Advanced Airway Management Simulation Training in Medical Education: A Systematic Review and Meta-Analysis

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Objective: To perform a systematic review and meta-analysis of the literature on teaching airway management using technology-enhanced simulation.

Data Sources: We searched MEDLINE, EMBASE, CINAHL, PsycINFO, ERIC, Web of Science, and Scopus for eligible articles through May 11, 2011.

Study Selection: Observational or controlled trials instructing medical professionals in direct or fiberoptic intubation, surgical airway, and/or supraglottic airway using technology-enhanced simulation were included. Two reviewers determined eligibility.

Data Extraction: Study quality, instructional design, and outcome data were abstracted independently and in duplicate.

Data Synthesis: Of 10,904 articles screened, 76 studies were included (n = 5,226 participants). We used random effects meta-analysis to pool results. In comparison with no intervention, simulation training was associated with improved outcomes for knowledge (standardized mean difference, 0.77 [95% CI, 0.19–1.35]; $n = 7$ studies) and skill (1.01 [0.68–1.34]; $n = 28$) but not for behavior (0.52 [−0.30 to 1.34]; $n = 4$) or patient outcomes (−0.12 [−0.41 to 0.16]; $n = 4$). In comparison with nonsimulation interventions, simulation training was associated with increased learner satisfaction (0.54 [0.37–0.71]; $n = 2$), improved skills (0.64 [0.12–1.16]; $n = 5$), and patient outcomes (0.86 [0.12–1.59]; $n = 3$) but not knowledge (0.29 [−0.28 to 0.86]; $n = 4$). We found few comparative effectiveness studies exploring how to optimize the use of simulation-based training, and these revealed inconsistent results. For example, animal models were found superior to manikins in one study ($p = 0.004$) using outcome of task speed but inferior in another study in terms of skill ratings ($p = 0.02$). Five studies comparing simulators of high versus low technical sophistication found no significant difference in skill outcomes ($p > 0.31$). Limitations of this review include heterogeneity ($I^2 > 50\%$ for most analysis) and variation in quality among primary studies.

Conclusions: Simulation-based airway management curriculum is superior to no intervention and nonsimulation intervention for important education outcomes. Further research is required to fine-tune optimal curricular design. (*Crit Care Med* 2013; 41:00–00)

Key Words: airway management; anesthesia; intubation; laryngeal mask airway; medical education; meta-analysis

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Advanced airway management is an essential skill for many healthcare providers. Failure of airway management remains a significant source of morbidity and mortality (1). Training healthcare professionals in airway management is essential to patient safety.

Due to decreased procedural exposure and safety concerns, simulation training has played an increasing role in medical training (2, 3). In general, technology-enhanced simulation improves procedure-related outcomes in comparison with no training or nonsimulation training, including patient safety and learner competence (4–6). Several studies have evaluated the effects of technology-enhanced simulation education for advanced airway management, but reviews on this topic have been limited by nonsystematic identification of eligible studies, absence of evaluation of study quality, and lack of quantitative synthesis of study results (7–10). A comprehensive quantitative synthesis of available evidence would enable educators to make informed decisions regarding the optimal use of simulation-based training for airway management.

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We sought to determine the effectiveness of and key features of instructional design for simulation education in advanced airway management training by performing a systematic review and meta-analysis.

METHODS

Protocol

This study reflects a planned focused analysis of studies identified in a comprehensive review of simulation-based health education (4); we briefly summarize below the methods specific to this study. Our study adheres to Preferred Reporting Items for Systematic Reviews and Meta-Analyses standards of quality for meta-analyses (11).

Eligibility Criteria

We included comparative studies that investigated the use of technology-enhanced simulation to teach advanced airway management to health professionals (at any stage in training) regardless of language, publication date, or follow-up duration. We defined technology-enhanced simulation as an educational tool with which the learner physically interacts to mimic airway management, including direct laryngoscopy (DL), fiberoptic intubation (FOI), supraglottic airway management (laryngeal mask airway [LMA] or Combitube), and surgical airway. Multitask courses (e.g., advanced cardiac life support) that explicitly included training for and assessment of airway management were included.

Search Strategy

We previously published our search strategy in full (4). A research librarian designed a strategy to search MEDLINE, EMBASE, CINAHL, PsycINFO, ERIC, Web of Science, and Scopus for eligible articles (last full search May 11, 2011). In addition, two reviewers examined the reference lists of several reviews of airway management simulation (7–9, 12, 13) and all articles published in *Simulation in Healthcare* and *Clinical Simulation in Nursing*. On February 4, 2013, we performed a focused search for recently published articles (**Appendix 1**, Supplemental Digital Content 1, http://links.lww.com/CCM/A711).

Study Selection

All aspects of study selection were performed by two independent reviewers with conflicts resolved by consensus, starting with review of titles and abstracts and proceeding to review of the article full text as needed.

Data Abstraction

We developed, tested, and iteratively refined a data abstraction form and coding document. We abstracted information independently and in duplicate, resolving conflicts by consensus.

We abstracted information on learners, the simulated clinical context (prehospital, hospital, operating room [OR], emergency department, or no clinical context), specific airway management strategy, and features of the intervention (feedback, mastery learning, distribution of training across > 1 d, and intentionally scripting an error into the training scenario). We abstracted information separately for learning outcomes of satisfaction, knowledge, skills, behaviors with patients, and patient effects. "Skills" were outcomes in simulated settings, distinguished as "time" (time to task completion), "process" (observed proficiency, economy of movements, or minor errors), and "product" (successful task completion or major errors). Outcomes in real clinical settings were similarly classified as "behavior time," "behavior process," and "direct effects on patients."

We evaluated study quality using the Medical Education Research Study Quality Instrument (MERSQI) (14) and an adaptation of the Newcastle-Ottawa Scale (NOS) for cohort studies (15).

Synthesis

For quantitative synthesis, we grouped studies according to the comparison (no intervention, nonsimulation intervention, or simulation intervention). We planned to use meta-analysis to pool the results of studies comparing simulation training with no intervention or nonsimulation intervention, with subgroup analyses based on study design, trainee level, airway management technique, and selected intervention features (single task vs multitask, single discipline vs multidiscipline, high vs low feedback, and training distributed across 1 vs > 1 d). For studies comparing two simulation interventions, we identified comparison themes by examining the research questions and conceptual frameworks and planned meta-analysis for themes with more than or equal to three studies.

To perform these analyses, we first calculated a standardized mean difference (SMD) (Hedges' g) (4). If an article contained insufficient information to calculate a SMD, we contacted authors for information. We used random effects models to pool weighted SMD using SAS 9.1 (SAS Institute, Cary, NC). Statistical significance was defined by a two-sided α of 0.05, and interpretations of clinical significance emphasized CIs in relation to Cohen's classifications (> 0.8 = large, 0.5–0.8 = moderate, 0.2–0.49 = small, < 0.2 = negligible) (16). We used funnel plots and Egger's test to evaluate possible publication bias and used trim-and-fill to estimate a revised SMD when indicated. We quantified inconsistency using the I^2 statistic (17). For all meta-analyses, we planned a sensitivity analysis excluding studies that used imprecise data (p value upper limits or imputed SD) to estimate the SMD. We also performed a sensitivity analysis incorporating data from articles identified in our updated search (**Supplemental Appendix Table 1**, Supplemental Digital Content 2, http://links.lww.com/CCM/A751).

For qualitative synthesis, we used a critical synthesis approach, iteratively examining articles for common themes. We summarized these findings using a narrative review.

RESULTS

Trial Flow

Our search yielded 10,904 articles with 986 comparative studies of simulation-based training (**Fig. 1**). From these, we found 77 studies of simulation-based training for advanced airway

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management. We excluded one study that did not report the sample size (author contact unsuccessful). The remaining 76 studies enrolled 5,226 trainees.

Study Characteristics

Table 1 summarizes key study characteristics, and **Appendix Table 2** (Supplemental Digital Content 3, http://links.lww.com/CCM/A752) reports detailed information for each study. Airway models for training included human patient simulators (HPSs) or manikins, animal models, cadavers, and standardized or anesthetized patients. Forty-three studies provided a scripted or simulated clinical context. Twenty-one studies required interaction with a multidisciplinary team. Four studies introduced an intentional error (i.e., discovery of an esophageal intubation), six studies used mastery learning in their design, and 18 studies distributed training over more than 1 day.

Nine articles reported behavioral outcomes with patients (5 DL, 5 FOI, and 1 supraglottic airway), such as an instructor's rating of procedural skill with patients, the time to procedural completion, or procedural proficiency (i.e., the number of times the bronchoscope hit the mucosa) (18–26). Sixteen articles reported patient outcomes (12 DL, 5 FOI, 3 supraglottic, and 1 surgical) including procedural success and procedural complications (such dental injury or esophageal intubation) (18–21, 23–34).

Study Quality

Study quality is summarized in **Table 2**. Thirty-five studies were randomized. Twenty-two studies reported data on fewer than 75% of enrolled participants (loss to follow-up not described). At least one outcome was determined objectively in 64 studies, but only 34 studies employed a blinded outcome.

Synthesis: Comparison With No Intervention

In comparison with no intervention, simulation training for airway management was associated with large statistically significant positive effects on skills. Twenty-eight studies (1,672 learners) measured skill outcomes, with a large pooled SMD of 1.01 (95% CI, 0.69–1.34; $p < 0.0001$) (**Fig. 2**). We found large inconsistency with $I^2 = 94\%$. Individual SMDs ranged from –0.29 to 3.85, although only two of 28 studies showed a negative SMD. To explore this inconsistency, we conducted planned subgroup analyses (**Fig. 3**). We found large pooled SMDs among all learner subgroups and for all airway management tasks except FOI, for which the SMD of 0.66 is considered moderate. We found no difference in skill outcome in subgroup analyses according to duration of training (1 vs > 1 d), feedback (high vs low), multitask (vs single task) design, or multidisciplinary (vs individual) training ($p_{interaction} \geq 0.19$ for all). The funnel plot was visually asymmetric; assuming this suggests publication bias, trim-and-fill analyses revealed a revised SMD of 0.87 (0.42–1.20). Sensitivity analysis excluding six studies with imprecise SMD estimations yielded a virtually identical SMD (1.03).

Ten studies assessed time skills (i.e., time to complete the task), seven studies assessed knowledge outcomes, four studies assessed behaviors in clinical practice, and four studies assessed direct patient outcomes. In all but the last analysis, the SMD was moderate or large and favored training, and inconsistency was high ($I^2 \geq 79\%$) (Fig. 2). Funnel plots for outcomes of knowledge and

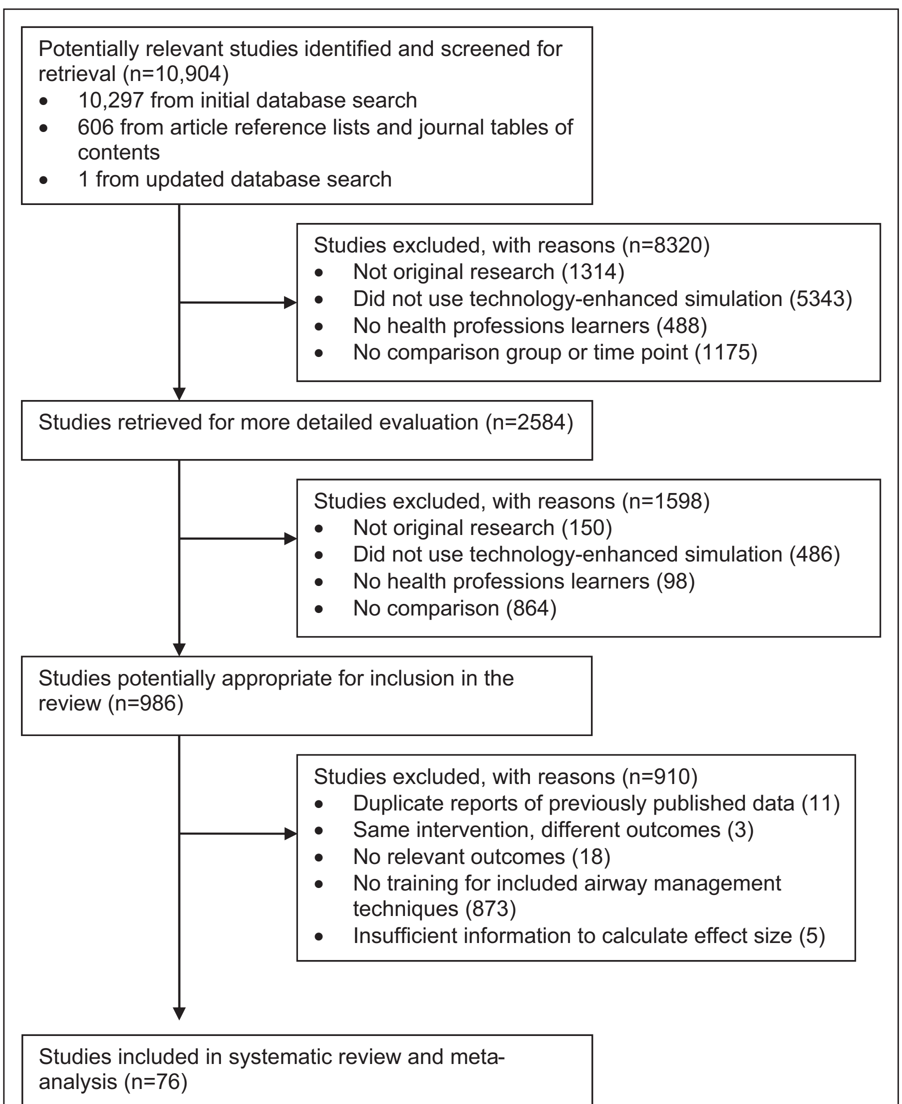

Figure 1. Trial flow of study selection, including stage and reason for exclusion.

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TABLE 1. Key Features of Studies Included in Systematic Review of Airway Management Simulation Training

Study Characteristic	Level	No. of Studies (No. of Participants[a])
All studies		76 (5,226)[b]
Study design	Two groups	51 (3,654)
	One group (pretest-posttest)	25 (1,572)
Group allocation	Randomized	35 (2,322)
Comparison	No intervention	39 (2,451)
	Nonsimulation training	10 (683)
	Alternate simulation training	29 (2,582)
Participants[c]	Medical students	18 (1,134)
	Physicians in postgraduate training	31 (1,149)
	Physicians in practice	20 (750)
	Nurses in practice	11 (249)
	Nursing students	3 (388)
	Emergency medical technicians or students	18 (912)
	Other/ambiguous/mixed	12 (588)
Approach[c]	Direct laryngoscopy	48 (4,006)
	Fiberoptic intubation	18 (789)
	Nasal/blind airway	1 (33)
	Surgical airway	18 (1,488)
	Supraglottic	14 (1,291)
Environmental or scripted setting of simulation scenario[c]	Emergency department	6 (624)
	Hospital (includes ICU)	4 (367)
	Operating room	26 (1,108)
	Prehospital	7 (849)
	No clinical context	34 (2,544)
Outcomes[b]	Satisfaction	6 (454)
	Knowledge	14 (1,436)
	Skill: time	19 (995)
	Skill: process	41 (2,717)
	Skill: product	11 (1,007)
	Behavior: time	4 (101)
	Behavior: process	8 (308)
	Patient effects	13 (757)
Quality	Newcastle-Ottawa Scale ≥ 4 points	30 (1,996)
	Medical Education Research Study Quality Instrument ≥ 12 points	45 (3,089)

[a]Numbers reflect the number enrolled, except for outcomes which reflect number of participants who provided observations for analysis.

[b]One additional study did not report the number of participating trainees (data not included in this table).

[c]The number of studies and trainees in some subgroups (summing across rows or columns) may sum to more than the number for all studies because several studies included > 1 comparison arm, > 1 trainee group, fit within > 1 training task or scenario, or reported multiple outcomes.

See Appendix Table 1 (Supplemental Digital Content 2, http://links.lww.com/CCM/A751) for details on individual studies.

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TABLE 2. Quality of Studies Included in a Systematic Review of Airway Management Simulation Training

Scale Item	Subscale (Points if Present)	No. Present (%)
Medical Education Research Study Quality Instrument[a]		
Study design (maximum 3)	1 group pre-post (1.5)	25 (33)
	Observational 2 group (2)	16 (21)
	Randomized 2 group (3)	35 (46)
Sampling: number of institutions (maximum 1.5)	1 (0.5)	65 (86)
	2 (1)	2 (3)
	> 2 (1.5)	9 (12)
Sampling: follow-up (maximum 1.5)	< 50% or not reported (0.5)	20 (26)
	50–74% (1)	2 (3)
	≥ 75% (1.5)	54 (71)
Type of data: outcome assessment (maximum 3)	Subjective (1)	12 (16)
	Objective (3)	64 (84)
Validity evidence (maximum 3)	Content (1)	19 (25)
	Internal structure (1)	20 (26)
	Relations to other variables (1)	5 (7)
Data analysis: appropriate (maximum 1)	Appropriate (1)	67 (88)
Data analysis: sophistication (maximum 2)	Descriptive (1)	5 (7)
	Beyond descriptive analysis (2)	71 (93)
Highest outcome type (maximum 3)	Reaction (satisfaction) (1)	2 (3)
	Knowledge, skills (1.5)	57 (75)
	Behaviors (2)	4 (5)
	Patient/healthcare outcomes (3)	13 (17)
Newcastle-Ottawa Scale (modified)[b]		
Representativeness of sample	Present (1)	20 (26)
Comparison group from same community	Present (1)	50 (66)
Comparability of comparison cohort, criterion A[c]	Present (1)	37 (49)
Comparability of comparison cohort, criterion B[c]	Present (1)	22 (29)
Blinded outcome assessment	Present (1)	34 (45)
Follow-up high or those lost described	Present (1)	57 (75)

[a]Mean (SD) Medical Education Research Study Quality Instrument score was 12.0 (2.0); median (range) was 12 (7–16).

[b]Mean (SD) Newcastle-Ottawa Scale score was 2.9 (1.7); median (range) was 3 (0–6).

[c]Comparability of cohorts criterion A was present if the study 1) was randomized or 2) controlled for a baseline learning outcome; criterion B was present if 1) a randomized study concealed allocation or 2) an observational study controlled for another baseline trainee characteristic.

behavior were visually symmetric, and Egger's test did not suggest publication bias. The funnel plot for time outcome was visually asymmetric; assuming this suggests publication bias, trim-and-fill analyses revealed a revised SMD of 0.81 (0.42–1.20). The pooled SMD for four studies evaluating effects on patients was negligible and not statistically significant SMD –0.12 (–0.41 to 0.16, $p = 0.4$) (24, 25, 31, 34). The funnel plot was visually asymmetric. Assuming this suggests publication bias, trim-and-fill analyses revealed a revised SMD of –0.04 (–0.38 to 0.29).

Sensitivity analysis including data from seven recently published articles did not appreciably change results for time and process skills, but for behavior process the revised SMD (adding one new study) was slightly lower (0.31 [-0.36 to 0.98]) (Appendix Table 1, Supplemental Digital Content 2, http://links.lww.com/CCM/A751).

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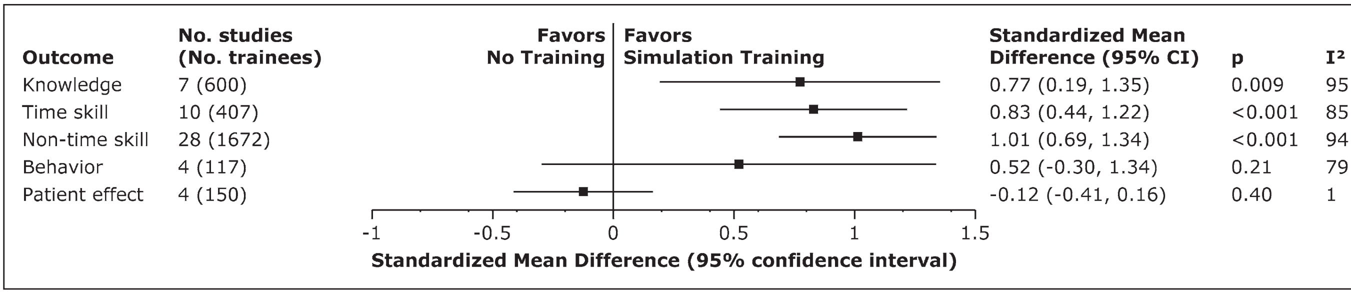

Figure 2. Outcomes of studies comparing simulation education with no intervention. The first column lists outcomes (knowledge, time skill, nontime skill, behavior, and patient effect), whereas the second column lists the number of studies and trainees contributing data to each analysis. The forest plot demonstrates point estimate of standardized mean difference (SMD; *black box*) surrounded by 95% CI (*line*). Positive SMDs favor the simulation intervention. *p* values reflect comparison of the estimated effect versus no effect. All SMDs reported represent a meta-analysis of pooled effect.

Synthesis: Comparison With Nonsimulation Instruction

A total of 10 studies compared simulation training with nonsimulation instruction, such as OR ($n = 3$) (28, 35, 36), self-study ($n = 1$) (37), video ($n = 3$) (26, 38, 39), and lecture/discussion ($n = 3$) (21, 40, 41). The pooled results of these studies are shown in **Figure 4**. Most analyses demonstrated an association between simulation training and improved outcomes; this association was moderate for satisfaction 0.54 (0.37–0.71, $n = 2$ studies) and nontime skills 0.64 (0.12–1.16, $n = 5$) and large for behaviors in practice 0.85 (0.01–1.68, $n = 1$) and patient outcomes 0.86 (0.12–1.59, $n = 3$). Neither knowledge ($n = 4$) nor time skills ($n = 1$) outcomes demonstrated a statistically significant difference.

Synthesis: Comparison of Simulation Versus Simulation Training

Twenty-nine studies compared simulation versus alternate simulation intervention. These studies offer insight to assist educators in optimizing curricular design and retention of skills.

Choice of Educational Model. Thirteen studies compared one type of simulation model with another. In these comparisons,

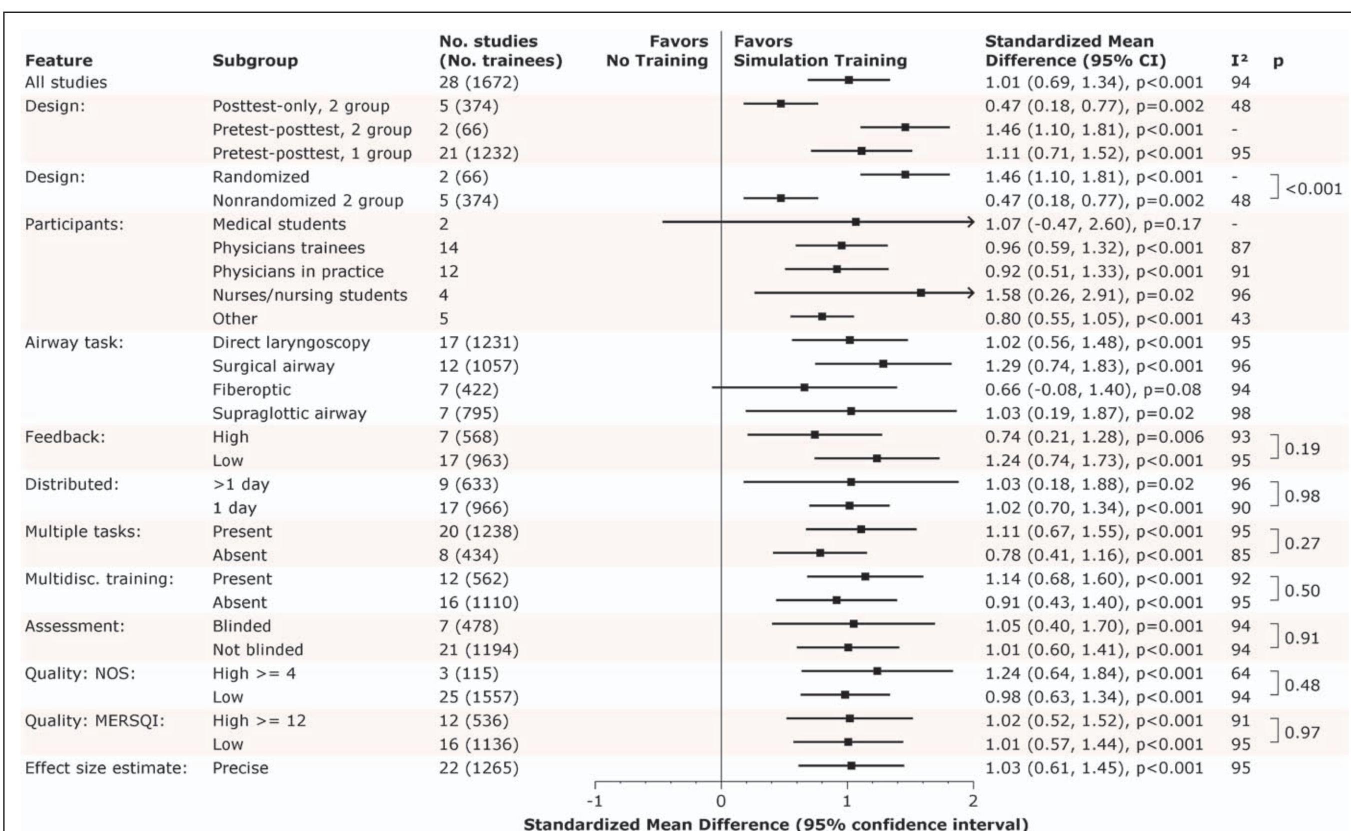

Figure 3. Subgroup analysis of skill outcomes for the studies comparing simulation with no intervention (28 studies total). Positive standardized mean differences (*black box*) favor the simulation intervention. *p* values reflect statistical tests exploring the differential effect of simulation training (i.e., interaction) for study subgroups. Participant and task groupings are not mutually exclusive, and thus, no statistical comparison is made, and the number of trainees is not reported. Some features could not be discerned for all studies; hence, some numbers do not add to 28. Multidisc. training = multidisciplinary training, NOS = Newcastle-Ottawa Scale, MERSQI = Medical Education Research Study Quality Instrument.

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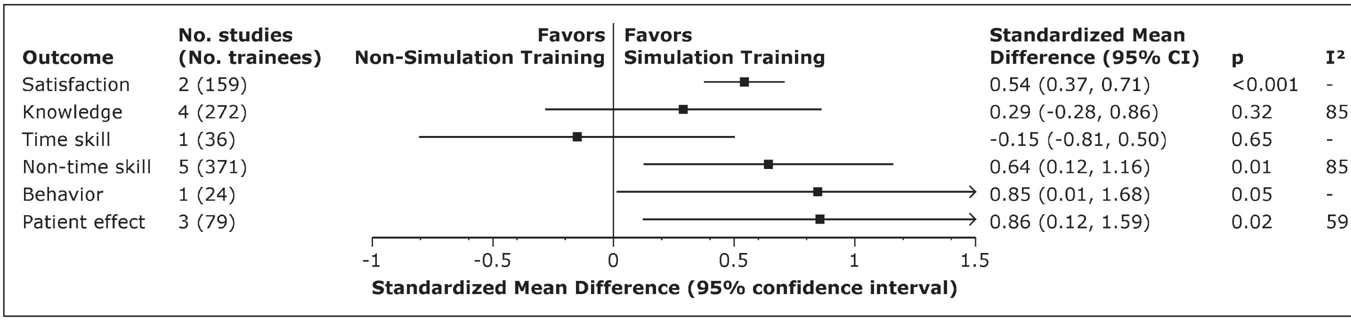

Figure 4. Outcomes of studies comparing simulation education with nonsimulation intervention. See Figure 2 for explanatory notes. Standardized mean differences (SMDs; *black box*) for those outcomes listing more than two included studies are pooled effects by meta-analysis (satisfaction, knowledge, nontime skill, and patient effect). Others represent the point estimate and CI reported in a single study. Positive SMDs favor simulation training, whereas negative values favor the nonsimulation intervention.

learners reported higher satisfaction with biologic (animal and cadaver) models over synthetic models, but data for skill, behavior, or patient outcomes did not substantiate this preference. Four studies compared animal with manikin models. Two studies (30, 42) explored outcomes of time skills, nontime skills, and patient effects, with inconsistent results (**Fig. 5*A***). Meta-analysis of three studies reporting learner satisfaction favored the animal model 0.70 (0.33–1.07) (42–44).

Four studies examined use of cadaver models (29, 30, 33, 45) (**Fig. 5*B***). Three studies compared cadaver versus manikin-based training using outcomes (one study each) of satisfaction, nontime skills, and patient effects, with inconsistent results (Fig. 5*B*) (29, 30, 45). In the fourth study, outcomes improved when HPSs were added to cadaver-based training (33).

Synthetic simulators vary dramatically in their ability to interact with the user and mimic physiology (8). Five studies compared synthetic simulator technology using a high sophistication model versus a low sophistication model (e.g., HPS vs corrugated tubing for cricothyrotomy, or manikin with built-in sensors vs no-sensor manikin for DL) and found no significant association with nontime skill 0.05 (–0.38 to 0.47) or time skill 0.34 (–0.31 to 0.98) outcomes (**Fig. 5*C***) (20, 23, 46–48).

Studies also examined the effects of blending simulation training with encounters with actual or standardized patients. Two studies compared OR plus simulation training to simulation training alone and found no difference in measured outcomes (27, 49). Two studies incorporated standardized patients to assist with the realism of the scripted scenario but found no benefit (43, 50).

Other Curricular Innovations Studied. Efforts to enhance learner engagement appeared to be associated with improved outcomes. For example, when the student directed the scenario (compared with observing) or needed to solve the task without assistance from an instructor (i.e., self-regulated learning, compared with instructor directed), the outcomes were better (51, 52). Similarly, learners who engaged in mental imagery and kinesiology (practice with surrogate tools) improved cricothyrotomy skills compared with standard Advanced Trauma Life Support training (53).

Skill Retention. Six studies focused on how to improve skill retention but were too dissimilar for meta-analysis (32, 39, 52, 54–56). In initial course design, self-regulated learning

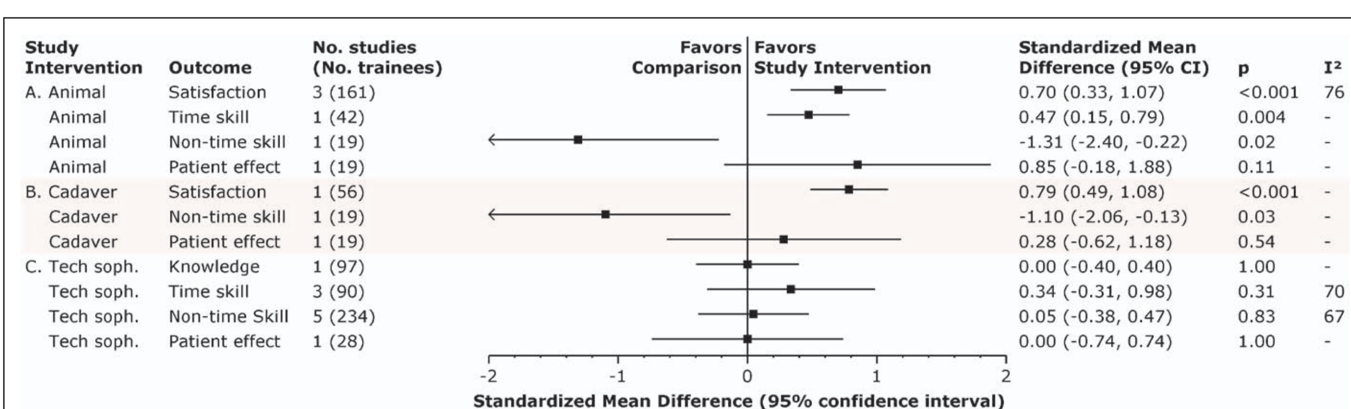

Figure 5. Outcomes of studies comparing alternate simulation models. The first column lists study intervention model type: A, animal model versus manikin (four distinct studies); B, cadaver model versus manikin (three distinct studies); and C, higher technical sophistication (Tech soph.) versus lower sophistication (five distinct studies). Second column lists the outcome, and the third column lists the number of studies (number of trainees) represented in each analysis. Standardized mean differences (SMDs; *black box*) for those outcomes listing more than two included studies are pooled effects by meta-analysis. Others represent the point estimate and CI reported in a single study. Positive SMDs favor the study intervention listed in the first column; negative values favor the comparison intervention (i.e., manikin for animal and cadaver, less technologically sophisticated for Tech soph.).

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improved skill retention for DL (compared with instructor-directed training) (52). However, a so-called four-stage curriculum (demonstration, formulation, deconstruction, and performance) compared with a two-stage model (deconstruction and performance) showed no difference in skill retention (56). Several interventions subsequent to the initial course were associated with improved skill retention, including refresher courses with practice, self-directed practice, and periodic evaluation with feedback and ongoing practice (32, 39, 54, 55).

DISCUSSION

Simulation for airway management training is associated with improved outcomes compared with no intervention and nonsimulation intervention. This general finding held true for specific training tasks, including surgical airway, DL, FOI, and supraglottic airway placement. In addition, simulation was associated with increased satisfaction, nontime skill, behaviors, and patient effects compared with nonsimulation interventions.

In studies comparing two simulation interventions, learners' satisfaction was higher with biologic (animal and cadaver) compared with synthetic manikin models, but results were inconsistent for other learning outcomes. Interventions with enhanced learner engagement, such as self-regulated learning or learner-directed scenarios, improved outcomes compared with more passive learner roles. Skill retention over time was enhanced by providing opportunities for ongoing practice with or without periodic evaluation with feedback, refresher courses, and self-regulated learning. We found studies evaluating models of high versus low sophistication, OR practice in addition to simulation, and use of standardized patients, but study results do not permit firm conclusions.

Comparison With Previous Reviews

To the 10 eligible studies identified in an earlier systematic review of airway management (7), the present review contributes 66 additional studies, as well as a meta-analytic synthesis of study results. These results are consistent with prior meta-analyses examining the efficacy of medical simulation for healthcare professional education in general (4, 57) and in focused tasks (58, 59). Our review also builds on a previous review of simulation-based instructional design by investigating educational best practices specific to airway training (60).

Measurement of patient outcomes has been the subject of recent discussions (61) and systematic review (62). In the present review, direct patient outcomes were measured in 16 studies and patient-associated behaviors were measured in nine studies. The diversity of patient-related outcomes was limited and included procedural time, proficiency, success, or complications.

Limitations

Our study has limitations. We limited our focus to published studies of DL, FOI, supraglottic airway, and surgical airway and therefore excluded studies that involved training for other airway tasks (such as bag-valve mask). As with any systematic review, the quality of underlying studies constrains the strength of the conclusions. In this study, loss to follow-up and lack of blinding in outcome assessment may have introduced bias. Also, some educators may disagree with our decision to combine some airway tasks for meta-analysis, such as combining LMA with Combitube into "supraglottic." Although different procedures, we feel they are similar enough to warrant these categorizations for the purpose of meta-analysis. Finally, primary studies offered a limited spectrum of patient-related outcomes.

We found substantial inconsistency in meta-analysis, and subgroup analyses did little to explain this between-study heterogeneity. This likely represents the underlying diversity of learners, instructors, instructional and study designs, and outcomes present in the primary studies. However, in most cases, these differences reflected variation in the magnitude but not in the direction of the effect (i.e., nearly all simulation-based interventions found a benefit in comparison with no intervention). Finally, we did not explore the cost of training, although we did address this issue in a previous review (63).

CONCLUSIONS

Implications for Education

Educators face many choices when designing a curricula—whether to use lecture, video, web-based teaching, and/or simulation. Our findings have substantial implications for educators and researchers. First, educators designing airway education courses can be confident that simulation is effective in comparison with no intervention for most measured outcomes. It also appears to be more effective than nonsimulation education (e.g., video, lecture, self-study, and OR training) for many educational outcomes. Second, simulation was associated with higher learner satisfaction compared with nonsimulation interventions.

Educators designing simulation curricula face further choices, such as which model(s) to use, how to ensure learners retain the skills, and how to provide feedback. This review begins to answer such questions. Learner satisfaction increased with biologic models. Such preferences may be important in designing curriculum, although evidence is presently lacking with regard to the impact on other learning outcomes. Formal training in the OR in addition to simulation training was not associated with benefit. Although evidence is limited, this finding is of considerable practical import given the substantial commitment by OR personnel and potential safety risks incurred by such training. Addition of standardized patients to airway management training likewise does not appear to be beneficial. Finally, curricula that include course repetition, ongoing practice with or without evaluation with feedback, and use of self-regulated learning appear effective in airway management skill retention and should be incorporated for those requiring skills maintenance.

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Implications for Future Research

Existing evidence supports the use of simulation in comparison with no intervention and nonsimulation interventions. Data are limited with respect to the spectrum of patient-measured outcomes, and further work is necessary to determine how to effectively implement training with direct benefits to patient care (64). In addition, exploring which aspects may benefit from self-regulated learning merits further study as a means to decrease costs by efficiently using instructor time (65). Refresher courses appear beneficial, but we need further clarity on how many and for how long. The best way to determine these answers is via comparisons of effectiveness of different simulation methods. For example, some studies attempted to situate the training in an authentic clinical context as shaped by the script, the superficial appearance of the training device, or the surrounding environment, yet the actual influence of such context modifications remains unknown.

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