Mechanical Ventilation Training During Graduate Medical Education: Perspectives and Review of the Literature

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ABSTRACT

Background Management of mechanical ventilation (MV) is an important and complex aspect of caring for critically ill patients. Management strategies and technical operation of the ventilator are key skills for physicians in training, as lack of expertise can lead to substantial patient harm.

Objective We performed a narrative review of the literature describing MV education in graduate medical education (GME) and identified best practices for training and assessment methods.

Methods We searched MEDLINE, PubMed, and Google Scholar for English-language, peer-reviewed articles describing MV education and assessment. We included articles from 2000 through July 2018 pertaining to MV education or training in GME.

Results Fifteen articles met inclusion criteria. Studies related to MV training in anesthesiology, emergency medicine, general surgery, and internal medicine residency programs, as well as subspecialty training in critical care medicine, pediatric critical care medicine, and pulmonary and critical care medicine. Nearly half of trainees assessed were dissatisfied with their MV education. Six studies evaluated educational interventions, all employing simulation as an educational strategy, although there was considerable heterogeneity in content. Most outcomes were assessed with multiple-choice knowledge testing; only 2 studies evaluated the care of actual patients after an educational intervention.

Conclusions There is a paucity of information describing MV education in GME. The available literature demonstrates that trainees are generally dissatisfied with MV training. Best practices include establishing MV-specific learning objectives and incorporating simulation. Next research steps include developing competency standards and validity evidence for assessment tools that can be utilized across MV educational curricula.

Introduction

Mechanical ventilation (MV) is a life-saving intervention in respiratory failure; however, it is complex and requires critical thinking. When managed inappropriately it carries a risk of major harm. Education related to appropriate MV management is imperative for all physicians in training who are caring for critically ill patients, including those in the areas of anesthesiology, emergency medicine, general surgery, internal medicine, critical care medicine, pediatric critical care medicine, and pulmonary and critical care medicine.[1–6]

Even among practicing intensivists, who are expected to be experts, there is evidence of insufficient knowledge of MV.[7–11] Intensivists perform poorly in interpreting ventilator waveforms for patient-ventilator dyssynchrony[7] and are poorly adherent to low tidal volume ventilation strategies for adult and pediatric patients with acute respiratory distress syndrome (ARDS) despite evidence of clear benefit.[8–11]

Commonly, MV is managed by physicians without subspecialized training in critical care, and there is evidence of insufficient MV education for this group.[12] A recent survey revealed that only 56% of reporting hospital critical care units had intensivists present during daytime hours or available for urgent consultation.[13] Furthermore, 77% of surveyed hospitalists reported providing critical care services and 66% reported serving as primary physicians in the intensive care unit (ICU).[12] When hospitalists were primarily managing ICU patients, intensivists were responsible for all ventilator management in less than half of cases. In addition, 35% of nonacademic hospitalists and 24% of academic hospitalists reported being expected to practice beyond their scope of residency training, and 85% of hospitalists managing critically ill patients expressed a need for further training in MV.[12] Patient outcomes are also negatively affected, as MV is specifically associated with a longer length of stay in ICUs managed by nonintensivists.[14]

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These findings are particularly concerning given the expected upcoming intensivist shortage.[15] In the emergency department, less than half of patients with identified ARDS received low tidal volume ventilation.[16] For patients not meeting ARDS criteria initially, there is an association with inappropriate initial ventilator settings and the subsequent development of ARDS.[17] Graduating from an emergency medicine training program that emphasizes MV education, however, correlates with better test scores on objective assessment of MV knowledge, including knowledge of low tidal volume ventilation.[18]

Our aim was to review the literature to determine best practices related to MV education regarding curricular content and formats as well as learner assessment. In this narrative review, we describe the available literature regarding MV training across graduate medical education (GME) specialties, identify areas where further research is needed, and formulate a strategy for improving the educational environment.

Methods

We conducted a narrative review of the available evidence for GME training in MV. Our authorship group was formed through the American Thoracic Society Section on Medical Education as an interest group focused on MV education. The group has diverse experience and includes pulmonary and critical medicine fellows in training, fellowship program directors, and division chiefs. We represent 8 institutions with broad geographic variability, including an international representative. When comparing our own institutional experiences, there was considerable variability in curricula, methods of instruction, and assessments being performed.

Two authors (J.M.K. and N.S.) searched MEDLINE, PubMed, and Google Scholar from the year 2000 through July 2018 using the following key words: mechanical ventilation education, mechanical ventilation training, graduate medical education, housestaff, resident, and fellow. No additional publications were identified after reviewing the references from identified articles. Studies were included if they were published in English-language, peer-reviewed journals and the abstracts described instruction, assessment, or opinions pertaining to MV in GME. Articles were excluded if they focused on non-GME learning groups or if no description of educational intervention or assessment was included. The full text of each article was reviewed by the coauthors to confirm inclusion.

The articles reviewed had considerable variability and heterogeneity in populations, methods, and analyses. The results were not amenable to traditional meta-analysis.[19] We synthesized the available literature using a narrative review approach involving critical evaluation of individual articles and their results.[20,21] We then identified the key points of the literature and generated consensus themes by discussion. After a preliminary review of included articles, the authors used a consensus approach to categorize studies: surveys of residents, fellows, or program directors regarding self-perceived MV skills and needs; articles describing objective assessments of MV education; articles defining ideal learning objectives for MV education; and studies implementing educational interventions to improve MV education.

Results

The literature search yielded 76 articles, of which 15 met the inclusion criteria. The excluded articles lacked educational interventions or assessments or did not pertain to the GME population. The search results are summarized in the TABLE.

Target Audience

The included publications represented resident and fellow learners, with specialty representation from anesthesiology, emergency medicine, general surgery, and internal medicine, as well as subspecialty training in critical care medicine, pediatric critical care medicine, and pulmonary and critical care medicine.

The majority of the MV educational data pertains to residents (FIGURE 1). One study was not specialty-specific. No studies pertained to pediatrics or family medicine residents and MV education.

Surveys Regarding Adequacy of MV Training

Four articles reported survey responses regarding experience with MV education from physician trainees and program directors.[22–25] Surveys asked about satisfaction or comfort level with the current training environment. Two studies reported good response rates of 70% or higher,[22,25] 1 had a poor response rate of 23%,[23] and 1 did not provide response rate information.[24] No studies included validity evidence for survey development.

The largest study, published in 2003, surveyed 259 graduating internal medicine residents, and found that nearly half were dissatisfied with their training in MV and perceived their knowledge to be close to minimum standards.[22] The disparity between resident and program director perceptions was noteworthy: 70% of internal medicine program directors indicated that they were satisfied with their program's MV instruction. Findings for pulmonary and critical care medicine and critical care medicine fellows were

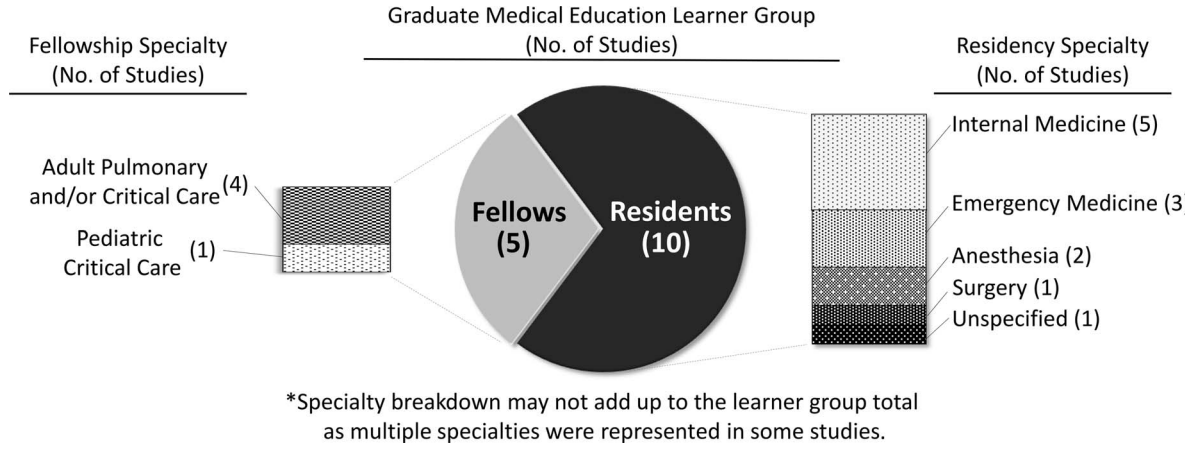

FIGURE 1
Target Learner Groups From Studies of Mechanical Ventilation Training

similar: 50% reported satisfaction with their education in MV in the 2008 study evaluating fellow satisfaction, though the response rate was very low.[23]

In a 2017 study of internal medicine residents in Brazil, nearly 30% of third-year residents said they would fear for patient safety if their patients required MV, and only 52% thought they would be able to safely manage a ventilated patient with significant airflow obstruction.[24] In a 2015 study, only 53% of emergency medicine residents reported feeling comfortable caring for mechanically ventilated patients despite having frequent contact with ventilated patients.[25] In the study, 77% of residents reported having 3 hours or less of MV education in the past year. We found no data pertaining to satisfaction with MV education or comfort with MV management in anesthesia, surgical, or pediatric GME programs.

Objective Assessment of MV Education

Two studies evaluated current trainee knowledge in MV.[22,24] The largest and most rigorous was the 2003 survey study of internal medicine residents.[22] Knowledge of respiratory physiology and MV management was evaluated among 259 graduating internal medicine residents using 19 case-based multiple-choice questions. Response rate was satisfactory at 74%. Residents scored above 70% on questions related to the topics of noninvasive ventilation, measurement of auto-positive end-expiratory pressure (auto-PEEP), and diagnosing tension pneumothorax. The lowest scores were seen with management of ARDS, hypoxemia, and ventilator weaning, which are fundamental tenets of MV management. Only 52% of respondents applied the correct tidal volume in the case study of a patient with ARDS. In the 2017 study of Brazilian internal medicine residents, there was overall poor performance on knowledge testing.[24] For example, 59% of residents inappropriately indicated that they would start MV based on a patient's actual weight rather than predicted body weight. This study was of low quality, however, and lacked a reported response rate, validity assessment, or further details of the assessment tool.

Development of Assessment Tools in MV Education

Two studies described the development and performance characteristics of knowledge assessment tools in MV education.[26,27] A 2016 study involved a 9-question multiple-choice assessment for emergency medicine residents.[26] The questions were developed by expert consensus, pretested and piloted, then given to residents with a reasonable 69% response rate. The study reported adequate internal reliability and an appropriate mix of item difficulty, suggesting that this assessment tool was sufficiently rigorous for evaluating emergency medicine residents. A study from 2014 evaluated a 35-item knowledge assessment tool of MV knowledge in pediatric critical care medicine fellows that had robust content validity, construct validity, internal consistency, and reliability metrics.[27] Experts performed best on the assessment tool, with a mean score of 75%, compared with 59% and 35% in the advanced and novice groups, respectively. The authors described this as the first example of a knowledge assessment tool in MV with validity evidence and suggested that it can be utilized to assess competency and identify knowledge gaps in MV training for pediatric critical care medicine fellows.

Learning Objectives

Learning objectives are important to establish for complex learning tasks, including MV training.

TABLE
Summary of Studies in Mechanical Ventilation Training During Graduate Medical Education

Category	Article	Learners	Description
Surveys of trainees and program directors regarding adequacy of MV training	Cox et al,[22] 2003	Senior IM residents	▪ Design: survey items developed by a panel of 8 intensivists ▪ Responses: ○ 259 of 347 residents responded (75%) ○ 29 of 31 program directors responded (94%) ▪ Findings: ○ 46% of graduating IM residents reported satisfaction with MV training ○ 70% of IM program directors reported satisfaction with MV instruction ○ Resident training satisfaction correlated strongly with: ▪ Program use of MV-specific learning objectives[a] ▪ Perceived adequacy of ventilator skills[a] ▪ Belief that time for instruction was adequate[a] ○ Resident training satisfaction did not correlate with: ▪ Program director satisfaction or confidence in resident skill level ▪ Number of attending physicians
	Brescia et al,[23] 2008	PCCM and CCM fellows	▪ Design: survey of fellowship education in MV ▪ Reponses: 331 of 1440 fellows responded (23%) ▪ Findings: ○ 50% of fellows reported satisfaction with MV education ○ Fellow satisfaction strongly correlated with: ▪ Presence of formal MV educational activities[a] ▪ Confidence with technical management of the ventilator[a] ▪ Active presence of respiratory therapists[a]
	Tallo et al,[24] 2017	IM residents in Brazil	▪ Design: survey evaluation of self-perception of MV knowledge in Brazil ▪ Reponses: ○ 231 residents were surveyed, of which 32 were third-year residents ○ Response rate not provided ▪ Findings: ○ 29% of third-year residents would fear for patient safety if MV were required ○ 52% of third-year residents felt able to safely manage a ventilated patient with significant airflow obstruction ○ 22% of third-year residents felt able to ventilate a patient with acute respiratory distress syndrome
	Wilcox et al,[25] 2015	EM residents	▪ Design: survey evaluation of EM residents' self-perception of MV training ▪ Responses: 218 of 312 residents responded (70%) ▪ Findings: ○ 53% reported feeling comfortable caring for mechanically ventilated patients ○ 64% reported caring for 4 or more ventilated patients per month in the emergency department ○ 77% reported having 4 hours or less of MV education in the past year

TABLE
Summary of Studies in Mechanical Ventilation Training During Graduate Medical Education (continued)

Category	Article	Learners	Description
Objective assessment of the current state of MV education	Cox et al,[22] 2003	Senior IM residents	▪ Design: 19 case-based multiple-choice questions about respiratory physiology and MV management delivered to IM residents via online survey ▪ Reponses: 259 of 347 residents responded (75%) ▪ Validity assessment: ○ Content validity determined by expert review ○ Criterion validity tested with empirical association with duration of training[a] ▪ Findings among graduating IM residents: ○ 52% applied the correct tidal volume for ARDS ○ 56% used PEEP appropriately for hypoxemia ○ 62% identified patient capable of entering weaning trial ○ 65% managed auto-PEEP correctly ○ 73% correctly identified candidates for noninvasive mechanical ventilation ○ 73% identified the correct method to measure auto-PEEP ○ 86% correctly diagnosed tension pneumothorax ○ 93% correctly diagnosed the presence of auto-PEEP
	Tallo et al,[24] 2017	IM residents	▪ Design: 56-item questionnaire about MV management delivered to IM residents in Brazil ▪ Responses: ○ 231 residents were surveyed, of which 32 were third-year residents ○ Response rate not provided ▪ Validity assessment: not provided ▪ Findings among graduating IM residents: ○ Correct responses: 17% for students, 21% for first-year residents, 31% for second-year residents, 45% for third-year residents, 22% for practicing EM physicians ○ Statistical analysis not provided ○ 59% of IM residents would incorrectly initiate MV based on a patient's actual weight (rather than predicted body weight) ○ More third-year residents felt secure in knowledge of MV (71%) compared with first-year residents (15%),[a] second-year residents (36%),[a] and practicing EM attendings (35%)[a]

TABLE
Summary of Studies in Mechanical Ventilation Training During Graduate Medical Education (continued)

Category	Article	Learners	Description
Development of assessment tools in MV education	Richards et al,[26] 2016	EM residents	▪ Design: 9-item MV knowledge assessment tool delivered to EM residents to study its psychometric and performance properties ▪ Responses: 214 of 312 residents responded (69%) ▪ Validity assessment: ○ The tool was pretested and piloted before implementation ○ Moderate reliability (Cronbach's alpha and Spearman-Brown coefficients of 0.6293 and 0.6437, respectively)
	O'Boyle et al,[27] 2014	Pediatric CCM fellows	▪ Design: 35-item multiple-choice test of MV management in severe asthma and ARDS assessed for use with pediatric critical care medicine trainees ▪ Validity assessment: ○ Content validity supported by review of literature, expert panel review, and pilot testing ○ Construct validity and internal consistency supported by administering the test to 3 different levels of experience in pediatric MV ▪ Findings: ○ The novice group (residents) scored 34.6%[a] ○ Advanced group (fellows) scored 59.4%[a] ○ Expert group (faculty) scored 74.8%[a] ○ Excellent reliability (reliability coefficient 0.89)
Define learning objectives for MV education	Goligher et al,[28] 2012	IM and anesthesia residents	▪ Design: MV-specific learning objectives developed by panel of 10 content experts, 3 resident training directors, and 1 medical education expert through Delphi process ▪ Findings: ○ 56 objectives included with $\geq$70% agreement ○ Included domains: respiratory physiology, lung protective ventilation, and weaning and withdrawing MV
	Dorman et al,[29] 2004	Residents and fellows	▪ Design: panel assembled by American College of Critical Care Medicine identified MV management principles for residents and fellows ▪ Findings: ○ Resident learning objective domains: invasive device, sedation, and analgesia management ○ Fellow learning objective domains: initiating, managing, and weaning patients from MV with a variety of techniques and ventilators
	O'Boyle et al,[27] 2014	Pediatric CCM fellows	▪ Design: 10 learning objectives were developed by literature review and expert opinion consensus ▪ Findings: learning objective domains included knowledge of ventilation modes, impact on physiologic parameters, and MV management principles relevant to pediatric MV

TABLE
Summary of Studies in Mechanical Ventilation Training During Graduate Medical Education (continued)

Category	Article	Learners	Description
Educational intervention	Schroedl et al,[30] 2012	IM residents (n = 60)	▪ Overview: randomized trial demonstrating that simulation-based training is superior to traditional training for bedside skills in MV management for first-year IM residents ▪ Intervention: 4-hour MV simulation curriculum before medical ICU rotation ▪ Assessment: ○ 14-item checklist for bedside skills assessment while caring for actual patients ○ Created with modified Delphi approach and piloted preintervention ○ Completed at the end of the medical ICU rotation by unblinded examiners ○ Topics: respiratory mechanics, ventilator settings, circulatory parameters ▪ Findings: ○ Simulator-trained residents scored higher than traditionally trained residents (83% versus 75%, respectively)[a] ○ No difference in self-reported confidence ○ High interrater reliability (κ coefficient 0.95)
	Singer et al,[31] 2013	IM residents (n = 40)	▪ Overview: simulation-trained first-year IM residents outperformed traditionally trained third-year IM residents on bedside skills assessment in MV management ▪ Intervention: 4-hour MV simulation curriculum delivered at the beginning of residency ▪ Assessment: ○ 20-item checklist for bedside skills assessment while caring for actual patient ○ Augmented from prior publication (Schroedl et al, 2012) ○ Completed at the end of the medical ICU rotation by unblinded examiners ▪ Findings: ○ Simulator-trained first-year residents scored higher than traditionally trained third-year residents (91% versus 81%, respectively)[a] ○ High interrater reliability (κ coefficient 0.98)
	Yee et al,[32] 2016	EM and surgery residents (n = 17)	▪ Overview: Simulation-trained residents performed better on knowledge and skills evaluation during simulated patient cases ▪ Intervention: 3-day MV simulation curriculum for first-year residents ▪ Assessment: ○ 20-item multiple-choice test and critical action checklist ○ Conducted preintervention and 10 days postintervention ○ No validity evaluation provided ▪ Findings: ○ Simulation training improved knowledge scores from a mean of 40% to 67%[a] ○ Critical action checklist scores during the simulation scenarios were significantly higher postintervention for ARDS and mucus plugging cases[a] but not significant for pneumothorax

TABLE
Summary of Studies in Mechanical Ventilation Training During Graduate Medical Education (continued)

Category	Article	Learners	Description
Educational intervention	Spadaro et al,[33] 2017	Anesthesia residents (n = 50)	▪ Overview: mannequin-based MV simulation training improved global rating and key action scores more than computer-based virtual MV simulation training ▪ Intervention: randomized trial with 1 group receiving mannequin-based simulation training and 1 group receiving computer-based virtual simulation training ▪ Assessment: ○ Key actions checklist and global rating scale performed by blinded raters during in situ mannequin-based simulation scenarios ○ Conducted 3 weeks after training ▪ Findings: ○ The mannequin-based simulation group had higher global rating and key action scores than the computer-based training group (3.0 versus 2.0, respectively, and 82% versus 71%, respectively)[a] ○ High interrater reliability (Cronbach's alpha 0.73) ○ Higher satisfaction scores in the mannequin-based training group[a]
	Mireles-Cabodevila et al,[34] 2015	PCCM or CCM fellows (n = 36)	▪ Overview: an online course followed by hands-on simulation training in MV improved knowledge scores of fellows ▪ Intervention: ○ Online interactive course followed by 8-hour simulation training ○ 6 skill stations and 4 mannequin-based case scenarios ▪ Assessment: ○ Multiple-choice questions administered immediately pre- and postintervention ○ No validity assessment provided ▪ Findings: ○ Online modules improved knowledge scores[a] ○ Hands-on simulation increased knowledge scores further (mean increase of 2.96)[a] ○ Fellow-reported satisfaction was high
	Ramar et al,[35] 2016	PCCM or CCM fellows (n = 13)	▪ Overview: both hands-on training and self-directed learning improved MV knowledge ▪ Intervention: ○ First-year fellows were exposed to self-directed learning (articles, papers, videos explaining MV modes and waveforms) or hands-on tutoring using a lung simulator ○ Simulation performed over 2 half days ▪ Assessment: ○ 25-item multiple-choice test performed 1-week postintervention ○ No validity evidence provided ▪ Findings: ○ Posttest scores improved in both groups but were not significantly different from each other (75% versus 77%, respectively) ○ Satisfaction scores were higher in the hands-on training group (4.5 versus 3.1)[a]

Abbreviations: MV, mechanical ventilation; IM, internal medicine; PCCM, pulmonary and critical care medicine; CCM, critical care medicine; EM, emergency medicine; ARDS, acute respiratory distress syndrome; PEEP, positive end-expiratory pressure; ICU, intensive care unit.

[a] $P < .05$ for all comparisons.

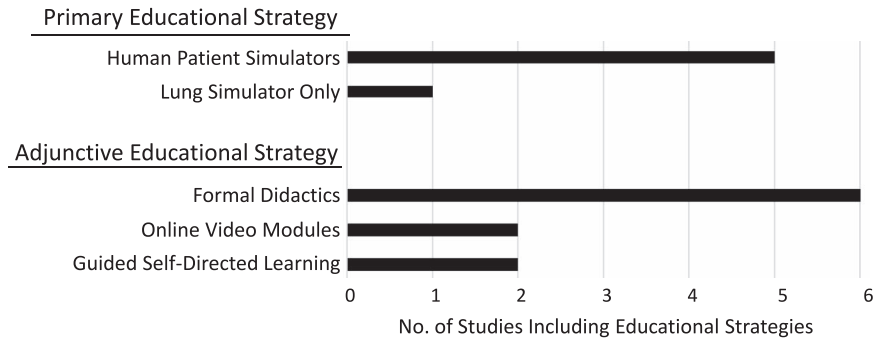

FIGURE 2
Educational Strategies Employed in Published Studies of Mechanical Ventilation Training

Reported discontent with MV education was, in fact, noted to be highest among training programs that lacked learning objectives specific to MV.[22] Three studies sought to define learning objectives for MV education.[27–29] In the largest study, from 2012, a panel of 14 content experts, educators, and trainees from internal medicine and anesthesia specialties generated learning objectives with high agreement through a Delphi consensus process.[28] Though the report included objectives pertaining to respiratory physiology, modes of ventilation, use of noninvasive ventilation, monitoring, complications of MV, and appropriate removal of MV, it did not describe any formal assessment using the defined learning objectives. In 2004, an expert panel associated with the American College of Critical Care Medicine identified both the management of invasive devices and the understanding of sedation and analgesia principles as core clinical topics with which all residents should demonstrate knowledge and technical skills. More advanced ventilation techniques, including use of multiple ventilator types, were identified as fellow-level objectives.[29] No information was provided, however, as to the process of developing the objectives. The 2014 study of MV education in pediatric critical care medicine sought to identify learning objectives for management of pediatric MV in addition to the published assessment tool.[27] The 10 objectives developed by consensus of the authors addressed knowledge of ventilation modes and their impact on physiological parameters.

Educational Interventions

Six studies, published between 2012 and 2017, evaluated educational interventions related to MV (FIGURE 2).[30–35] All studies incorporated hands-on simulation training, and all assessments were limited to pretesting and immediate postintervention testing. No studies assessed skill or knowledge retention beyond 1 month. All studies included outcomes related to change in learning or knowledge, in addition to self-reported satisfaction or reaction of participants.[36] Four studies included assessment of MV management skills using a performance checklist,[30–33] and 2 studies included only evaluation of trainee knowledge through multiple-choice questions.[34,35] Two studies uniquely showed change in trainee performance scores during evaluation with actual patients after simulation-based educational interventions.[30,31] These 2 studies also most extensively described the validity evidence for the assessment tools. Overall satisfaction was highest for simulation-based interventions compared with other methodologies across studies. No studies evaluated patient-level outcomes, such as ventilator free days, ICU length of stay, or mortality.

Educational content varied considerably across studies, including such topics as respiratory physiology, ventilator setup and waveform analysis, case-based management of ARDS, bronchospasm, patient-ventilator dyssynchrony, chronic obstructive pulmonary disease, and severe hypoxemia (FIGURE 3).

Across all studies, the average time spent on an educational intervention for MV was 7 ± 3 hours, and the average number of learners was 37 ± 17 (FIGURE 4).

Discussion

Our narrative review of the literature demonstrated substantial heterogeneity within MV education. Learners in GME are generally dissatisfied with their training in MV[22–25] and perform suboptimally on objective testing of MV management knowledge.[22,24] There are indications that the lack of educational rigor translates to the clinical environment, with practicing physicians demonstrating variable adoption of best practices and evidence-based interventions and inadequately recognizing important complications of MV, including ventilator-induced lung injury, delayed MV liberation, and patient-ventilator dyssynchrony.[7–11,14,16,17,36]

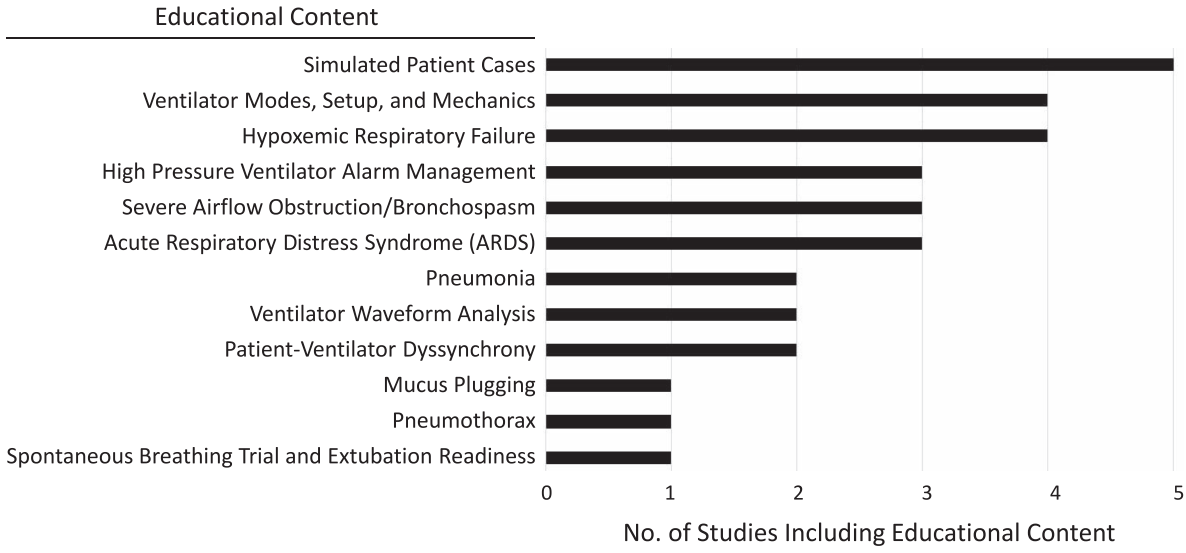

FIGURE 3
Educational Content Delivered in Published Studies of Mechanical Ventilation Training

While most organizations governing the education of trainees involved in the management of critically ill patients recognized that ventilator management is an educational priority,[2,4–6] surprisingly little is known regarding the ideal methods for instruction and assessment. Few studies have attempted to rigorously define learning objectives for MV education and develop validity evidence for evaluation tools to assess training, typically formulated through expert consensus.[26–28] Studies evaluating educational interventions in MV are generally low quality with poor evaluation of validity evidence, and only 2 studies have assessed postintervention trainee performance in caring for actual patients.[30,31]

Several best practices emerge from analysis of the available literature base. Every GME program where critically ill patients are managed should establish or adopt MV-specific learning objectives and incorporate simulation into training curricula. Simulation interventions, especially with case-based scenarios, generally improved MV knowledge and technical skills beyond other instructional methods and were highly rated by participants. The curriculum should also incorporate interprofessional collaboration with those directly involved in day-to-day management of MV, such as nurses or respiratory therapists. Once the curriculum is in place, there should be a framework to assess the curriculum over time and allow for retraining when new ventilators or technology are introduced.

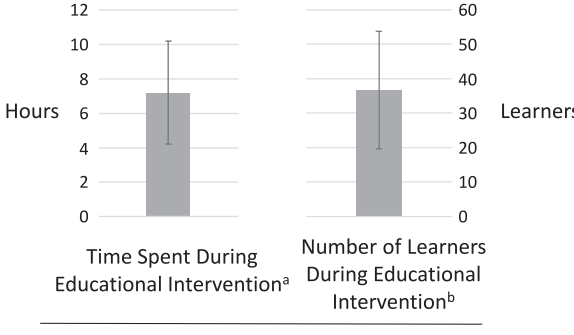

FIGURE 4
Educational Interventions in Published Studies of Mechanical Ventilation Training

[a] The average time spent was 7 ± 3 hours.

[b] The average number of learners was 37 ± 17.

Limitations of the review include a low number of studies pertaining to MV education and difficulty aggregating the available data given inconsistency in educational methods and assessments. In addition, most studies lacked validity evidence for assessments, and only 2 studies assessed outcomes at the patient level.

Future studies of MV education should focus on patient-level outcomes as much as possible, rather than improvement in satisfaction or knowledge scores alone. Given that these studies are logistically difficult, starting with simulated patient models is reasonable. Published MV curricula use a variety of methods and content, which is expected across multiple levels of trainee expertise, though minimum performance standards need to be established. While statistically significant improvements in postintervention performance scores are a start, we need to first define minimum performance scores and then assess whether residents and fellows are achieving them. High-quality, rigorously tested assessment tools

are needed, coupled with specialty-specific competencies.

Conclusion

Proficiency in MV management is an educational priority for physician trainees involved in critical care, yet they are generally dissatisfied with MV education and feel ill-prepared for ventilator management in clinical practice. Programs should have MV-specific learning objectives and incorporate simulation into MV training, although more work is needed to define specialty-specific competencies and develop assessment tools.

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