity, interactive, computer-assisted patient simulators</td>
<td>Life-sized mannequins with a variety of electronic and physical sensors and responses and some capacity to be programmed.</td>
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<tr>
<td>Hybrid simulation</td>
<td>Combinations, such as a standardized patient alongside a task trainer.</td>
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<tr>
<td>Immersive environments</td>
<td>Combinations of technologies providing the entire frame of reference for the participant, such as surroundings created by 3-dimensional virtual images (including motion and audio components) combined with standardized patients.</td>
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allows for the replication of this exercise in other institutions.

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REFERENCES


