Critical care, defined as the diagnosis and management of life-threatening conditions that require close or constant attention by a group of specially trained health professionals, is inherent to the practice of cardiovascular medicine. The demand for cardiovascular critical care is increasing with the aging of the population and is reflected by trends in the use of critical care in general. Between 2000 and 2005, although the total number of hospital beds in the United States declined by 4.2%, the number of critical care beds increased by 6.5% and the annual costs attributed to critical care increased by 44%, representing 13.4% of hospital costs. Projections for the next 15 years suggest that the need for critical care will increase markedly in the United States and globally. For example, in Canada, a 57% increase in the need for critical care beds is anticipated during that period.

Concurrent with increases in demand, the demographic shift toward a patient population with an increasing number of comorbid medical conditions who require more prolonged and more technologically sophisticated invasive support. As a result, the delivery of critical care is advancing substantially in its complexity. Moreover, accumulating evidence has indicated that outcomes are better when critical care is provided by specially trained providers in a dedicated intensive care unit (ICU).

In the context of this evolution, provision of optimal care in the contemporary cardiac ICU (CICU) presents a different set of challenges and requires an expanded set of skills compared with 10 years ago. Cardiovascular medicine has lagged behind other medical disciplines that have met the "critical care crisis" with ICU-focused innovations in organization, training, and quality improvement. Therefore, the American Heart Association Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation, the Council on Clinical Cardiology, the Council on Cardiovascular Nursing, and the Council on Quality of Care and Outcomes Research have sponsored this writing group to formulate a roadmap to meet the changing needs of the population with cardiovascular disease requiring critical care.

Evolution of the CICU

Early History of Critical Care Cardiology

In the early 1960s, after the successful implementation of open- and then closed-chest defibrillation and the intro-
duction of the first continuous electrocardiographic monitoring, the first coronary care units (CCUs) were formed with the premise that rapid identification and termination of peri-infarction arrhythmias could dramatically alter the natural history of acute myocardial infarction (MI).13,14 The earliest CCUs opened almost simultaneously in 1962 in the United States and Europe, providing electrical cardioversion and resuscitation care for patients with MI in a single unit continuously staffed by specially trained personnel. When Desmond Julian, at the time a senior medical registrar of the Royal Infirmary of Edinburgh (Scotland), presented his novel conception of the CCU to the British Thoracic Society in 1961,13 he enumerated 4 basic mandates that have withstood the test of time: (1) Continuous electrocardiographic monitoring linked to alarms, (2) rapidly initiated cardiopulmonary resuscitation and defibrillation, (3) personnel trained to manage specialized equipment within a single unit, and (4) skilled nurses empowered to independently initiate resuscitation. As is the case today, nurses “properly indoctrinated in electrocardiographic pattern recognition, and qualified to intervene skillfully with a pre-rehearsed and well-disciplined repertoire of activities in the event of cardiac arrest” were at the forefront of delivery of care in the early CCU.15 These same principles were described concurrently by Morris Wilburne in an abstract describing a CCU with an “organized program and step-by-step plan of resuscitation” submitted to the American Heart Association annual meeting in 1961.16 In the late 1960s, the next phase of development of the CCU was ushered in by Bernard Lown and colleagues at the Peter Bent Brigham Hospital in Boston, MA, who described a shift from resuscitation at the time of an arrest to monitoring for early signs of clinical change and prevention of a cardiac arrest.15 A precedent for admitting a broader group of patients with suspected acute MI to a dedicated CCU was established, and a rapid proliferation of CCUs throughout industrialized countries ensued.

The advent of CCUs was temporally associated with and often credited for a substantial decrease in the in-hospital mortality rate after MI from 30%–40% in the 1950s to 15%–20% in the 1970s.14,17–19 For example, Killip and Kimball, in their landmark article on acute MI management, described a nearly 20% decline in the post-MI mortality rate after implementation of their CCU.17 By 1980, the major cause of death related to MI had shifted from arrhythmias to ventricular failure. New bedside monitoring techniques such as pulmonary artery catheterization and echocardiography allowed evaluation of cardiac performance peri-MI, which led to the characterization of hemodynamic subsets with prognostic and pathophysiological implications for patient management.20 Albeit based on observational data, the available evidence substantiated the vision of Julian and others that meaningful improvements in outcomes could be achieved by management of patients within the specialized environment of the CCU.21–23

Evolving Demographics and Emergence of the Contemporary CICU

Despite this evidence of a favorable impact of CCUs over their first 2 to 3 decades and the continued decline in case fatality with MI, at least 1 descriptive study has shown negligible subsequent improvements in the overall mortality rate since the 1980s in a major academic CCU.24 The findings from this24 and other studies identified a dramatically changing demographic profile of the patient population in the contemporary CCU. The proportions of the elderly, women, and minorities admitted to the CCU have all increased steadily over the past several decades. Likewise, chronic illnesses, including diabetes mellitus, hypertension, renal dysfunction, and obstructive lung disease, now commonly coexist with cardiovascular illness in today’s CCU, which leads to greater case-mix and escalating illness severity.25 Moreover, competitive demand for ICU beds has resulted in triage of lower-risk patients to non-ICU settings. On a broader scale, the aging of the US population, acute and chronic sequelae of nonfatal MI, and a rising frequency of complications of invasive devices have amplified the frequency and morbidity of multiorgan dysfunction during critical illness.26 At the same time, emerging technologies and improved therapeutics have altered the natural history of critical illness in some groups of patients previously considered unsalvageable, thereby increasing the length of stay, risk of iatrogenic complications, and resource consumption.

As a result of each of these trends, the medical and procedural issues that determine outcome in the contemporary CCU are often ones that require substantial expertise in general critical care medicine.26 For example, CCUs now appear strikingly similar to general medical and surgical ICUs with respect to patient characteristics, resource utilization, and mortality rates.27 Moreover, overall medical complexity dominates the outcomes of patients in the modern CCU.28 In an analysis of trends over 2 decades of academic CCU care, Katz and colleagues24 observed a marked increase in the prevalence of sepsis and acute renal failure complicating acute and chronic cardiovascular conditions in the CCU. Not surprisingly, this pattern was also associated with an increase in the use of bronchoscopy and renal replacement therapy, along with an increase in the proportion of patients requiring prolonged mechanical ventilation and a relative decrease in the use of cardiovascular procedures (Figure 1).24,25,26 Each of these findings underscores the evolution from the earliest CCUs, focused on the management of acute MI, into the modern CICU, equipped to meet the complex critical care needs of the patient with cardiovascular disease (Figure 2).

Advanced Technologies and Special Populations in the CICU

The development of new technologies has heavily influenced the practice of critical care in cardiovascular medicine (Figure 2). As a result, physicians in the modern CICU must be experienced in managing the use and complications of advanced medical technologies, including noninvasive and invasive hemodynamic monitoring tools, complex modes of mechanical ventilation, renal replacement therapies, imaging guidance for bedside vascular procedures, methods for induction of therapeutic hypothermia, and mechanical circulatory support. In addition, the growing populations of patients with severe pulmonary hypertension and advanced structural heart
disease merit particular consideration in the formulation of a blueprint to meet the expanding needs of the CICU population.

**Advanced Heart Failure and Mechanical Circulatory Support**

Although the rate of admissions to the CICU for ST-segment–elevation MI has been decreasing over time, the number of heart failure admissions has been escalating. Patients with acute heart failure syndromes and end-stage heart failure can now be stabilized emergently with the use of mechanical circulatory support devices and extracorporeal life support. As such, management of severe heart failure by use of advanced pharmacological agents (eg, intravenous inotropes, vasopressors, and vasodilators) and technologies (intra-aortic balloon counterpulsation, percutaneous and surgically implanted ventricular assist devices, extracorporeal membrane oxygenation, and renal replacement therapies) has become a major focus of the CICU and requires a well-coordinated multidisciplinary approach that involves heart failure specialists and CICU staff. Percutaneous support measures are being used with increasing frequency for the management of acute cardiogenic shock and to support high-risk percutaneous interventions and electrophysiology procedures. Such patients are highly susceptible to progressive critical illness, often develop multiorgan dysfunction, and consume substantial clinical resources. Some large centers have developed specialized “heart failure ICUs” to care for this growing population. Optimal management of this population of patients and the technology itself requires that the providing clinicians are experienced in the appropriate selection of candidates for implantation, the correct use of such devices, and the early recognition or anticipation of complications related to such devices.

**Therapeutic Hypothermia in Cardiac Arrest**

The care of patients with out-of-hospital cardiac arrest has improved significantly since the inception of the CICU.

![Figure 1](http://circ.ahajournals.org/)

**Figure 1.** Temporal trends in discharge diagnoses and critical care procedures within the Duke University Coronary Care Unit from 1989 to 2006. Data from Katz et al. STEMI indicates ST-segment–elevation myocardial infarction; NSTEMI, non-ST-segment–elevation myocardial infarction; PCI, percutaneous coronary intervention; and PA, pulmonary artery.

![Figure 2](http://circ.ahajournals.org/)

**Figure 2.** Evolution of the cardiac intensive care unit. Advances in technology, medical care, critical care unit organization, and changes in the patient population have contributed to evolution of the contemporary cardiac intensive care unit from a coronary care unit focused on rapid resuscitation to a unit providing comprehensive critical care for patients with cardiovascular diseases. MI indicates myocardial infarction; STEMI, ST-segment–elevation myocardial infarction; ACS, acute coronary syndrome; HTN, hypertension; and CV, cardiovascular.
Since landmark trials demonstrated the benefits of therapeutic hypothermia, rapid implementation of cooling has been recommended for all eligible patients who remain comatose after successful restoration of spontaneous circulation after ventricular fibrillation or pulseless ventricular tachycardia. Whether cooled invasively or through external methods, the use of induced hypothermia mandates a carefully orchestrated plan with substantial resource requirements. Patients treated with hypothermic techniques commonly require specialized monitoring, prolonged mechanical ventilation, and extended ICU care. From a critical care perspective, those with cardiac arrest are frequently unstable, at risk for end-organ injury, and particularly vulnerable to infectious complications, including severe pneumonia. Prognostication regarding neurological recovery after therapeutic hypothermia has evolved such that longer time may be required to determine a low chance of recovery. Although often challenging, such prognostication is central to medical decision making after rewarming. Multidisciplinary clinical collaboration and experienced clinical management are important to improve outcomes for such patients. As therapeutic hypothermia becomes applied more broadly, the evolution of the CICU must anticipate the growing needs of the heterogeneous group of patients with restoration of spontaneous circulation after cardiac arrest.

**End-of-Life Care in the CICU**

As a consequence of greater disease severity and expanded supportive technologies within the CICU, end-stage disease states have become commonplace. Coordination of end-of-life care, including discussions with patients and families, decision making about deactivation of devices such as internal defibrillators, ethics consultation, pain management, and symptom relief, is now a central part of compassionate care in the CICU. Family members consistently emphasize the importance of effective communication in the intensive care environment and most often rank communication above clinical skills when assessing physician quality of care. Better communication reduces psychological trauma symptoms, depression, and anxiety; shortens ICU length of stay; and improves the experience during terminal care. Therefore, a focus on family communication during the delivery of critical care is an essential element of best practice in the CICU. The CICU staff must also be familiar with options for palliative interventions and services to provide effective transitions in care.

**Important Trends in Critical Care: Lessons Learned From General Medical and Surgical ICUs**

Significant technical, medical, and organizational advances have changed the face of general critical care medicine. The evidence underlying these advances has originated almost entirely from applied research conducted in general medical and surgical ICUs; however, this progress bears lessons vital to the continued maturation of the contemporary CICU and therefore will be discussed in detail in this section before turning back to the CICU in “Roadmap for the Future in Critical Care Cardiology.” In particular, 3 major evidence-based trends in critical care medicine can be identified: (1) A focus on interventions to optimize patient safety, driven by the recognition that ICU-related complications are a major determinant of outcomes; (2) a shift toward staffing models and structures of ICU coverage that place emphasis on involvement of dedicated intensivists, with advanced training and/or experience in critical care; and (3) recognition of the importance of integrated multidisciplinary care with coordinated activities of physicians, nurses, respiratory therapists, pharmacists, nutritionists, social workers, and consultants.

Notably, despite the increase in admissions of elderly patients with complicated medical conditions to general ICUs, there has not been an increase in ICU mortality rates, which provides indirect evidence for steady improvement in the quality of ICU care. Moreover, these improvements in clinical performance, tied to patient safety and quality of care, have been recognized as important not only by ICU personnel and hospitals but also to accrediting and public agencies. The evidence supporting each of these trends will be reviewed within this section, with a particular focus on staffing models that have been developed and investigated in the general critical care environment.

**Patient Safety and Preventive Practices**

Infections and other complications of the multitude of invasive methods for monitoring and treatment used routinely in the ICU have attracted substantial attention as potentially preventable causes of morbidity and mortality in patients receiving critical care. Sepsis remains a significant cause of death in the ICU and is related to an aging population, indwelling devices such as vascular and urinary catheters, prolonged intubation with mechanical ventilation, and more prevalent immunosuppressive therapy. Prudent use of invasive devices is essential to reduce sepsis and its attendant morbidity and mortality. When invasive devices are necessary, experienced operators should use rigorous protocols for sterile catheter placement and maintenance. Such protocols can substantially reduce catheter- and central line–related bloodstream infections (CLABSIs or CLABIs). Other interventions that may reduce ICU-related complications include restrictive blood transfusion strategies, measures to prevent and contain *Clostridium difficile* infections, and daily awakening of patients from sedating medications to reduce the duration of both mechanical ventilation and length of stay in the ICU.

Additional improvements in patient safety have become possible through technical advances in noninvasive ICU methods. For example, noninvasive mechanical ventilation has reduced intubation- and ventilator-associated pneumonia (VAP) rates for selected patients with pulmonary edema or hypercarbic respiratory failure. Critical care providers are now trained in these and other important techniques, such as ultrasound methods that are now widely used in ICUs to assist in line placement and other percutaneous procedures such as thoracentesis. Noninvasive methods for hemodynamic assessment continue to be refined. Lastly, the role of intelligent information systems in the ICU has grown, providing new opportunities for decision support, safety...
flags, and tools for improved communication and quality improvement.

**Physician Staffing Patterns and Clinical Outcomes**

Each of the interventions described in the preceding sections, including procedural practices, noninvasive methods, and safety and communication protocols, contribute to a complexity of the ICU environment that requires experience and expertise. Because of this complexity, organizational and staffing models for the ICU have been a focus of research in critical care medicine. The results of this research have motivated an ongoing global shift in the predominant structure and clinical operations in ICUs to place value on providing an experienced, multidisciplinary team, led by an ICU-based physician skilled in critical care medicine (the “dedicated intensivist”).

**Open Versus Closed ICUs**

In the United States, several organizational models for ICUs exist: Open, semi-open (hybrid), and closed. In an open ICU, patients are admitted or transferred and subsequently managed by their individual physicians, without routine assessment by an intensivist. The admitting attending physician, however, may seek consultation from relevant subspecialists. By comparison, in a closed ICU, an ICU-based physician evaluates all admissions and assumes primary responsibility for all aspects of patient care. In a semi-open ICU, in which the structure lies somewhere between the open and closed models, patients are admitted under the care of a primary attending physician, with ICU-based intensivists available for consultation and comanagement at the discretion of the primary attending physician.

In multiple observational studies, compared with open ICUs, closed medical and surgical ICUs have reported lower morbidity and mortality without an increase in resource utilization.59–62 In a rigorously performed meta-analysis of 27 observational studies of critically ill adults and children that compared outcomes in open versus closed ICUs, closed ICUs, which by design provide high-intensity staffing (as discussed in “Intensivist Versus Nonintensivist Coverage”), were associated with reduced hospital and ICU mortality and with reduced use of resources and length of stay.9 The potential influence of unidentified selection or publication biases, as well as confounding factors, such as from temporal changes in mortality, must be considered in these observational studies with principally historical controls. Nevertheless, better outcomes reported in closed ICUs may plausibly be related to the presence of an intensivist directing care, to improved overall consistency of care and collaboration between team members inherent to the closed-unit environment, or to both elements contributing to more sophisticated patient management. In one retrospective study of outcomes in open and closed ICUs simultaneously managed by the same group of faculty intensivists, mortality was lower in the closed system, without a significant increase in cost.63 This finding suggests that the superior outcomes observed in closed ICUs are related to aspects of closed ICU care that are not provided solely by the availability of a consulting intensivist. Some experts have suggested that team care should be adopted as an alternative term to a closed ICU to emphasize the benefits of integrated multidisciplinary care of critically ill patients.64

**Intensivist Versus Nonintensivist Coverage**

The results of more than 10 nonrandomized studies indicate that ICUs managed by intensivists achieve superior clinical outcomes, including reduced length of stay and associated costs,65,66 length of mechanical ventilation,60 and mortality.6–9,61,67,68 In the majority of these studies, high-intensity ICU physician staffing has been defined as mandatory intensivist consultation or a closed ICU and compared with low-intensity staffing, defined as no intensivist or elective intensivist consultation. In a meta-analysis of these studies, high-intensity ICU physician staffing was associated with a 39% lower ICU mortality rate (relative risk, 0.61; 95% confidence interval, 0.50–0.75) and 29% lower hospital mortality (relative risk, 0.71; 95% confidence interval, 0.62–0.82), as well as reduced ICU and hospital length of stay (Figure 3).8

Limitations to this evidence should be recognized. The majority of studies of ICU staffing models were conducted >10 years ago, were relatively small in size, and had nonrandomized designs. In addition, in one analysis of a large administrative data base of ICU patients, hospital mortality was actually higher for patients managed by intensivists.69
However, in that study, the majority of the ICUs included were open units with elective intensivist consultation. For these reasons, multicenter, well-controlled (such as cluster-randomized) outcome studies would be valuable to rigorously test the hypothesis that intensivist-based ICU care confers both a survival benefit and economic savings. Other studies would also be useful to tease out the multiple factors that influence ICU outcomes and costs, including severity of illness, divergent therapeutic approaches, increasing physician workload, and patient insurance status.

Despite the limitations to these data, the overall consistency of the available evidence and the rational basis for improved outcomes with enhanced experience, which is a central tenet of medical and procedural training, are compelling. Intensivists may improve outcomes through common practices, provision of urgent therapy, familiarity with acute conditions usually seen only in the critical care setting, facilitation of multidisciplinary care, increased use of evidence-based measures for prevention of complications, and provision of an ICU leadership role. Intensivists are more likely to implement newer care technologies and routinely introduce basic improvements, such as a reduction in use of central lines or use of simple and effective checklists. Lengthy ICU stays have been associated with lack of access to an intensivist. Taken together, there is a strong rationale for systems that are built on a pivotal role for dedicated intensivists.

**Twenty-Four-Hour In-House Intensivist Coverage**

In the United States, intensivists have traditionally provided ICU coverage during daytime business hours, with an estimated availability of intensivist care during night hours of ≈10% of ICUs. Many critically ill patients are admitted to ICUs during off hours, and if proper and rapid therapy is delivered, mortality may be similar to daytime admissions. However, some studies suggest that patients admitted to the ICU during off hours have higher mortality even after adjustment for severity of illness. This evidence has led to consideration of continuous (“24/7”) intensivist care. At least 4 observational studies report that introduction of 24-hour in-hospital intensivist coverage of the ICU was associated with lower mortality, fewer complications, and reduced hospital length of stay.

Although nocturnal intensivist coverage has been associated with shorter hospital length of stay and lower overall cost for the sickest patients, this may not necessarily be the case for less severely ill patients. Some experts have argued that 24/7 (24 hours per day, 7 days per week) intensivist staffing itself does not reduce mortality or length of stay. A number of factors could account for the differences in mortality rates seen when times of ICU admission are compared, such as differences in illness severity for patients admitted at night and general system issues such as lower levels of medical, nursing, and administrative staffing during off hours.

One study raised the hypothesis that the presence of training programs in many academic centers may adversely impact care and that 24/7 attending physician oversight may prove advantageous. Another benefit is that the intensivist can continue to educate residents during evening hours. Such new educational opportunities may become especially valuable as resident duty hours are restricted or further reduced.

However, 24-hour in-hospital intensivist coverage has been reported to reduce job satisfaction and produce “burnout” in a manner that is correlated with the increased number of night shifts on duty. Introduction of continuous in-hospital intensivist coverage therefore requires a balanced assessment of each of these issues within an individual healthcare system.

**Telemedicine**

Because of the obvious impact on staffing and workforce composition necessitated by 24-hour coverage schemes, a majority of ICUs in smaller hospitals may be unable to support such a model. Care by remote supervision from an intensivist using information technology–supported or video-assisted monitoring may help to resolve this issue and lower costs. Telemedicine can increase intensivist availability through information technology–based communication and provide direct intensivist input when a physician is not immediately available at the bedside. Such a system may use intelligent algorithms to monitor physiological and laboratory data, identify concerning trends or results, and reduce errors that could result in adverse outcomes.

Evidence showing benefits from use of telemedicine in ICUs has supported promise for the strategy, but findings have not been uniformly positive. Observational studies compared with historic controls have reported reductions in length of stay and mortality in the ICU and hospital, fewer complications, improvements in best practices and quality of care, and a positive financial impact. Other studies have described no significant change in mortality or morbidity after implementation of an electronic ICU. In one meta-analysis, there was lower mortality and length of stay within the ICU after implementation of telemedicine but no difference in hospital mortality or overall length of stay. These inconsistent findings could be explained by crossover effects between comparator groups or differences in application of the telemedicine model itself. Moreover, telemedicine as a monitoring tool is likely to be effective only in the context of other important interventions to improve quality care. Issues of cost, reimbursement, and legal and ethical factors arise with consideration of telemedicine. The scope and extent of coverage, proper licensure of participating physicians, development of accurate performance measures, lack of direct physician contact, and related job satisfaction are significant but not insurmountable hurdles to implementation.

Telemedicine may be considered an adjunct to the current ICU system to alleviate the impact of a shortage of intensivists that is not likely to be resolved in the near future. Telemedicine may be especially useful for remotely located ICUs and could improve physician efficiency in the management of very large or multiple ICUs.

**Physician Workforce Issues**

An estimated 25% of all US ICUs have an intensivist who manages most (>80%) of the patients, and ≈50% of all ICUs have no intensivist at all. Because of this lack of staff intensivists, a large number of US hospitals employ hospital-
ists to provide ICU care.\textsuperscript{79,110} Importantly, if universal ICU coverage by intensivists were to become an objective, the existing workforce would be insufficient to provide such coverage.\textsuperscript{1,79,111,112}

Efforts to increase the size of the intensivist workforce have been supported by professional societies, for example, with the recent proposal that emergency medicine residents train in critical care\textsuperscript{113} and subsequent approval of the pathway by the Accreditation Council for Graduate Medical Education (ACGME). Moreover, a pathway for dual certification of cardiologists in critical care medicine and cardiovascular medicine is already in place and is discussed in detail below ("A Model for Training in Critical Care Cardiology"). In addition, to manage the expanding demand for intensivists in the face of a constrained workforce, there is also a need to explore more basic organizational changes, including regionalization of services, establishment of protocols for care, greater nighttime use of other medical personnel or physician extenders, better information technology systems, and consideration of telemedicine in some settings.\textsuperscript{114}

This need may be heightened in some academic settings because of concurrent restrictions to trainee work hours.\textsuperscript{115}

**Multidisciplinary Care**

Attention to the organizational environment in the ICU is essential to ensure the best practice of critical care medicine.\textsuperscript{2,116–118} Specialized critical care nurses are essential to high-quality ICU care (as discussed in “Nursing, Advanced Practice Providers, Pharmacy, and Other Staffing for CICUs”). In addition, as the medical complexity of the patient population has increased, so too has the complexity of pharmacotherapy, with increased potential for adverse drug events and drug-drug interactions. The addition of pharmacists to the critical care team has been associated with lower rates of adverse drug events and complications related to drug therapy, lower mortality rates in the ICU, and shorter length of hospital stay.\textsuperscript{119–121} As the profession of pharmacy has moved from a product-focused to a patient-focused one, pharmacists have been successful in protocol development and implementation, therapeutic drug monitoring, adverse drug event surveillance and reporting, orchestration of clinical trials, and provision of drug information within the ICU setting.\textsuperscript{122} Nutritional management of critically ill cardiovascular patients, particularly those with multiple coexisting disorders, is challenging. Dieticians evaluate dietary intake, formulate tailored nutritional delivery, and help patients to attain or maintain optimal nutritional status. Physical therapists identify and treat impairments in strength, range of motion, and potential adverse functional outcomes from prolonged critical illness.\textsuperscript{123–125} Prolonged immobility in the ICU can lead to ICU-acquired weakness and other neuromuscular impairment.\textsuperscript{126} Promotion of early mobility and physical therapy in critically ill patients, including those with ongoing mechanical ventilation, is feasible and safe\textsuperscript{127,128} and has been associated with reductions in the incidence of pulmonary complications, delirium, the number of ICU and hospital days, and subsequent readmissions.\textsuperscript{127,129,130} Social workers contribute to the care of the complex cardiovascular patient through counseling and case management, ensuring that patient and family goals are communicated and incorporated in transitions and discharge plans.\textsuperscript{131}

**Quality Improvement in the ICU**

**Quality Measures in the ICU**

Given the high mortality rate, increased resource utilization, and potential for iatrogenic complications, ICUs have been a focus of quality assessment and improvement activities. In particular, the multiple levels of interprofessional and professional-patient communications in an ICU result in greater potential for gaps in such exchanges. Successful quality assessment requires the quantification of relevant metrics. Donabedian’s model of quality improvement guides quality assessment and includes evaluation of structure (how care is organized), process (care delivered), and outcomes (results achieved).\textsuperscript{132} Others have adapted this model to include culture (collective attitudes and beliefs of caregivers), which is particularly relevant in the ICU given the many individuals involved in the care of each patient and the necessary communication and collaboration.\textsuperscript{133}

Quality assessment initiatives in the ICU have traditionally focused on outcomes, particularly on mortality rates. A number of prediction models or acuity adjustment scores are available for ICU or hospital length of stay and mortality, such as the Acute Physiology and Chronic Health Evaluation (APACHE), Simplified Acute Physiology Score (SAPS), Mortality Probability Model (MPM), and Sequential Organ Failure Assessment (SOFA).\textsuperscript{134,135} With such models, an acuity adjustment score can be applied to compare the actual mortality in an ICU and the mortality predicted by the model (eg, the standardized mortality rate), which provides a benchmark for comparison.\textsuperscript{136} However, how this and other critical care predictive models perform in patients with primary cardiovascular disorders is less explored. In addition, many risk models developed among cardiovascular patients (such as risk scores in patients with MI) do not include measures of general medical illness and may underestimate risk in patients with severe medical comorbid conditions.

The rate of CLABSI has become an important outcome measure of morbidity in the ICU. Such infections can be measured in a systematic manner, and focused interventions have been shown to prevent them. Examples of other process measures that are now widely integrated into ICU practice include appropriate sedation guidelines, prevention of VAP, stress ulcer prophylaxis, and deep vein thrombosis prophylaxis. Structural measures (organization of care) include the presence of intensivists, higher nurse-to-patient ratios, and pharmacist presence during rounds.

Regulators, accreditors, and professional societies have also adopted or developed quality measures and data collection tools. The Joint Commission developed a set of 4 measures (VAP prevention, ulcer prophylaxis, deep vein thrombosis prophylaxis, and CLABSI) and 2 test measures (ICU length of stay, hospital mortality for ICU patients) specific to the ICU. The measure set was unique in that it was setting-specific rather than condition-specific and that the 2 test measures required clinical data collection instead of relying completely on administrative data for risk adjustment. These measures were rigorously tested and reviewed by a
Technical advisory panel but were suspended in 2005 before being implemented because of prioritization of surgical-related care. The measures remain in the Joint Commission Measure Reserve Library, and it is likely that these or similar measures will be implemented in the future as external benchmarks of quality in the ICU.

**Benchmarking and Public Reporting of Performance Data**

Collection and reporting of ICU performance data have been encouraged by local initiatives, professional cooperatives, and accreditors but to date are not required in the United States. Performance can be evaluated by comparing an ICU against itself over time, against other comparable ICUs, or to other benchmarks such as best practice. Feedback is intended to then drive performance improvement. In addition, there are many medical domains in which performance and benchmarking are now publicly reported, allowing consumers and stakeholders access to the information. Beginning in early 2012, the Centers for Medicare and Medicaid Services began publically reporting CLABSI rates in ICUs throughout the United States. This reporting initiative presents data that are predominantly voluntarily reported to the Centers for Disease Control and Prevention’s National Healthcare Safety Network. In addition, mandatory reporting of VAP exists in at least 3 states (Oklahoma, Washington, and Pennsylvania). It is anticipated that ICU-based metrics such as VAP and CLABSI rates will ultimately be subject to more widespread mandated public reporting. In some instances, performance may be tied to payment. From a cardiovascular critical care perspective, acute MI and heart failure core measure sets are already benchmarked and publically reported as hospital quality measures. In addition, established continuous quality improvement efforts such as the American Heart Association’s Get With The Guidelines quality program in heart failure, stroke, resuscitation, and coronary artery disease have well-developed in-hospital modules. Although these measures are condition- rather than setting-specific, a number of these measures are relevant to the CICU setting.

**External Expectations for ICU Staffing**

On the basis of the strong association between ICU structure, the presence of an intensivist, and patient outcomes, a number of groups external to individual hospital systems or medical professional societies have articulated goals for staffing of ICUs. For example, Leapfrog, a business group that promotes “big leaps” in healthcare safety, quality, and customer value through voluntary hospital surveys, has proposed that ICUs should be closed units with a board-certified intensivist present during the day and an intensivist immediately available by pager in off hours. Furthermore, Leapfrog recommends that all ICU admissions should be managed or co-managed by intensivists. Financial estimates have suggested that such a model would reduce hospital costs significantly and should be adopted by hospital administrators. Although their methods are not universally accepted as ideal, Leapfrog is one example of the growing number of organizations recognizing and promoting healthcare quality, as well as setting external expectations toward these ends. Another professional group, the Committee on Manpower for the Pulmonary and Critical Care Societies, has suggested that ≥80% of ICU patients be under the care of full-time intensivists.

**Roadmap for the Future in Critical Care Cardiology**

These key lessons from general critical care medicine detailed in the preceding section, including the well-founded focus on patient safety, the more favorable outcomes when care is delivered by clinicians with advanced skills in critical care medicine, and the value of structured multidisciplinary care, are vital to the continued maturation of the CICU. In the context of a growing interest of business entities, consumer focus groups, and public agencies tasked with improving the quality of ICU care, there is an imperative for the cardiovascular community to develop a pathway to respond to the “critical care crisis.” Not only is this effort in the best interest of patients, but some of these changes will likely become externally mandated.

The substantial evidence accumulated over the past 30 years in critical care medicine may be used to guide the next phase of evolution of the CICU. Although these data were derived predominantly in general ICUs, they provide the best available information on which to base rational judgments in developing a roadmap for advancing practice in the CICU. In particular, the available data suggest that the open model for organization and staffing of CICUs that is prevalent in the United States may not provide the best possible outcomes in the setting of current practice and patient demographics in the CICU.

**Potential Models of Physician Staffing in the CICU**

Although the advanced expertise of the cardiovascular specialist is essential to providing optimal care for patients with acute cardiovascular diseases, the increasingly challenging and extensive medical comorbid disease of patients cared for in the CICU has created a need for clinicians skilled in general critical care medicine. Thus, increasing the availability of clinicians with general critical care skills is an important objective for sustaining and advancing the quality of care in the modern CICU. A pathway toward achievement of this goal must also take into account the diversity of needs and resources across varied settings, including rural environments, community-based hospitals, and major tertiary referral centers. As such, to be successful, the organization and staffing of the CICU must be individualized to the care setting. Nevertheless, the writing group believes that access to clinicians who have specialized skills in critical care is important for all settings in which cardiovascular critical care is provided. The writing group also finds that the evidence supports a closed structure with staffing by dedicated cardiac intensivists (as discussed below in “Dedicated Cardiac Intensivists”) as a preferred approach for the advanced CICU level 1 CICU, “Proposal for Categorization of CICUs”). However, we present first a model of shared responsibility that is more broadly applicable to the current predominant structure and diverse care environments of CICUs in the United States.
Shared Responsibility With Consulting Intensivists

The most flexible organizational paradigm is a semiopen unit in which cardiologists and a general intensivist comanage each patient or selected patients in the CICU. This structure also is most adaptable for CICUs that care for patients with both higher and lower severity of illness, such as low-risk patients with suspected acute coronary syndrome or hemodynamically stable arrhythmias (level 2 or 3 CICU, “Proposal for Categorization of CICUs”). Within this model, the writing group favors a structure in which an experienced intensivist takes primary responsibility for the care of each critically ill patient in the CICU (eg, patients with multiorgan dysfunction or those requiring mechanical ventilation), with ongoing collaborative comanagement by the cardiologist. However, a collaborative model with a primary cardiovascular specialist with close, daily consultative care by a dedicated intensivist may be most appropriate in some health systems. In some settings with limited physician resources, this approach might include accessibility of a consulting intensivist via a telemedicine program.

Under this approach, physician leadership of the CICU might include both a cardiologist and an intensivist board certified in critical care medicine working collaboratively. Key principles guiding the development of this structure include high-intensity involvement of an intensivist, coordination of an experienced multidisciplinary team, established preventive programs for complications of ICU care (VAP, stress ulcers, and CLABSI), and meaningful quality improvement initiatives. The major advantage of the shared responsibility model is that it can be adapted to a broad array of staffing environments, including smaller community-based hospitals where the CICU might be combined with a general medical intensive care unit or where critical care staff are few in number or supported by other disciplines such as anesthesiology critical care. Its success is dependent on effective collaboration between the cardiologist and intensivist in creating a unified plan for care of the critically ill patient with cardiovascular disease.

Dedicated Cardiac Intensivists

The creation of a staffing model with dedicated cardiac intensivists is an alternative approach. The cardiac intensivist must have well-developed expertise in both general critical care and cardiovascular medicine. Such skills may have been developed through clinical experience focusing in cardiac critical care, as has been formalized in Europe (“The CICU: Models in Other Countries”) or through formal advanced training in general critical care (“Training Programs in Cardiovascular Medicine and Critical Care”). Leapfrog has suggested that intensivists must maintain their skills through at least 6 weeks of full-time ICU care each year.146 Ideally, the cardiac intensivist will function within a closed CICU model, in which the intensivist, while caring for patients in the CICU, provides care exclusively in the ICU, is present at all times during daytime hours, and when not present on-site is available for consultation with suitably skilled team members who are on-site. This model can be adapted to provide 24-hour in-hospital intensivist coverage if desired.

This innovative paradigm more directly matches the needs created by the dramatic changes in the CICU since its inception 50 years ago. This model has the advantage of providing for the most seamless direction of complex care through the leadership of a single physician who takes primary responsibility for the patient. In this model, the ICU-based physician is experienced in coordinating a large multidisciplinary team that is integral to the functioning of the advanced contemporary CICU. The writing group also reaffirms the value of primary responsibility for management of patients whose dominant medical problem is cardiovascular residing with a clinician with advanced skills in cardiovascular disease.

Because of the need for full-time staffing by cardiac intensivists despite a limited workforce, this model is not likely to be suitable for many community-based hospitals; however, it is likely to be the optimal model for the large tertiary referral center. Widespread implementation of this model to meet the needs of existing CICUs would require an increase in the number of cardiologists with advanced experience or training in critical care cardiology and would likely benefit from an increase in the number of cardiovascular clinicians with formal training in critical care cardiology. Such a broadly trained critical care cardiologist would be ideally suited for leadership and staffing of the level 1 CICU, the most advanced CICU (“Proposal for Categorization of CICUs”).

Integration With Other ICUs

Another possible structure for CICUs would be to combine the CICU patients with surgical or medical ICU patients, producing a multidisciplinary unit that manages a very broad array of patients. Such a CICU would require leadership from cardiology, critical care medicine, surgical critical care, and/or anesthesia critical care. This combined ICU could have some geographic segmentation of surgical, medical, and cardiovascular patients into pods, with flexibility to overlap beds depending on patient demand. This model provides the flexibility to mitigate the impact when specialty ICU bed availability does not allow appropriate triage of patients to particular ICUs. This model would be similar to some ICUs formed in Europe and other parts of the world.

“Service Line” ICUs

This solution also has the potential to best serve the expanding group of patients with advanced heart disease who require complex care for chronic heart disease and acute management for cardiogenic shock, percutaneously placed ventricular support devices, or extended mechanical hemodynamic support from surgically placed devices while awaiting destination therapies. With this approach, a more disease-centric (or service line) model of care can be delivered, which also centers the care around the patient rather than the therapies provided. In this paradigm, a CICU would care for all patients with advanced heart disease throughout the entire course of their critical illness. Importantly, the entire spectrum of their care, including hemodynamic guided therapy, before and after cardiovascular surgery, before and after complex cardiovascular procedures, and palliative services, would be
provided in a single ICU. Specialized heart failure units are an example of such an approach.

Nursing, Advanced Practice Providers, Pharmacy, and Other Staffing for CICUs

From the inception of the first CCUs, specialized nursing has been a foundation of excellence in cardiology critical care. Cardiovascular specialty certification is available to registered nurses with experience in cardiac patient care or as a subspecialty after achieving certification as a critical care specialist as either a registered nurse or advanced practice nurse (ie, nurse practitioner or clinical nurse specialist). Certification among nurses has been associated with high quality of care, high patient satisfaction, and potential for improved reimbursement. Moreover, the integration of advanced practice providers (nurse practitioners and physician assistants) into the cardiac critical care team can improve patient outcomes, including reduced length of stay and decreased complications, particularly among the chronically critically ill population. Advanced practice providers with specific training and experience in cardiac conditions contribute to cost-effective care, improved staffing, and continuity of care.

Among pharmacists, additional specialty certification in cardiology is available to those who are board certified in pharmacotherapy through the Board of Pharmaceutical Specialties and have additional training or advanced experience in cardiology. These pharmacists can petition the Board of Pharmaceutical Specialties for the credential of Added Qualifications in Cardiology. Additionally, postdoctoral specialized residency training and fellowships exist for pharmacists in cardiology and critical care medicine who have also completed a first-year general practice residency after graduation with a doctor of pharmacy degree.

Although there is less information about the effects of specialty certification on patient care for other cardiac care team members, certifications are available to physical therapists (cardiac and pulmonary care), dietitians, respiratory therapists, and social workers who do not have specialty cardiovascular certification but may benefit from developed expertise based on continuity of experience in a CICU.

Proposal for Categorization of CICUs

Because it is not necessary nor possible for all healthcare environments to support an advanced closed CICU with full-time intensivist staffing, the writing group recognizes that a variety of organizational models with different levels of professional and technological resources will be used to care for patients. The writing group has proposed a schema for describing the level of care offered by the CICU within the structure of the individual healthcare system (Table 1). This nomenclature is similar to the American College of Surgeons trauma center verification. In the trauma center classification, centers must not only meet specific criteria established by the American College of Surgeons but also pass a site review by a verification review committee. The official designation as a trauma center is determined by individual state law provisions, with the level varying according to the specific capabilities, ranging from level I being the highest to level III as the lowest category in most states. A level I trauma center provides comprehensive trauma care (immediate availability of specialized surgeons, anesthesiologists, and other clinical staff, as well as all necessary resuscitation equipment), with a minimum number of major trauma patients per year; serves as a regional resource; and provides leadership in education, research, and system planning. Analogously, we propose to define levels of CICUs as follows.

Level 1 CICU

The level 1 CICU is capable of management of all cardiovascular conditions and major noncardiovascular comorbid conditions. This unit may contain advanced heart failure patients dependent on percutaneous ventricular assist devices and in some circumstances patients who have undergone surgical ventricular assist device placement or cardiac transplantation. The level 1 CICU has all forms of invasive and noninvasive monitoring capabilities, and advanced technologies will be available to support the cardiovascular system and manage patients with refractory shock or resuscitated cardiac arrest. Patient care in this setting would be of high intensity, with management by full-time intensivists, either cardiac intensivists or general intensivists working collaboratively with cardiologists. The level 1 CICU is designed to care for patients with primary cardiovascular problems or those in whom underlying cardiac disease is sufficiently severe that it presents imminent risk in the context of another medical illness. Therefore, a primary role of cardiovascular specialists is optimal. Physicians with specialized skills in critical care are available at all times and may be on-site continuously. An on-site nursing director is present, and nurse-to-patient ratios would be expected to be 1:1 or 1:2. Pharmacy, nutrition, and respiratory therapy services would complete the multidisciplinary CICU team. Access to interventional cardiology and cardiac surgical support is expected. In a level 1 CICU, resident and/or fellow training programs would usually be present, and there would typically be a commitment to perform clinical and translational research. Physician leadership ideally would be provided by a cardiac intensivist or codirectorship with a cardiologist and general intensivist. A level 1 CICU would be the likely paradigm for most large tertiary medical centers.

Level 2 CICU

The level 2 CICU is capable of providing the initial evaluation and management of most acute cardiovascular conditions and medical comorbid conditions. All invasive and noninvasive monitoring is available. Mechanical hemodynamic support is available but limited to non–ventricular assist devices, including intra-aortic balloon counterpulsation. Advanced medical interventions such as continuous venovenous hemofiltration may not be available. A level 2 CICU should have protocols in place to provide for initiation of therapeutic hypothermia in survivors of cardiac arrest. Physician staffing for CICU patients is generally by cardiologists, and intensivists are available for consultation or comanagement of complex patients. The unit may be combined with a general medical or surgical ICU. A nursing director is designated, and nurse-to-patient ratios are usually 1:1 to 1:3. Training of
residents and clinical research may be present. Transfer to a level 1 CICU should be considered for patients requiring advanced hemodynamic support; for patients under consideration for high-risk valvular, coronary, or heart failure surgery; and for patients with intractable arrhythmias or refractory multiorgan system dysfunction.

**Level 3 CICU**
The level 3 CICU is the lowest-level CICU. The level 3 CICU should have the capacity to manage respiratory failure, administer vasopressors and inotropes for hypotension, and provide immediate resuscitation of cardiac arrest but may be focused on the care of patients with suspected acute coronary syndrome, heart failure without shock, and hemodynamically stable arrhythmias. The latter group of patients, for example, those with suspected acute coronary syndrome or stable arrhythmias, may be cared for on cardiac step-down telemetry units in hospitals with level 1 or level 2 CICUs. Like the level 2 CICU, the level 3 CICU may be combined with a general medical ICU. Noninvasive monitoring and echocardiography are available. Invasive monitoring and mechanical hemodynamic support are not usually provided in this unit. Cardiology service admission or consultation is expected for management of patients admitted with primary cardiac conditions to this unit. Critical care primary or consultative services are available. Nurse-to-patient ratios are usually 1:2 to 1:3. Patients who develop the need for mechanical hemodynamic support or advanced medical interventions not available in

<table>
<thead>
<tr>
<th>Level</th>
<th>Patient Population</th>
<th>Monitoring Technology</th>
<th>Therapeutic Technology</th>
<th>Physician Leadership</th>
<th>Physician Patient Management</th>
<th>Nursing/Other Personnel</th>
<th>Education Programs</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All CV diagnoses</td>
<td>All invasive and noninvasive cardiac monitoring</td>
<td>IABP</td>
<td>Cardiac intensivist or cardiologist (nonintensive and general intensivist)</td>
<td>High-intensity management: All care directed by intensivist (cardiac or general), or intensivist consultation</td>
<td>Nursing Director</td>
<td>Usually resident and fellow training programs</td>
<td>Commitment to perform clinical research</td>
</tr>
<tr>
<td></td>
<td>Most comorbidities</td>
<td>PA catheter</td>
<td>Percutaneous or implantable VADs</td>
<td>Intensivist available at all times</td>
<td>RN-to-patient ratio 1:1 or 1:2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Advanced heart failure</td>
<td>Echocardiography</td>
<td>Mechanical ventilation</td>
<td>May be 24/7 in-hospital intensivist</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>STEMI primary PCI capable</td>
<td>Coronary angiography</td>
<td>Therapeutic hypothermia</td>
<td>Continuous renal replacement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>May include post-CV surgery</td>
<td>Interventional cardiology available 24/7</td>
<td>Cardiologist or intensivist</td>
<td>Cardiology admission or consultation; intensivist is available at all times</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Initial diagnosis and management of most CV conditions</td>
<td>All invasive and noninvasive cardiac monitoring</td>
<td>IABP and/or other non-VAD devices</td>
<td>Cardiologist or intensivist</td>
<td>Intensivist (cardiac or general) available at all times</td>
<td>Nursing Director</td>
<td>May be resident or fellow training programs</td>
<td>May conduct research</td>
</tr>
<tr>
<td></td>
<td>May be STEMI primary PCI capable</td>
<td>PA catheter</td>
<td>Mechanical ventilation</td>
<td>RN-to-patient ratios 1:1 to 1:3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transfer to level 1 ICU if patient remains unstable</td>
<td>Echocardiography</td>
<td>Therapeutic hypothermia initiation</td>
<td>Coronary angiography available on-site or via transfer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Initial diagnosis and management of common cardiovascular conditions (usually low complexity), respiratory failure</td>
<td>Noninvasive and some invasive monitoring (eg, arterial lines)</td>
<td>Mechanical ventilation</td>
<td>Cardiologist or intensivist</td>
<td>Cardiology admission or consultation; intensivist is available at all times</td>
<td>Nursing Director</td>
<td>RN-to-patient ratio 1:2 to 1:3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transfer to level 1 or 2 ICU if unstable</td>
<td>Echocardiography</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other cardiovascular care units that are not cardiac ICUs include chest pain units for low-risk patients with chest symptoms and intermediate-care step-down units. Specialized units for advanced heart failure are described in the text.

ICU indicates intensive care unit; CV, cardiovascular; IABP, intra-aortic balloon pump; PA, pulmonary artery; VAD, ventricular assist device; RN, registered nurse; 24/7, 24 hours per day, 7 days per week; STEMI, ST-segment–elevation myocardial infarction; and PCI, percutaneous coronary intervention.
the level 3 CICU should be transferred promptly to an appropriate center with a level 1 or 2 CICU. Selection of the appropriate timing and destination of transfer for the patient with refractory illness is an important aspect of overall management in the level 3 CICU.161,162

The writing group acknowledges the frequent presence of other specialized cardiovascular care units that are not ICUs. For example, chest pain units or clinical decision units have been developed in many health systems to facilitate rapid diagnosis and triage of patients with possible acute ischemic heart disease and may identify patients who warrant transfer to a CICU.

The CICU: Models in Other Countries
Other regions of the world have already made formal recommendations for staffing of CICUs. The European Society of Cardiology (ESC) Working Group for Acute Cardiac Care has recommended that intensive cardiac care units (ICCs) be directed by board-certified cardiologists specially trained and accredited as acute cardiac care specialists, including training in the general intensive care unit.163 The ESC working group recommended that intensive cardiac care units have 24/7 coverage by physicians skilled in acute cardiac care, with attending cardiologists available for consultation and assistance. The ESC panel concluded that ICU nurses are as important as ICU physicians for optimal patient care in an intensive cardiac care unit. The ESC panel advocates the ICU team concept to include physicians, nurses, respiratory therapists, pharmacists, social workers, dieticians, physical therapists, and other ancillary staff.163

Training Programs in Cardiovascular Medicine and Critical Care
A roadmap to keep pace with evolution of the contemporary CICU must include enhanced training to ensure development of the basic skills necessary to provide care in this setting, as well as opportunities for advanced training in critical care cardiology for those who intend to specialize as a cardiac intensivist.

General Cardiovascular Training
Cardiovascular fellowship training offers comprehensive, hands-on education in a variety of aspects of cardiovascular patient care. Fellowship education is composed of bedside, didactic, simulation, and other learning opportunities.164 The ACGME training plan is based on the 6 core competencies, which include medical knowledge, patient care, professionalism, communication, and interpersonal skills, practice-based learning and improvement, and systems-based practice, which are meant to provide structure and standardization to all programs.165 The American College of Cardiology Foundation Recommendations for Training in Adult Cardiovascular Medicine Core Cardiology Training (COCATS) also help to standardize the fellowship training process by defining training levels, in which level 1 indicates the most basic training level and level 3 indicates the highest training level.166 COCATS is largely based on procedural numbers and time spent in training to assess level of competency. According to COCATS, fellowship training in cardiovascular medicine should include 9 months in nonlaboratory clinical practice, a portion of which is typically spent in the CICU. Present-day critical care training in cardiovascular training programs is varied. All programs expose the trainees to critically ill patients, but the structure and duration of time spent by cardiology fellows caring for patients in the ICU setting depends on the structure of the hospital, departments, and training programs. At the present time, there are no specific ACGME or COCATS guidelines or recommendations for critical care training within cardiovascular fellowship training. Although some programs offer fellows dedicated fellowship training months in the ICU, with complex patient populations and experienced staff and physician teachers, others have modest ICU exposure for fellows. Given the complexity of present-day cardiology patients, fellows are generally exposed to a variety of critically ill patients; however, some fellows may have more limited experience with mechanical support, ventilator management, renal replacement therapy, and other advanced therapies limited to the CICU setting.

There are impediments to the expansion of critical care training during general cardiology fellowship. Fellow duty hours are increasingly scrutinized, and more time in the ICU is likely to further impact training time. In addition, cardiology training programs need to be cognizant of the expanding need for exposure to new areas such as advanced cardiac imaging, including magnetic resonance imaging and computed tomography imaging. In light of the rapid changes in environment and technology that are increasingly unique to the CICU, trainees in cardiovascular medicine must have opportunities to participate in the care of critically ill patients with cardiovascular disease so as to build basic (COCATS level 1 or 2) competency in this area. However, given the constraints imposed by the essential exposure to a broad base of clinical practice, trainees in general cardiovascular medicine are not likely to be able to acquire additional exposure to critical care medicine in the present training paradigm. As such, there is ample rationale for the development of opportunities for advanced training in critical care cardiology (level 3 competency).

A Model for Training in Critical Care Cardiology
The progressively increasing severity of illness, the rapid emergence of new technologies, the crucial role of experience in mitigating the risk of iatrogenic CICU complications, and the overall complexity of the CICU environment each point toward value in developing training pathways for selected cardiovascular trainees who wish to acquire advanced skills in critical care medicine and critical care cardiology in particular. Moreover, the obvious shortfall in intensivists available to meet the needs of staffing models endorsed by this writing group adds to the rationale for establishing avenues by which to train cardiac intensivists.

Existing Pathway for Dual Certification in Cardiovascular and Critical Care Medicine
Current ACGME recommendations require 3 years of training in cardiovascular disease, of which at least 24 months is full-time clinical training, to meet the American Board of
Table 2. Existing Training Requirements for Dual Certification in CVD and Critical Care Medicine

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Details</th>
<th>CVD</th>
<th>Critical Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eligibility criteria</td>
<td>Completion of 3 years of accredited CVD fellowship and certification by the ABIM</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Training within a critical care fellowship program in a department of medicine</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Training requirements</td>
<td>Completion of 24 mo of full-time clinical training in an accredited fellowship in cardiovascular medicine</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Completion of 12 mo of accredited clinical fellowship training in critical care medicine</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Up to 6 months of critical care medicine experience in CVD and critical care medicine training can be applied to admission for both examinations</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Minimum total full-time clinical training for dual certification in CVD and critical care medicine of 30 mo (total training time 48 mo)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Procedural competency</td>
<td>Cardioversion; electrocardiography, including ambulatory monitoring and exercise testing; echocardiography; insertion and management of temporary pacemakers; and left-sided heart catheterization and diagnostic coronary angiography</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Advanced cardiac life support (ACLS)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Placement of arterial, central venous, and pulmonary artery balloon flotation catheters</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Calibration and operation of hemodynamic recording systems</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Airway management and endotracheal intubation</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Ventilator management and noninvasive ventilation</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Insertion and management of chest tubes; thoracentesis</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proficiency in use of ultrasound to guide central line placement and thoracentesis strongly recommended</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Additional areas of knowledge and practical experience</td>
<td>Indications, contraindications, complications, and limitations of the following procedures:</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intra-aortic balloon pump</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pericardiocentesis</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Transvenous pacemaker insertion</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Continuous renal replacement therapy and hemodialysis</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Fiber-optic bronchoscopy</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

CVD indicates cardiovascular disease; ABIM, American Board of Internal Medicine.

Internal Medicine requirement for certification in cardiovascular medicine. For critical care medicine, the ACGME suggests a minimum of 12 months of clinical training. The American Board of Internal Medicine presently recognizes a pathway for dual subspecialty training and certification in cardiovascular disease and critical care medicine (Table 2). Because of the overlapping elements of the curriculum and clinical experience within these 2 training pathways, 6 months of cardiovascular clinical training may be applied toward the critical care medicine training requirements. Therefore, overall, this pathway for dual certification requires 4 years of fellowship with a minimum of 30 months of clinical training, of which 6 months of clinical training must be in critical care medicine within a critical care training program accredited by the ACGME. This total period of training is commensurate with training in other cardiovascular subspecialties, such as electrophysiology. Functionally, trainees seeking dual certification have typically done so through application to an ACGME-accredited 1-year program in critical care medicine before or on completion of their cardiovascular training program.

A summary of the curriculum and current training requirements for dual board certification in cardiovascular disease and critical care medicine is provided in Tables 2 and 3. This curriculum builds on elements already included in the cardiovascular medicine training requirements and expands the exposure of the trainee to aspects of management of respiratory failure, acute renal failure, sepsis, and multiorgan system failure that are prevalent in the modern CICU. In addition, more broad procedural skills are established, such as performance of bronchoscopy and placement of chest tubes. This enhanced expertise should well equip the cardiac intensivist to manage the broad range of medical problems encountered in the CICU. However, the writing group also supports the value of establishing more innovative pathways for training in critical care cardiology that tailor the critical care medicine experience to develop expertise that the practitioner is likely to apply in the CICU.

Adaptation and Innovation in Critical Care Cardiology Training

The writing group recognizes 2 approaches toward developing enhanced training opportunities in critical care cardiology (Table 3). The first adapts and formalizes the existing pathway for dual certification toward providing the medical knowledge and patient practice experience for a fellow to become a cardiac intensivist with the requisite skills necessary to work effectively in a CICU. Building on the current general critical care medicine training requirements for combined certification, a tailored program for the cardiac intensivist would integrate options for rotations in the cardiac surgical intensive care unit, emphasize focused experiences...
or elective rotations in advanced heart failure and pulmonary hypertension, and include expanded exposure to complex adult congenital heart disease and percutaneous/surgical circulatory assistance devices. Additional research and elective time would also provide an opportunity to develop specific skills in epidemiology, conduct outcomes research in clinical trials, or explore laboratory-based and translational research in areas of interest relevant to cardiovascular critical care. The training program would be staffed by faculty in cardiovascular medicine and critical care medicine and require formative and summative evaluations as required by the ACGME. At present, such training is accredited only if provided within an ACGME-approved 1-year critical care program. In 2011, of the 187 training programs in cardiovascular disease, only 31 had associated 1-year programs in critical care medicine at the same institution/program. In the future, working collaboratively with faculty from both critical care medicine and cardiovascular medicine, the organization of program leadership in some centers may optimally reside within the cardiovascular medicine training program, with accreditation of the integrated program by the ACGME. In Europe, such cardiac intensivist training has already been implemented by the European Board for the Speciality of Cardiology with a formal curriculum and detailed COCATS-type training to ensure clinical and procedural competence.\(^{167-169}\)

The second approach is substantially farther from existing programmatic options, involving the development of a discrete, dedicated program for training a cardiac intensivist with requisite skills to function expertly in the CICU, cardiac surgical ICU, or other general ICU. In this framework for training, a 4-year curriculum drawing from both cardiovascular and critical training requirements from the American Board of Internal Medicine would be formulated and enable an even broader experience in general critical care medicine but would substitute elective rotations in this domain for some of the cardiovascular clinical training requirement (Table 3). On the basis of input from certifying authorities, the training would require documentation of clinical experiences and procedural competence to certify dual proficiency in critical care medicine and noninvasive and invasive cardiology.

Recently, a leadership group within the American Board of Thoracic Surgery has discussed the development of a critical care certification pathway for the perioperative care of cardiothoracic surgery patients.\(^{170}\) If such a program were to be developed, it would provide an additional opportunity for a cardiovascular intensivist to develop skills that would be useful in the CICU, a cardiothoracic surgical ICU, or a combined unit (“Integration With Other ICUs”). Given that most subspecialty ICUs in the United States are located in

<table>
<thead>
<tr>
<th>Table 3. Proposed Models for Training in Critical Care Cardiology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clinical, mo</strong></td>
</tr>
<tr>
<td><strong>CVD</strong></td>
</tr>
<tr>
<td>Noninvasive</td>
</tr>
<tr>
<td>Vascular</td>
</tr>
<tr>
<td>Catheterization laboratory</td>
</tr>
<tr>
<td>Electrophysiology</td>
</tr>
<tr>
<td>Nonlaboratory clinical practice*</td>
</tr>
<tr>
<td>Advanced heart failure</td>
</tr>
<tr>
<td>Pulmonary hypertension</td>
</tr>
<tr>
<td>Outpatient continuity clinic</td>
</tr>
<tr>
<td><strong>Critical care</strong></td>
</tr>
<tr>
<td>MICU or CICU</td>
</tr>
<tr>
<td>Nonmedical ICU†</td>
</tr>
<tr>
<td>Cardiopulmonary surgery ICU</td>
</tr>
<tr>
<td>Research and elective, mo</td>
</tr>
<tr>
<td>Total months of training</td>
</tr>
<tr>
<td><strong>Program faculty and leadership</strong></td>
</tr>
<tr>
<td>Separately managed programs in CVD and critical care medicine</td>
</tr>
<tr>
<td>Integrated faculty and collaborative leadership from CV medicine and critical care medicine</td>
</tr>
<tr>
<td>Integrated faculty and collaborative leadership from CV medicine and critical care medicine</td>
</tr>
<tr>
<td><strong>Program accreditation</strong></td>
</tr>
<tr>
<td>Separate accredited programs: CV medicine</td>
</tr>
<tr>
<td>Accredited programs in CV medicine and critical care medicine exist within system</td>
</tr>
<tr>
<td>Integrated program in critical care cardiology with single accreditation</td>
</tr>
<tr>
<td>Critical care medicine (1-y program)</td>
</tr>
<tr>
<td>Either the critical care medicine or CV medicine programs may have 1-y accredited program in critical care cardiology</td>
</tr>
</tbody>
</table>

CVD indicates cardiovascular disease; MICU, medical intensive care unit; cardiovascular; CICU, coronary intensive care unit; ICU, intensive care unit; and CV, cardiovascular.

*Ward, consult, CICU.
†Nonmedical patients, including surgical intensive care unit, burns, transplant, and neurological ICU or equivalent.
Assessing Competency
Demonstration of proficiency is important for all medical disciplines and has been the focus of professional societies, individual medical systems, and independent organizations such as the American Board of Internal Medicine that seek to certify that physicians possess the knowledge, skills, and attitude necessary to provide excellent care. Verification of initial training and continued competency is crucial to maintaining conformance to established standards of care and may be of particular importance for those engaged in the care of the most severely ill patients who require critical care. Such assessment should follow a clearly established program and consider knowledge, skills, and attitude. The detailed curriculum and mechanisms for verification of competency developed by the ESC may serve as a model for similar efforts in the United States. The establishment of opportunities for continuing medical education and reassessment of proficiency is also important and would be enhanced by expansion of existing programs and development of new programs aimed at critical care cardiology in particular.

At present, mechanisms exist for assessment, certification, and recertification of these elements in both cardiovascular medicine and critical care medicine through the American Board of Internal Medicine/American Board of Medical Specialties Maintenance of Certification program. Future deliberations may consider whether there is a value to developing processes for maintenance of certification in critical care cardiology, such as through a certification in cardiac critical care and outcomes, including among patients cared for in emergency and critical care settings. Randomized trials of revascularization in cardiogenic shock, use of left ventricular assist devices in end-stage heart failure, use of pulmonary artery catheters, use of intra-aortic balloon pumps in MI, and therapeutic hypothermia for out-of-hospital cardiac arrest are examples of research restricted to the critical care setting with patients with primary cardiovascular conditions. However, there has been relatively little research focusing on the evolution of critical care cardiology to include patients with multisystem organ dysfunction. There are also important opportunities to study how staffing models, provider training, team composition, and electronic systems, including decision support, may impact process and outcomes. Moreover, there is a need for investigation of structured approaches to enhance communication and facilitate transitions between the CICU and external providers inside and outside the hospital.

The important research into building regional systems of care for acute MI with integration of emergency medical systems, community hospitals, and specialized tertiary care centers could be extended to other critical care conditions. As well, recent work in the treatment of hyperglycemia and shock and previous randomized studies of the routine use of pulmonary artery catheters have highlighted the importance of prospective, well-controlled clinical investigation in general critical care medicine and the impact that it may have in the CICU. End-of-life care and level-of-care decisions by patients and families are other areas that have undergone some study but need more investigation.

As electronic medical records and evolving coding of patient conditions allow more sophisticated analysis of various aspects of care and outcomes, there will be new opportunities to characterize critically ill cardiovascular patients. This will only be possible with standardized definitions and accurate coding, as well as multicenter collaboration. Research networks in general critical care medicine, such as the Canadian Clinical Trials Group, the ARDS (Acute Respiratory Distress Syndrome) Network, and the US Critical Illness and Injury Trials Group, have served to advance the agenda of research in critical care. These models, combined with the rich history and expertise of cardiovascular researchers in conducting large clinical trials, could be used to build important evidence to improve care for this understudied population. With an increasing proportion of healthcare dollars going into care during the last months of life, much of this in intensive care units, research into efficient use of resources is also warranted.

Research Directions for Critical Care Cardiology
The breadth and volume of cardiovascular research has outpaced many other medical specialties over the past decades and has made an enormous impact on improving care and outcomes, including among patients cared for in emergency and critical care settings. Randomized trials of revascularization in cardiogenic shock, use of left ventricular assist devices in end-stage heart failure, use of pulmonary artery catheters, use of intra-aortic balloon pumps in MI, and therapeutic hypothermia for out-of-hospital cardiac arrest are examples of research restricted to the critical care setting with patients with primary cardiovascular conditions. However, there has been relatively little research focusing on the evolution of critical care cardiology to include patients with multisystem organ dysfunction. There are also important
experienced cardiac intensivists, either as primary caregivers or as consultants, is central to the optimal delivery of advanced cardiac critical care. Such specialized skills may have been acquired through experience or formal advanced training. The writing group also reaffirms the value of primary responsibility for management of patients whose dominant medical problem is cardiovascular residing with a clinician with advanced skills in cardiovascular disease. We have described a classification system that could be formalized to characterize the capabilities and resources of the individual CICU or health system, with the 2 highest levels (level 1 and level 2) requiring the availability of intensivists and specialized multidisciplinary teams. In particular, the writing group concluded that the evidence supports a closed structure staffed by dedicated cardiac intensivists as a preferred approach for the level 1 CICU. The writing group also finds that successful implementation of such models will require the development of new pathways for training of cardiologists with advanced skills in critical care cardiology. We have proposed adaptations to existing training models that tailor them toward developing the skills of a cardiac intensivist, and we have raised the possibility of more substantial restructuring of training in the future. These proposals may be a useful starting point for a meaningful dialogue between the major stakeholders in training and certification of such specialists. The future of cardiovascular critical care medicine is rapidly evolving, with an opportunity to improve the education and skills of clinicians and the care of their patients.

Disclosures

Writing Group Disclosures

<table>
<thead>
<tr>
<th>Writing Group Member</th>
<th>Employment</th>
<th>Research Grant</th>
<th>Other Research Support</th>
<th>Speakers’ Bureau/Honoraria</th>
<th>Expert Witness</th>
<th>Ownership Interest</th>
<th>Consultant/ Advisory Board</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>David A. Morrow</td>
<td>Brigham &amp; Women’s Hospital/Harvard Medical School</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>James C. Fang</td>
<td>University Hospitals Case Medical Center</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Dan J. Fintel</td>
<td>Northwestern Memorial Faculty Foundation</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Christopher B. Granger</td>
<td>Duke University Medical Center</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Jason N. Katz</td>
<td>University of North Carolina</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Frederick G. Kushner</td>
<td>Heart Clinic of Louisiana</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Jeffrey T. Kuviv</td>
<td>Tulia Medical Center</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Jose Lopez-Sendon</td>
<td>Hospital Universitario La Paz, Madrid, Spain</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Dorothea McAreavey</td>
<td>National Institutes of Health</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Brahajee K. Nallamothu</td>
<td>University of Michigan</td>
<td>NIH*</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Prescription Solutions*</td>
<td>Abbott Vascular*</td>
<td>None</td>
</tr>
<tr>
<td>Robert Lee Page II</td>
<td>University of Colorado School of Pharmacy and Medicine</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Joseph E. Parrillo</td>
<td>Cooper University Hospital</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Pamela N. Peterson</td>
<td>Denver Health Medical Center</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Chris Winkelman</td>
<td>Case Western Reserve University and MetroHealth Medical Center</td>
<td>NIH*</td>
<td>None</td>
<td>None</td>
<td>AAOVPR*</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

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 (1) the person receives $10,000 or more during any 12-month period, or 5% or more of the person’s gross income, or (2) the person owns 5% or more of the voting stock or share of the entity, or owns $10,000 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.
### Reviewer Disclosures

<table>
<thead>
<tr>
<th>Reviewer</th>
<th>Employment</th>
<th>Research Grant</th>
<th>Other Research Support</th>
<th>Speakers’ Bureau/ Honoraria</th>
<th>Expert Witness</th>
<th>Ownership Interest</th>
<th>Consultant/ Advisory Board</th>
<th>Other</th>
<th>Advisory Board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gerasimos Fillipatos</td>
<td>Evangelismos Hospital, Athens, Greece</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Mike Kontos</td>
<td>Virginia Commonwealth University/ Medical College of Virginia</td>
<td>NIH*</td>
<td>None</td>
<td>AstraZeneca*</td>
<td>Plaintiff, postoperative MI*</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Steve Pastores</td>
<td>Memorial Sloan-Kettering Cancer Center</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Ileana L. Piña</td>
<td>Case Western Reserve University</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Cathy Ryan</td>
<td>University of Illinois at Chicago</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>C.A. Swaram</td>
<td>University of Oklahoma</td>
<td>None</td>
<td>None</td>
<td>Medtronic*</td>
<td>None</td>
<td>None</td>
<td>Medtronic*</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

This table represents the relationships of reviewers that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all reviewers are required to complete and submit. A relationship is considered to be “significant” if (1) the person receives $10,000 or more during any 12-month period, or 5% or more of the person’s gross income; or (2) the person owns 5% or more of the voting stock or share of the entity, or owns $10,000 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.

### References

The Evolution of Critical Care Cardiology

1425


**Key Word:** AHA Scientific Statements. • cardiovascular diseases. • critical care. • heart-assist device. • resuscitation.
Evolution of Critical Care Cardiology: Transformation of the Cardiovascular Intensive Care Unit and the Emerging Need for New Medical Staffing and Training Models: A Scientific Statement From the American Heart Association

David A. Morrow, James C. Fang, Dan J. Fintel, Christopher B. Granger, Jason N. Katz, Frederick G. Kushner, Jeffrey T. Kuvin, Jose Lopez-Sendon, Dorothea McAreavey, Brahmajee Nallamothu, Robert Lee Page II, Joseph E. Parrillo, Pamela N. Peterson and Chris Winkelman

Circulation. 2012;126:1408-1428; originally published online August 14, 2012;
doi: 10.1161/CIR.0b013e31826890b0

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2012 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/126/11/1408

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/