Circulation

AHA SCIENTIFIC STATEMENT

Evolution of Critical Care Cardiology: An Update on Structure, Care Delivery, Training, and Research Paradigms: A Scientific Statement From the American Heart Association

Endorsed by the American College of Cardiology

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ABSTRACT: Critical care cardiology refers to the practice focus of and subspecialty training for the comprehensive management of life-threatening cardiovascular diseases and comorbid conditions that require advanced critical care in an intensive care unit. The development of coronary care units is often credited for a dramatic decline in mortality rates after acute myocardial infarction throughout the 1960s. As the underlying patient population became progressively sicker, changes in organizational structure, staffing, care delivery, and training paradigms lagged. The coronary care unit gradually evolved from a focus on rapid resuscitation from ventricular arrhythmias in acute myocardial infarction into a comprehensive cardiac intensive care unit designed to care for the sickest patients with cardiovascular disease. Over the past decade, the cardiac intensive care unit has continued to transform with an aging population, increased clinical acuity, burgeoning cardiac and noncardiac comorbidities, technologic advances in cardiovascular interventions, and increased use of temporary mechanical circulatory support devices. Herein, we provide an update and contemporary expert perspective on the organizational structure, staffing, and care delivery in the cardiac intensive care unit; examine the challenges and opportunities present in the education and training of the next generation of physicians for critical care cardiology; and explore quality improvement initiatives and scientific investigation, including multicenter registry initiatives and randomized clinical trials, that may change clinical practice, care delivery, and the research landscape in this rapidly evolving discipline.

Key Words: AHA Scientific Statements ■ clinical competence ■ cardiology ■ coronary care units ■ critical care ■ intensive care units ■ quality of health care

Critical care cardiology (CCC) refers to the practice focus of and subspecialty training for the comprehensive management of life-threatening cardiovascular diseases and comorbid conditions that require advanced critical care in an intensive care unit (ICU).[1] In specialized centers, CCC is often practiced in cardiac ICUs (CICUs), which are specifically designed to care for such patients. The year 2023 marked the centennial anniversary of the first case series of 19 patients with acute myocardial infarction (MI) published in 1923. Dr Desmond Julian first articulated the concept of coronary care units (CCUs) to the British Thoracic Society in 1961.[2] The development of CCUs is often credited for a dramatic decline in mortality rates after acute MI

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throughout the 1960s. The foundational principles of the first CCUs were based on the premise of 4 key elements: (1) geographic grouping (grouping of patients to a common physical space by need for specialized care); (2) use of continuous telemetry monitoring to identify arrhythmias; (3) rapid provision of emergency cardiopulmonary resuscitation; and (4) training and empowerment of nurses to initiate resuscitative efforts.[3,4]

As the underlying patient population became progressively sicker, changes in organizational structure, staffing, care delivery, and training paradigms lagged. In 2007, a call was issued to the cardiovascular community on challenges in CCC care delivery.[5] Three years later, a study from Katz and colleagues[6] underscored the 17-year experience of nearly 30 000 patients admitted to the CICU at a single academic center in the United States from 1989 to 2006, identifying important clinical characteristics and epidemiologic trends, including that primary noncardiac diagnoses, such as sepsis, acute kidney injury, and acute respiratory failure, had risen in prevalence in the CCU, comprising nearly half of all admissions in the CICU in both single-center and claims-based reports.[6,7] The fastest-declining primary cardiac diagnosis was coronary artery disease (32.3% to 19.0%; $P<0.001$). The prevalence of both cardiovascular and noncardiovascular comorbidities had risen—heart failure (HF) from 13.9% to 34.4%, pulmonary vascular disease from 1.2% to 7.1%, valvular heart disease from 5.0% to 9.8%, and kidney injury from 7.1% to 19.6% ($P<0.001$ for all)—among elderly Medicare beneficiaries.[7] In response, the American Heart Association (AHA) subsequently issued a scientific statement on the evolution of CCC in 2012.[8] Because of changes in the underlying patient population and case mix, as well as considerable advances in technology, medical care, training, and staffing, the CCU evolved from a focus on rapid resuscitation from ventricular arrhythmias in acute MI into a comprehensive CICU designed to care for the sickest patients with cardiovascular disease.

Over the past decade, the CICU has continued to transform, with an aging population, increased clinical acuity, burgeoning cardiac and noncardiac comorbidities, technologic advances in cardiovascular interventions, and increased use of temporary mechanical circulatory support devices.[6,8–10] In academic centers, the most common indications for CICU admission are acute respiratory failure, unstable dysrhythmias, and shock.[11] Furthermore, not only have admissions with cardiogenic shock increased, but the most common cause of shock in the CICU has shifted from acute coronary syndromes to cardiogenic shock in the setting of de novo or acute-on-chronic HF.[12–16] The prevalence of temporary mechanical circulatory support devices, especially percutaneous left ventricular assist devices and venoarterial extracorporeal membrane oxygenation, has also increased.[17–19] Along with the technologic advances in temporary mechanical circulatory support, similar innovations in structural interventions, both percutaneous and surgical, for patients with complex valvular diseases have been developed.[20,21] Patients requiring admission to tertiary and quaternary care center CICUs for high-risk percutaneous coronary interventions (including for chronic total occlusions), structural heart interventions (such as transcatheter aortic valve replacement or tricuspid and mitral valve edge-to-edge repair), and evaluation for advanced therapies including durable left ventricular assist device and cardiac transplantation are increasingly common. As the population ages, these procedures are being offered to increasingly clinically complex patients with multimorbidity and frailty who were previously deemed to be at too high risk for such interventions.

These epidemiologic trends have brought greater focus to substantial unmet clinical and scientific research needs in CCC, including those related to broader issues such as value-based care and cost-effectiveness. Herein, we provide a contemporary expert perspective on organizational structure, staffing, and care delivery in the CICU; examine the challenges and opportunities present in the education and training of the next generation of physicians for CCC; and explore quality improvement initiatives and scientific investigation, including multicenter registry initiatives and randomized clinical trials, that may change clinical practice, care delivery, and the research landscape in this rapidly evolving discipline.

CICU ORGANIZATIONAL STRUCTURE, STAFFING, AND INTERDISCIPLINARY TEAM–BASED CARE

Organizational Structure in the CICU

Contemporary ICUs are often described on the basis of their organizational structure, staffing characteristics, and critical care therapeutic resources. CICUs have been traditionally characterized as using either open or closed models of care. The open ICU model connotes a unit where various physicians can admit patients and will continue to primarily direct their management. A closed, or ICU-based, staffing model connotes a unit where a dedicated physician (often a physician trained in critical care medicine [CCM]) and treatment team manage all patients admitted to the ICU. The "closed" nomenclature fails to recognize and promote the collaborative nature of CICU care and the important contributions that an ICU patient's longitudinal physicians (eg, primary care physician, primary cardiologist) may provide in key decision-making within the course of a patient's critical illness. In addition, several key stakeholders positively affect and contribute to crucial conversations regarding end-of-life and complex decision-making, including social workers, case managers, behavioral health professionals, psychiatrists, and spiritual or community leaders. The Writing Committee thus favors the term "high-intensity, CICU-based staffing" rather than "closed" and will use that terminology throughout this scientific statement. By definition, a high-intensity, CICU-based staffed model of critical care delivery cannot exist in an open unit.

Although we recognize that various definitions have been formulated, the Writing Group has defined a critical care cardiologist as a board-certified clinician with dual training and certification in cardiovascular diseases and CCM.[1,7] The Writing Group also recognizes a legacy pathway into CCC, whereby board-certified cardiologists with extensive contemporary CCC clinical experience and excellence in CICU-based practice may continue to practice as critical care cardiologists. Future novel pathways for advanced training and certification in CCC are also in development.

The optimal strategy for CICU physician staffing is a topic of immense interest as the provision of care for critically ill cardiovascular patients grows increasingly complex. General medical and surgical, as well as other subspecialty, ICUs have almost uniformly moved to a high-intensity ICU-based staffing model.[22,23] The components of this high-intensity staffing model can vary, but typically include a dedicated, ICU-based physician who assumes primary care of all CICU patients, with mandatory involvement of a specialist with critical care expertise, either as the primary physician or in consultation. "Dedicated CICU physician" refers to a physician whose primary responsibility is to the care of patients in the CICU for the entirety of their shift. We use the term "dedicated" to refer to the fact they are geographically based or bound to the CICU, as opposed to the catheterization laboratory or wards. In the case of a critical care cardiologist, this person can be one and the same. This high-intensity staffing model contrasts with an alternative low-intensity staffing model, in which individual physicians manage patients as they transition to an ICU with optional or no involvement of a critical care specialist.

In an effort to standardize the varying nomenclature present in the literature, the Writing Group provides the following summary of terms with illustrative examples of how these terms may relate to one another:

- "Closed" versus "open": This legacy terminology refers to whether a dedicated ICU-based team is present and whether the same physician or teams, or both, follow their patients inside and outside of the ICU, respectively. It is possible to have ICU-based staffing that is not high intensity (eg, a dedicated ICU team without any CCM or CCC expertise).
- "High-intensity" versus "low-intensity" staffing: This organizational model requires CCM expertise. As it was initially defined across multiple studies, high-intensity staffing includes a primary ICU physician with critical care expertise or describes a hybrid model in which a physician with critical care expertise consults on all patients (eg, in the instance where the primary CICU clinician or cardiologist does not have critical care expertise). Thus, in the hybrid model, it is possible that "high-intensity" staffing could exist in an open unit (eg, a primary non-ICU physician follows the patient into the ICU, but then a critical care physician consults on all patients). In addition, an ICU-based, low-intensity model may also exist (ie, a general cardiologist attending on all patients in the CICU would constitute ICU-based low-intensity staffing).

CICU Staffing Models

The recommendation for high-intensity, CICU-based physician staffing in both general medical and surgical ICUs is based on data from >50 studies, most of which are observational, that found an association between high-intensity staffing and lower mortality rates and shorter length of stay.[23–25] Meta-analysis of 13 such studies provides evidence that high-intensity staffing lowers mortality rates, resource consumption, and complications of ICU care.[26,27] Because historical controls were used in most studies, residual confounding related to temporal changes in practice patterns, therapeutic interventions, and patient population cannot be excluded. However, it is conceivable that better outcomes may be related to more consistent provision of care in the context of oversight by a dedicated, ICU-based physician with routine involvement of a specialist trained in critical care delivery. These data were derived almost exclusively from noncardiovascular critical care populations. In an effort to better describe the landscape of cardiac critical illness, several surveys have assessed the organization of staffing in CICUs in the United States.[28,29] In an appraisal of predominantly academic medical center CICUs in 2012, among 123 respondents (featuring a 69% response rate), only 68% had dedicated CICUs, of which 55% had a CICU-based physician as the attending of record and responsible for all aspects of patient care during the ICU admission; 32% had routine involvement of a critical care physician.[28] In 46% of CICUs, a general critical care physician consult was available, but not routinely involved in the care of critically ill cardiac patients. Most CICU directors (87%) surveyed agreed that a high-intensity, CICU-based staffed unit structure provided better care than a low-intensity staffing model, and 81% of respondents identified an unmet need for cardiologists with critical care training. Five years later, a different cross-sectional survey of 612 sites, including 128 AHA Mission: Lifeline and 474 ACTION Registry–GWTG (Acute Coronary Treatment and Intervention Outcomes Network Registry–Get With The Guidelines) sites, demonstrated that nearly three-quarters of CICUs surveyed in the United States were "open or low intensity," perhaps reflecting the larger proportion of community hospitals surveyed.[29] When stratified by tertiary academic centers, however, the proportion of "open" or low-intensity units still represented a majority (62.6%).[29]

Since the publication of the 2012 AHA Scientific Statement and conduct of the aforementioned surveys of US CICU structure, multiple studies have evaluated staffing models specifically in the CICU. Two studies reported an improvement in mortality rate associated with "high-intensity staffed" CICU care.[30,31] Miller and colleagues[30] demonstrated after multivariable adjustment that transition to high-intensity staffed CICU care at an urban academic center was associated with lower in-hospital mortality rates (odds ratio [OR], 0.69 [95% CI, 0.53–0.90]; P=0.007). Sims and colleagues[31] demonstrated that "high-intensity staffing" by full-time HF specialists at an academic center was associated with lower overall CICU mortality rate (OR, 0.63 [95% CI, 0.43–0.93]). A third study reported a reduction in length of stay and CICU costs per patient, with a concomitant improvement in metrics of interdisciplinary communication and education when transitioning from a "low-intensity" to "high-intensity" CICU-based staffing structure.[32] In 2016, Na and colleagues[33] reported the results of a single-center study of the transition from a "low-intensity staffing" to "high-intensity staffing" model that included interdisciplinary team–based rounding with a dedicated critical care cardiologist in the CICU at Samsung Medical Center in Seoul, South Korea. In a propensity-matched analysis including 2356 patients, the CICU mortality rate was lower with the high-intensity model (adjusted OR, 0.53 [95% CI, 0.32–0.86]; P=0.01), with similar patterns for both cardiovascular and noncardiovascular causes of death. In overall and propensity-matched analyses, there were no significant differences in either median length of CICU stay or readmission rates between the 2 groups. In a single-center, quasi-experimental study of consecutively admitted patients requiring mechanical ventilation in a single academic center, Kapoor and colleagues[34] reported a statistically significant, risk-adjusted lower mortality rate when using a mandatory general critical care physician comanagement model with either a clinical cardiologist or HF cardiologist for mechanically ventilated patients (OR, 0.40 [95% CI, 0.24–0.65]; P<0.001). They also observed an associated improvement in CICU charges ($30 067.25±$1900.09 versus $43 265.27±$3239.28; P<0.001), increase in ventilator-free days (23.7±3.4 versus 22.1±6.0 days; P=0.004), and reduction in both CICU (7.4±0.6 versus 9.6±0.9 days; P=0.04) and hospital lengths of stay (14.2±1.2 versus 20.1±2.1 days) associated with a comanagement approach to care.[34] In a multivariable analysis adjusting for the Acute Physiology and Chronic Health Evaluation II score, the comanagement model was associated with a significantly lower odds of death (OR, 0.40 [95% CI, 0.24–0.65]; P<0.001).

The transition to a high-intensity, CICU-based staffing model in these studies generally included a change to a CICU-based staffing model as well as a change to the attending staffing expertise (eg, critical care cardiologist or another cardiovascular subspecialty). As such, it is difficult to disentangle the individual elements of the change in staffing models that may have led to a potential benefit. Moreover, these studies were limited by their single-institutional design, retrospective data capture, and small sample size.[30,31] Nevertheless, these findings corroborate the notion that the findings from the large number of studies in general ICUs are consistent in CICUs and support the ongoing evolution of CICU staffing models, particularly, in tertiary care centers, to implement high-intensity, CICU-based staffing models led by a critical care cardiologist or clinical cardiologist with consultation by a critical care physician.[35]

Although evidence supports a benefit of critical care expertise in the management of contemporary CICU patients, additional data are needed to guide the structure and staffing models of cardiac critical care delivery. Even with a modest increase in the availability of dual-trained critical care cardiologists, the estimated demand currently far exceeds the available supply.[29] There is, in fact, a growing shortage even among the general critical care physician workforce, many of whom report that they are not comfortable managing patients with primary cardiac problems.[36]

Levels of Care

The AHA, European Society of Cardiology, and Canadian Cardiovascular Society have each published statements, based on expert consensus, suggesting a 3-tier CICU categorization with graded patient acuity, professional staffing, training, resourcing, and educational environment across the categories.[7,37,38] We suggest that, at all levels, CICUs function collaboratively within regional systems of care. A detailed framework is delineated in Table 1. Level 1 centers may serve as destination centers capable of comprehensive care for all cardiovascular conditions. Level 2 centers are best suited to serve as secondary referral centers capable of providing some advanced critical care therapies, and level 3 centers provide community-based access to CICU care with basic critical care capabilities.

New suggestions for clinical practice include a deemphasis of individual cardiovascular diagnoses as the basis for triage to CICU-level care, with an emphasis on reducing potential overutilization of higher-acuity resources by ensuring that patient needs are aligned with the available CICU level of monitoring, therapies, or nursing care.[39–47] These data suggest the potential value of implementing standardized admission criteria with admission and triage audits (in level 1 CICUs) for quality assurance.[40] Regional care systems should consider written standardized consultation, transfer, and repatriation criteria based on each region's hospital resources and expertise (Table 1). We suggest that, in appropriately selected patients, escalation to higher levels of care may broadly include patients with Society for Cardiovascular Angiography and Interventions stage D or E cardiogenic shock, multisystem organ dysfunction, or clinical deterioration, or those who need

Table 1. 2024 Updated CICU Categorization: Staffing, Training, Therapeutic Technologies, Education, and Quality Improvement

Category	Level 3 CICU	Level 2 CICU	Level 1 CICU
Patient population and admission criteria	Most common lower-complexity cardiovascular conditions, including need for telemetry Limited provision of critical care therapies Transfer more complex patient to level 1 or 2 CICU May not be STEMI, primary PCI capable No on-site 24/7 cardiac surgery available	Initial diagnosis and management of most cardiovascular conditions and ongoing management of intermediate-complexity conditions Selected ongoing provision of critical care therapies or monitoring in patients not meeting transfer criteria Transfer of complex patients to level 1 Should be STEMI, primary PCI capable No on-site 24/7 cardiac surgery available	Primary (or substantial concurrent) cardiovascular diagnosis requiring critical care restricted monitoring, nursing care, or therapies Patients at high risk of clinical deterioration Centralized care of all cardiovascular conditions Consider repatriating improving patients to level 2 or 3 Should be STEMI, primary PCI capable Should have on-site 24/7 cardiac surgery available
Monitoring	Cardiac telemetry Arterial lines	Transthoracic and transesophageal echocardiography Arterial lines Pulmonary arterial catheter All level 3	Pacemaker and ICD interrogation VAD interrogation Transesophageal echocardiography Pulmonary arterial catheter or noninvasive cardiac output monitoring, or both All level 2
Critical care therapeutic resources	Intravenous antiarrhythmic Inotropes Intravenous vasopressors Invasive mechanical ventilation Noninvasive ventilation	Temporary pacing Pericardiocentesis Intra-aortic balloon pump Intermittent hemodialysis All level 3	Temporary mechanical circulatory support (in CICU or on-site) Targeted temperature control Continuous renal replacement Intermittent hemodialysis Bronchoscopy All level 2
Care model	High-intensity CICU-based staffing or hybrid model	High-intensity CICU-based staffing	High-intensity CICU-based staffing
Physician leadership	Cardiologist or general CCM physician	CCC or joint leadership with a cardiologist with CPF and CCM	CCC or joint leadership with CPF and CCM
Physician staffing	Cardiologist with CCM consultant or CCM with cardiology consultant	CCC or comanagement between CPF/CCM	CCC or comanagement between a CPF/CCM whenever CCC not available
Training standard for future cardiology attendings	General cardiovascular medicine	CCC or CPF	CCC
Nursing ratios and allied health resources	1:1–1:3 Respiratory therapy Pharmacy Physical and occupational therapy Dietitian Social work	1:1–1:3 Pharmacy (unit-based) All level 3	1:1–1:2 All level 2
Teams	Cardiac arrest response team Palliative care	Shock teams All level 3	Shock teams Pulmonary embolism response team ECMO team Advanced heart failure and transplant cardiology All level 2
Education and training	Rotating trainees	Rotating trainees Cardiology training	Cardiology and subspecialty training Dedicated CCC fellowship training program
Research	Registry data collection	Registry data collection Randomized controlled trial enrollment	Registry data collection Randomized controlled trial enrollment
Quality assurance and safety prevention protocols	Morbidity and mortality review Standardized admission orders for common conditions VTE, CLI prevention protocols Delirium screening/sedation protocols Early mobilization VAP prevention protocols	Standardized admission criteria Tracking for risk-standardized mortality All level 3	Tracking admission appropriateness criteria CICU patient safety and quality dashboard All level 2
Regional systems care and transfer protocols	Protocolized guidelines for escalation and transfer Telephone, virtual, or e-consultative support from advanced CICU		

This table provides an overarching framework from which there may be exceptions within individual elements. Black text indicates metrics suggested for clinical practice; blue text indicates metrics to consider for clinical practice. CCC indicates critical care cardiologist; CCM, critical care medicine–trained physician; CICU, cardiac intensive care unit; CLI, central line infection; CPF, cardiologist with a cardiac intensive care unit practice focus; ECMO, extracorporeal membrane oxygenation; ICD, implantable cardioverter defibrillator; PCI, percutaneous coronary intervention; STEMI, ST-segment–elevation myocardial infarction; VAD, ventricular assist device; VAP, ventilator associated pneumonia; and VTE, venous thromboembolism.

additional therapies or evaluation by subspecialty services not available at the referring hospital. Moreover, within each level 1 CICU, accumulating evidence supports the development of cardiogenic shock teams as onsite and regional resources to improve patient outcomes.[48–51]

Additional study and interdisciplinary collaboration will be needed to chart a course forward to design and implement viable and sustainable evidence-based models of care for the contemporary CICU. Surveyed CICU directors believe that it may not be feasible for all hospitals to implement high-intensity staffing with full-time critical care expertise.[28] Moreover, deployment of resource-intensive technologies in all local hospitals within a regional system is inefficient and costly. Critical access hospitals in rural communities almost universally implement open or low-intensity ICUs, and often have no access to critical care physicians. Data indicate that the diffusion of evidence-based ICU organizational practices can be a slow and heterogeneous process.[52,53] These constraints on resources balanced against local needs must be taken into account when designing approaches to CICU care delivery.[35] Telemedicine ICUs, which gained prominence during the COVID-19 pandemic, have been proposed as a potential alternative to supplement management and identify appropriate escalation of critical care delivery in resource-limited environments, although data regarding their safety and effectiveness are emerging.[54]

Suggestions for Clinical Practice

Based on the cumulative evidence demonstrating an association between high-intensity staffing models and improved outcomes, we suggest that level 1 CICUs adopt a high-intensity, CICU-based staffing model as best practice (Figure 1).[30,32,33] Moreover, the Writing Group suggests that, given their highest level of patient complexity, level 1 centers should be staffed by clinicians with advanced expertise in CCC through dual certification in cardiology and critical care, or engage in a collaborative comanagement model with board-certified cardiologists and board-certified general critical care consultants whenever CCC expertise is not readily available.[31,33,34] The Writing Group also suggests a potential value of implementing standardized admission criteria with admission and triage audits (in level 1 CICUs) for quality assurance.[40] Regional care systems should consider written standardized consultation, transfer, and repatriation criteria based on each region's hospital resources and expertise.

Interdisciplinary Team–Based Care

Teamwork is important to a high-performing CICU regardless of staffing intensity. The critical care cardiologist plays a pivotal role in the leadership, education, and cohesiveness of this highly specialized, interdisciplinary team.[55] This Writing Group favors the nomenclature of interdisciplinary versus multidisciplinary in this context because the former underscores the development of integrated knowledge and methods from multiple disciplines whereas the latter refers to people from different disciplines working together, drawing on their domain expertise. The exact roles and responsibilities, as well as the composition and staffing, of the CICU team vary widely depending upon the size of the institution and unit, teaching versus nonteaching hospital status, high-intensity versus low-intensity staffing model, and available resources. However, apart from clinical trainees and some select specialists, most of the interdisciplinary team members in Supplemental Table 1 would be anticipated to be available in any size of ICU that specializes in acute cardiovascular care. In concert with the evolution of CCC training pathways and credentialing, several other interdisciplinary roles are undergoing evolution in their training pathways and scope of clinical practice. In particular, the role of advanced practice providers has expanded considerably in many CICUs, including opportunities to serve as primary clinicians, educators, consultants, emergency responders, researchers, quality improvement specialists, and leaders.[56] In addition, pharmacists play an indispensable role in assisting CICU clinicians with pharmacotherapy decision-making, assessing potential drug–drug interactions, reducing medication errors, and enhancing medication safety systems to optimize patient outcomes.[57]

The complexity and time-sensitive nature of cardiac critical illness warrants early recognition, coordination of care across interdisciplinary teams, and implementation of therapeutic interventions that epitomize this collaborative paradigm. Over the past 2 decades, a systems of care approach culminating in CICU interdisciplinary care has transformed clinical care in high-acuity conditions such as ST-segment–elevation MI, in-hospital and out-of-hospital cardiac arrest, acute pulmonary embolism, cardiogenic shock, and acute aortic syndromes.[50,58–63] As a paradigm, early recognition, rapid triage and transfer, interdisciplinary collaboration, timely and effective treatment implementation, and consistency of care have all contributed to achieving more favorable outcomes for patients with ST-segment–elevation MI. Critical care cardiologists are well-trained to lead these interdisciplinary teams among myriad other key roles and responsibilities (Figure 2).

CICU Nursing Staffing: Challenges to Maintaining a Qualified Workforce

Whereas the majority of studies regarding CICU structure and staffing have focused on physicians and their levels of expertise, specialized nursing was and remains the foundation for CICUs.[3] The practice of critical care nursing requires advanced organizational and technologic skills, unique training, and mastery of critical care

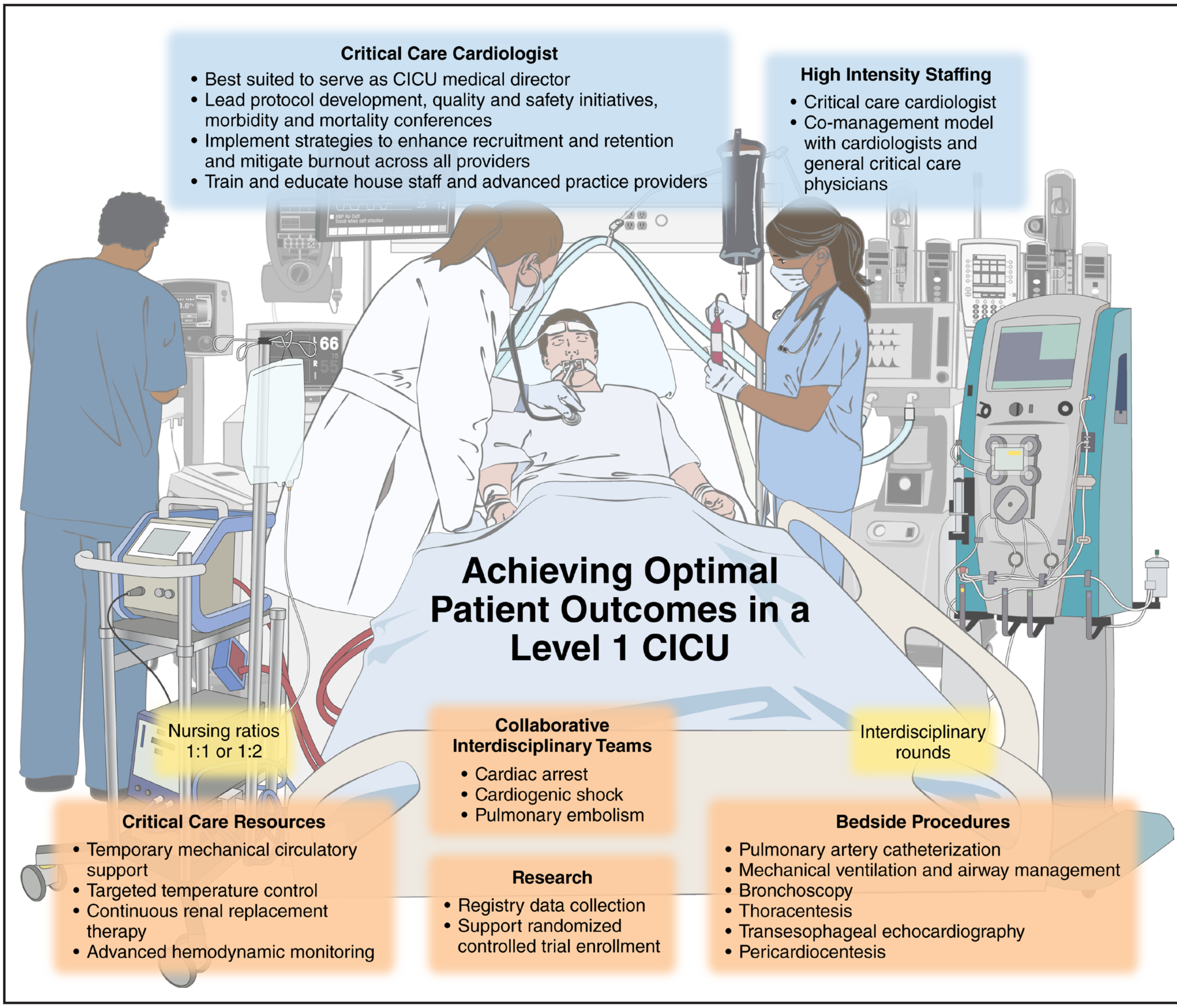

Figure 1. Achieving optimal patient outcomes in a level 1 cardiac intensive care unit.
A level 1 cardiac intensive care unit (CICU) should include high-intensity staffing with critical care cardiologists or a comanagement model with cardiologists and general critical care physicians, collaborative interdisciplinary teams, key critical care resources, availability for bedside procedures, optimal nursing ratios, interdisciplinary rounds, and infrastructure to support registry-based and randomized controlled trial research. Note the examples presented here under each domain are intended to be illustrative and not comprehensive.

competencies. Providing nursing care within this fast-paced, technologically rich environment also requires astute clinical judgement to respond to sudden changes in a patient's critical condition and the ability to work as a collaborative member of a high-acuity, interdisciplinary team. Whereas maintaining hemodynamic stability is one focus of a critical care nurse's practice, so is the provision of compassionate and individualized holistic care and maintaining patient safety and quality. Maintaining and building a cadre of highly skilled and experienced critical care nurses has been challenged by a contemporary staffing crisis amidst the recent COVID-19 pandemic.

The attrition of critical care nurses who contribute to CICU care delivery may be attributed to several factors. The COVID-19 pandemic has exacerbated burnout, exhaustion, high staff turnover, retirements, and the increased use of agency and travel nurses.[64] Many nurses are matriculating to advanced nursing roles such as nurse practitioners and nurse anesthetists. Working in a high-stress environment also places critical care nurses at increased risk for posttraumatic stress disorder, exacerbating feelings of being overwhelmed, burnout, compassion fatigue, emotional exhaustion, and moral distress, all of which contribute to decisions to leave critical care nursing and contribute to staffing shortages.[65] For the remaining nurses, many of whom are less experienced, they are often left without seasoned nurses as preceptors, exacerbating stress and burnout.[65]

The impending retirement of senior nurse faculty and the resultant lack of veteran experience amplifies the challenges of building the critical care nurse workforce in the CICU. Without adequate numbers of nurse faculty,

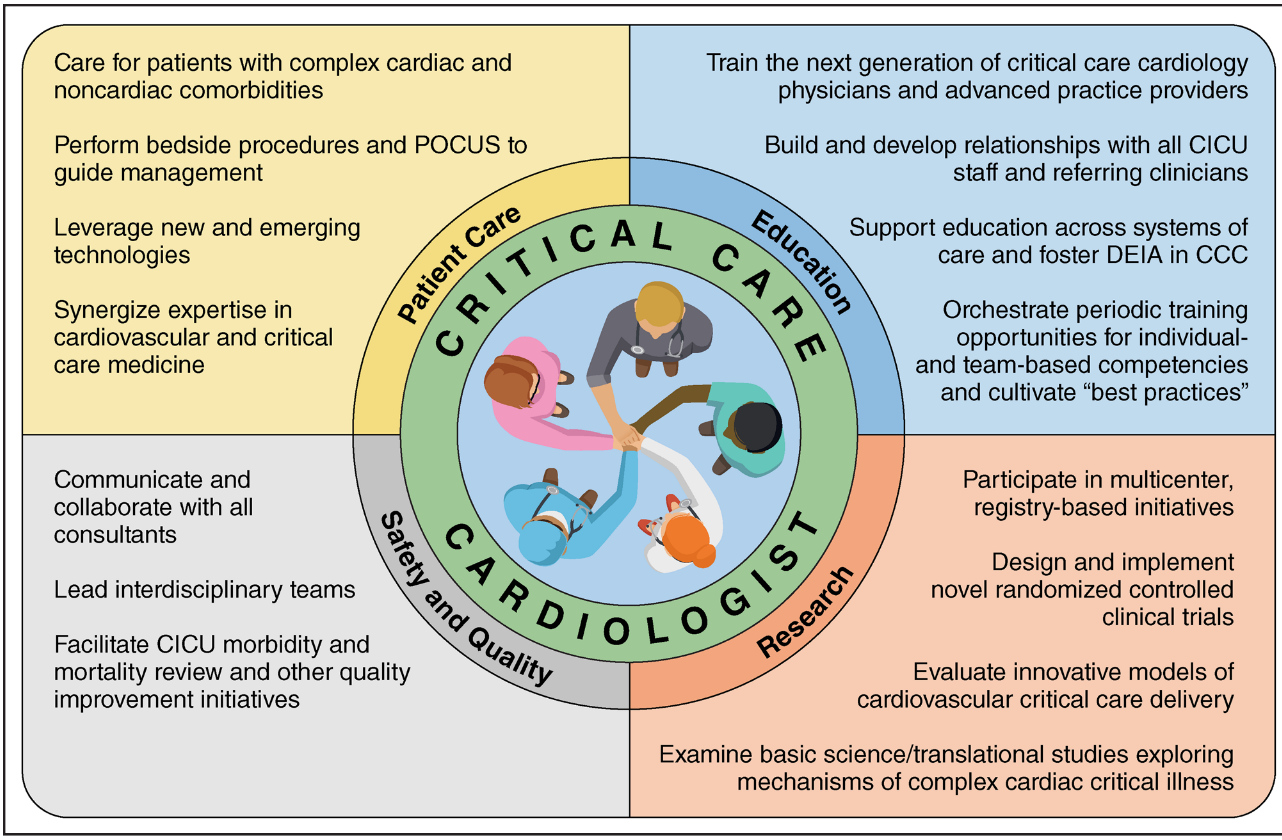

Figure 2. The myriad roles and responsibilities of a critical care cardiologist.
The critical care cardiologist is well-suited to address myriad essential roles and responsibilities across patient care, education, safety and quality, and research. Fostering diversity, equity, inclusion, and accommodation (DEIA) efforts in critical care cardiology (CCC) should be a core practice focus. CICU indicates cardiac intensive care unit; and POCUS, point-of-care ultrasound.

the ability to recruit and prepare nurses to assume baccalaureate and graduate-prepared nursing roles within the CICU will be severely jeopardized.

Strategies for Optimizing CICU Nursing Care

To craft and restore a sustainable career in critical care nursing and to reduce unit-level turnover requires strategies that will build a supportive work culture to reduce burnout among nurses. A recent study of 779 nurses in 24 critical care units at 13 hospitals identified 3 critical aspects of the work environment necessary to reduce burnout: adequate staffing, meaningful recognition, and effective decision-making.[66] To this end, the following strategies have been put forth: (1) partnering with unit and hospital leadership to identify workforce issues and develop solutions to make critical care nurses' contributions recognized; (2) involving nurses in effective decision-making that includes partnering in unit-level policy creation, evaluating clinical care, and promoting both inter- and intraprofessional collaboration; (3) providing adequate staffing by matching nurse competencies and patient needs; and (4) providing meaningful recognition including monthly recognition newsletters with photographs and celebrations of professional and personal achievements.[67] The ideal nurse:patient ratio may vary across institutions, but the 1:1 staffing ratio is optimal in some situations, such as for patients who require advanced temporary mechanical circulatory support devices or patients who are comatose after cardiac arrest who require targeted temperature control and continuous renal replacement therapy. A culture of a healthy, engaged workforce that promotes nurses' mental and physical health is fundamental to maintaining a highly skilled critical care workforce in the CICU.[67] In addition, innovative solutions must be developed to mitigate the burden of electronic health records and their charting demands on bedside CICU nurses to promote patient care and enhanced professional satisfaction.[68]

Other strategies include partnering with technical and paraprofessional schools to apply work hours toward professional nursing degrees, offering scholarships and tuition support, providing equitable financial compensation, and recruiting and retaining a diverse and inclusive health workforce that prioritizes lifelong learning and graduated responsibility as an experienced bedside CICU nurse. Other potential solutions for staff retention include team engagement, debriefing after sentinel events, individual and team recognition, and the implementation of patient survivorship celebration events, enabling the CICU team to appreciate the vital importance of their contributions to patients' survival and quality of life.

Suggestions for Clinical Practice

The Writing Group suggests several strategies for restoring and maintaining a compassionate and competent workforce, including nursing. Strategies include (1) partnering with unit leadership to identify workforce issues and develop solutions to make critical care nurses' contributions recognized; (2) involving nurses in effective decision-making that includes partnering in unit-level policy creation, evaluating clinical care, and promoting both inter- and intraprofessional collaboration; (3) providing adequate staffing by matching nurse competencies and patient needs; (4) providing meaningful recognition of professional and personal achievements; and (5) hosting patient survivorship events.[67]

TRAINING MODELS FOR THE NEXT GENERATION OF CICU PHYSICIANS

Clinical Competencies in CCC

Establishing clinical competencies in CCC remains an important area of development and many details are beyond the scope of this article. Nonetheless, the Writing Group has identified common curricular elements for training that merit discussion. The American College of Cardiology Core Cardiology Training Symposium training statement, COCATS-4, defined the training competencies for CCC for United States–based training programs.[69] Other pathways to competency in managing critically ill cardiac patients, including through critical care and cardiovascular anesthesiology, are defined elsewhere. As noted in Task Force 13 of the COCATS-4 training statement, training can range from exposure to CCC, representing level 1 training, which encompasses basic core competencies in CICU management, to level 3 training, which prepares physicians to direct a CICU.[69] The knowledge and skills for CCC should be attained during clinical exposure in the CICU, cardiac surgical ICU rotations, and other critical care units, but time invested learning about acute cardiovascular care within other domains, such as interventional cardiology, electrophysiology, HF, and cardiac imaging, is necessary for the holistic development of the contemporary CCC physician. In addition, clinical experience in the general medical ICU, surgical ICUs, and other subspecialty ICUs is critical to acquire the requisite knowledge and skills of physicians seeking level 3 training. Similar core curricula and levels of training have been established by the European Acute Cardiac Care Association and the Canadian Cardiovascular Society, and we refer readers to those training documents for further details.[38,70]

Maintaining core procedural and knowledge-based competency in CCC is also a challenge; however, novel solutions have emerged, such as hands-on training workshops, interactive simulation sessions, and precourse sessions during national congress or annual scientific meetings, which may serve as potential opportunities.[71] Formalized continuing medical education should form a substantial aspect of lifelong learning for every CICU physician, as the field continues to evolves rapidly. Furthermore, these formal learning methods may serve to provide baseline competencies in the field for existing CICU physicians, who may care for these patients without formal critical care training.[38] Mechanisms exist for assessment, certification, and recertification of knowledge-based competencies separately in both cardiovascular medicine and CCM through the American Board of Internal Medicine (ABIM)/American Board of Medical Specialties Maintenance of Certification program. CCC training pathways that lead to ABIM cardiovascular diseases and CCM board certification are depicted in Figure 3. Other exploratory alternative pathways that do not lead to ABIM board certification in CCM are depicted in Figure 4.

CCC Training Pathways

The previous iteration of this scientific statement and similar statements from Canadian and European societies have broadly discussed potential training pathways for staffing CICUs.[7,37,38] The most common US pathway to dual certification involves a traditional model of training in CCM and cardiovascular medicine after completion of residency training in internal medicine. Three years of training in cardiovascular medicine and 1 to 2 years of training in CCM are required for ABIM board eligibility in cardiovascular medicine and CCM, respectively.[72] With respect to dual certification for cardiovascular medicine and CCM, the total time duration of training is 4 to 5 years (including research experience) after internal medicine residency. Challenges with this pathway include wide variation in curricula across programs and a limited number of CCM fellowships.[73] Furthermore, cardiovascular medicine and CCM fellowship programs exist as distinct entities with separate faculty leadership, programmatic funding sources, and clinical staffing.[74] Data are limited on whether an optimal sequence of training exists (ie, CCM before or after cardiovascular medicine fellowship training; Figure 3).[74] We refer the reader to ABIM and Accreditation Council for Graduate Medical Education policies for further details.

Training in CCM before cardiovascular medicine provides more exposure to CCM (ie, usually 24 months training), ability to develop vascular access and 2-dimensional echocardiography skills before cardiovascular medicine fellowship, ability to learn triage skills for critically

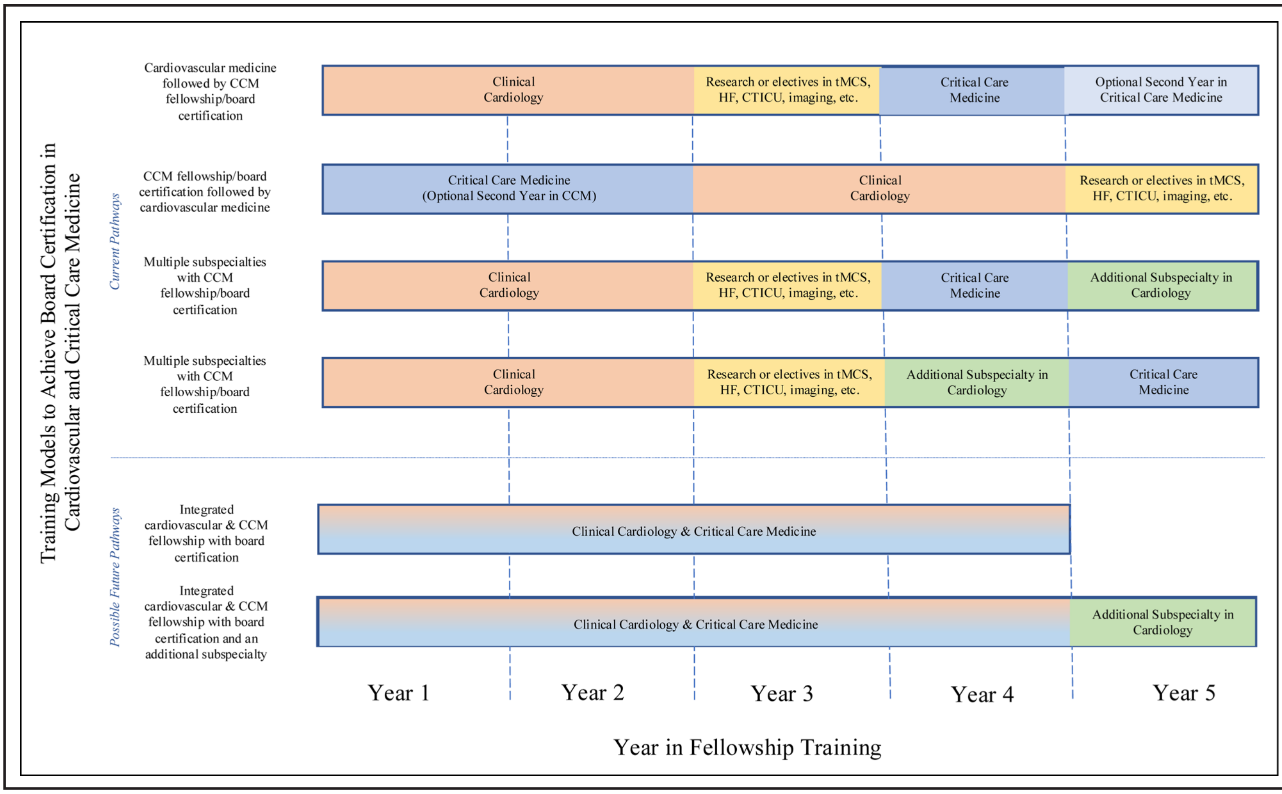

Figure 3. Training pathways for critical care cardiology.
Training sequence and timeline provided for models used to achieve American Board of Internal Medicine (ABIM) board certification in cardiovascular and critical care medicine in the United States. These training models apply to those who have successfully completed residencies in internal medicine. A possible future pathway in which integrated cardiovascular and critical care fellowship training with board certification is presented for consideration. Additional subspecialty training in cardiology may include interventional cardiology, advanced heart failure and transplant cardiology, cardiac electrophysiology, advanced imaging, and adult congenital heart disease. CCM indicates critical care medicine; CTICU, cardiothoracic intensive care unit; HF, heart failure; and tMCS, temporary mechanical circulatory support.

ill patients, and potentially serves to provide a strong scaffold for scholastic pursuits during the subsequent cardiovascular medicine fellowship.[74] For trainees who seek to pursue CCM training after cardiovascular medicine, the CCM training duration is potentially shorter (ie, 12 versus 24 months), and they are able to focus on targeted critical care training while maintaining their cardiovascular cognitive and procedural skills.[74] Such trainees will need to broaden their clinical practice to include aspects of internal medicine or CCM that may not have been a priority during general cardiovascular medicine training (eg, infectious diseases, nephrology, endocrinology).[75]

The Writing Group advocates for a role for the development of an integrated critical care cardiologist pathway (Figure 3, bottom), wherein a potential candidate is trained either sequentially or in an integrated manner for a professional focus as a CICU-based critical care cardiologist.[7,37,38] The fundamental difference between this integrated pathway and the aforementioned dual-trained critical care cardiologist pathway is that the former allows the development of a curriculum that spans most, if not all, of the 4 years of fellowship training; it also encompasses an interdisciplinary faculty with a focused mindset on CCC rather than 2 separate and distinct training programs and experiences. Although intuitively appealing, the design of such a curriculum would take considerable investment and foresight from both program directors and trainees. Variable models that meet board eligibility have been proposed, but this pathway might also incorporate additional training in the cardiac catheterization laboratory, advanced HF, pulmonary hypertension, adult congenital heart disease, mechanical circulatory support, and advanced imaging outside the auspices of both traditional cardiovascular and CCM fellowships.[1] In addition, it may offer trainees the potential benefit of training in one institution as opposed to multiple programs, which may require relocation to another venue.

Hybrid Training Models in Multiple Cardiovascular Subspecialties

In recent years, multiple expert perspectives have highlighted proposed training in acute cardiovascular care in various combinations of subspecialties, including CCM, cardiovascular medicine, interventional cardiology, and advanced HF and transplant cardiology (referred to as “HF” henceforth).[75,76–79] Those embarking on interventional and HF fellowships may have burgeoning interest in pursuing

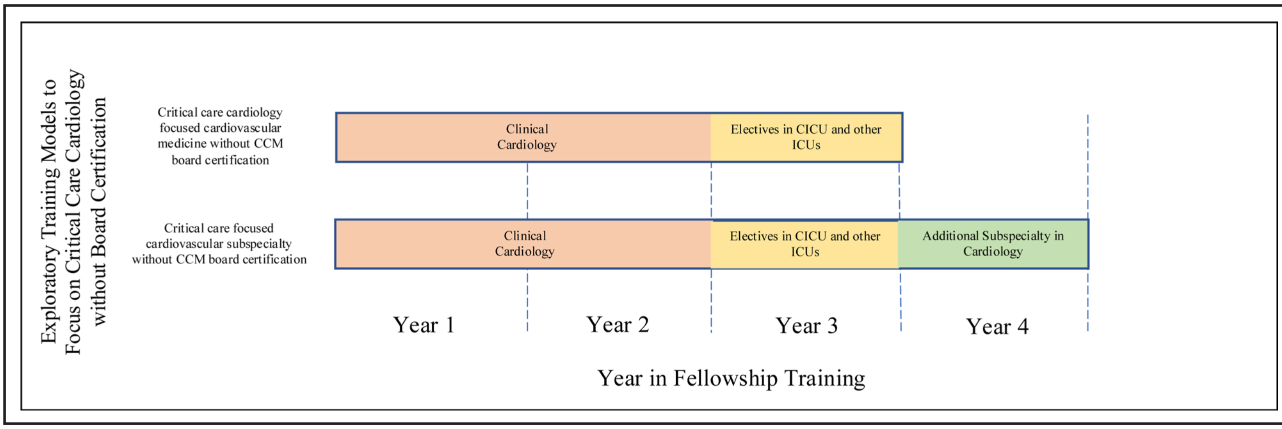

Figure 4. Exploratory training pathways for critical care cardiology.
Alternative, exploratory training models to focus on critical care cardiology without board certification in critical care medicine (CCM) are presented. These training models apply to those who have successfully completed residencies in internal medicine. These training pathways may be better suited to staffing level 2 rather than level 1 cardiac intensive care units (CICUs). Additional subspecialty training in cardiology may include interventional cardiology, advanced heart failure and transplant cardiology, cardiac electrophysiology, advanced imaging, and adult congenital heart disease. ICU indicates intensive care unit.

dual training in CCM to staff CICUs (Figure 4). In 2020, according to the ABIM, there were 149 physicians who have ever dually held certifications in interventional cardiology–critical care and 15 physicians who have ever dually held certifications in critical care–HF.[75]

Whereas structural heart diseases, complex and high-risk interventions, and peripheral interventions are established pathways for subspecialization in interventional cardiology, in recent years, there has been an interest in a dedicated pathway for interventional cardiologists in CCM.[75,78,80–82] The combination of interventional–CCC may have instinctive appeal, as the catheterization laboratory is often the first point of contact for acute cardiovascular emergencies, such as acute coronary syndromes, cardiogenic shock, cardiac arrest, or postsurgical emergencies, including pericardial tamponade. The ability to combine procedural skills, such as percutaneous coronary interventions, invasive hemodynamic assessments, and temporary percutaneous mechanical circulatory support, is a potentially attractive option. Many centers with a level 2 CICU employ an interventional cardiologist, who with additional CCM training might be readily available to care for this population appropriately.[75] The interventional–critical care cardiologist may be uniquely qualified and well-positioned to manage acute coronary and vascular emergencies, vascular access complications, including bleeding and acute limb ischemia, and other potential complications from temporary mechanical circulatory support devices.[83,84]

In recent years, there has been a growing interest from advanced HF and transplant cardiologists to have a dedicated practice focus in the CICU. Because of the higher use of temporary mechanical circulatory support, and the need for destination therapies such as left ventricular assist devices and cardiac transplantation, these patients benefit from the engagement of HF specialists.[17,19] Patients with decompensated HF have a more insidious course rather than the dramatic cardiogenic shock presentation seen in patients with acute MI.[85] Therefore, the involvement of a HF cardiologist with additional training in CCM may ensure timely care and evaluation for advanced therapies, as well as appropriate triage of patients to the right clinical care location both within and outside the hospital.[76,77,79] HF physicians trained in CCM may have the unique opportunity to work across the spectrum of medical and surgical CICU care, posthospitalization long-term care, and clinical follow-up, which provides a longitudinal relationship for this patient population.[86]

There are advantages to training in multiple cardiovascular subspecialties, but these training pathways have a number of consequences, such as requiring longer training (in order to be board certified in critical care), needing to maintain multiple skill sets, maintaining expertise in multiple subspecialties, and finding a career that allows the cardiologist to harness their wide-ranging skill set successfully. In particular, defining the optimal professional balance between cardiovascular subspecialties (eg, interventional cardiology and CCC, advanced HF and transplant cardiology and CCC) to maintain adequate volume and robust outcomes while providing opportunity for growth and experience across disciplines remains an area of fertile investigation. At the time of this writing, a competency statement is underway that may address these issues more specifically with respect to formal training guidelines.

Diversity, Equity, and Inclusion in CCC Training Programs

There has been increasing recognition of health care disparities in acute cardiovascular care for women and underrepresented racial and ethnic groups.[87–91] A lack of diversity among physicians is considered to be a major contributor to this phenomenon, resulting in multiple efforts by training programs and national societies to recruit women and people from historically excluded and underrepresented racial and ethnic groups to cardiovascular medicine.[92–95] There are limited data specific to CCC, but similar disparities in trainees are likely seen in this cohort. CCC training programs should seek to embrace diversity in their workforce, which may serve to reduce health care disparities in the CICU. Diversity, equity, and inclusion efforts are vitally important in staffing and practice of CCC, and enhancing diversity in CCC physicians may help close some of these gaps described in acute cardiac care, including patients with ST-segment–elevation MI, cardiogenic shock, HF, or cardiac arrest.[91,96–104]

Suggestions for Clinical Practice

The Writing Group acknowledges that there are several pathways leading to board certification in both cardiology and CCM. Whereas the optimal sequence remains to be determined and alternative pathways are being explored, trainees are encouraged to pursue programs that culminate in board eligibility for dual certification in cardiovascular disease and CCM. Diversity, equity, and inclusion efforts should be prioritized as an important area of focus for the field both during training and in clinical practice with respect to staffing and care delivery.

PATIENT SAFETY AND QUALITY IMPROVEMENT INITIATIVES

Patients with cardiac critical illness are inherently at risk for complications related both to their underlying illness and to their need for advanced intensive care, including the frequent use of invasive monitoring and critical care therapies. As in general ICUs, such complications are likely to be associated with higher morbidity, mortality, and use of health care resources. Therefore, drawing from experience in general ICUs, mitigation of the risk of these events is an essential element of high-quality cardiovascular critical care.[105] A previous AHA scientific statement provided a comprehensive review of potentially preventable complications of care in the CICU and delineated practices shown to improve safety in populations relevant to CICU care delivery, including checklists (Table 2).[106] These practices include minimizing the risk of ventilator-associated complications, ensuring delirium and sedation management, early mobility, family engagement, glucose control, nutrition, and gastrointestinal and venous thromboembolism prophylaxis, and managing device use and opportunities for discontinuation or removal. Nevertheless, there are substantial gaps in knowledge regarding application of these practices in the CICU.

The safety of mechanical circulatory support devices is particularly important in cardiac critical care. Vascular complications of cardiovascular devices, including vascular trauma, limb ischemia, thrombosis, and bleeding, are strongly associated with adverse outcomes in critically ill cardiac patients.[107] For example, the risk of acute limb ischemia increases 4-fold with insertion of percutaneous mechanical circulatory support in patients with acute MI and shock, and is associated with a 20-fold higher rate of death in the hospital.[107] Rational approaches aimed at reducing the risk of complications include using both ultrasound and fluoroscopy to guide arterial access, confirmatory angiography after placement, serial assessment for vascular access site bleeding, careful management of anticoagulation, assessment of limb perfusion, and structured approaches to device removal.[107] However, few data exist to establish the efficacy of these approaches.

Table 2. Areas of Importance Related to Patient Safety and Potential Complications in the Cardiac Intensive Care Unit

Category of ICU complication	Examples
Analgesia- or sedation-related	Acquired ICU-related myopathy Anxiety and agitation Delirium Pain Post–intensive care syndrome
Gastrointestinal	Aspiration Bowel dysmotility Gastrointestinal bleeding Hyperglycemia and hypoglycemia Malnutrition
Infection	Antibiotic resistance Central line–associated bloodstream infections Catheter-associated urinary tract infections Other health care–associated infections Percutaneous MCS-related infections Ventilation-associated pneumonia
Medication-related	Acute kidney injury Arrhythmias (other than QT-related) Bleeding Skin necrosis Torsade de pointes Medication interactions leading to under- or overdosing of medications
Vascular access–related	Vascular access site bleeding Limb ischemia Thromboembolism (See also infection)
Ventilator-related	Adverse hemodynamic consequences Pressure ulcers Swallowing dysfunction Ventilator-associated lung injury

ICU indicates intensive care unit; and MCS, mechanical circulatory support.

Quality Improvement in CCC

Quality improvement initiatives in the ICU traditionally have focused on mortality rates. However, it is the consensus opinion of this Writing Committee that tracking of intermediate metrics that assess implementation of evidence-based safety practices (eg, individualized sedation goals/daily interruption of sedation when appropriate, spontaneous breathing trials, delirium prevention, removal of intravascular lines, minimization of Foley catheter days) is a necessity in CICUs.[106,108] Iteration of the Donabedian model of quality improvement can guide quality assessment and includes evaluation of structure (how care is organized), process (care delivered), outcomes (results achieved), and culture (collective attitudes and beliefs of caregivers).[109,110] Ubiquitous implementation of electronic health record systems has created opportunities for dashboards that identify missing execution of safety interventions in the ICU and can provide real-time feedback to the managing team (Figure 5). The emergence of multicenter registries of cardiac critical care allows the sharing of data across institutions to identify variations in care.[11] Robust quality improvement programs that are multidisciplinary and respond to locally acquired data are important to support patient safety in CICUs.

Benchmarking and Public Reporting

Collection and reporting of ICU performance data have been encouraged by local initiatives, professional cooperatives, and accreditors, but are not required in the United States. In 2022, the AHA added a cardiogenic shock registry to its support of continuous quality improvement powered by the Get With The Guidelines quality program. Such longitudinal data collection will enable performance to be evaluated by comparing an ICU with itself over time, with other comparable ICUs, or with evidence-based benchmarks, when available.

Suggestions for Clinical Practice

The Writing Group suggests using a daily bedside checklist (Figure 6) to minimize the risk of potentially preventable complications of care in the CICU as well as delineated practices shown to improve safety in populations relevant to CICU care delivery. The Writing Group also suggests leveraging electronic health record systems to create opportunities for real-time, actionable dashboards that identify missing execution of safety interventions in the ICU and to provide timely feedback to the managing team.

CLINICAL KNOWLEDGE GAPS AND RESEARCH OPPORTUNITIES IN CCC

Despite substantial advancements in our understanding of the epidemiology and innovations in the care of patients admitted to the CICU, there remain major gaps in

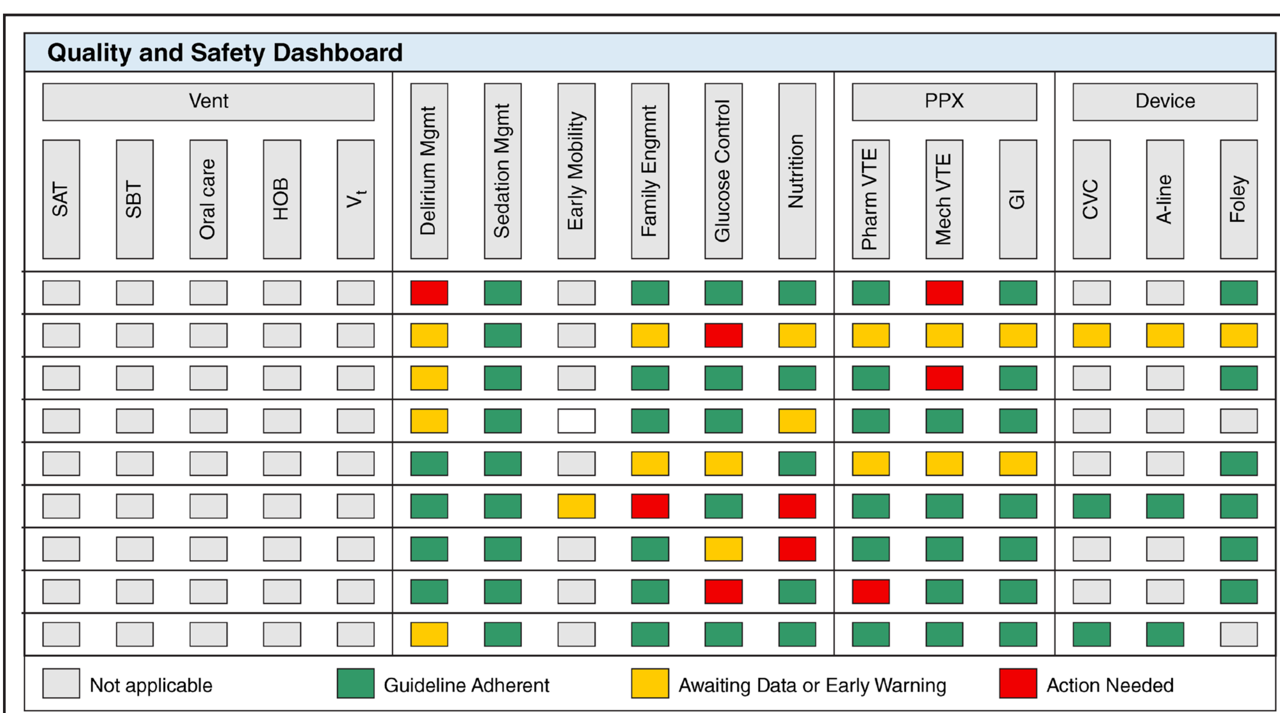

Figure 5. Patient safety and quality improvement dashboard to improve cardiac intensive care unit outcomes.
An example of a real-time quality and safety dashboard leveraging an electronic health record that may be used to minimize the risk of ventilator-associated complications and delirium, assist sedation management, enhance early mobility, improve family engagement, facilitate glucose control, augment nutrition, implement gastrointestinal (GI) and venous thromboembolism (VTE) prophylaxis (PPX), and review device-based use and opportunities for discontinuation or removal is shown. The green, yellow, and red boxes signify guideline adherent, early warning, and action needed items, respectively. CVC indicates central venous catheter; HOB, head of bed elevation; SAT, spontaneous awakening trial; and SBT, spontaneous breathing trial. Credit to Dr. Anthony Massaro for development of this dashboard.

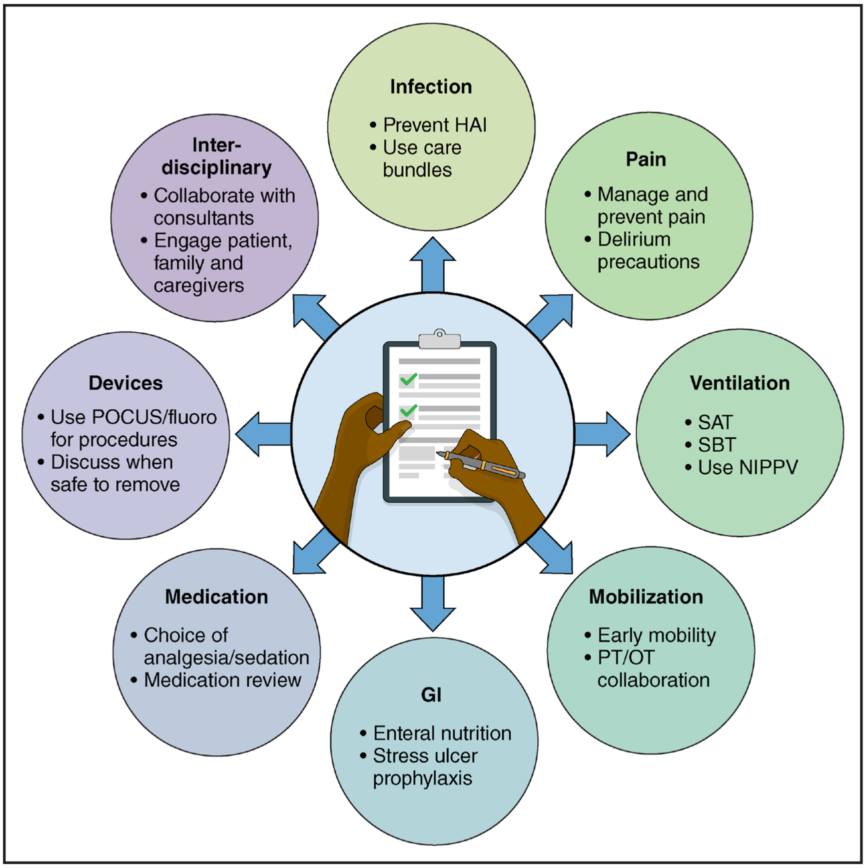

Figure 6. Bedside checklist to prevent complications and improve cardiac intensive care unit outcomes.
A daily bedside checklist to encourage best practices and to prevent complications for patients admitted to the cardiac intensive care unit is provided. Fluoro indicates fluoroscopy; GI, gastrointestinal; HAI, hospital-acquired infection; NIPPV, noninvasive positive pressure ventilation; OT, occupational therapy; POCUS, point of care ultrasound; PT, physical therapy; SAT, spontaneous awakening trial; and SBT, spontaneous breathing trial. Modified and adapted from Fordyce et al.[106] Copyright ©2020, American Heart Association, Inc.

knowledge regarding the efficacy and safety of specific diagnostic and therapeutic strategies, staffing and organization, and processes of care in the CICU. Many, if not most, therapeutic strategies commonly used in cardiac critical care lack evidence from randomized controlled trials to establish their efficacy and safety. Inherent challenges in the conduct of randomized controlled trials, including informed consent among the highest-acuity conditions in the CICU, mandate the exploration of novel methodologic approaches in these patients. At the same time, epidemiologic studies have revealed important heterogeneity in patients presenting to the CICU with syndromes such as cardiogenic shock, and cultivated interest in deeper phenotyping of such populations with the aspiration of improving diagnosis, risk stratification, and tailored therapeutics.[112]

Establishment of cardiac critical care multicenter registries has elucidated recognition of epidemiologic trends, practice patterns, and facilitated the conduct of clinical trials to improve patient-centered outcomes for cardiac critical care patients.[113] Standardization of data collection using electronic platforms across sites can facilitate systematic data capture, suggest interoperability solutions for data sharing between clinical trials and registries, and provide means for quality assurance. Establishment of such networks worldwide may help enhance enrollment in clinical trials evaluating the efficacy and safety of new and established therapies for acute cardiovascular conditions, allow for expansion of biorepositories for translational research, and provide a platform for innovation in cardiovascular diagnostic, bioinformatics, drug, and device development. In addition, the emergence of robust research networks will enable studies of care processes, protocols, and algorithms as opposed to drugs or devices.[114] A recent multinational perspective identified 4 major priorities in CCC research: defining epidemiology and practice variation in the CICU, performing critical evaluation of available and emerging CICU monitoring technologies, improving phenotyping of patients with cardiac critical illness, and advancing medical and device management.[115] In addition, basic science and translational research endeavors will be instrumental in redefining our conceptual models of critical illness and elucidating mechanistic insights into complex heterogenous syndromes.[116] It is vitally important to recognize the limitations of critical care effectiveness research, especially as it pertains to the deleterious harm that can result through mischaracterization of usual care.[117–119]

Opportunities to leverage innovations in technology may help shape the future of CCC. Electronic medical record systems facilitate comprehensive cardiac assessment, reporting of cardiovascular quality metrics, and exchange of clinical data. Machine learning and predictive analytics applied to these immense data sets may have a role in improving processes of care, including effective use of resources, reduced drug administration errors and drug interactions, introduction and adherence to evidence-based medical therapies, and distribution of services and care delivery in the complex CICU environment, with the ultimate result of optimizing health outcomes. Moreover, machine learning methods may accelerate precision medicine in cardiac critical care by processing large numbers of "features" collected in the ICU as part of clinical care and using supervised or semi-supervised artificial intelligence models.[120] For example, collecting continuous features of hemodynamic data may help improve diagnostic accuracy and facilitate disease phenotyping for patients with cardiogenic shock.[48,111] The CICU provides a unique clinical environment replete with an abundance of data and the successful application of machine learning and data science instruments may facilitate effective implementation of clinical decision tools to help guide clinical management and improve outcomes.

The care of older adults and those with end-stage cardiac disease is a rapidly accelerating challenge in the CICU. Because older adults are disproportionately affected by cardiovascular disease, the aging of the US population is reflected in all aspects of acute cardiac illness, including cardiac critical care. Precepts of geriatric and palliative care medicine are being gradually integrated in the management of CICU patients.[121] Research priorities should focus on the development of instruments and tools that assess older patients who may benefit most from invasive cardiovascular therapeutics. At the same time, engagement of geriatric cardiologists or palliative care clinicians to address goals of care early during admission is valuable. Outcomes for older patients with advanced forms of geriatric syndromes (eg, cognitive impairment, frailty, multimorbidity, polypharmacy) should be evaluated in pragmatic trials that aim to (1) assess the efficacy and safety of cardiovascular drugs and devices; (2) evaluate perceived outcomes and quality of life by patients and their families; (3) and examine the impact on the health care system as a whole, because these patients are systematically excluded from clinical trials, but constitute an important minority of patients admitted to the CICU. Observational studies suggest that the integration of palliative care services in the CICU is highly variable and comfort measures preceded death in 68% of cases, frequently without palliative care involvement.[122] Thus, optimal strategies on how best to improve access to and integrate palliative care teams in the CICU should be explored further.[123] Critical care cardiologists will need to become increasingly comfortable delivering primary palliative care while consulting specialists for more complex needs in order to provide the most goal-concordant care in the CICU.[124]

Prospective observational studies and clinical trials are also needed to evaluate processes of care that incorporate assessment of futility among patients with end-stage disease or when irreversible processes occur during acute cardiovascular illness (eg, irreversible anoxic brain injury after cardiac arrest). Definitions of futility in cardiac critical care have become more ambiguous in the context of advancement of cardiovascular interventions and mechanical support devices that can prolong life without a reasonable expectation of improvement in function or quality of life.[125] Studying hard clinical end points in the CICU (eg, CICU survival) remains important, but clinical trials should also prioritize studying patient-reported outcomes, including quality of life, functional independence, self-efficacy, or other metrics that are meaningful to patients during follow-up.[121] Survivorship from critical illness and assessing long-term outcomes is also another important area of fertile investigation.[86] There remain unmet clinical and scientific needs in CCC around broader issues such as value-based care and cost-effectiveness, which should be a focus for CCC investigation in the next decade.

Suggestions for Clinical Practice

The Writing Group suggests leveraging registries and novel pragmatic trial designs to address important unanswered questions in CCC clinical practice, including efficacy and safety of specific diagnostic and therapeutic strategies across various critical illnesses, staffing and organization of the CICU, and processes of care delivery in the CICU. Dedicated efforts to address value-based care and cost-effectiveness should be prioritized for scientific investigation.

CONCLUSION

The landscape of CCC has continued to evolve considerably over the past 10 years. Evidence for organizational structure, staffing, and care delivery in CICUs has substantially expanded and continues to develop. Many challenges and opportunities are present in training the next generation of physicians in CCC, with multiple professional society organizations seeking to standardize clinical competencies over the next few years. Data exploring the career arc of a critical care cardiologist will continue to emerge, including minimum requirements for maintenance of cognitive and procedural competencies, pathways for recertification, and strategies to mitigate burnout syndrome. Patient safety and quality improvement initiatives remain paramount, although real-time, actionable data dashboards through the electronic health record are not yet readily accessible. Research, including multicenter registry initiatives and pragmatic randomized clinical trials, is needed to ultimately change clinical practice and transform care delivery in this rapidly evolving field.

ARTICLE INFORMATION

The American Heart Association makes every effort to avoid any actual or potential conflicts of interest that may arise as a result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest.

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Disclosures

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Amanda R. Vest	Cleveland Clinic Foundation	None	None	None	None	None	None	None

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $5000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $5000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

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Gillian Grafton	Henry Ford Health System	None	None	None	None	None	None	None

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