Reimagining Undergraduate Critical Care Medical Education

A Path for the Next Decade

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ABSTRACT

Foundational training in critical care medicine is an integral part of both undergraduate and graduate medical education. Yet, many medical school graduates enter residency underprepared to care for critically ill patients because of a lack of ubiquity of undergraduate critical care education and the heterogeneity of existing didactic and clinical experiences. This Perspective explores the importance of undergraduate critical care education, the current national and international landscape, innovative educational strategies and exemplar curricula, and recent advances in assessment that may better reflect learner-centered educational outcomes. As broad curricular reforms push medical education toward a more innovative, interactive, and collaborative future, now is the time to rethink and reimagine undergraduate critical care education.

Keywords:
andragogy; curriculum; competency-based education; entrustment

For four decades, a decennial persuasive call to strengthen and enhance undergraduate medical education (UME) in critical care emerges (1–3). More than a decade ago, Dr. Henry Fessler recommended establishing competencies for critical care, for outcomes-based curricula guided by such competencies and linked to student

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performance, and for educational research to identify pedagogical methods to maximize such outcomes (4). Since that time, there has been advancement toward establishing critical care competencies, as the Association of American Medical Colleges (AAMC) released Core Entrustable Professional Activities (CEPAs) describing fundamental proficiencies in critical care through CEPA 10. However, despite curricular reforms across the majority of medical schools and the global coronavirus disease (COVID-19) pandemic, exposure to critical care medicine during medical school remains limited, with the proportion of schools with required critical care experiences stagnant (5, 6). This leaves medical school graduates entering residency underprepared to care for a growing population of critically ill patients (7). Furthermore, there remains a relative paucity of assessments to measure performance-based learning outcomes. As existing research suggests undergraduate critical care curricula improve learner confidence and knowledge (8, 9), there will likely be an association of these experiences with improved learner performance in the clinical environment. However, the association between critical care curricula and improved clinical performance has not yet been demonstrated. To better prepare medical graduates in the care of critically ill patients, not only is expansion of undergraduate training experiences necessary but also it must accompany the implementation of a national curriculum and expansion of outcomes-based assessments to demonstrate impact on learner entrustment, performance, and patient outcomes. From this perspective, we review the importance of undergraduate critical care education, the current landscape, innovative educational strategies, exemplar curricula, and recent advances in assessment that guide our recommendations for improvement over the next decade.

IMPORTANCE OF UNDERGRADUATE CRITICAL CARE EDUCATION

The ability to recognize a patient requiring urgent or emergent care and initiate evaluation and management is the 10th of 13 CEPAs for graduating medical students defined by the AAMC (10). CEPA 10 has been rated the fourth most essential CEPA for medical students to perform on the first day of the intern year (11). Yet, in the review of CEPA pilot data from 10 medical schools in 2020, CEPA 10 was identified to have absent or underdeveloped curricula, few assessment methods, and, for those students assessed, a low proportion of learners deemed ready for entrustment (12). As the majority of medical school graduates will work in an intensive care unit (ICU) during their residency training, the expansion of meaningful, authentic learning experiences and assessments is needed for entrustment and adequate preparation. Six of the seven largest specialty training programs in the United States (internal medicine, family medicine, pediatrics, surgery, emergency medicine, and anesthesiology) require critical care training. As of 2022, residents in these six specialties comprised 64% of all currently practicing residents (13). Beyond the need to provide direct care in an ICU, every graduating medical student will encounter an acutely ill patient, with the requisite to initiate stabilizing care. In addition, as exemplified by the COVID-19 pandemic, many non–critical care–trained physicians were called on to provide care for critically ill patients, further emphasizing the need for foundational knowledge at an early stage of training as generalists, depending on the practice setting, need to maintain competency in these skills (14). In the postpandemic era, there is a growing intensivist shortage worldwide that will become increasingly more important as the population ages and requires a proportionally greater amount of critical care (15, 16). Encouraging interested students to pursue careers that involve critical care medicine, whether that be through internal medicine, anesthesiology, emergency medicine, surgery, pediatrics, or neurology, will be vital to maintaining the intensivist workforce.

Benefits of early training in critical care during medical school include lessened anxiety and improved learner confidence, greater knowledge, and increased interest in the specialty field (8, 17, 18). A critical care curriculum integrated within a third-year internal medicine clerkship at a Veterans Affairs Medical Center with an open-ICU staffing model improved the student clerkship experience, increased student comfort managing critically ill patients, and increased the likelihood of a student pursuing a critical care experience during the fourth year of medical school (9). Greater exposure to intensive clinical courses during the fourth year of medical school, defined as subinternships, surgical clerkships, emergency medicine rotations, and ICU rotations, was associated with improved clinical performance during internship (19). Resultantly, critical care rotations are commonly identified as recommended experiences by program directors (20).

THE CURRENT LANDSCAPE OF UNDERGRADUATE CRITICAL CARE EDUCATION

Less than half of American medical schools require dedicated critical care rotations. During the 2013–2014 academic year, only 32% of U.S. medical schools required a critical care clerkship. After the AAMC published the 13 CEPAs for entering residency in May 2014, the number of medical schools requiring a critical care clerkship increased slightly to 39% during the next academic year (2014–2015). Since that time, the percentage of medical schools requiring a critical care clerkship has not significantly changed (6). The average duration of a required critical care rotation is 3–4 weeks (21). There are no published data regarding the duration of optional or elective ICU experiences at U.S. medical schools.

Internationally, there is variability in critical care training experiences. A 2009 survey found that 56% of tertiary referral teaching hospitals in Australia and New Zealand offered a mandatory intensive care teaching program. Twenty-two percent of teaching hospitals offered an optional program. The majority of intensive care teaching programs were less than 1 week in duration (22). A 2013–2014 survey in Ireland found that although five of six Irish medical schools required intensive care medicine education, the majority of placements (81%) lasted 5 days or less (23). A 2020 cross-sectional survey of final-year medical students at three Saudi medical schools found that 75% of students reported less than 1 day of ICU experience, 80% of students reported less than 5 hours of formal ICU teaching, and only 21% of students reported adequate training in medical school in the identification of critically ill patients (24).

Although there is significant heterogeneity in current undergraduate critical care training experiences, expert consensus and recommendations for content exist. A recent survey of critical care subinternship directors demonstrated variability in the curricular learning objectives, the use of didactic and simulation-based education, the type of assessment modalities, and a unified desire for standardized curricular resources (25). As an initial step, a critical care content outline has been established. Using Delphi consensus, an expert panel with members from the fields of anesthesiology, emergency medicine, internal medicine, obstetrics and gynecology, pediatrics, and surgery identified 19 highly recommended topics that interns should have "prior exposure" or could "manage under supervision" on the first day of internship across five broad categories: the neurologic system, the respiratory system, the circulatory system, the renal/electrolyte system, and supplemental ICU topics. Highly recommended topics within these categories included shock, respiratory failure, mechanical ventilation, acute renal failure, and invasive monitoring (26). Based on this expert consensus document, core critical care content and competencies that medical students should possess by graduation and matriculation to residency have been established (26).

Limited undergraduate critical care education impacts whether interns possess these desired competencies before the start of residency training. Self-assessed competency among incoming internal medicine interns at a large academic medical center fell below the Delphi consensus recommendation for 60% of recommended topics. This "competency gap" was exacerbated for interns without prior critical care experience, who were below consensus recommendation for 90% of recommended topics (27). Expanding undergraduate critical care education would provide roles, opportunities, and experiences for students to build entrustment, making CEPA 10, previously described as aspirational (28), achievable.

EXEMPLAR CRITICAL CARE CURRICULA AND EDUCATIONAL STRATEGIES

As an undergraduate critical care content outline has been described, further work is needed to build on the defined consensus content to map a curriculum. The curriculum should incorporate competency-based goals and objectives, integrate multidimensional educational strategies, spiral foundational physiology content, and supplement clinical learning experiences.

Existing curricula, either from entire courses or from specific skill sessions, can guide and inform this approach. The Fundamental Critical Care Support (FCCS) course offered by the Society of Critical Care Medicine provides a foundational curriculum for nonintensivists to manage critically ill patients, with emphasis on basic principles and multidisciplinary approaches (29). The goals of FCCS align well to achieve the entrustment goals of medical students described by CEPA 10, and, as such, FCCS has been adapted and implemented internationally (30–32). The educational strategies of FCCS include didactics, hands-on skills, and simulation learning. Within UME and graduate medical education (GME), FCCS has been implemented to supplement the education of medical students and residents during clinical rotations (33). Undergraduate critical care courses implemented at single academic sites have similar educational frameworks, with goals of introducing basic principles of caring for critically ill patients and reinforcing physiologic and pathophysiologic concepts to complement clinical learning (9, 18, 34). The physiology inherent to critical care medicine affords a unique opportunity to bridge pre-clerkship curricular content with clinical education, such as using auto–positive end-expiratory pressure to reinforce the physiology of expiration and appropriate vasopressor selection in shock to revisit adrenoreceptor physiology (35, 36). In addition, the interprofessional dynamics of critical care lend themselves well to undergraduate education. A multifaceted sepsis curriculum consisting of didactics, case discussions, and simulation delivered to medicine, pharmacy, nursing, and nurse practitioner students improved knowledge, teamwork, and interprofessional communication at a large academic institution (37).

Simulation training provides a safe, controlled environment to acquire and advance knowledge and skills for the management of critically ill patients and is an essential educational strategy in undergraduate critical care education. Because medical students have fewer clinical opportunities to care for critically ill patients and are more likely to take on peripheral roles in the ICU, simulation is a valuable resource to build their entrustment (38, 39). Standardized simulation cases paired with asynchronous instructional videos have been demonstrated to improve medical student performance in CEPA 10 competencies and entrustment scores (40). In comparison to other educational interventions, simulation is more effective for skill acquisition but is often limited by cost, time and space limitations, and faculty expertise (41). Virtual reality simulation is an emerging technology that offers a less resource-intensive, lower-fidelity, but overall satisfactory provision of critical care education (42).

These curricular exemplars share similar structural principles, as there is a combination of didactic and case-based learning, skills workshops, simulation, and clinical learning experiences. These curricula exemplify how multifaceted instructional design integrates principles of educational science. Didactic sessions provide spaced practice (revisiting core topics with each session), retrieval practice (recalling information from prior sessions), and interleaving (mixing of related topics during an educational session) (43). Skills workshops allow the practice of psychomotor procedural skills. Simulation-based training reinforces the clinical application of didactic content and advances the degree of mastery. Students participating in a multifaceted critical care elective, comprising didactic and simulation-based learning paired with clinical experiences, demonstrated improved postcourse knowledge and increased comfort within the ICU compared with students who participated in a prior critical care elective with only clinical experiences, demonstrating that multidimensional pedagogical approaches can enhance learning (34).

RECOMMENDATIONS MOVING FORWARD

The goal of undergraduate critical care education should be to better prepare all medical graduates to recognize and care for critically ill patients. To do this requires the expansion of curricula and clinical learning experiences as well as the creation of entrustment assessments to measure the impact of educational interventions.

As content and desired competencies have been defined and exemplary educational strategies described, we recommend the creation of a national critical care curriculum and open-access compendium of educational resources to assist educators in designing and implementing multifaceted critical care experiences at their institutions. Integrating the existing literature, we summarize our recommendations for the fundamental curricular content, potential subtopics, competencies, and educational strategies in Table 1. With recognition of both the impacts and the costs of simulation, we recommend its

Table 1. Proposed structure and framework for an undergraduate medical education critical care curriculum

Content Organized by Organ System	Potential Subtopics	Learning Goals and Competencies	Educational Strategies
Neurologic system			
Altered mental status	• Toxic-metabolic encephalopathy • Encephalitis/meningitis • Stroke • Intracranial hemorrhage	• Recognize and differentiate causes of acute altered mental status	Didactic, case-based
ICU agitation, delirium, pain control	• Analgesic pharmacology • Sedative pharmacology • ICU delirium • Spontaneous awakening and spontaneous breathing trials	• Recognize and differentiate causes of ICU agitation and delirium • Select appropriate sedative and analgesic agents based on patient- and disease-specific factors	Didactic, case-based
Seizure/status epilepticus	• Diagnosis of status epilepticus • Antiepileptic pharmacology	• Recognize and differentiate causes • Initiate stabilizing therapies	Didactic, case-based
Respiratory system			
Respiratory failure	• Acute hypoxemic respiratory failure • Acute hypercapnic respiratory failure • Postoperative respiratory failure	• Recognize and differentiate causes of respiratory failure • Initiate stabilizing respiratory support therapies	Didactic, case-based, low- or high-fidelity simulation, AR, VR
Mechanical ventilation	• Control vs. support modes of ventilation • Volume control vs. pressure control modes of ventilation • Physiology of positive pressure ventilation	• Identify indications for invasive mechanical ventilation • Select initial ventilation settings • Assess respiratory mechanics, including peak and plateau pressures	Didactic, case-based, low- or high-fidelity simulation, AR, VR
Noninvasive mechanical ventilation	• Continuous positive airway pressure ventilation • Bilevel positive airway pressure ventilation	• Identify indications and contraindications for NIV • Determine initial NIV settings and monitoring plan	Didactic, case-based, low- or high-fidelity simulation, AR, VR
Bag-valve mask ventilation	• Indications • Technique	• Perform bag-valve mask ventilation	Low-fidelity simulation
Circulatory system			
Shock (anaphylactic, cardiogenic, hemorrhagic, septic)	• Volume resuscitation • Vasopressor pharmacology • Anaphylaxis • Heart failure with reduced or preserved ejection fracture • Gastrointestinal hemorrhage • Traumatic hemorrhage • Sepsis	• Recognize and differentiate shock states and causes • Initiate stabilizing therapies	Didactic, case-based, low- or high-fidelity simulation, AR, VR
Arrhythmias	• Bradyarrhythmias • Supraventricular tachyarrhythmias • Advanced cardiac life support	• Recognize and initiate appropriate diagnostic evaluation • Initiate stabilizing management	Didactic, case-based, low- or high-fidelity simulation, AR, VR

Table 1. *Continued.*

Content Organized by Organ System	Potential Subtopics	Learning Goals and Competencies	Educational Strategies
Renal and endocrine systems			
Acute renal failure	• Acute kidney injury • Intermittent hemodialysis • Continuous renal replacement therapy	• Recognize and differentiate causes • Identify urgent and emergent indications for renal replacement therapy	Didactic, case-based
Electrolyte abnormalities	• Hyperkalemia • Hypokalemia • Hypernatremia • Hyponatremia	• Recognize and initiate stabilizing therapies for severe electrolyte abnormalities	Didactic, case-based
Hypo/hyperglycemia	• Hypoglycemia • Diabetic ketoacidosis • Hyperosmolar hyperglycemic state	• Recognize and initiate stabilizing therapies for glycemic emergencies	Didactic, case-based
Supplemental ICU topics			
Blood gas interpretation	• Metabolic acidosis • Metabolic alkalosis • Respiratory acidosis • Respiratory alkalosis	• Recognize and differentiate causes of acid–base disturbances	Didactic, case-based
Interprofessional collaboration and communication	• Nursing • Pharmacy • Occupational therapy • Physical therapy • Dietitian/nutrition • Social work	• Identify roles and responsibilities of interprofessional team members • Apply evidence-based communication strategies with team members, patients, and families	Didactic, case-based, low- or high-fidelity simulation, AR, VR

Definition of abbreviations: AR = alternate reality; ICU = intensive care unit; NIV = noninvasive ventilation; VR = virtual reality.
Didactic educational strategies include lectures, asynchronous just-in-time videos, or modules. Case-based learning includes team-based or problem-based learning. High-fidelity simulation refers to experiential learning using manikin-based simulation, medical equipment, and role-playing actors. Low-fidelity simulation refers to experiential learning using some components of high-fidelity simulation to provide learner feedback on skills. AR refers to technology in which users interact with a computer-generated environment for learning purposes. VR refers to fully immersive interactive auditory and visual experiences. "Content Organized by Organ System" from previously published Delphi consensus critical care content outline (26).

use for curricular content that a student learner is either most likely to encounter independently or for content that naturally integrates multiple learning domains. We recommend that a critical care curriculum be implemented during the later phases of undergraduate medical education, for example during the latter half of the third year or during the fourth year of American medical training. By this time, students have learned foundational physiology concepts, spent time in non–critical care clinical environments, and practiced a broad range of clinical skills. The critical care rotation would, therefore, provide an opportunity to reinforce previously learned physiology and advance established clinical skills in an environment of higher acuity and complexity. Within this time frame, and using our proposed curricular framework, we recommend educators implement 2- to 4-week critical care rotations. For medical schools with access to specialty ICUs, the rotation experience could be tailored to the student's future career goals, if known. For example, students pursuing internal medicine would rotate through a medical ICU, and students pursuing general surgery or anesthesiology would rotate through a surgical or trauma ICU.

In addition to the creation of a national curriculum, increased undergraduate critical care learning experiences are needed. For this to come to fruition, stakeholders within UME and GME would likely need to see objective data showing a positive correlation between undergraduate critical care experiences and performance in the clinical environment. There is currently no published research assessing the relationship between clinical critical care experience in medical school and clinical competency, entrustment, and overall performance in critical care rotations during residency training.

Therefore, to better assess these relationships, we recommend developing workplace-based assessments that better capture trainee entrustment and clinical competence in the ICU. Workplace-based assessment is a form of competency assessment designed to evaluate the "real-world" performance of a trainee in a clinical setting. In workplace-based assessment, the evaluator is typically the trainee's direct supervisor (i.e., attending physician). Clinical entrustment references the degree to which a supervisor trusts the trainee to successfully complete a task or perform a procedure. Previously developed workplace-based entrustment tools, the Ottawa Clinic Assessment Tool (OCAT) and Chen Scale, distinguish degrees of entrustment of learners across five CEPAs (not including CEPA 10) (44). The OCAT was initially developed to assess resident entrustment and competence in the surgical clinic and subsequently found to be reliable for assessing residents in internal medicine clinic (45, 46). The modified Chen scale has been applied during simulation assessments of medical students so could similarly be studied in the clinical learning environment (40). Assessing validity evidence of the OCAT, or a similar assessment tool, for learners and trainees in the ICU is one potential avenue to improving outcomes-based assessments for future critical care curricula.

Finally, we recommend assessing the long-term relationship between undergraduate critical care experiences and career choice. Although current research suggests that students who participate in a critical care experience are more likely to choose a specialty that involves critical care medicine, there are currently no longitudinal data evaluating this relationship (9). With the current intensivist shortage expected to worsen in the coming decades, early exposure to critical care medicine may prove critical in attracting the next generation of trainees to the field.

CONCLUSIONS

Foundational training in critical care medicine is an integral part of both UME and GME. Yet, the percentage of medical schools requiring a critical care clerkship has been stagnant over the past decade, and the objective benefits of undergraduate critical care experiences remain largely unknown. As the landscape of medical education shifts toward a more innovative, interactive, and collaborative future, we believe that now is the time to rethink and reimagine undergraduate critical care education. This is best accomplished by creating a standardized subinternship curriculum that can be used to design innovative multifaceted experiences, increasing participation in those experiences and developing outcomes-based assessments to demonstrate impact on learner entrustment and performance and patient outcomes.

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