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Improving Cardiac Arrest Resuscitation Outcomes: A Valentine Worth Sending

In the United States, February 14 is Valentine’s Day, when expressions of love are sent to those we care about most. The American Heart Association’s (AHA’s) designation of February as American Heart Month reminds us that we could extend those sentiments beyond a single day by demonstrating how to protect our loved ones from cardiac disease, still ranked as the nation’s number 1 cause of death. In recognition of the burden that heart disease represents in our patient populations, this issue of Critical Care Nurse is devoted to the topic of cardiac arrest, a challenging condition that teeters its victims between life and death. One of the particularly vexing and longstanding attributes of this disorder is our limited success in prevailing against its potentially ominous outcomes.

Definition of Cardiac Arrest

Cardiac arrest is defined as the abrupt loss of cardiac function in someone who may or may not have a diagnosis of heart disease. It arises instantaneously, often without preceding symptoms, making it virtually impossible to anticipate and challenging to correctly recognize, manage, and reverse before irreversible and fatal consequences ensue. Although it may arise from a number of distinct etiologies, most cases of cardiac arrest are associated with development of a cardiac arrhythmia, typically ventricular fibrillation.

Survival Rates Remain Disheartening

Each year nearly 568,500 sudden cardiac arrests occur in the United States. Of these, approximately 359,400 (63%) are out-of-hospital cardiac arrests (OHCAs) and 209,000 (37%) are in-hospital cardiac arrests. Of the nearly 360,000 cardiac arrests that happen outside hospitals, 88% occur in the home. If effective cardiopulmonary resuscitation (CPR) can be delivered immediately after cardiac arrest, the victim’s probability of survival is doubled or tripled. However, despite decades of research, the instruction of millions of laypersons and professional health care providers, countless public service announcements, and national programs provided by organizations such as the AHA and American Red Cross, only 32% to 40% of OHCAs are responded to with bystander CPR. Among all OHCA victims, only 8% to 9.5% survive to hospital discharge.

A few distinctions between out-of-hospital and in-hospital patient populations are worth noting. An OHCA can be defined as “cessation of cardiac mechanical activity that occurs outside of the hospital setting and is confirmed by the absence of signs of circulation.” Although it may develop from a variety of noncardiac etiologies such as trauma or drug overdose, a substantial majority of OHCAs is attributable to cardiac causes.

An in-hospital cardiac arrest occurs in a hospital and typically includes resuscitation efforts such as defibrillation, chest compressions, or both. As admission to a hospital becomes
more selective based on need for services, in-hospital patients who experience cardiac arrest are likely to be sicker and have more clinically significant comorbidities compared to their neighbors living at home. As a result, despite the greater availability of health care professionals to provide CPR, in-patient cardiac arrest victims may have more clinically advanced systemic disorders that could limit their ability to benefit from CPR.

During the 1990s, reports of survival to discharge rates following in-hospital cardiac arrest and CPR ranged from 7% to 26%. In the United States, the most recent in-hospital cardiac arrest statistics from the Resuscitation Outcomes Consortium Cardiac Epistry and Get With The Guidelines-Resuscitation data show an overall survival rate to hospital discharge for adult victims of cardiac arrest of 23.9%. For patients in the United Kingdom, the National Cardiac Arrest Audit found an overall survival to hospital discharge rate of 18.4%. As in the United States, higher rates of survival to hospital discharge are found in patients with shockable rhythms (ventricular fibrillation or pulseless ventricular tachycardia) compared to those with nonshockable rhythms (asystole or pulseless electrical activity).

For patients over 70 years, the chance of survival to hospital discharge following in-hospital CPR ranges at a lower plateau between 11.6% and 18.7%, with declining survival associated with increasing age. Although some improvements in cardiac arrest survival can be noted, the body of research in this area suggests that significant improvements have not yet been realized. Until those advances can be identified to influence clinical practice, critical care nurses might consider making their contributions by pursuing alternative efforts that represent potential inroads toward improving cardiac arrest outcomes.

Critical Care Nurses Can Contribute to Improved Outcomes

Recent research suggests that 2 of the inroads that may lead to better cardiac arrest resuscitation outcomes include doing more and doing less than we are currently doing in managing this condition.

Doing More

The Doing More strategy recognizes that 92% of the 360,000 Americans who suffer an OHCA each year will die, that a majority of those deaths might have been avoided if timely and effective interventions known to improve survival from cardiac arrest had been provided, and that one of those timely and effective interventions is provision of bystander CPR. As a recent AHA Science Advisory explained, OHCA survival rates have increased in communities where bystander CPR participation was expanded. These are especially important initiatives in poor, non–English-speaking, Black, and Latino neighborhoods, where few know how to provide bystander CPR. Instructional and recruitment programs to inform, involve, and teach CPR to residents of these neighborhoods could launch lifesaving efforts with immediate impact.

Doing Less

As in many aspects of life, doing less at times yields more. Two approaches to doing less with resuscitation for cardiac arrest suggested by recent literature include focusing on immediate and effective provision of Basic Life Support (BLS) rather than delaying or interrupting that to provide Advanced Life Support (ALS) and teaching laypersons to perform chest compressions-only CPR rather than standard CPR that includes intermittent breaths.

An intriguing study reported by Sanghavi and colleagues at Harvard University used a nationally representative sample of Medicare beneficiaries from nonrural areas of the United States that included 1643 patients managed with BLS and 31,292 managed with ALS. The researchers concluded that OHCA patients had higher survival at discharge (BLS 13.1% vs ALS 9.2%, 95% CI, 2.3-5.7), higher survival at 90 days (BLS 8.0% vs 5.4% for ALS; 95% CI, 1.2-4.0), and lower rates of poor neurological functioning (BLS 21.8% vs ALS 44.8%; 95% CI, 18.6-27.4) when they received only BLS rather than ALS from emergency medical services. These results need to be interpreted with caution (the ALS was provided by emergency medical services staff rather than hospital physicians or nurses, the timing of initiation of either form of resuscitation is not included in data, data rely on billing record rather than clinical documentation of measures provided, and ALS is usually preceded by BLS, so it is not clear how those influences were distinguished to capture measurement of ALS alone, some patients require the medications, equipment, and therapies reserved for ALS) to ensure
that the methodology and analysis are sufficiently vetted and not found wanting. Despite that customary admonition, the results are thought-provoking and worthy of further consideration and repeat testing.

A second avenue of Doing Less involves the use of compression-only CPR in place of traditional CPR procedures that include intermittent use of mouth-to-mouth breaths. Since the AHA updated its CPR guidelines in 2005 to recommend use of chest-compression CPR by untrained rescuers as well as in dispatcher-assisted CPR in an effort to expand the quality and provision of bystander CPR, a number of reports have heralded support for compression-only CPR (hands-only) as an effective form of CPR with survival outcomes comparable to those of conventional CPR. Additional studies have noted better neurological outcomes at 1 month with hands-only CPR compared to conventional CPR when hands-only CPR is combined with public-access automated external defibrillators. More recently, a meta-analysis of studies including more than 92,000 adult patients with OHCA further supported the efficacy of hands-only CPR in producing survival rates comparable to those achieved with conventional CPR for patients whose arrest was of cardiac etiology.

Because nearly 90% of cardiac arrests occur within the home, most of us will encounter victims who are family members, close friends, or neighbors, as stated by the AHA mantra: “The life you save with CPR is mostly likely to be someone you love.” For those of us already thoroughly trained and certified to provide lifesaving resuscitation, our ability to respond to that emergency is automatic, immediate, and competent. In addition, critical care nurses could join with colleagues in home health, school and community health, and numerous other surrounding organizations to instruct and empower residents in our neighborhoods, schools, communities, places of worship or recreation, towns or cities to serve their own loved ones as bystander-CPR providers. Sending them a text, e-mail, tweet, card, or brochure that reads “If you love someone, learn how to save their life” and invites them to see the brief video of how easily and quickly they can learn hands-only CPR can represent the best Valentine’s gift they ever received. Critical care nurses can do that. We know you can.

Join the Conversation
If you can suggest other strategies for improving patient outcomes following cardiac arrest, please send them to us at ccn@aacn.org so Critical Care Nurse can share these with our readers. CCN

References

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JoAnn Grif Alspach, RN, MSN, EdD
Editor, Critical Care Nurse


Corrections

In the December article by Chaisson et al, “Improving Patients’ Readiness for Coronary Artery Bypass Graft Surgery” (*Crit Care Nurse*. 2014;34[6]:29-38), the e-mail address listed for the corresponding author (Kristine Chaisson) was invalid. The correct e-mail is krischaisson@gmail.com.

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Methods Used by Critical Care Nurses to Verify Feeding Tube Placement in Clinical Practice

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BACKGROUND: The American Association of Critical-Care Nurses practice alert on verification of feeding tube placement makes evidence-based practice recommendations to guide nursing management of adult patients with blindly inserted feeding tubes. Many bedside verification methods do not allow detection of improper positioning of a feeding tube within the gastrointestinal tract, thereby increasing aspiration risk.

OBJECTIVES: To determine how the expected practices from the American Association of Critical-Care Nurses practice alert were implemented by critical care nurses.

METHODS: This study was part of a larger national, online survey that was completed by 370 critical care nurses. Descriptive statistics were used to analyze the data.

RESULTS: Seventy-eight percent of nurses used a variety of methods to verify initial placement of feeding tubes, although 14% were unaware that tube position should be confirmed every 4 hours. Despite the inaccuracy of auscultation methods, only 12% of nurses avoided this practice all of the time.

CONCLUSIONS: Implementation of expected clinical practices from this guideline varied. Nurses are encouraged to implement expected practices from this evidence-based, peer reviewed practice alert to minimize risk for patient harm. (Critical Care Nurse. 2015;35[1]:e1-e7)

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http://dx.doi.org/10.4037/ccn2015984
Nurses commonly experience scenarios where hemodynamic monitoring is focused on hypovolemia (see case study) in clinical practice. In this article, we provide an overview of the use of stroke volume (the amount of blood ejected from the left ventricle with each beat) for hemodynamic management of critically ill patients. We also discuss the limitations of conventional assessment parameters, methods of measuring stroke volume, hemodynamic variables that influence stroke volume, the stroke volume optimization (SVO) replacement algorithm, supporting literature, and nursing considerations.

Much of the supporting literature (mostly studies in perioperative patients) on stroke volume as a primary hemodynamic monitoring parameter focuses on the treatment of hypovolemia.

Critical care practices have evolved to rely more on physical assessments for monitoring cardiac output and evaluating fluid volume status because these assessments are less invasive and more convenient to use than a pulmonary artery catheter. Despite this trend, level of consciousness, central venous pressure, urine output, heart rate, and blood pressure remain assessments that are slow to be changed, potentially misleading, and often manifested as late indications of decreased cardiac output. The hemodynamic optimization strategy called stroke volume optimization might provide a proactive guide for clinicians to optimize a patient’s status before late indications of a worsening condition occur. The evidence supporting use of the stroke volume optimization algorithm to treat hypovolemia is increasing. Many of the cardiac output monitor technologies today measure stroke volume, as well as the parameters that comprise stroke volume: preload, afterload, and contractility. (Critical Care Nurse. 2015;35[1]:11-28)

Nurses commonly experience scenarios where hemodynamic monitoring is focused on hypovolemia (see case study) in clinical practice. In this article, we provide an overview of the use of stroke volume (the amount of blood ejected from the left ventricle with each beat) for hemodynamic management of critically ill patients. We also discuss the limitations of conventional assessment parameters, methods of measuring stroke volume, hemodynamic variables that influence stroke volume, the stroke volume optimization (SVO) replacement algorithm, supporting literature, and nursing considerations.

Much of the supporting literature (mostly studies in perioperative patients) on stroke volume as a primary hemodynamic monitoring parameter focuses on the treatment of hypovolemia, as in the case...
study. In the following section, we review the clinical importance of hypovolemia that may go undetected (occult hypovolemia) when conventional assessment techniques are used.

Importance of Occult Hypovolemia

To illustrate the nature of subclinical or occult hypovolemia and to test the sensitivity of gastrointestinal tonometry for detecting such hypovolemia, Hamilton-Davies et al. conducted a study on 6 healthy volunteers in the critical care unit at University College of London Hospitals, London, England. Each of the volunteers had a mean of 25% (21%-31%) of their overall blood volume removed during a 1-hour period, and the volunteers’ response was measured. Variables such as heart rate, blood pressure, serum levels of lactate, and stroke volume were measured every 30 minutes throughout the study. After 90 minutes, decreases in gut intramucosal pH were observed, as well as marked decreases in stroke volume, by a mean of 16.5 mL (P < .01). Despite this compromised flow, no clinically significant or consistent postinterventional changes were noted in serum levels of lactate, arterial blood pressure, heart rate, or arterial blood gases according to serial measurements obtained throughout the study period. Retransfusion was started after 90 minutes. The results of this study may provide insight into the reliability of routinely used measurements such as heart rate and systolic blood pressure as volume depletion progressed in these volunteers.

Hypovolemia (defined as inadequate left ventricular filling volumes) affects the cardiovascular system in a characteristic sequence of events as the hypovolemia worsens (Table 1). First, stroke volume decreases

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Classes of shock by Advanced Trauma Life Support (ATLS) designation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Class 1</td>
</tr>
<tr>
<td>Blood loss, %</td>
<td>&lt;15%</td>
</tr>
<tr>
<td>Heart rate, beats per minute</td>
<td>&lt;100</td>
</tr>
<tr>
<td>Blood pressure, mm Hg</td>
<td>Normal</td>
</tr>
<tr>
<td>Pulse pressure</td>
<td>Normal or increased</td>
</tr>
<tr>
<td>Respiratory rate, breaths per minute</td>
<td>14-20</td>
</tr>
<tr>
<td>Mental status</td>
<td>Slightly anxious</td>
</tr>
</tbody>
</table>

Authors

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because of decreased overall circulating volume (class 1). Next, heart rate increases and vasoconstriction occurs to maintain blood pressure and cardiac output (the volume of blood pumped by the heart per minute) (class 2). A surge of endogenous catecholamines helps shunt blood from the periphery and splanchnic circulation to the brain and great vessels to preserve vital organs. Once compensatory mechanisms are exhausted, cellular respiration begins to change from aerobic metabolism to anaerobic metabolism, and tissue oxygenation is threatened. Oxygen extraction rates increase, and mixed venous oxygen saturation ($SvO_2$) and central venous oxygen saturation ($ScvO_2$) decrease because of decreased cardiac output, compromised blood flow, and decreased oxygen delivery to tissues (class 3). Finally, urine output, level of consciousness, and blood pressure decrease (class 4). Each event may take minutes to hours. Despite this known sequence, aggressive intervention often is not implemented until hypotension occurs. Traditionally, clinicians are trained to monitor for early indications of decompensation, and the first hemodynamic monitoring parameter to decrease in hypovolemia is stroke volume.

Hypovolemia frequently occurs in patients during surgery and in the critical care unit because of bleeding, hypoalbuminemia, capillary leak and interstitial edema, diarrhea, vomiting, and insensible water loss. If the hypovolemia is left untreated (or undertreated), circulatory hypoxia may develop because of the decreased blood flow and hypoperfusion. Compensatory diversion of blood flow centrally, away from the peripheral and splanchnic circulation, often masks hypoperfusion.

If not recognized and treated promptly, decreased circulating volume (particularly at the microvascular level) leads to diminished oxygen delivery, depletion of intracellular energy reserves, acidosis, anaerobic glycolysis, and lactate accumulation. Hypovolemia can also lead to ischemic gastrointestinal complications, including nausea, vomiting, and intolerance of oral intake. Therefore, diligent monitoring, via accurate assessment of cardiac output and stroke volume, for hypovolemia is important for monitoring blood flow.

**Limitations of Conventional Assessments**

Current conventional assessments such as heart rate, blood pressure, urine output, central venous pressure (CVP), and level of consciousness often lack precision as indicators of changes in a patient’s status. Although the values obtained in these assessments somewhat correlate with hemodynamic variables, the values are slow to change and the changes are often late indications of a patient’s worsening condition. Several studies suggest that using physical assessment to evaluate cardiac output may yield inaccurate findings. More recent data suggest that the predictive power of blood lactate levels for mortality and morbidity are independent of blood pressure and common physiological triage variables (eg, heart rate, blood pressure, mental status, capillary refill).

Despite these limitations, assessments such as blood pressure are still considered a standard of care, and current practice mandates use of the assessments. However, blood pressure itself is a composite of so many factors (Figure 1) that it is of limited value as an early sign of hemodynamic derangements such as hypovolemia. Compensatory mechanisms such as vasoconstriction and tachycardia influence the cardiovascular system to keep blood pressure normal, making the correlation between blood pressure and blood flow slow to change as circulating volume decreases. The terms *compensated shock* and *cryptic shock* are now being used to define patient scenarios that meet clinical criteria for shock in
the presence of normal blood pressures. Blood pressure measurements are more useful for conditions that involve treatment of hypertension rather than treatment of hypovolemia or shock. International guidelines such as the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure help guide care providers in the management of hypertension according to a systematic and stepwise approach. However, currently no such guidelines exist for the management of hypotension.

Reconsidering Fluid Replacement End Points

In an article published in 1996, Connors et al suggested that use of a pulmonary artery catheter (PAC) was associated with an increased likelihood of patient death. Since then, use of PACs has generally decreased. Although values obtained via a PAC were once considered the gold standard for bedside hemodynamic monitoring, the precision of a PAC for assessing preload status via filling pressures is limited. As early as 1971, Forrester et al pointed out the inaccuracies of CVP monitoring. In a more recent systematic review of CVP as a predictor of cardiac output and fluid responsiveness, Marik et al concluded that CVP should not be used as a basis for clinical decisions on fluid management. In fact, Marik et al noted that the only published study suggesting CVP could be an accurate indication of preload was done in horses. Even though guidelines such as those of the Surviving Sepsis Campaign recommend using CVP to monitor preload, no study of CVP or pulmonary artery occlusive pressure (PAOP) has shown that these pressures consistently correlate with blood flow or volume status. Early and aggressive use of fluid replacement to preestablished end points such as ScvO₂ is more likely than the measurement of CVP itself to provide patients benefit. The limitations of CVP are further pointed out in the landmark study on septic shock by Rivers et al published in 2001. These investigators randomized 263 patients with septic shock to receive either treatment according to a protocol on fluid replacement known as early goal-directed therapy or conventional care (control group). The patients treated according to the protocol had a 17% reduction in mortality, even though CVP was used as part of the basis for treatment in both the interventional and the control group.

PAOP is also an inaccurate predictor of fluid responsiveness in critically ill patients, further indicating that blood pressures do not correlate with blood flow parameters such as cardiac output and stroke volume. This lack of correlation occurs because many factors can alter the pressure-volume relationship within the heart. For example, conditions that increase PAOP but not preload include, but are not limited to, positive-pressure mechanical ventilation, positive end-expiratory pressure, and decreased ventricular compliance. Conditions that alter cardiac compliance include aging, obesity, diabetes, myocardial ischemia, and sepsis. The challenge encountered with interpreting PAOP is further illustrated in Figure 2; the 3 hearts in the drawing have different cardiomyopathies and various left ventricular end-diastolic volumes (LVEDVs), but each heart has the same PAOP. As a result, the baseline Frank-Starling pressure-volume curves for the 3 hearts differ vastly (Figure 3). When LVEDV increases in normal hearts, pressure increases in a characteristic curvilinear relationship. However, in conditions such as left ventricular hypertrophy, decreased wall compliance increases intracardiac pressure without a concomitant increase in volume. Measurements based on blood flow, such as stroke volume, help clinicians avoid incorrect assumptions based on pressure-volume curves. Ultimately, blood flow is more reliable and precise than blood pressures, and blood flow can decrease before blood pressures decrease.

CVP and PAOP were never intended to be used alone; both are filling pressures meant to guide the optimization of stroke volume. The fundamental reason to administer a fluid bolus to a patient is to increase stroke volume. Although stroke volume monitoring is not considered a standard of care, as is conventional monitoring of vital signs, plotting or documenting stroke volume in response to a fluid challenge may be the closest clinicians can come to using the Frank-Starling curve in routine bedside practice. Stroke volume is more likely to indicate hypovolemia before other monitoring parameters do because the former is not influenced by most compensatory mechanisms. Treatments that include giving fluids and medications such as drugs that improve contractility (inotropes) are often administered with the goal of improving stroke volume. Specifically targeting...
Stroke volume for hemodynamic management is termed SVO. Indications for use of SVO include age, heart failure, low urine output, bleeding, monitoring of fluid boluses and vasoactive infusions, cardiac conditions, and risk for hypoperfusion or organ dysfunction. Awareness of contraindications is just as important: for example, esophageal Doppler monitoring is contraindicated in patients with esophageal strictures or varices.

**Stroke Volume As the Newest Cardiac Vital Sign**

Assessing for Adequate Perfusion

Using mean arterial pressure to evaluate a patient for adequate perfusion to the vital organs is a controversial but important idea for bedside clinicians to consider. As oxygen supply decreases or oxygen demand increases, tissue hypoxia can develop. However, exactly when the hypoxia occurs in an individual patient is unclear. ScvO2 can be a helpful global indicator; however, monitoring microcirculatory perfusion at the end-organ level is not readily available yet. When compromised perfusion progresses to the point of eventual acidosis, organ damage most likely is occurring, even when blood pressures are normal.1

The complexity of these changes defies overreliance on parameters such as blood pressure. Ongoing fluid replacement decisions should be based on stroke volume, variations in pulse pressure, cardiac output derived by using a minimally invasive method, and passive leg-raising maneuvers supported by integrated assessment to more
Methods of Measuring Stroke Volume

Traditionally, echocardiography has been the most commonly used method to measure stroke volume at the bedside. However, this method is expensive and technically difficult and continuous or serial measurements are often not practical in critical care. Several new technologies enable ongoing measurement of stroke volume at the bedside, including noninvasive Doppler imaging (USCOM), esophageal Doppler imaging (Deltex Medical; Figure 4), bioimpedance (SonoSite), endotrachely applied bioimpedance (ConMed Corporation), bioreactance (Cheetah Medical), pulse contour methods (Edwards Lifesciences, LidCo Ltd, Pulsion Medical Systems), an exhaled carbon dioxide method (Philips, Respironics), and the PAC. All use various methods to calculate stroke volume, and the results have various degrees of accuracy. Some devices measure stroke volume directly (eg, esophageal Doppler imaging) and may be considered the preferred method because of the high degree of accuracy of the results. Other technologies simply divide the cardiac output by the heart rate to obtain stroke volume (eg, PAC). Table 2 provides a more detailed comparison.

Clinical application of technology is based on knowledge and experience in obtaining and applying the information received. If a care provider targets the wrong hemodynamic end points or interprets a poor waveform as an accurate tracing, benefits may be limited. These concerns were cited in the technology assessment report published by the Agency for Healthcare Research and Quality in 2008 as some of the most likely reasons studies have collectively suggested no benefit for monitoring with PACs.

Disagreement may exist about which technology is best for monitoring stroke volume because none of the technologies is appropriate for all patients in all situations. Each technology has a unique profile of advantages and limitations, and a patient’s situation may dictate which technology is best at a given time.
<table>
<thead>
<tr>
<th>Technology</th>
<th>Manufacturer</th>
<th>Where used</th>
<th>Randomized controlled trials regarding patient outcome</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Doppler imaging</td>
<td>USCOM, Sydney, Australia</td>
<td>Anywhere</td>
<td>None</td>
<td>Stroke volume estimate obtained via ultrasound probe placed at the sternal notch or parasternally; ultrasound beam directed at the aortic or pulmonic valve</td>
</tr>
<tr>
<td>Esophageal Doppler imaging</td>
<td>Deltex Medical, West Sussex, England</td>
<td>Operating room, intensive care unit, emergency department</td>
<td>9 trials(^{44-52}) (2 trials had conflicts of interest to disclose) showing reduced length of stay, complications, use of vasopressors, renal insufficiency, and mortality and lower lactate levels</td>
<td>Stroke volume estimate directly obtained via Doppler signal of descending aorta; typically, patient must be sedated; inserted similarly to a nasogastric tube</td>
</tr>
<tr>
<td>Endotracheal bioimpedance</td>
<td>ConMed Corporation, Utica, New York</td>
<td>Operating room, intensive care unit</td>
<td>None</td>
<td>Bioimpedance technology via endotracheal tube; stroke volume obtained from impedance signal from ascending aorta; patient must be intubated</td>
</tr>
<tr>
<td>Transcutaneous bioimpedance</td>
<td>SonoSite, Bothell, Washington</td>
<td>Anywhere</td>
<td>None</td>
<td>Transcutaneous electrodes placed on neck and chest; electrical impedance between electrodes during cardiac cycle entered into nomogram to compute stroke volume; for best readings, patient must have normal anatomy</td>
</tr>
<tr>
<td>Pulse contour</td>
<td>FloTrac, Edwards Lifesciences, Irvine California LidCo Ltd, Cambridge, United Kingdom PiCCO, Pulsion Medical Systems, Munich, Germany</td>
<td>Operating room, intensive care unit</td>
<td>3 trials (each with conflicts of interest to disclose) suggesting decreased complications and length of stay (LidCO),(^{53}) (FloTrac),(^{54}) and (PiCCO)(^{55}) 3 trials suggesting unclear benefit (PiCCO)(^{56}) (conflict of interest disclosed) or no benefit (FloTrac)(^{57}) and (PiCCO)(^{58})</td>
<td>Stroke volume estimated from arterial pressure waveform via methods such as lithium infusion, pulse pressure variation, or thermodilution; continuous cardiac output and beat-to-beat variability proportional to stroke volume; changes in systemic vascular resistance and arterial pressure necessitate recalibration; dampening, dysrhythmias, and ventilator triggering also limit accuracy</td>
</tr>
<tr>
<td>Exhaled carbon dioxide method</td>
<td>Philips Respironics, Andover, Massachusetts</td>
<td>Operating room, intensive care unit</td>
<td>None</td>
<td>Exhaled carbon dioxide method, with Fick equation; needs controlled mechanical ventilation to work; additional personnel, such as respiratory therapist, may be required; patient must be intubated</td>
</tr>
<tr>
<td>Pulmonary artery catheter</td>
<td></td>
<td>Operating room, intensive care unit</td>
<td>Several trials,(^{59,60}) with both pro and con findings</td>
<td>Measures cardiac output via thermodilution, temperature sensed by the catheter thermistor; stroke volume calculated by dividing cardiac output by heart rate; central venous access required via catheterization of right side of heart</td>
</tr>
<tr>
<td>Bioreactance</td>
<td>Cheetah Medical, Portland, Oregon</td>
<td>Operating room, intensive care unit</td>
<td>None</td>
<td>Like bioimpedance, uses transcutaneous electrodes; however, signal acquisition eliminates impedance errors present with the first-generation technology</td>
</tr>
</tbody>
</table>
that cross the ultrasound transducer beam through the aorta during the systolic phase (Figures 4A and 4B). FTc corresponds to the width of the pulse waveform base and can be used to estimate preload. For example, a longer FTc suggests that the left ventricle is pumping forward an increased amount of blood (ie, increased preload).

The width of the pulse wave is measured in milliseconds and represents the amount of time spent in systole compared with total cardiac cycle time, and FTc is also corrected for heart rate. The correction is based on a heart rate of 60/min, although the current heart rate is taken into account. If a patient’s heart rate is 60/min, then each cardiac cycle will last 1 second, or 1000 ms. Normal FTc is 330 to 360 ms. In other words, for a cardiac cycle lasting 1 second, the systolic flow period should last approximately 330 to 360 ms, provided that adequate preload exists. An easy way to remember the reference range is to remember that the heart is in diastole two-thirds of the time and that normal FTc multiplied by 3 equals 1 second, or 1000 ms (Figure 5). But normal reference ranges are really just reference points, not necessarily static physiological targets to be used for all patients. The most important value of FTc is the degree to which it changes in response to intravenous administration of fluids. Increases in FTc in response to volume challenge help confirm hypovolemia, which is manifested as a narrow waveform base and a low FTc (Figure 3).

The accuracy of FTc has been questioned. However, a complete understanding of the variable is critical before FTc and be used effectively in clinical practice. Simply put, FTc is suggestive of the amount of circulating volume that passes the tip of the ultrasound probe during systole. Therefore, conditions such as bleeding (hypovolemia), heart failure (low contractility), and high afterload (eg, vasoconstriction) may contribute to low blood-flow states and thus low FTc. These influences must be considered before FTc is accepted as a surrogate for preload in individual patients. Several investigators have suggested that FTc is as good as or better than PAOP for indicating changes in preload. Most important, however, improvement in stroke volume after fluid administration is what was intended to form the basis on which preload

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**Figure 5** Waveform components for stroke volume optimization (SVO): aortic pulse waveform from an esophageal Doppler examination. Corrected flow time (ie, the time spent in systole) corresponds to the width of the pulse waveform and is an index of preload. Peak velocity corresponds to the height of the wave and is a measure of contractility. Stroke distance represents the area under the curve and is used to compute stroke volume.
responsiveness is ultimately determined (in each of the outcome trials studying SVO). In other words, FTc (as well as CVP and PAOP) is best used as a decision-making aid for optimizing stroke volume.

**Measurement of Contractility: Peak Velocity**

Peak velocity, a measure of contractility, is indicated by the amplitude of a Doppler waveform (Figure 5). It indicates the acceleration of blood flow in the systolic phase, or the speed at which a pressure wave goes from baseline to the peak height of contraction. An overall reference range is 50 to 120 cm/s. Peak velocity can be age dependent; the expected range for a 20- to 30-year-old is 90 to 120 cm/s, with gradually decreasing expected peak velocity as a person ages. Patients more than 65 years old are expected to have a peak velocity greater than 50 cm/s. Values less than 50 cm/s are suggestive of poor left ventricular contractility, as in heart failure. However, peak velocity should be evaluated with respect to a patient’s baseline values and how those values respond to treatments. For example, an increase in peak velocity is expected with administration of an inotrope.

A low stroke volume can occur for 1 of 2 main reasons: hypovolemia or decreased ventricular contractility. The immediate measured availability of peak velocity with Doppler techniques provides better information than do the derived contractility parameters of the PAC regarding why stroke volume may be low. For example, if stroke volume is low but peak velocity is normal, the problem most likely is hypovolemia. However, if both stroke volume and peak velocity are low, the problem most likely is left ventricular dysfunction. A patient’s response to medications such as preload reducers, afterload reducers, or inotropes can help differentiate the cause of the left ventricular dysfunction (eg, fluid overload, high afterload, or low contractility, respectively).

Peak velocity may also help detect acute decompensating systolic heart failure earlier than do other techniques for monitoring cardiac output. In critical illness, poor left ventricular contractility (low ejection fraction) may initially lead to a compensatory increase in end-diastolic volume, a change that implies a normal stroke volume. The ability to monitor peak velocity allows clinicians to recognize this decrease in contractility in real time and intervene before a decrease in stroke volume occurs. Further research is needed to better establish SVO treatment guidelines for patients with heart failure.

**Measurement of Afterload: Systemic Vascular Resistance**

Systemic vascular resistance (SVR) is the resistance that must be overcome by the ventricles to develop force and contract, propelling blood into the arterial circulation. Most of the newer hemodynamic monitoring technologies (eg, esophageal Doppler imaging, bioimpedance, pulse contour methods) have the capability to calculate SVR. However, SVR was not a major parameter in the algorithms used in any of the SVO trials that showed improved outcomes in surgical patients.

Evidence of lack of inclusion suggests that SVR is a more of a secondary monitoring parameter. Elevated SVR usually occurs in response to systemic hypertension or as a compensatory mechanism due to decreased cardiac output, as in shock states (Figures 1A and 1B). Therefore, nurses must know why the SVR is elevated. If the value is elevated in response to low cardiac output, once cardiac output is improved with treatment (eg, fluid, inotropes), SVR should decrease because of a decreased need for compensatory vasoconstriction. If SVR is elevated because of systemic hypertension, treatment may include administration of an afterload reducer.

When SVR decreases, the left ventricular ejection of blood encounters lower resistance. Low afterload states may be less problematic when blood pressure and cardiac output are normal (Figure 1A). However, attempts to increase low SVR generally include administration of vasopressors. ScvO₂ and stroke volume should also be followed as end points to ensure that blood flow and tissue oxygenation improve in response to the vasopressor (Figure 6). Titrating the dose of a vasopressor used to alter ScvO₂ and stroke volume allows clinicians to focus on optimizing blood flow to both the microcirculation and the macrocirculation. Several studies of fluid replacement protocols that include use of vasopressors suggest that optimizing ScvO₂ and stroke volume improve patients’ outcomes. However, further research is needed to better establish how vasopressors and ScvO₂ are best used in SVO protocols.

**Stroke Volume, Stroke Index, and Stroke Distance**

Stroke volume is one of the primary end points for detecting fluid responsiveness and guiding goal-directed therapy. Stroke index is a standardized parameter in which a patient’s body surface area is taken into account.
However, monitoring both stroke volume and stroke index is generally not necessary, because they use different units of measure to quantify the same value. Table 3 gives reference ranges for these parameters.21,77-79 However, the ideal stroke volume value is the one that contributes to adequate blood flow for tissue oxygenation without increasing heart rate.

Despite the unique advantages of measuring stroke volume, available technologies to measure this parameter at the bedside have some limitations. Even esophageal Doppler imaging, which provides a highly flow-directed estimation of stroke volume, uses a calculated estimation of aortic diameter based on the patient’s height and weight.80 Stroke distance may be a more accurate reflection of the Doppler estimation of stroke volume. Stroke distance is the distance a column of blood moves through the descending thoracic aorta during each systolic phase.61 Because stroke distance is used to calculate stroke volume, the recommendation is that stroke distance be evaluated to determine if the measurement of stroke volume is accurate.

### The SVO Algorithm: Putting It All Together

The Frank-Starling principle states that the strength of cardiac contraction is directly related to the length of muscle fibers at end diastole, or preload.84 Administration of fluid on the basis of stroke volume allows clinicians to directly apply this principle. Figure 7 displays a standard example of an SVO fluid replacement algorithm, cited by Schober et al,82 that is based on a synthesis of experimental SVO protocols and literature.44-52,73,74 In this type of algorithm, determination of fluid responsiveness is used: fluid boluses are administered as long as stroke volume continues to improve by 10% or more. When administration of fluid boluses ceases to improve stroke volume by

---

**Table 3 Reference ranges for hemodynamic parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac output, L/min</td>
<td>4-8</td>
</tr>
<tr>
<td>Stroke volume, mL</td>
<td>50-100</td>
</tr>
<tr>
<td>Stroke indexb</td>
<td>25-45</td>
</tr>
<tr>
<td>Flow time corrected, ms</td>
<td>330-360</td>
</tr>
<tr>
<td>Peak velocity, cm/s</td>
<td>30-120</td>
</tr>
<tr>
<td>Stroke distance, cm</td>
<td>10-20</td>
</tr>
<tr>
<td>Cardiac indexc</td>
<td>2.8-4.2</td>
</tr>
<tr>
<td>Systemic vascular resistance, dyne sec cm⁻⁵</td>
<td>900-1600</td>
</tr>
<tr>
<td>Saturation of central venous oxyhemoglobin, %</td>
<td>65-80</td>
</tr>
<tr>
<td>Central venous pressure, mm Hg</td>
<td>2-8</td>
</tr>
<tr>
<td>Stroke volume variation, %</td>
<td>&lt; 10-15</td>
</tr>
</tbody>
</table>

a Based on data from Ahrens,21 Lynn-McHale Wiegand,77 Lynn-McHale Wiegand and Carlson,78 and Edwards Lifesciences.79
b Calculated as stroke volume in milliliters per heartbeat divided by body surface area in square meters.
c Calculated as cardiac output in liters per minute divided by body surface area in square meters.
10% or more, no more fluid is needed. Using this method of fluid administration can mitigate the risk of pulmonary edema, and bedside clinicians can be better assured that the patient is receiving enough fluid to optimize the macrocirculation but not more fluid than is needed.

SVR and blood pressure are usually not included in SVO algorithms and are considered secondary monitoring parameters in SVO. According to the SVO algorithm, SVR and blood pressure are evaluated only after peak velocity (contractility) and stroke volume are optimized, because SVR and blood pressure are more indirect reflections of cardiac output and are influenced by other factors (see Figures 1A and 1B). Furthermore, when blood flow and tissue oxygenation are measured rather than assumed, doses of vasopressors can be adjusted to optimize the end points of stroke volume (macrocirculation) and ScvO2 (microcirculation) rather than SVR and blood pressure (Figure 6). Stroke volume may improve initially with initiation and escalating doses of vasopressors, but changes in afterload due to further increases in the medication may impede stroke volume and cardiac output.

Surveillance of ongoing stroke volume and cardiac output may help clinicians avoid this decrease in stroke volume and cardiac output.

Challenges to SVO implementation may include incorporating new hemodynamic monitoring technology into daily practice (eg, esophageal Doppler imaging, pulse contour method), education of staff members, support from physicians and leaders, and the paucity of literature to support use in nonsurgical patients. However, potential benefits include use of minimally invasive techniques, allowing earlier detection of unstable hemodynamic status, and reductions in morbidity, mortality, and length of stay.

More research is needed to determine how values such as peak velocity and ScvO2 can be incorporated into the SVO algorithm. The following case studies illustrate these points and indicate how SVO can be applied in cases involving alterations in preload, afterload, and contractility.

**Case Study 1: Decreased Preload**

A 59-year-old man was admitted to the surgical intensive care unit after having a partial liver lobectomy.
after a motor vehicle accident (Table 4). On postoperative day 5, he was evaluated for discharge to a general care unit. His urine output had decreased during the preceding 12 hours, suggestive of hypovolemia. The hypovolemia was evidenced by low stroke volume, low FTc, and low ScvO2 in the presence of a normal peak velocity. After injection of a 1000-mL bolus of physiological saline, stroke volume improved from 34 mL to 48 mL, more than a 10% (3.4 mL) improvement. So, another bolus was given. Satisfactory response to the bolus was manifested by normal FTc and ScvO2. Stroke volume improved to 49 mL only with the second bolus (<10% improvement), indicating the beginning of the plateau along the Frank-Starling curve where increased stretching of the ventricular myocytes does not improve stroke volume. Thus, no further administration of fluid was indicated.

Case Study 2: Decreased Preload Leads to Decreased Afterload

A 55-year-old woman was admitted because of sepsis (Table 5). The patient had a dangerously reduced stroke volume, decreased FTc, decreased ScvO2, and a normal peak velocity, indicating hypovolemia. She was deemed fluid responsive as indicated by an improvement in stroke volume from 26 mL to 50 mL, a greater than 10% (2.6 mL) improvement, after administration of a bolus of 1000 mL of physiological saline. So, another saline bolus was indicated. However, the patient did not respond to the second bolus, as evidenced by an improvement in stroke volume from 50 mL to only 51 mL (<10%), suggesting that the macrocirculation had been optimized. Norepinephrine was started because of the reduced ScvO2 and persistent hypotension despite volume correction. The patient responded appropriately as evidenced by the

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Stroke volume, mL</th>
<th>Flow time, corrected, ms</th>
<th>Peak velocity, cm/s</th>
<th>Heart rate, beats per minute</th>
<th>Central venous oxygen saturation, %</th>
<th>Central venous pressure, mm Hg</th>
<th>Blood pressure, mean (SD), mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administer 1000-mL bolus of physiological saline</td>
<td>34</td>
<td>300</td>
<td>96</td>
<td>102</td>
<td>49</td>
<td>3</td>
<td>100/48 (64)</td>
</tr>
<tr>
<td>Administer 1000-mL bolus of physiological saline</td>
<td>48</td>
<td>335</td>
<td>95</td>
<td>100</td>
<td>69</td>
<td>5</td>
<td>94/55 (68)</td>
</tr>
<tr>
<td>Response</td>
<td>49</td>
<td>337</td>
<td>95</td>
<td>99</td>
<td>70</td>
<td>6</td>
<td>100/60 (73)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Stroke volume, mL</th>
<th>Flow time, corrected, ms</th>
<th>Peak velocity, cm/s</th>
<th>Heart rate, beats per minute</th>
<th>Central venous oxygen saturation, %</th>
<th>Central venous pressure, mm Hg</th>
<th>Blood pressure, mean (SD), mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administer 1000-mL bolus of 0.9% normal saline</td>
<td>26</td>
<td>254</td>
<td>78</td>
<td>107</td>
<td>26</td>
<td>4</td>
<td>68/36 (47)</td>
</tr>
<tr>
<td>Administer 1000-mL bolus of physiological saline</td>
<td>50</td>
<td>341</td>
<td>76</td>
<td>105</td>
<td>48</td>
<td>9</td>
<td>76/42 (53)</td>
</tr>
<tr>
<td>Administer norepinephrine 10 μg/min</td>
<td>51</td>
<td>341</td>
<td>76</td>
<td>105</td>
<td>50</td>
<td>9</td>
<td>80/44 (59)</td>
</tr>
<tr>
<td>Response</td>
<td>55</td>
<td>344</td>
<td>72</td>
<td>106</td>
<td>68</td>
<td>8</td>
<td>92/62 (72)</td>
</tr>
</tbody>
</table>

Table 4: Interventions used and response of 59-year-old man admitted after a motor vehicle accident

Table 5: Interventions used and response of 55-year-old woman admitted for sepsis
increase in ScvO₂ to 68%, suggesting normalization of the microcirculation.

**Literature Supporting Clinical Usefulness of SVO**

Before they adopt a new practice, astute clinicians want to know that the practice is strongly supported in the literature. Randomized controlled trials are the highest-level research design, and the number of well-designed randomized controlled trials is directly correlated with the level of evidence assigned to a given practice.83-85 The findings of 11 randomized controlled trials,44-52,73,74 including 9 prospective trials,44-52 suggest that SVO results in improved patient outcomes. Despite a thorough literature review, we were unable to find a fluid replacement strategy supported by more research. The results of the 9 prospective trials,44-52 which included a total of about 1000 patients, consistently suggested that compared with conventional fluid replacement, SVO fluid replacement protocols contribute to decreases in overall hospital length of stay (by 2 days or more), complication rates, renal insufficiency, infection, use of vasopressors, blood lactate levels, and time-to-tolerance of oral intake. Appropriately implemented SVO programs that replicate these outcomes may also be associated with decreased costs.86

Notably, the sample in all 11 trials44-52,73,74 included perioperative patients. Although 2 of these trials44,47 also focused on postoperative care in the critical care unit, more research is needed to indicate the efficacy of SVO in nonsurgical patients. However, in perioperative patients, the strength of the supporting evidence in favor of SVO has been substantiated by large-scale systematic literature reviews conducted by the Agency for Healthcare Research and Quality,87 the National Health Service,86 and third-party payers such as the Centers for Medicare and Medicaid Services88 and Aetna.89

In 3 of these studies,86-88 the agencies recommended SVO protocols be used for monitoring cardiac output of patients receiving mechanical ventilation in the critical care unit and for surgical patients who require intraoperative fluid optimization. Esophageal Doppler imaging,88 bioimpedance,90 and PACs91 are all reimbursed by the Centers for Medicare and Medicaid Services90 on the basis of systematic literature reviews. However, esophageal Doppler imaging is the only technology also supported by the Agency for Healthcare Research and Quality.87

Similarly, the Cochrane Collaborative59 and the Agency for Healthcare Research and Quality60 have published technology assessments based on meta-analyses of outcomes related to use of PACs. The analyses indicated that the patients studied showed no evidence of benefit or harm from PACs. Among the reasons cited for the perceived lack of benefit was clinician-to-clinician variability in management of hemodynamic data obtained via PACs. In addition, the authors59,60 questioned the accuracy of the interpretation of the hemodynamic information in the studies analyzed and whether or not patient management strategies based on hemodynamic data were appropriate. Furthermore, none of the studies included use of a specific protocol for PAC use. This lack of a protocol is a key difference between PAC studies and SVO studies. Each of the 9 randomized control trials44-52 on SVO included a protocol for use of SVO. Use of a protocol is consistent with other studies of replacement protocols that include fluid therapy, which can be lifesaving when initiated early in the course of treatment. Findings from a meta-analysis of hemodynamic optimization by Poeze et al92 also suggest that replacement strategies such as SVO improve outcomes, including patient mortality, in high-risk surgical patients.

**Nursing Considerations**

Nursing considerations associated with incorporating SVO into bedside practice include acquiring and evaluating hemodynamic data, maintenance of skin integrity, sedation and analgesia, and nursing research.

**Acquisition and Evaluation of Hemodynamic Information**

Clinical proficiency with applying or inserting the hemodynamic monitoring device and adequate signal acquisition are key.83 Each device has its own unique signal acquisition technique and competency requirements. Inappropriate application of the device may produce inaccurate hemodynamic readings, leading to improper treatment decisions.77,78 Once accurate readings are obtained, understanding the appropriate application of “normal”
hemodynamic reference ranges to all patients is crucial. Tracking trends in hemodynamic values over time is generally more useful than is monitoring and treating on the basis of single data points, because transient changes in values may not be clinically importantly.

When readings are considered accurate and hypovolemia is identified, rapid infusion of a fluid bolus may optimize a patient’s response. Fluid infused via a pressure bag often produces a more dramatic increase in stroke volume than does fluid administered via an intravenous infusion pump. A maximum rate of commonly used intravenous pumps is 999 mL/h. Because hypovolemia and hypoperfusion are time-sensitive conditions, the provider’s judgment and the patient’s condition may determine that a more rapid infusion rate is needed.

The latest revision of the Surviving Sepsis Campaign guidelines also suggests an increased emphasis on earlier and more aggressive fluid replacement. For example, the 2008 guidelines recommended a 20 mL/kg crystalloid fluid challenge in a 6-hour replacement bundle. In the 2012 revised guideline, the recommended amount of fluid was increased (to 30 mL/kg) in a shorter time (3-hour bundle). Clinicians must strongly consider strategies to infuse such a volume rapidly enough, in accordance with institutional policy as appropriate.

Maintenance of Skin Integrity
Care must be taken to avoid skin breakdown under and around skin electrodes. With bioimpedance and bioreactance, signals are acquired transcutaneously, and skin care should be in accordance with the manufacturer’s recommendations and institutional policy. Mouth ulcerations are also possible with monitoring devices such as those used for esophageal Doppler imaging and endotracheally applied bioimpedance. Diligent oral care should be performed as needed while those devices are in place. Site care is also important when caring for patients monitored with intravenous pulse contour devices or PACs. Catheter infections can be minimized by using sterile conditions during insertion and aseptic technique during dressing changes.

Sedation and Analgesia
Sedation is sometimes required with techniques such as the exhaled carbon dioxide method, which requires controlled mechanical ventilation, and esophageal Doppler imaging. These techniques may have limited accuracy when increased respiratory rates or restlessness, respectively, occur. Therefore, sedative agents or analgesics may be administered as needed. Although not a major focus with respect to SVO, pain cannot be overlooked; it is not only an overall priority but can also influence hemodynamic readings.

Nurse Research
The implications of patient advocacy extend beyond routine patient care and include nurses’ participation in designing and implementing future research on the clinical usefulness of SVO in critical care. Critical care nurses monitor and treat hypovolemia daily and have a unique opportunity to contribute to the existing scientific body of knowledge through participation in SVO studies in medical critical care patients.

Summary
The growing body of evidence supporting SVO suggests that implementation of SVO into daily practice should be considered. A new era is emerging in which blood-flow monitoring is taking precedence over the monitoring of blood pressures. Cardiac pressures help provide estimates of blood volume; however, normal cardiac pressures can be observed in a patient in shock and provide little information about blood flow. Interpretation and treatment of blood pressures incorporate assumptions, whereas stroke volume may be considered a more precise measure of fluid responsiveness and an earlier warning sign of volume depletion than are urine output, altered mental status, CVP, heart rate, and blood pressure. Earlier signals such as stroke volume allow clinicians to anticipate rather than react to changes, improving the likelihood of maintaining a stable metabolic state at the organ and cellular level.
existing for bedside clinicians. Fortunately, technology has improved the hemodynamic monitoring landscape. Compared with old devices, newer technology is less invasive, safe, evidence based, flow directed, cost-effective, easier to use, and accurate. Although further research on SVO and dynamic indices are needed to establish the clinical efficacy of SVO in critical care units, the current body of literature indicates that SVO is associated with fewer complications and reduced hospital lengths of stay, particularly in patients receiving mechanical ventilation and in surgical patients. Until more randomized trials on the impact of SVO protocols on the outcomes of critical care patients are published, SVO is supported by more evidence than is use of filling pressures for fluid replacement in critical care units.27,32,44-52,73,74,86-88 On the basis of our review of the current available literature, we suggest that the SVO algorithm for fluid replacement be considered in place of use of cardiac filling pressures for patients in critical care, as appropriate, with attention to outcomes. In the meantime, more research is needed to evaluate the impact of SVO on patients other than perioperative patients and on nonintubated patients. CCN

Acknowledgments
The authors thank Terry Sears and Julie Stielstra for their contributions. We also thank the critical care staff, physicians, and leaders at Central DuPage Hospital—Northwestern Medicine. Without their help and support, this manuscript would have been much more difficult to complete.

Financial Disclosures
Tom Ahrens has lectured for hemodynamic monitoring companies (including Deltex Medical Inc) and is a hemodynamic monitoring consultant.


References


CNE Test  Test ID C1513: Stroke Volume Optimization: The New Hemodynamic Algorithm

Learning objectives: 1. Discuss the use of stroke volume optimization in a hypovolemic patient  2. Define corrected flow time, peak velocity, stroke distance, and stroke index  3. State various methods used to obtain blood flow measurement

1. Which of the following hemodynamic values help determine responsiveness to fluid replacement?
   a. Stroke volume within normal values
   b. Normal stroke volume with normal filling pressures
   c. Adequate blood flow for tissue oxygenation without increasing heart rate
   d. Afterload and preload stabilized

2. Which of the following is the first hemodynamic parameter to decrease in hypovolemia?
   a. Pulmonary artery occlusive pressure (PAOP)
   b. Central venous pressure (CVP)
   c. Cardiac output
   d. Stroke volume

3. After mitral valve replacement, your patient’s urine output decreases over 3 hours. The monitor displays sinus tachycardia with heart rate 108 beats/min, CVP 8 mm Hg, cardiac output 4 L/min, and mean arterial pressure (MAP) 80 mm Hg. The MAP remains within normal range because of which of the following?
   a. Normal cardiac output
   b. No change in circulating volume
   c. Compensatory mechanisms
   d. MAP is an independent parameter

4. Monitoring stroke volume gives the clinician insight into which of the following?
   a. Blood flow and circulating volume
   b. Cardiac filling pressures
   c. Oxygenation
   d. Contractility

5. Which of the following explains why clinicians prefer blood flow monitoring versus blood pressure monitoring?
   a. Compensatory mechanisms mask hypoperfusion
   b. Afterload, preload, and contractility are influenced by medications
   c. Blood pressure, MAP, and heart rate are late indicators of hypoperfusion
   d. All of the above

6. Which of the following changes is expected in a patient who received a 1000-mL fluid challenge that confirms hypovolemia?
   a. Increase in PAOP
   b. Increase in urine output
   c. Increase in stroke volume, corrected flow time, and cardiac output
   d. Increase in CVP and MAP

7. Volume and vasopressors are often the treatment of choice in a patient with shock. Which of the following parameters are best used as end points to guide therapy?
   a. Stroke volume, peak velocity, and corrected flow time
   b. Stroke volume, systemic vascular resistance, and central venous oxygen saturation (ScvO2)
   c. ScvO2, corrected flow time, and peak velocity
   d. ScvO2 and stroke volume

8. Nursing implications in obtaining hemodynamic data include which of the following?
   a. Proficiency in application of monitoring device
   b. Application of data obtained to patient population
   c. Achieving optimal signal acquisition
   d. All of the above

9. Mechanical ventilation with positive end-expiratory pressure can impede blood flow and increase PAOP. How can clinicians determine proper interventions for this patient population?
   a. Trend and optimize stroke volume
   b. Trend cardiac filling pressures
   c. Closely follow pulmonary vascularity on the chest radiograph
   d. Trend blood pressure

Test answers: Mark only one box for your answer to each question. You may photocopy this form.

1.   2.   3.   4.   5.   6.   7.   8.   9.
   a  a  a  a  a  a  a  a  a
   b  b  b  b  b  b  b  b  b
   c  c  c  c  c  c  c  c  c
   d  d  d  d  d  d  d  d  d

Test ID: C1513 Form expires: February 1, 2018 Contact hours: 1.0 Pharma hours: 0.0 Fee: AACN members, $0; nonmembers, $10 Passing score: 7 correct (78%)

Synergy CERP Category A  Test writer: Carol Ann Brooks, BSN, RN, CCRN-K, CSC

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Use of a Nursing Checklist to Facilitate Implementation of Therapeutic Hypothermia After Cardiac Arrest

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Therapeutic hypothermia has become a widely accepted intervention that is improving neurological outcomes following return of spontaneous circulation after cardiac arrest. This intervention is highly complex but infrequently used, and prompt implementation of the many steps involved, especially achieving the target body temperature, can be difficult. A checklist was introduced to guide nurses in implementing the therapeutic hypothermia protocol during the different phases of the intervention (initiation, maintenance, rewarming, and normothermia) in an intensive care unit. An interprofessional committee began by developing the protocol, a template for an order set, and a shivering algorithm. At first, implementation of the protocol was inconsistent, and a lack of clarity and urgency in managing patients during the different phases of the protocol was apparent. The nursing checklist has provided all of the intensive care nurses with an easy-to-follow reference to facilitate compliance with the required steps in the protocol for therapeutic hypothermia. Observations of practice and feedback from nursing staff in all units confirm the utility of the checklist. Use of the checklist has helped reduce the time from admission to the unit to reaching the target temperature and the time from admission to continuous electroencephalographic monitoring in the cardiac intensive care unit. Evaluation of patients’ outcomes as related to compliance with the protocol interventions is ongoing. (Critical Care Nurse. 2015;35[1]:29-38)

In the United States, 359 400 people experience an out-of-hospital cardiac arrest each year, and less than 9.5% of those people survive.¹ Out-of-hospital cardiac arrest continues to be associated with high mortality, and among those patients who do survive the initial cardiac arrest, two-thirds die as a result of neurological injury.² Postresuscitation care is increasingly recognized as an integral component in improving the quality of survival and neurological outcomes. Although advances have been made in initial resuscitative efforts; anoxic neurological injury remains a major concern after return of spontaneous circulation (ROSC).²³ Therapeutic hypothermia improves neurological outcomes after ROSC.³
Despite recommendations from the American Heart Association,3 the European Resuscitation Council and the International Liaison Committee on Resuscitation4 that therapeutic hypothermia be used in comatose survivors following ROSC, challenges to implementation of therapeutic hypothermia in clinical practice remain. Therapeutic hypothermia is a complex but uncommon intervention, and because of this, prompt implementation of the many steps involved and quickly achieving the desired temperature goal can be difficult.

Background

In 2002, researchers in 2 studies5,6 reported improved neurological outcomes and a decrease in mortality with the use of therapeutic hypothermia after out-of-hospital cardiac arrest. Recently published guidelines from both the American Heart Association and the International Liaison Committee on Resuscitation incorporated evidence from research and recommended that clinicians implement therapeutic hypothermia to increase the likelihood of improved neurological outcome.3,7 Brain cells die because of several biochemical processes resulting from cardiac arrest and the inflammatory process following that injury. Therapeutic hypothermia is believed to be effective because it reduces cerebral metabolism, decreases cerebral blood flow, and decreases intracranial pressure.8-10 The neuroprotective mechanisms of therapeutic hypothermia are now widely recognized and implemented as a standard of care.3 The American Heart Association recommended that comatose adult patients with ROSC following out-of-hospital cardiac arrest be cooled to 32°C to 34°C (90°F-93°F) for 12 to 24 hours, with the strongest evidence of survival for those patients who had pulseless ventricular tachycardia or ventricular fibrillation rhythms.3 Less well understood is how the timing of these therapeutic hypothermia interventions affects patients’ outcomes. In the 2002 studies published by Bernard et al5 and the Hypothermia After Cardiac Arrest Study Group,6 target temperature was reached within 8 hours after ROSC. Although a prospective observational study11 of 986 patients did not reveal an association between the timing of therapeutic hypothermia and neurological outcomes, observational evidence demonstrates a 20% increase in risk of death for every hour delay in initiating therapeutic hypothermia.12 The evidence is not conclusive; however, the American Heart Association’s 2010 guidelines recommended initiating therapeutic hypothermia as soon as possible after ROSC.3 Our institution’s policy states that therapeutic hypothermia should be initiated within 6 hours of ROSC with a goal of achieving target temperature within 4 hours of initiation of therapeutic hypothermia.13 Therapeutic hypothermia has few absolute contraindications. The ultimate decision to initiate therapeutic hypothermia should be based on an assessment of the potential risks and benefits of hypothermia in each individual patient while considering the complete clinical situation and comorbid conditions.9,13

The effectiveness of a surgical safety checklist has been documented.

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Recommendations for the Use of Checklists

The implementation of institution-specific standardized protocols, order sets, and a bundled care approach have proven a successful method in combating the barriers to implementation of therapeutic hypothermia14-20 and were associated with an increased efficiency in achieving target temperature.21,22

The effectiveness of a surgical safety checklist on rates of postoperative death and complications was documented by Haynes et al,23 who reported a decrease in death rate and complication rate after implementation of a checklist. In addition to decreasing mortality and complication rates, surgical checklists have improved compliance with safety measures, teamwork, and communication.24
Beginning in 2009, checklists have been adapted and used to improve patients’ outcomes in other practice situations such as in interdisciplinary rounds and meetings, during shift handoff, and at discharge.\textsuperscript{25-29} Researchers have documented that tools such as checklists can increase adherence to evidence-based practice guidelines,\textsuperscript{30} so we considered adding a checklist to our therapeutic hypothermia bundle to support the safe, effective, and efficient implementation of the therapeutic hypothermia protocol.

**Local Problem**

At our hospital, we have implemented therapeutic hypothermia in 182 patients in the past 5 years. Until 2009, therapeutic hypothermia was exclusively implemented in the coronary care unit (CCU). Although most patients who are treated with therapeutic hypothermia continue to be admitted to the CCU (73%) or the medical intensive care unit (18%), therapeutic hypothermia is sometimes provided in the other intensive care units (ICUs). The number of patients receiving therapeutic hypothermia has increased steadily each year to a total of 59 patients in 2013 (Figure 1). Because of the low frequency of therapeutic hypothermia cases and the large number of nursing staff across different ICUs, months can pass between case exposures, and each exposure could be at a different phase of the protocol.

In a review of cases of therapeutic hypothermia at our institution, we found inconsistencies in the implementation of the protocol and a lack of clarity and urgency in managing the patients during the different phases of the protocol (initiation, maintenance, rewarming, and normothermia). Despite our having a standardized order template and nursing policy for therapeutic hypothermia, our data indicated a need for improvement in our implementation of the therapeutic hypothermia protocol.

**Intended Improvement**

Caring for patients after cardiac arrest in a critical care unit is a complex, tense, and time-sensitive undertaking. Applying an infrequently used but multifaceted procedure such as therapeutic hypothermia under these conditions is challenging and may diminish reliable and consistent implementation of the intervention. Barriers to timely implementation exist, including a delayed decision to implement therapeutic hypothermia, lack of protocols to guide implementation, the volume of cardiac arrest patients treated, training, and experience of staff.\textsuperscript{31} Providing therapeutic hypothermia requires an interdisciplinary collaborative approach initiated in the field by emergency medicine services (EMS) and continued by the emergency department, catheterization laboratory, and the ICUs. The different phases of therapeutic hypothermia cause physiological changes that require intense assessment, monitoring, and intervention to manage shifts in hemodynamics (bradycardia, hypotension, hypovolemia), electrolytes (hyper- and hypoglycemia, hypo- and hyperkalemia), achieving desired temperature, managing infection, and assessing for evidence of myoclonus and seizure activity.\textsuperscript{8,9,32} Successful implementation of the therapeutic hypothermia protocol requires collaboration among many disciplines and is a labor-intensive task that requires continuous monitoring, assessment, and multitasking by the bedside nurse to rapidly initiate the many required protocol interventions during the 4 different phases of therapeutic hypothermia in a 3- to 5-day period.\textsuperscript{31-33} In addition, nurses are responsible for promoting patients’ comfort and providing support to patients’ families during the tenuous period after cardiac arrest.\textsuperscript{33-35}

Although we were decreasing the time it took to achieve target temperature, we were not reliably achieving our
target temperature in fewer than 4 hours after the initiation of therapeutic hypothermia (see Table). We proposed a checklist as an intervention to improve achieving the desired temperature goal within the recommended 4 hours and to manage the various protocol interventions and minimize complications.

Since the release of the World Health Organization’s surgical safety checklist study,23 checklists have gained prominence in clinical care as visual tools for standardizing communication, especially during high-risk processes.24 Because checklists have been documented as effective tools to improve teamwork and communication,24 we theorized that a checklist could improve performance in reaching target temperature during therapeutic hypothermia.

Study Purpose

The purpose of our checklist was to guide ICU nurses and the health care team in safely, effectively, and efficiently implementing the therapeutic hypothermia protocol during the different phases of the intervention in the ICU to decrease the time required to achieve the target temperature.

Methods

Ethics

Our cardiac arrest registry was reviewed by the Human Research Committee and was approved as research limited to health medical records. Data from the cardiac arrest registry were collected and managed by using REDCap electronic data capture tools hosted at Brigham and Women’s Hospital. REDCap (Research Electronic Data Capture) is a secure, web-based application designed to support data capture for research studies.26 All patient identifiers (date of birth, medical record number) are restricted from data reporting within REDCap to protect the confidentiality of the data.

Setting

Brigham and Women’s Hospital is a 793-bed academic medical center with 100 adult ICU beds in 6 units and a total of 436 critical care staff nurses.

Planning the Intervention: Improving Therapeutic Hypothermia Implementation With a Checklist

To achieve optimal, consistent standardized care for patients receiving therapeutic hypothermia in our hospital, an interprofessional committee on therapeutic hypothermia was established in 2008 with representation from nursing, pharmacy, cardiology, neurology, pulmonary critical care, emergency medicine, and interventional cardiology.27 Our committee began by developing a protocol in 2009, an order template in 2010, and a shivering algorithm in 2011. These resources had been developed as we gained experience with the implementation of therapeutic hypothermia and were based on current evidence. Nurses received ongoing education on the therapeutic hypothermia protocol via in-service training sessions and annual competency sessions. As we gained experience in caring for patients receiving therapeutic hypothermia and as new data were published, our hospital’s protocol for therapeutic hypothermia underwent annual revisions.

Based on the positive feedback from the ICU nursing staff on the 1-page shivering algorithm and building on the success of the World Health Organization’s surgical

<table>
<thead>
<tr>
<th>Time measured</th>
<th>Before checklist (n = 60)</th>
<th>After checklist (n = 61)</th>
<th>Goal time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of therapeutic hypothermia to target temperature</td>
<td>7:00 (5:30-8:11)</td>
<td>6:30 (4:32-9:57)</td>
<td>&lt;4:00</td>
</tr>
<tr>
<td>Admission to unit to target temperature</td>
<td>5:47 (4:22-8:03)</td>
<td>4:00 (2:00-6:56)</td>
<td>&lt;3:00</td>
</tr>
<tr>
<td>Admission to unit to placement of Arctic Sun</td>
<td>1:05 (0:30-2:29)</td>
<td>0:30 (0:30-1:00)</td>
<td>—</td>
</tr>
<tr>
<td>Admission to unit to continuous electroencephalographic monitoring</td>
<td>37:27 (15:00-55:27)</td>
<td>14:17 (9:15-22:42)</td>
<td>&lt;18:00</td>
</tr>
</tbody>
</table>
safety checklist, the nursing representatives on the Therapeutic Hypothermia Committee proposed developing a checklist on therapeutic hypothermia for intensive care nurses. The goal of this checklist was to improve the timeliness of achieving the target temperature within the recommended 4 hours and to manage the various interventions at all phases of the therapeutic hypothermia protocol while minimizing complications and maintaining safe and high-quality patient care. Relying on a standardized protocol improves the quality and outcomes of an intervention such as therapeutic hypothermia.

Checklist Development

The design of our checklist was motivated by our desire to shorten the time required to reach the target temperature and provide direction to managing the many treatment interventions at each stage of the therapeutic hypothermia protocol. Our existing guideline and order template became the key interventions captured on the checklist. Based on the American Heart Association’s guidelines for postresuscitation care and our guidelines of care for use of therapeutic hypothermia after cardiac arrest, we divided interventions into the 4 stages of the therapeutic hypothermia protocol. The first phase is the “initiation of cooling” from 0 to 4 hours. The goal is that the patient will reach the target temperature of 33°C (91.4°F) within 4 hours of initiation of therapeutic hypothermia. The next phase is “maintenance of cooling” from 4 to 24 hours. Cooling is maintained for 24 hours from the initiation of therapeutic hypothermia.

Twenty-four hours after the initiation of therapeutic hypothermia, the “rewarming” phase begins. Rewarming is done very slowly at a rate of 0.25°C (0.5°F) per hour and takes 12 to 16 hours. Once the patient reaches 37°C (98.6°F), the last phase, “normothermia,” is maintained for 48 hours. We were now able to identify all of the interventions that needed to be completed to achieve our first goal of target temperature within 4 hours.

The checklist is designed as 1 page to be kept at the bedside. It is a quick, easy, just-in-time resource for nurses, includes a box to be checked when each item is completed, and is used during handoff communication. The checklist was first pilot tested in the CCU and was revised on the basis of staff feedback. We incorporated the checklist into the hospital policy available online, and we placed hard copies in a reference book on the unit for nurses to integrate into patient care. This therapeutic hypothermia checklist (Figure 2) for intensive care nurses has been in use since September 2012.

Evaluation and Analysis

Data are collected in real time by our research coordinator. An initiation of therapeutic hypothermia report is generated each time orders for therapeutic hypothermia are implemented and is sent to all members of the therapeutic hypothermia committee for review. This report includes patients’ demographics (eg, age), initial rhythm, downtime, times from ROSC to arrival in the emergency department, from emergency department to ICU admission, from ROSC to target temperature, from ICU admission to target temperature, from ICU admission to placement of Arctic Sun surface cooling device, and from ICU admission to electroencephalography. The reports allow us to accurately track the use of therapeutic hypothermia throughout the hospital and to review cases both as they occur and over time.

The development and implementation of the therapeutic hypothermia checklist have provided the nursing staff in all ICUs with an easy-to-follow reference to facilitate compliance with the required interventions in the therapeutic hypothermia protocol. Since 2009, we have cared for 183 patients receiving therapeutic hypothermia at our institution. Despite the various systems in place, the median time to target temperature from ROSC was 8 hours, double our desired goal of 4 hours. Since we began using the checklist, we have reduced our time from CCU admission to target temperature from a median time of 5 hours 47 minutes (2009-2011) to 4 hours (2012-2013) in the CCU, where the checklist was first pilot tested and used consistently. The time from CCU admission to placement of the Arctic Sun cooling device has decreased from 1 hour before use of the checklist to 30 minutes since implementation of the checklist (see Table).
### Therapeutic Hypothermia (TH) After Cardiac Arrest: ICU Nursing Checklist

This is intended to be a quick reference only—Refer to the ADM 1.4.18 and Nursing NCPM ICU-44 policies for details on patient management of therapeutic hypothermia. This document is not part of the medical record.

#### Initiation of Cooling 0-4 hours
- BICS OE template completed by house staff
- EEG ordered in Precipio
- Establish 2 sources of temperature
  - Monitoring to Arctic Sun — preferred order is Foley, esophageal, rectal
- Place Arctic Sun pads on admission to ICU
- Sedation infusion (propofol or midazolam)
- Analgesia infusion (fentanyl or hydromorphone)
- BIS monitoring
- Baseline TOF
- Magnesium 4 g IVB over 4 hours
- Cover head, hands, feet with towels/blankets
- BSAS every hour
  - If BSAS ≥ 1, follow shivering algorithm
- BBG q 1 hour
  - If Glu > 200, start modified BHIP
  - Turn insulin OFF if Glu < 200
- MAP goal > 75 mm Hg
- CVP goal > 12 mm Hg
- Document hourly: Patient temp, Arctic Sun flow, water temperature
- EEG performed
- Draw labs q 4 hours after TH initiation at:
  - 8 hours: Chem 7, CBC, CK, CK-MB, cTnt, lactic acid, ABG
  - 12 hours: Glu, K
  - 16 hours: Chem 7, CBC, CK, CK-MB, cTnt, lactic acid, ABG
  - 20 hours: Glu, K
  - 24 hours: Chem 7, CBC, CK, CK-MB, cTnt, lactic acid, ABG
- Hold K+ replacement 4 hours prior to rewarming (unless K < 3.5)

#### Maintenance of Cooling 4-24 hours
- BIS monitoring
- Continue sedation/analgesia infusions
- BSAS q 1 hour
  - If BSAS ≥ 1, follow shivering algorithm
- BBG q 1 hour
  - If Glu > 200, start modified BHIP
  - Turn insulin OFF if Glu < 200
- MAP goal > 75 mm Hg
- CVP goal > 12 mm Hg
- Document hourly: Patient temp, Arctic Sun flow, water temperature
- EEG performed
- Draw labs q 4 hours after TH initiation:
  - 24 hours: Glu, K
  - 32 hours: Glu, K
  - 36 hours: Glu, K
- BIS monitoring
- BSAS q 1 hour
  - If BSAS ≥ 1, follow shivering algorithm during rewarming
- BBG q 1 hour
  - If insulin infusion, check BBG every 30 minutes
  - Turn insulin OFF if Glu < 200
- MAP goal > 75 mm Hg
- CVP goal > 12 mm Hg

#### Rewarming 24-38 hours
- Rewarming begins 24 hours after initiation of TH
- Set Arctic Sun to:
  - Target temp of 98.6°F/37°C
  - Rewarm at rate of 0.5°F (0.25°C) per hour
  - When TOF 4/4, wean/discontinue sedation/analgesia infusions
- Refer to directions on Arctic Sun and in nursing policy
- Continue sedation/analgesia infusions
- Draw labs q 4 hours after TH initiation:
  - 28 hours: Glu, K
  - 32 hours: Glu, K
  - 36 hours: Glu, K
- BIS monitoring
- BSAS q 1 hour
  - If BSAS ≥ 1, follow shivering algorithm during rewarming
- BBG q 1 hour
  - If insulin infusion, check BBG every 30 minutes
  - Turn insulin OFF if Glu < 200
- Document hourly: Patient temp, Arctic Sun flow, water temperature
- Once target temp of 98.6°F/37°C achieved: Normothermia phase
- Wean off of sedation

#### Normothermia x 48 hours
- Keep Arctic Sun pads on and target temp set at 98.6°F/37°C for 48 hours
- Wean/discontinue sedation/analgesia infusions
- If NMBA infusion
  - D/C NMBA infusion
  - Assess TOF every hour
  - When TOF 4/4, wean/discontinue sedation/analgesia
- Observe for temp spikes and rigors
  - Refer to normothermia section of shivering algorithm
- Document hourly: Patient temp, Arctic Sun flow, water temperature
- Draw labs every 8 hours:
  - Glu, K, Mg, Ca

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**Figure 2** Therapeutic hypothermia (TH) after cardiac arrest: ICU nursing checklist.

Abbreviations: ABG, arterial blood gas analysis; BBG, bedside blood glucose; BHIP, Brigham and Women’s Hospital intravenous insulin protocol; BICS OE, Brigham Integrated Computing System order entry; BIS, bisspectral index monitoring; BSAS, Bedside Shivering Assessment Scale; Ca, calcium; CBC, complete blood count; CK, creatine kinase; CK-MB, creatine kinase-MB fraction; cTnt, cardiac troponin T; CVP, central venous pressure; D/C, discontinue; EEG, continuous electroencephalographic monitoring; Glu, glucose; ICU, intensive care unit; IVB, intravenous bolus; K, potassium; labs, samples for laboratory tests; MAP, mean arterial pressure; Mg, magnesium; NMBA, neuromuscular blocking agent; q, every; temp, temperature; TOF, train of four.

Courtesy Brigham and Women’s Hospital, Boston, Massachusetts.
Mr C, a 55-year-old man, was out jogging one evening when he experienced a witnessed ventricular fibrillation cardiac arrest. Bystander cardiopulmonary resuscitation was initiated, and EMS-activated prompt defibrillation and ROSC were achieved within 10 minutes. EMS initiated therapeutic hypothermia with an infusion of iced normal saline (4°C) and ice packs applied to the neck, axillae, and groin. Mr C arrived in the emergency department at 9:05 PM with a body temperature of 36.5°C (97.8°F). Despite Mr C’s history of hypertension and coronary artery disease (drug-eluting stent to circumflex artery 5 years earlier), the 12-lead electrocardiogram did not show evidence of myocardial ischemia or infarction.

An assessment by the emergency department’s team and a neurology consultant confirmed that Mr C met the criteria for therapeutic hypothermia: he had experienced a ventricular fibrillation cardiac arrest with ROSC after 10 minutes, he was comatose (no meaningful response to verbal stimuli), and there were no contraindications for therapeutic hypothermia. The emergency department continued cooling with ice packs and initiated continuous infusions of propofol and fentanyl.

Mr C was admitted to the CCU at 12:30 AM with a body temperature of 35°C (95.2°F). The CCU nursing staff had prepared for his arrival and anticipated Mr C’s care needs by using the therapeutic hypothermia checklist. The physicians had entered the therapeutic hypothermia order set and the necessary equipment including the Arctic Sun surface cooling device was ready for placement upon Mr C’s arrival and was started at 12:40 AM. Interventions to prevent shivering and maintain comfort were initiated. Bispectral monitoring was initiated, and a baseline train of 4 was obtained. Blood samples for laboratory tests were collected per the therapeutic hypothermia protocol. Mr C did experience some shivering that was promptly treated by referring to the shivering algorithm from the therapeutic hypothermia checklist and a target temperature of 32.7°C (90.9°F) was achieved at 2 AM. Electroencephalographic monitoring was initiated at 9 AM. Cooling was maintained for 24 hours from the start of therapeutic hypothermia. The nurse coming on for the next shift was alerted that Mr C would be due to be rewarmed in 2 hours. Using the checklist, the nurses reviewed the completed interventions during the maintenance phase. A potassium level of 3.2 mEq/L had been repleted per protocol 2 hours previously. The glucose levels had remained less than 200 mg/dL, so insulin had not been initiated during the cooling phase. Mr C rewarmed at a rate of 0.25°C (0.5°F) per hour without significant hypotension, hypoglycemia, or hyperkalemia. Normothermia (37°C, 98.6°F) was achieved in 14 hours and maintained per protocol for 48 hours. Mr C’s neurological and cardiac status improved during his 5-day stay in the CCU, and he was discharged home on day 10 after receiving an implantable cardioverter defibrillator. He had good neurological recovery as evidenced by a Cerebral Performance Category score of 1. Mr C returned to work 2 weeks after discharge from the hospital and resumed his exercise regimen.

Observations of practice and feedback from the nursing staff in all the ICUs all support the utility of the therapeutic hypothermia checklist for intensive care nurses. The checklist has been implemented in units other than the CCU where therapeutic hypothermia is used less often. Nurses have reported that using the therapeutic hypothermia checklist helps them prepare, prioritize, and organize their interventions when admitting a critically ill patient. Nurses have reported that the checklist guides nursing documentation and ensures that future interventions remain on schedule, while also supporting teamwork and communication. The checklist helps the nurses to focus on the immediate tasks and simultaneously view the entire process from beginning to end so that they can anticipate changes as the patient progresses. We have observed increased use of the shivering algorithm and nursing documentation of the management of shivering. The checklist has provided an opportunity for case discussions with the clinical nurse educator and has led to an increased understanding of the rationale for the different therapeutic hypothermia interventions, including the early use of electroencephalographic monitoring. We have noted a decrease in time from CCU admission to initiation of continuous electroencephalographic monitoring from 37.5 hours to 14.25 hours (see Table). The nurses have stated that the therapeutic hypothermia checklist aids in clinical decision making by providing prompts to assist with maintaining hemodynamic stability and preventing complications from therapeutic hypothermia.

**Discussion**

The use of the therapeutic hypothermia checklist helps maintain consistent care of patients in the dynamic ICU
environment, where many team members need to collaborate with one another. Further, it supports nursing practice by decreasing the uncertainty for nurses less familiar with implementing the protocol in this complex time-pressured situation.

We have introduced a novel checklist for the implementation of therapeutic hypothermia and demonstrated further support for the growing body of evidence indicating that checklists and other types of cognitive aids are effective in improving various complex processes. Using a checklist for therapeutic hypothermia has many implications in addition to the potential to improve patients’ outcomes. Given that checklists have been documented as improving teamwork and communication, their use in therapeutic hypothermia could lead to improved interdisciplinary collaboration. Further, this type of support for nursing work increases nurses’ autonomy and allows them more time to focus on providing holistic care to patients and patients’ families.

Limitations

This report of the implementation of an ICU nursing checklist for therapeutic hypothermia to integrate the evidence for therapeutic hypothermia into practice is limited by the lack of control over possible confounding variables that may have affected the time to achieve the temperature target. Although our practice has improved, we cannot conclude that this is solely a result of using the checklist. Nonetheless, we easily integrated the checklist into practice, and it can be adapted for use in other institutions.

Summary

Thus far, the therapeutic hypothermia checklist for intensive care nurses has helped the CCU improve 2 metrics related to the implementation of evidence-based practice of therapeutic hypothermia: the time from CCU admission to achieving the target temperature and the time from CCU admission to continuous electroencephalographic monitoring.

Our next challenge will be to focus on the processes within our system to continue the cooling initiated by EMS and decrease the time from ROSC to ICU admission. Further evaluation of compliance with the therapeutic hypothermia checklist and the effects on patients’ outcomes is needed for continuous quality improvement. CCN

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Financial Disclosures

None reported.

To learn more about therapeutic hypothermia, read “Use of Therapeutic Hypothermia in Cocaine-Induced Cardiac Arrest: Further Evidence” by Scan ling et al in the American Journal of Critical Care, January 2014;23:89-92. Available at www.ajconline.org.

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Use of a Nursing Checklist to Facilitate Implementation of Therapeutic Hypothermia After Cardiac Arrest

Facts

Therapeutic hypothermia has become a widely accepted intervention that is improving neurological outcomes following return of spontaneous circulation (ROSC) after cardiac arrest. This intervention is highly complex but infrequently used, and prompt implementation of the many steps involved, especially achieving the target body temperature, can be difficult.

- A checklist was introduced to guide nurses in implementing the therapeutic hypothermia protocol during the different phases of the intervention (initiation, maintenance, rewarming, and normothermia) in an intensive care unit.
- We divided interventions into the 4 stages of the therapeutic hypothermia protocol so that we were able to identify all of the interventions that needed to be completed to achieve our first goal of target temperature within 4 hours.
- The first phase is the “initiation of cooling” from 0 to 4 hours. The goal is that the patient will reach the target temperature of 33°C (91.4°F) within 4 hours of initiation of therapeutic hypothermia.
- The next phase is “maintenance of cooling” from 4 to 24 hours. Cooling is maintained for 24 hours from the initiation of therapeutic hypothermia.
- Twenty-four hours after the initiation of therapeutic hypothermia, the “rewarming” phase begins. Rewarming is done very slowly at a rate of 0.25°C (0.5°F) per hour and takes 12 to 16 hours.
- Once the patient reaches 37°C (98.6°F), the last phase, “normothermia,” is maintained for 48 hours.
- The checklist is a quick, easy resource for nurses, and is used during handoff communication. The nursing checklist has provided all of the intensive care nurses with an easy-to-follow reference to facilitate compliance with the required steps in the protocol for therapeutic hypothermia.
- Using a checklist for therapeutic hypothermia has many implications in addition to the potential to improve patients’ outcomes. Given that checklists have been documented as improving teamwork and communication, their use in therapeutic hypothermia could lead to improved interdisciplinary collaboration. Further, this type of support for nursing work increases nurses’ autonomy and allows them more time to focus on providing holistic care to patients and patients’ families.
- Use of the checklist has helped reduce the time from admission to the unit to reaching the target temperature and the time from admission to continuous electroencephalographic monitoring in the cardiac intensive care unit. Evaluation of patients’ outcomes as related to compliance with the protocol interventions is ongoing.

Delirium has a substantial impact on health care. This complication is associated with a 15-day increase in hospital length of stay (LOS), a financial impact of $4 billion to $16 billion annually, and a 19% increase in 6-month mortality. Delirium is common across all patient settings; the prevalence, however, varies according to acuity of illness. Delirium develops in general medicine patients at rates ranging from 11% to 42%. The highest prevalence of delirium, as high as 87%, occurs in critically ill patients. Understanding the impact of delirium on hospitalized patients makes prevention and optimal treatment of this complication a priority. Two approaches are used to manage delirium: use of pharmacological agents and application of nonpharmacological therapies.
The 2013 pain, agitation, and delirium guidelines of the American College of Critical Care Medicine provide recommendations for the use of pharmacological agents in the prevention and treatment of delirium. Because of a lack of compelling data, the guidelines do not provide a recommendation for a pharmacological protocol or for a combined nonpharmacological and pharmacological protocol for prevention of delirium. Furthermore, the guidelines give a -2C recommendation for pharmacological prevention with either haloperidol or atypical antipsychotics. The lack of evidence supporting the use of pharmacological agents creates a void in the effective management of delirium.

The guidelines give the highest grade within the delirium section (1B) to a nonpharmacological prevention strategy, meaning the recommendation is a strong one backed by a moderate level of evidence. Unfortunately, most of the literature is on nonpharmacological interventions used in either general medicine, geriatric, or perioperative patients. Although critically ill patients certainly differ from most of the populations of patients studied, one can reasonably assume that critically ill patients, who are at the highest risk for delirium, would also benefit from nonpharmacological interventions. Large randomized controlled trials with a multi-interventional approach that includes pharmacological and nonpharmacological approaches to prevent delirium are needed. A strong appropriate attempt at such a study requires the strong understanding of nonpharmacological approaches. The purpose of this systematic review is to summarize the available literature on nonpharmacological management of delirium among all populations of patients. The ultimate goal is to identify which strategies are beneficial to facilitate the development of a nonpharmacological protocol that could be implemented for critically ill patients.

Methods

A literature search was completed by using MEDLINE and EMBASE. With PubMed, the following terms were used to search MEDLINE for material from 1946 to October 15, 2013: delirium AND (critically ill, intensive care, ICU, intensive care unit, OR critical illness), AND (treatment, prevention, prophylaxis, adjunctive therapy, OR adjunct therapy). Additional searches in MEDLINE were then performed with the terms (mobility, animation, exercise, rehabilitation, physical therapy, OR bicycle), (light, window, curtains, shades, OR blinds), (earplugs, ear, noise, OR hearing aid), (sleep, sleep hygiene, OR sleep deprivation), (eyeglasses, glasses, OR magnifying lens), orientation, and hydration, each combined with AND delirium, AND (critically ill, intensive care, ICU, intensive care unit, OR critical illness). EMBASE was searched by using the same strategy. The search was restricted to studies conducted in humans and reported in English. A second reviewer independently performed the same search for validation. The titles of all citations retrieved from the search were reviewed for relevance.

On the basis of the relevance of the title, articles were selected to be reviewed at the abstract level. Abstracts were considered for full-text review if delirium was measured as an outcome (incidence or severity), and the screening for delirium was completed by using a standardized screening tool. No further review of an abstract was done if the study covered was not original research, addressed exclusively pharmacological approaches, or used a combination of pharmacological and nonpharmacological approaches. If, after review, the abstract was still deemed applicable, a full-text review was done in which the same inclusion criteria were applied.
and exclusion criteria were applied to the text of the article. No inclusion restrictions were placed on the study setting or population of patients (critically ill or not critically ill). Studies with mixed nonpharmacological interventions, including nonpharmacological protocols with many interventions, were included. The exclusion of any involvement of pharmaceuticals was necessary to evaluate the true benefit of a nonpharmacological protocol and minimize confounding variables. The references of the included articles were reviewed to ensure a comprehensive assessment.

Results
All Studies
A total of 17 articles7–24 met the inclusion criteria and were selected for review (see Figure and Tables 1 and 2). Seven studies18–24 were done in critically ill patients, 5 in geriatric general medicine patients,9–13 and 2 in patients who had a hip fracture.7,8 A total of 13 of the studies were prospective investigations,7,8,10,13,16,18,21–24 and 4 were randomized control trials.14–16,24 The Confusion Assessment Method or the Confusion Assessment Method for the Intensive Care Unit (CAM-ICU) was the most frequently used tool and was used in 10 studies.10,13,19–23 The Neelon and Champagne Confusion Scale was used in 4 evaluations,14–16,24 and the Intensive Care Delirium Screening Checklist,18 the Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition; DSM-IV),12 and the Delirium Screening Scale were each used once. The frequency of delirium screening ranged from less than daily to 3 times per day.

The incidence of delirium was determined in 12 studies.7–10,12–14 Among these, 9 revealed a benefit of the nonpharmacological intervention.8–10,12–14 Table 3 gives the interventions used in the individual studies. Among the interventions that were beneficial, the mean reduction in the incidence of delirium was 24.7%, with a range of 9.7% to 31.8%. In 6 studies,7,8,10,11,22,23 the duration of delirium decreased after the addition of the nonpharmacological intervention. Additionally, among the 6 evaluations of the severity of delirium, all but 1 study indicated a reduction in severity. Patients’ LOS was examined in 6 studies.7,8,10,11,16–20 Of the 6 studies, the results of 2 revealed a decrease in LOS.11,19 Among the 6 studies done in the ICU, only 1 indicated a reduction in LOS.19 When any outcome related to delirium (incidence, duration, severity) was examined, only 2 studies11,19 did not show any benefit from the addition of a nonpharmacological intervention.

Delirium is associated with multiple negative consequences, including increased length of stay, higher health care costs, and even increased mortality.

A total of 28 unique nonpharmacological interventions were used in the clinical studies. The most common interventions associated with any clinical benefit were mobilization,8,10,20–23 reorientation,8,10,11,18,21 education of nurses,7,10,12,18,23 and music therapy.8,10,12,20,21 A single nonpharmacological intervention was examined in 5 studies,12,14,16,18,24 and multiple nonpharmacological interventions were examined in 12 investigations.7,8,10,11,13,18,23
Table 1  Studies included that involved patients who were not critically ill

<table>
<thead>
<tr>
<th>Reference, year</th>
<th>Design</th>
<th>Screening tool used (frequency)</th>
<th>Population (N)</th>
<th>Notable exclusions</th>
<th>Nonpharmacological interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milisen et al,7 2001</td>
<td>Prospective</td>
<td>CAM, modified CAM</td>
<td>Hip fracture, emergency department/trauma, (26)</td>
<td>Metastatic cancer, life expectancy &lt;6 months</td>
<td>Nursing education Poster in units</td>
</tr>
<tr>
<td>Marcantonio et al,8 2001</td>
<td>Prospective, randomized, double-blind</td>
<td>CAM (daily)</td>
<td>Hip fracture, ≥65 years old (126)</td>
<td></td>
<td>Module: dehydration, dentures, nutrition supplements, mobilization (physical/occupational therapy), glasses, hearing aids, clock, calendar, family presence</td>
</tr>
<tr>
<td>Inouye et al,9 1999</td>
<td>Prospective, individual matching</td>
<td>CAM (daily)</td>
<td>General medicine, &gt;70 years old (852)</td>
<td>Inability to complete interview, low risk for delirium</td>
<td>Protocol: orientation with care-team names and day’s schedule, cognitive stimulation activities, sleep protocol (warm drink, relaxing music, back massage, noise reduction, medication reschedule), mobilization, visual aids, adaptive equipment, hearing aids, hydration</td>
</tr>
<tr>
<td>Vidán et al,10 2009</td>
<td>Prospective, controlled</td>
<td>CAM (daily)</td>
<td>Geriatric unit, age &gt;70 years (542)</td>
<td>None</td>
<td>Staff education Poster in units Orientation: clock, calendar, reason for admission, date, place, family letter Glasses, hearing aids Sleep: warm drink, reschedule medications and procedures Mobilization: out of bed, catheter removal, change positions, avoid restraints Hydration: schedule water if ratio of blood urea nitrogen to serum level of creatinine &gt;40 Nutrition</td>
</tr>
<tr>
<td>Lundström et al,11 2005</td>
<td>Prospective</td>
<td>DSM-IV criteria (days 1, 3, and 7)</td>
<td>Age &gt;70 years, geriatric unit (400)</td>
<td>None</td>
<td>Medical team education Reorganization of nursing staff</td>
</tr>
<tr>
<td>Tabet et al,7 2005</td>
<td>Case-control, single-blind</td>
<td>Delirium Rating Scale</td>
<td>Age &gt;70 years, geriatric unit (250)</td>
<td>Patient not present on unit during assessment</td>
<td>Medical team education</td>
</tr>
<tr>
<td>Caplan and Harper,13 2007</td>
<td>Prospective</td>
<td>CAM (every other day) MDAS for severity if CAM positive</td>
<td>Age &gt;70 years, geriatric unit (37)</td>
<td>Severe dementia Discharged within 48 hours</td>
<td>Reorientation Cognitive stimulation activities Feeding assistance Hydration Vision protocol Hearing protocol</td>
</tr>
<tr>
<td>Ono et al,14 2011</td>
<td>Randomized, randomized controlled trial</td>
<td>NEECHAM (no comment on how often)</td>
<td>Esophagectomy (22)</td>
<td></td>
<td>Bright light therapy</td>
</tr>
<tr>
<td>Taguchi et al,15 2007</td>
<td>Prospective, randomized controlled trial</td>
<td>NEECHAM (twice a day)</td>
<td>Esophagectomy (11)</td>
<td></td>
<td>Bright light therapy</td>
</tr>
<tr>
<td>McCaffrey,16 2009</td>
<td>Prospective, randomized controlled trial</td>
<td>NEECHAM (daily for 3 days)</td>
<td>Hip or knee surgery, &gt;75 years old (22)</td>
<td></td>
<td>Music therapy</td>
</tr>
</tbody>
</table>

Abbreviations: CAM, Confusion Assessment Method; DSM-IV, Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition); LOS, length of stay; MDAS, Memorial Delirium Assessment Scale; NEECHAM, Neelon and Champagne Confusion Scale.
<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Comments</th>
<th>Antipsychotic use</th>
</tr>
</thead>
<tbody>
<tr>
<td>No difference in incidence</td>
<td>Used resource study nurses</td>
<td>Not reported</td>
</tr>
<tr>
<td>3-day reduction in duration</td>
<td>Screened only patients with CAM if NEECHAM identified them as high risk</td>
<td></td>
</tr>
<tr>
<td>Reduction in the severity (2.94 points)</td>
<td>Screened only on days 1, 3, 5, and 8</td>
<td></td>
</tr>
<tr>
<td>No difference in LOS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18% reduction in incidence</td>
<td>Recommendations by geriatric consultant based on module</td>
<td>Yes</td>
</tr>
<tr>
<td>17% reduction in severity</td>
<td>Recommendations not made if team was already doing them</td>
<td></td>
</tr>
<tr>
<td>1.2-day reduction in duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No difference in LOS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1% reduction in incidence</td>
<td>Less than 50% screened met inclusion criteria</td>
<td>Not reported</td>
</tr>
<tr>
<td>56 fewer days delirious</td>
<td>Used research nurses</td>
<td></td>
</tr>
<tr>
<td>28 fewer episodes</td>
<td>Geared intervention against risk factors</td>
<td></td>
</tr>
<tr>
<td>No difference in severity</td>
<td>Same medical team provided care to both groups</td>
<td></td>
</tr>
<tr>
<td>No difference in recurrence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.8% reduction in incidence</td>
<td>Must have risk factor for inclusion</td>
<td>Not reported</td>
</tr>
<tr>
<td>0.4 decrease in severity</td>
<td>Disposition to either geriatric or general medicine decided by emergency department physician</td>
<td></td>
</tr>
<tr>
<td>2.5-hour reduction in duration</td>
<td>Baseline characteristics not very similar</td>
<td></td>
</tr>
<tr>
<td>No difference in recurrence</td>
<td>Note intervention more helpful in intermediate risk</td>
<td></td>
</tr>
<tr>
<td>No difference in recurrence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No difference in functional decline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No difference in death</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No difference in prevalence at 24 and 72 hours</td>
<td>Extensive nursing training for the intervention</td>
<td>Not reported</td>
</tr>
<tr>
<td>4-day reduction in LOS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.7% reduction in point prevalence of delirium</td>
<td>Investigators had no role in day-to-day management</td>
<td>Not reported</td>
</tr>
<tr>
<td>Use of daytime assessment and point prevalence could be underestimated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31.8% reduction in incidence</td>
<td>Patient must have 1 risk factor for enrollment</td>
<td>Not reported</td>
</tr>
<tr>
<td>3.9-point reduction in MDAS score</td>
<td>Mean intervention time 14-19 h/wk</td>
<td></td>
</tr>
<tr>
<td>Very small sample size</td>
<td>Cost analysis</td>
<td></td>
</tr>
<tr>
<td>31.7% reduction in prevalence</td>
<td>Mean LOS 24.8 days</td>
<td>Not reported</td>
</tr>
<tr>
<td>Two dropped out because light was too bright</td>
<td>All male population</td>
<td></td>
</tr>
<tr>
<td>All male population</td>
<td>Screening stopped on postoperative day 5</td>
<td></td>
</tr>
<tr>
<td>34% reduction in incidence at day 3</td>
<td>All male population</td>
<td>Not reported</td>
</tr>
<tr>
<td>Decrease in delirium each of the 3 days</td>
<td>All patients received standard pain, mobilization protocol</td>
<td>Not reported</td>
</tr>
<tr>
<td></td>
<td>Music set to play 4 times a day for 1 hour; patients could do more if they wished to</td>
<td></td>
</tr>
</tbody>
</table>
In 6 of those studies,\textsuperscript{8,10,13,20,21} the interventions were incorporated into a protocol. The mean number of interventions used per study was 4.1.

**ICU Studies**

Of the 7 studies\textsuperscript{18-24} (Table 2) conducted in ICU patients, 6 investigations\textsuperscript{18,20-24} indicated a benefit in at least 1 delirium-related outcome, including incidence, duration, or severity. In the remaining study,\textsuperscript{19} a 0.6-day reduction in ICU LOS occurred. Only 1 study\textsuperscript{18} indicated a reduction in subsyndromal delirium. In all but 1 study,\textsuperscript{24} more than 1 nonpharmacological intervention was used; mobilization, a noise-reduction protocol, and a sleep protocol were used most often. All studies\textsuperscript{20-24} that included either mobilization or noise-reduction or sleep protocols indicated a statistically significant benefit in at least 1 delirium-related outcome.

**Discussion**

ICU delirium is associated with numerous adverse consequences, ranging from increased cost to mortality.\textsuperscript{3,5} As in a multitude of other ailments, prevention is the optimal strategy, especially when effective treatment options are unavailable. Haloperidol has been studied for prevention and treatment of ICU delirium, but the results have been inconclusive.\textsuperscript{25,26} Because of the unconvincing evidence

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Table 2  
Studies included that involved patients who were critically ill

<table>
<thead>
<tr>
<th>Reference, year</th>
<th>Design</th>
<th>Screening tool used (frequency)</th>
<th>Population (N)</th>
<th>Notable exclusions</th>
<th>Nonpharmacological interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skrobik et al,\textsuperscript{18} 2010</td>
<td>Prospective</td>
<td>ICDSC (3 times a day)</td>
<td>Medical-surgical ICU (1133)</td>
<td></td>
<td>Nursing education Radio or compact disc player, reorientation</td>
</tr>
<tr>
<td>Arenson et al,\textsuperscript{19} 2013</td>
<td>Randomized, cohort</td>
<td>CAM, CAM-ICU (3 times a day)</td>
<td>Cardiac surgery (ICU/medicine) (1010)</td>
<td>Inpatient death, preexisting structural brain disease</td>
<td>Private room, no barriers Windows</td>
</tr>
<tr>
<td>Kamdar et al,\textsuperscript{20} 2013</td>
<td>Observational, pre-post design</td>
<td>CAM-ICU (2 times a day)</td>
<td>Medical ICU (300)</td>
<td>Visual or hearing impairment</td>
<td>Sleep: minimize overhead page, turn off television, dim hallway, group care activities Open blinds Prevent napping Mobilization Minimize caffeine before bed Sleep: earplugs, eye mask, music</td>
</tr>
<tr>
<td>Colombo et al,\textsuperscript{21} 2012</td>
<td>Prospective, observational, 2 stage</td>
<td>CAM-ICU (2 times a day)</td>
<td>Medical-surgical ICU (314)</td>
<td></td>
<td>Reorientation: follow mnemonic—use first name, give information about location, LOS, and illness Clock Read paper or book, music, radio Reduction of night noise</td>
</tr>
<tr>
<td>Schweickert et al,\textsuperscript{22} 2009</td>
<td>Prospective, randomized</td>
<td>CAM-ICU (daily)</td>
<td>Medical ICU (104)</td>
<td>Absent limbs, 6-month mortality &lt;50%, cardiac arrest</td>
<td>Mobilization, physical/occupational therapy Passive range-of-motion exercises</td>
</tr>
<tr>
<td>Needham et al,\textsuperscript{23} 2010</td>
<td>Prospective</td>
<td>CAM-ICU (daily)</td>
<td>Medical ICU (57)</td>
<td>No exclusions</td>
<td>Mobilization, physical/occupational therapy Nursing education</td>
</tr>
<tr>
<td>Van Rompaey et al,\textsuperscript{24} 2012</td>
<td>Prospective, randomized controlled trial</td>
<td>NEECHAM (daily)</td>
<td>ICU (136)</td>
<td>Minimum score of 10 on Glasgow Coma Scale Hearing impairment Sedation</td>
<td>Ear plugs</td>
</tr>
</tbody>
</table>

Abbreviations: CABG, coronary artery bypass graft; CAM, Confusion Assessment Method; ICDSC, Intensive Care Delirium Screening Checklist; ICU, intensive care unit; LOS, length of stay; NEECHAM, Neelon and Champagne Confusion Scale; RASS, Richmond Agitation-Sedation Scale.
for pharmacological management of delirium, nonpharmacological strategies need to be further evaluated.

The nonpharmacological intervention specifically discussed in the pain, agitation, and delirium guidelines of the American College of Critical Care Medicine is early mobilization. Our review fully supports this recommendation, and we think early mobilization should be included, when feasible, in any nonpharmacological prevention protocols implemented across all practice settings. Some type of mobilization was used in 6 studies, and 4 of the types were included in protocols with many interventions. The 2 studies in which mobilization was not part of a protocol were conducted in medical ICU patients receiving mechanical ventilation, and the results showed benefits for all outcomes evaluated.

The onus then switches to the development of a nonpharmacological protocol to prevent delirium, but the ideal protocol has not yet been developed. One starting point would be to use the known risk factors for delirium and target interventions to patients who have these risk factors. This strategy was used by Inouye et al, who created a standardized protocol to combat risk factors: cognitive impairment, sleep deprivation, immobility, visual impairment, auditory impairment, and dehydration. The observational PRE-DELIRIC (PREdiction of DELIRium in ICu patients) study was done in

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Comments</th>
<th>Antipsychotic use</th>
</tr>
</thead>
<tbody>
<tr>
<td>No difference in rate of delirium</td>
<td>Hospital does not provide cardiac surgery or trauma care</td>
<td>Yes</td>
</tr>
<tr>
<td>8.7% reduction in ICDSC score = 0</td>
<td>Nurses could give haloperidol if ICDSC score &gt; 3</td>
<td></td>
</tr>
<tr>
<td>8.4% reduction in subsyndromal delirium</td>
<td>No difference in antipsychotic administered</td>
<td></td>
</tr>
<tr>
<td>No difference in LOS (patients with delirium)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No difference between environments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 3 median day of onset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.8-day reduction in ICU LOS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% increase in delirium-free or coma-free days</td>
<td>Primary outcome delirium-coma combination according to CAM/RASS</td>
<td>Yes</td>
</tr>
<tr>
<td>20% reduction in incidence of delirium or coma</td>
<td>Delirium secondary outcome</td>
<td></td>
</tr>
<tr>
<td>No difference in ICU mortality</td>
<td>Compared ICU with post-ICU</td>
<td></td>
</tr>
<tr>
<td>No difference in ICU LOS</td>
<td>Primarily respiratory failure patients</td>
<td></td>
</tr>
<tr>
<td>13.5% reduction in incidence</td>
<td>Primary outcome of sleep quality: no difference</td>
<td></td>
</tr>
<tr>
<td>Mean onset on day 2</td>
<td>Used research nurses</td>
<td>Yes</td>
</tr>
<tr>
<td>Delirium increased ICU LOS by 2 days</td>
<td>Standardized sedation protocol</td>
<td></td>
</tr>
<tr>
<td>2-day reduction in ICU delirium days</td>
<td>All treatment haloperidol or olanzapine</td>
<td></td>
</tr>
<tr>
<td>24% decrease in ICU time with delirium</td>
<td>Midazolam use hazard ratio of 2.145</td>
<td></td>
</tr>
<tr>
<td>13% decrease in hospital days with delirium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8% reduction in days delirious</td>
<td>Inclusion was mechanical ventilation ≥ 4 days</td>
<td>Not reported</td>
</tr>
<tr>
<td>32% increase in days not delirious</td>
<td>Routine delirium screening not part of standard care before project started</td>
<td></td>
</tr>
<tr>
<td>24% decrease in days unable to assess</td>
<td>No delirium assessments on 15 (pre) and 28 (post) patient days</td>
<td></td>
</tr>
<tr>
<td>2-point reduction on NEECHAM score</td>
<td>NEECHAM scorer blinded to use of ear plugs</td>
<td>Not reported</td>
</tr>
<tr>
<td>25% reduction when delirium and mild confusion grouped together</td>
<td>Lowest NEECHAM score used for calculation of incidence</td>
<td></td>
</tr>
</tbody>
</table>
an ICU, and multivariate logistic regression analysis indicated that 10 of the 25 risk factors evaluated were predictive of delirium. Unfortunately, the majority of the predictors, such as age and scores on the Acute Physiology and Chronic Health Evaluation II, were characteristics that could not be altered by use of a nonpharmacological intervention. Although creation of a protocol based on risk factors is an excellent starting point, efforts must be directed toward modifiable health care–associated exposures and not nonmodifiable susceptibilities.

Implementation of the appropriate recommendations for each patient resulted in one of the largest reductions in both incidence and severity of delirium.

Protocols with many interventions would be needed in order to include the many risk factors for delirium identified through the literature and to combat each factor appropriately. Marcantonio et al8 attempted to devise such a protocol. They developed a geriatric consultation that encompassed 10 modules with at least 2 recommendations to be made for each module. Collectively, 31 recommendations potentially could have been used. Implementation of the appropriate recommendations for each patient resulted in one of the largest reductions in both incidence and severity of delirium. Vidán et al10 also used a multicomponent intervention and had results similar to those of Marcantonio et al.8 The inevitable follow-up question becomes, Is a certain aspect of these multicomponent interventions leading to the positive results, and, if so, what aspect?

The importance of a protocol that includes multiple interventions is evident when the outcomes of studies with 2 or fewer interventions7,11,18,19 are compared with the outcomes of studies with many interventions8-10,13,20,21 For incidence of delirium, the multi-interventional protocols resulted in a 15.9% mean reduction, whereas those with 2 or fewer interventions showed an 11% reduction. The 11% reduction is slightly misleading because 4 of the 11 studies7,18,19 with 2 or fewer interventions did not

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### Table 3 Interventions showing benefita

<table>
<thead>
<tr>
<th>Reference</th>
<th>Nursing education</th>
<th>Visual displays</th>
<th>Hydration</th>
<th>Dentures</th>
<th>Nutrition</th>
<th>Mobility</th>
<th>Eye protocol</th>
<th>Hearing protocol</th>
<th>Clock</th>
<th>Calendar</th>
<th>Family</th>
<th>Reorientation</th>
<th>Music</th>
<th>Daily schedule</th>
<th>Cognitive simulation</th>
<th>Warm drink</th>
<th>Back massage</th>
<th>Light therapy</th>
<th>Noise reduction</th>
<th>Medication/procedure reschedule</th>
<th>Adaptive equipment</th>
<th>Catheter removal</th>
<th>Avoidance of restraints</th>
<th>Open blinds</th>
<th>Minimization of caffeine before bed</th>
<th>Dim hallways at night</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>X</td>
<td></td>
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<tr>
<td>8</td>
<td></td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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</table>

*a Key: X, trial in patients who were not critically ill; #, trial in critically ill patients.*
indicate any difference in the incidence of delirium, whereas all 6 of the multi-interventional studies indicated a reduction in incidence of at least 5.1%.

Another strategy, included in 6 studies, was extensive education of nurses. The specifics of the education were typically not reported, but the material tended to focus on the effects of delirium, screening for delirium, and, at times, implementation of the investigators’ protocol. This strategy was used as the sole intervention in 2 studies. Milisen et al used education of nurses and prominent display of educational material, both of which resulted in no difference in the incidence of delirium or the LOS, but a positive reduction in both the duration and the severity of delirium. Tabet et al concentrated on an education-only strategy for both nurses and physicians and reported a 9.7% reduction in the point-prevalence of delirium. However, the investigators used the Delirium Rating Scale, a screening tool that is not recommended in the guidelines of the American College of Critical Care Medicine. Whether or not the results would be the same if either the Intensive Care Delirium Screening Checklist or the CAM-ICU were used is not clear. Last, Lundström et al used a similar strategy but also included a reorganization of the nursing staff. These investigators noted no difference in the prevalence of delirium at 24 or 72 hours. Patients in the study were tested for delirium by using the DSM-IV on hospital days 1, 3, and 7. Because the DSM-IV is a set of diagnostic criteria and not a delirium screening tool, whether or not these results can reliably be compared with the results of other studies in which screening for delirium was used is unclear.

We would be remiss if we did not address the notion that perhaps the best protocol simply involves high-level nursing care. Most of the unique interventions used in the studies reviewed could be easily incorporated into everyday nursing for every patient regardless of the patient’s risk factors for delirium. Notable exceptions would be early mobility, nutrition, and catheter removal. An inability to determine if certain aspects of a newly implemented protocol were already routine nursing practice before the protocols were implemented is a limitation of most published studies of nonpharmacological interventions. Unfortunately, a study that could indicate a true level of the benefit of each intervention would not be feasible, because such a study would require nurses to stop providing standard care. Additionally, any future studies must include use of a standardized screening tool, preferably either the CAM-ICU or the Intensive Care Delirium Screening Checklist, to allow accurate interpretation of the impact of any future interventions or protocol.

Implications for Critical Care Nurses

Although we reviewed of studies of both critically ill and non–critically ill patients, we think that a variety of interventions that benefit patients who are not critically ill would still be useful in an ICU. The evidence shows that targeting interventions to prevent or treat known risk factors for delirium have the greatest benefit (eg, cognitive stimulation, reorientation), and a great deal of overlap exists between risk factors for both critically and non–critically ill patients. A wide variety of patients are treated in ICUs, and the variety of specialized ICUs can be as unique as the patients treated within the units. For these reasons, strong consideration should be given to having ICUs implement nonpharmacological interventions that have been beneficial for patients who were not critically ill.

Multicomponent intervention protocols to combat delirium have proved beneficial. On the basis of guideline recommendations and the strength of literature, these protocols should include early mobilization, education of nurses, and cognitive stimulation with reorientation. Depending on the severity of a patient’s illness, a variety of ways can be used to accomplish early mobilization. All studies that included mobilization, noise-reduction, or sleep protocols displayed a benefit in the reduction of delirium.

Mobilization can be as complete as full physical or occupational therapy treatments or merely passive range-of-motion exercises. Bedside nurses and other members of the medical team work together to decide the level of mobilization a patient can complete. Additionally, nurses can advocate for removal of tubes, catheters, or restraints that may prevent early mobilization.

Second, education of nurses is an essential component of the success of any new intervention or initiative. The literature describes a variety of strategies for educating nurses, including didactic lectures, visual displays, and one-on-one sessions. In order to include the potentially large number of nurses who need to be educated, education should be directed at all types of learners. Last,
cognitive stimulation and reorientation is a rather broad term that allows each nurse to develop a strategy that works for him or her. Still, each nurse’s intervention should incorporate a few key components, such as determining how the patient would like to be addressed, frequent reorientation to date and time, providing updates on the patient’s schedule and clinical status, and conversing with the patient in a manner that requires memory recall by the patient.

The implementation of a new intervention or initiative is often met with resistance to change. In order to minimize this resistance, obtaining nurses’ acceptance of and willingness to support the change becomes imperative. One strategy to eliminate high levels of resistance is to educate nurses about the dangers and implications of the development of delirium while stressing that patients become increasingly difficult to care for once delirium occurs. Another frequent reason for resistance is an overall lack of time during the nursing shift to add additional tasks to be completed; however, most interventions we have mentioned in this review could be worked into a nurse-implemented protocol that would require no more than 5 to 10 minutes per nursing shift to accomplish. Assembling a multidisciplinary team (physician, nurse, pharmacist, and respiratory therapist) to determine which nonpharmacological interventions are feasible within each specific unit is important. Ultimately the success of a nonpharmacological protocol to prevent delirium lies with the bedside nurses, who have the most frequent contact with patients.

**Conclusion**

Use of nonpharmacological interventions is essential for the prevention of delirium. These interventions can be a low-risk, low-cost strategy that has shown a benefit in most studies. Nonpharmacological therapy also has the potential to decrease the off-label use of antipsychotics for the treatment of delirium. The largest challenge in developing a nonpharmacological protocol is determining what interventions to include. Although a “one-size-fits-all” protocol may not be available, a strong body of evidence supports the inclusion of education of the medical team, reorientation with cognitive stimulation, and early mobility in any protocol created. ICU staff should assemble a multidisciplinary team to review interventions of known benefit to determine which ones can be implemented within the staff’s specific unit.

**Financial Disclosures**

None reported.

**Multicomponent protocols targeting known risk factors for delirium appear to have benefits over single interventions.**

**References**

Nonpharmacological Interventions to Prevent Delirium: An Evidence-Based Systematic Review

Facts

Development of delirium in critical care patients is associated with increased length of stay, hospital costs, and mortality. The pain, agitation, and delirium guidelines of the American College of Critical Care Medicine provide the strongest level of recommendation for the use of nonpharmacological approaches to prevent delirium, but questions remain about which nonpharmacological interventions are beneficial.

- Prevention is the optimal strategy, especially when effective treatment options are unavailable. Haloperidol has been studied for prevention and treatment of intensive care unit (ICU) delirium, but the results have been inconclusive.
- A variety of interventions that benefit patients who are not critically ill would still be useful in an ICU. The evidence shows that targeting interventions to prevent or treat known risk factors for delirium have the greatest benefit (eg, cognitive stimulation, reorientation), and a great deal of overlap exists between risk factors for both critically and non–critically ill patients.
- Multicomponent intervention protocols to combat delirium have proved beneficial. These protocols should include early mobilization, education of nurses, and cognitive stimulation with reorientation.
- Mobilization can be as complete as full physical or occupational therapy treatments or merely passive range-of-motion exercises. Bedside nurses and other members of the medical team work together to decide the level of mobilization a patient can complete. Additionally, nurses can advocate for removal of tubes, catheters, or restraints that may prevent early mobilization.
- Education of nurses is an essential component of the success of any new intervention. In order to include the potentially large number of nurses who need to be educated, education should be directed at all types of learners.
- Cognitive stimulation and reorientation is a broad term that allows each nurse to develop an individual strategy. Still, each nurse’s intervention should incorporate a few key components, such as determining how the patient would like to be addressed, frequent reorientation to date and time, providing updates on the patient’s schedule and clinical status, and conversing with the patient in a manner that requires memory recall by the patient.
- Obtaining nurses’ acceptance of and willingness to support the new intervention is imperative.
- One reason for resistance is a lack of time during the nursing shift to add additional tasks. Assembling a multidisciplinary team (physician, nurse, pharmacist, respiratory therapist) to determine which nonpharmacological interventions are feasible within each specific unit is important.
- Ultimately the success of a nonpharmacological protocol to prevent delirium lies with the bedside nurses, who have the most frequent contact with patients.
Learning objectives: 1. Describe the nursing literature on nonpharmacological interventions to prevent delirium 2. Discuss nonpharmacological interventions that have been shown to be effective in preventing delirium 3. Explain the tools developed for the measurement of delirium in intensive care unit patients

1. The highest prevalence of delirium occurs in which of the following patient populations?
   a. Nursing home patients
   b. Critically ill patients
   c. General medicine patients
   d. Perioperative patients

2. Exclusion criteria of the research described in this manuscript include which of the following?
   a. Not original research
   b. Delirium measured as an outcome
   c. Screening for delirium using a standardized screening tool
   d. Incidence or severity of delirium was an outcome measure

3. Excluding any manuscripts involved with pharmaceuticals was necessary to evaluate the true benefit of a nonpharmacological protocol and to minimize which of the following?
   a. Validity and reliability issues
   b. Hierarchies of evidence
   c. Confounding variables
   d. Cleaning and coding data

4. Which of the following tools was used most frequently in the delirium research?
   a. Delirium Screening Scale
   b. Neelon and Champagne Confusion Scale
   c. Intensive Care Delirium Screening Checklist
   d. Confusion Assessment Method for the Intensive Care Unit

5. In several studies, the duration of delirium decreased after the addition of which of the following?
   a. Nonpharmacological interventions
   b. Pharmacological interventions
   c. Haloperidol
   d. Lorazepam

6. Which of the following factors were examined in outcomes related to delirium?
   a. Incidence, duration, and severity
   b. Decreasing length of stay
   c. Mobility
   d. Reorientation

7. Which of the following is the nonpharmacological intervention specifically discussed in the pain, agitation, and delirium guidelines of the American College of Critical Care Medicine?
   a. Music therapy
   b. Reorientation
   c. Nursing education
   d. Early mobilization

8. Which of the following is used to allow accurate interpretation of the impact of future interventions to reduce delirium?
   a. Biostatistics
   b. Multiple regression analysis
   c. Bonferroni multiple comparison test
   d. Standardized screening tool

9. The evidence-based literature supports which of the following nonpharmacological interventions to combat delirium?
   a. Nursing education, mobility, and cognitive stimulation with reorientation
   b. Nursing education, mobility, and art therapy
   c. Mobility, cognitive stimulation with reorientation, and art therapy
   d. Mobility, exercise therapy, and cognitive stimulation with reorientation

10. Which of the following nonpharmacological interventions allows each nurse to develop a strategy that works for him or her?
    a. Mobilization
    b. Nursing education
    c. Cognitive stimulation and reorientation
    d. Music therapy

11. Which of the following is a strategy for educating nurses about nonpharmacological interventions that help reduce delirium?
    a. Visual displays
    b. Case study analysis
    c. Excel spread sheet
    d. PowerPoint self-learning modules

12. Which of the following is essential for the prevention of delirium?
    a. Pharmacological therapy
    b. Nonpharmacological interventions
    c. Occupational therapy
    d. Speech therapy
Heat stroke is a persistent problem among firefighters, athletes, and military personnel, all of whom have occupations that require physical exertion in humid or hot environments. Military occupations in particular involve physically demanding tasks, such as carrying heavy loads for extended periods, often with unpredictable rest periods. When protective equipment such as body armor is worn, heat dissipation is further blocked. These extreme conditions place US military personnel and the military nurses who care for them at risk for heat injuries.

Heat stress is determined by environmental (ie, radiant and ambient temperature, air movement, and humidity) and behavioral (eg, ergogenic agents, work intensity, and protective clothing) factors. Just a few of these risk factors combined can quickly lead to an exertional heat injury. The less severe conditions can be treated on site with the person resuming normal activities the same day. Conversely, exertional heat stroke (EHS) is a life-threatening emergency, and rapid cooling must be administered immediately to ensure survival. The high incidence of heat illnesses in the US military might indicate that rapid recognition of heat injury and use of sound clinical nursing practices are not being applied consistently from ship to ship or unit to unit. Because EHS morbidity and mortality are preventable, it is important that critical care nurses in the Navy and other branches of the military rapidly recognize...
and treat patients with potential EHS during military operations. Previous military reviews have focused on organizational practices and the onus of responsibility for EHS up the chain of command. For critical care military nurses, however, it is crucial to rapidly recognize and treat heat stroke in the field. Therefore, the aim of this column is to discuss the definition, risk factors, treatment, and nursing implications of EHS.

### Definition of Heat Stroke
Heat stroke is a life-threatening emergency characterized by a rapid increase in the body’s core temperature (T_core) to greater than 40°C (104°F), multiple organ dysfunction, and central nervous system abnormalities (eg, delirium, confusion, agitation), with a mortality rate as high as 18% in military populations. Exertional heat stroke, especially when combined with strenuous activity, can occur during exposure to hot or mild climates. Conversely, classic heat stroke occurs only in hot climates. The heat injury spectrum is listed in Table 1.

### Incidence of Exertional Heat Stroke
EHS mortality is significant in athletes and certain occupations, such as agricultural workers. Among athletes, EHS is the third leading cause of mortality. Moreover, among athletes and military personnel, the frequency of EHS continues to increase despite safety measures. Despite knowledge of EHS risk factors, the incidence of heat stroke or heat exhaustion in the US military has not decreased in the past 5 years, estimated in 2013 at 0.25 and 1.57 per 1000 person years, respectively. Highly motivated individuals might be tempted to ignore heat safety rules, especially during

### Table 1 Heat-related illness criteria

<table>
<thead>
<tr>
<th>Clinical condition</th>
<th>Definitiona</th>
<th>Core temperature</th>
<th>Related symptoms</th>
<th>Related signs</th>
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<tbody>
<tr>
<td>Heat syncope</td>
<td>Dizziness or fainting in a hot environment due to postural blood pooling in lower extremities</td>
<td>Normal</td>
<td>Generalized weakness, syncope</td>
<td>Postural syncope with rapid recovery once supine</td>
</tr>
<tr>
<td>Heat cramps</td>
<td>Painful muscle spasms during exercise in the heat</td>
<td>Normal or elevated but &lt; 40°C (104°F)</td>
<td>Painful muscle contractions (commonly in calf, quadriceps, or abdominal muscles)</td>
<td>Affected muscles are stiff and tender to palpation</td>
</tr>
<tr>
<td>Heat exhaustion</td>
<td>Diminished physical activity in the heat due to cardiovascular compromise</td>
<td>37°C-40°C (98.6°F-104°F)</td>
<td>Fatigue, nausea, vomiting, headache</td>
<td>Flushed, profuse sweating with or without clammy skin, normal mental status</td>
</tr>
<tr>
<td>Classic heat stroke</td>
<td>Severe hyperthermia primarily due to heat exposure</td>
<td>&gt; 40°C (104°F)</td>
<td>Heat exhaustion symptoms present before mental status changes</td>
<td>Hot skin with or without sweating, mental status changes (disorientation, ataxia, loss of consciousness); can develop slowly over several days</td>
</tr>
<tr>
<td>Exertional heat stroke</td>
<td>Severe hyperthermia primarily due to strenuous exercise</td>
<td>&gt; 40°C (104°F)</td>
<td>Heat exhaustion symptoms present before mental status changes</td>
<td>Hot skin with or without sweating, mental status changes (disorientation, ataxia, loss of consciousness); rapid onset</td>
</tr>
</tbody>
</table>

a Definitions from Pryor et al9 and Epstein and Roberts.13

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#### Authors
Carl Goforth is the clinical subject matter expert for the Marine Corps Combat Development Command located in Quantico, Virginia. He has more than 20 years of combined Navy and Marine service and has deployed as a critical care and flight nurse attached to US Marine units overseas.

Josh Kazman is a research associate with the Consortium for Health and Military Performance at Uniformed Services University of the Health Sciences. He has worked on a variety of projects and publications related to health disparities, heat tolerance, cardiovascular disease, and injury prevention.

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dangerous operations, placing them at even greater risk of EHS. Military units' awareness of heat injury is also important. One military unit or ship might place greater emphasis on work/rest cycles, environmental monitoring, and so on than another unit.

Risk Factors
Recognizing inherent risk factors can help Navy critical care nurses make informed clinical decisions during training and deployments. Additionally, US Navy medical missions, such as disaster response, usually include the care of diverse, vulnerable populations, such as the young and the elderly. EHS risk factors (Table 2) are commonly classified into 1 of 2 areas: intrinsic (related to the individual) and extrinsic (environmental, task-related, or contextual).

Intrinsic Risk Factors
In addition to a history of heat illness, intrinsic risk factors can range from sickle cell trait to high motivation. Military training includes the indoctrination of military culture, such as “mission first,” which can lead motivated persons to ignore important physiological warning signs. Other data from the US military show that overweight military personnel have a higher risk for sustaining heat injuries. Low aerobic fitness has been cited as a predisposing factor for EHS. Poorly conditioned athletes must work harder to keep up with fit teammates and thus may ignore warning signs such as dehydration, tachycardia, or sweating cessation. Numerous classes of medications have also been implicated in heat stroke (Table 3).

The mechanism by which common medications contribute to heat stroke depends on the class of drug. Anticholinergics (antihistamines, antidepressants, or antipsychotics) decrease production of sweat. Cardiovascular agents, such as antihypertensives or diuretics, decrease the natural physiological responses to dehydration and hyperthermia. Of special concern to young, healthy populations is the recent increase in use of dietary supplements. Recent publications indicate that US Marines are among the highest military users of dietary supplements. Ergogenic stimulants, such as amphetamines or ephedra, increase heat production. Ephedra, from the Chinese plant ma-huang, along with 1,3-dimethylamylamine (DMAA), is associated with serious heat injury in athletes and with EHS and death in the military. Although the exact mechanism underlying heat injury in many ergogenic aids is not fully characterized, published reports clearly

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### Table 2 Risk factors for heat illness

<table>
<thead>
<tr>
<th>Intrinsic (internal) factors</th>
<th>Extrinsic (environmental) factors</th>
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<tbody>
<tr>
<td>History of heat-related event</td>
<td>Level of exertion</td>
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<tr>
<td>Age (&lt;15 or &gt;65 years)</td>
<td>Excess clothing or protective equipment</td>
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<td>Alcohol consumption</td>
<td>Lack of water</td>
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<td>Existing medical conditions (ie, respiratory, hematologic, or cardiovascular)</td>
<td>Temperature (ambient)</td>
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<td>Dehydration</td>
<td>Humidity</td>
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<td>Sleep deprivation</td>
<td>Wet bulb globe temperature</td>
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<td>Medications or supplements</td>
<td>Obesity</td>
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<tr>
<td>Overmotivation</td>
<td>Inadequate acclimatization, poor aerobic conditioning, or both</td>
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<tr>
<td>Recent illness</td>
<td>Recent illness</td>
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<tr>
<td>Sickle cell trait</td>
<td>Sickle cell trait</td>
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</tbody>
</table>

* Based on information from Armstrong et al, Epstein et al, Cassa et al, GLahn et al, and Wallace et al.

### Table 3 Medications implicated in exertional heat illness

<table>
<thead>
<tr>
<th>Type of medication</th>
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<tbody>
<tr>
<td>Reduces rate of sweating</td>
</tr>
<tr>
<td>Anticholinergics</td>
</tr>
<tr>
<td>Alters skin blood flow</td>
</tr>
<tr>
<td>Female reproductive hormones</td>
</tr>
<tr>
<td>Capsaicin</td>
</tr>
<tr>
<td>Lowers cardiac contractility</td>
</tr>
<tr>
<td>Calcium channel blockers</td>
</tr>
<tr>
<td>Increases heat production (ergogenic), hypothalamic set point, or both</td>
</tr>
<tr>
<td>Amphetamines</td>
</tr>
<tr>
<td>Ephedra</td>
</tr>
<tr>
<td>1,3-dimethylamylamine (sympathomimetic properties)</td>
</tr>
<tr>
<td>Salicylates (supratherapeutic doses)</td>
</tr>
</tbody>
</table>

* Based on information from Howe and Boden, Seto et al, Kao et al, Lee, Lopez and Casa, Fink et al, Oh et al, and Eliason et al.

Exertional heat stroke develops as a result of many complex factors and can vary from person to person.
indicate that US Navy and other critical care nurses should screen EHS patients for recently used medications or ingestion of dietary supplement.

Extrinsic Risk Factors
Professions in the US Armed Forces are particularly hazardous, with constant exposure to strenuous physical exertion and climate extremes. For instance, summer temperatures in Afghanistan routinely reach 51°C (124°F). During military operations, personnel perform tasks while wearing body armor, which weighs a mean of 12.3 kg (27 lbs), often without sufficient rest. Because of the nature of military operations, these factors are difficult to modify and might place military personnel in scenarios that exceed their physical capacity. Therefore, these individuals are at increased risk when subjected to individual and environmental factors that predispose them to EHS. It is clear from the evidence that EHS develops as a result of many complex factors and can vary from person to person. However, hyperthermia is always the common denominator underlying any risk factor.

Hyperthermia
Hyperthermia is an increase in Tcore above the body’s natural set point. Human homeostasis requires a narrow operating temperature around 37°C. To accomplish this, a thermoregulatory system composed of compensatory and noncompensatory systems communicate together for thermoregulation when Tcore fluctuates. During strenuous physical activity, body temperature increases in healthy persons, but as metabolic processes and/or environmental conditions exceed cardiovascular and central nervous system compensation, hyperthermia (Tcore > 40°C) ensues and the risk of EHS increases.

Temperatures as high as 46.5°C (116°F) have been reported in patients who have recovered from heat stroke, but survival at such an extreme Tcore is rare. The severity of tissue injury due to hyperthermia depends on the critical thermal maximum, defined as the maximum intensity and duration of tissue heating before cellular death occurs. At extreme core temperatures, thermoregulatory mechanisms are overwhelmed, cellular proteins begin denaturing, and apoptosis (programmed cellular death) can occur within 5 minutes. Failure to promptly recognize and treat hyperthermia can lead to EHS within minutes, a life-threatening medical emergency. The integrated effects of hyperthermia leading to derangement of the central nervous system and multiorgan dysfunction are typical of EHS (Figure 1). More extensive reviews are available.

Clinical Management
The extent and severity of EHS might not be readily apparent in the chaos of military operations. Because mild forms of heat illness, if not recognized, might rapidly progress to EHS, immediate evaluation is necessary to assess the severity of symptoms and, if needed, to initiate cooling rapidly. When cooling is provided immediately, survival is near 100%. Reducing Tcore to less than 40.5°C in less than 30 minutes is the current recommendation.

Supportive Interventions
The initial priorities most relevant to EHS are hemodynamic status, Tcore, and mental status. Upon presentation of EHS, critical care nursing staff must assess and stabilize vital signs, correctly recognize signs and symptoms of EHS, and begin cooling. The hallmark of EHS is altered function of the central nervous system, such as confusion and combative behavior. Nursing management for EHS starts with assessing airway, breathing, and circulation (ABCs). Baseline consciousness should also be immediately established, along with an initial score on the Glasgow Coma Scale. Additional assessments include, when possible, medical history, medications, and/or dietary supplements used, body temperature at admission and maximum known temperature, clinical features apparent at admission, and vital signs. Critical care nursing interventions also include advanced hemodynamic monitoring and initiating fluid resuscitation with crystalloid intravenous solutions per the institution’s protocol, preferably chilled (4°C) 0.9% sodium chloride solution. Lactated Ringer solution is not used, because liver function can be suppressed by overheated tissues, leading to unmetabolized lactate and worsening lactic acidosis. Numerous studies have demonstrated that axillary, aural (tympanic), oral, and skin temperatures often indicate a falsely low Tcore, especially after intense exercise in the heat. Rectal temperature remains the reference standard for assessment.
of $T_{\text{core}}$ in a potential EHS patient and the end point is a $T_{\text{core}}$ less than 39°C (102°F).

**Cooling**

Once hyperthermia is confirmed by rectal temperature, or if a high suspicion of hyperthermia exists while one is waiting for positive confirmation, cooling measures should begin without delay. Effective heat dissipation relies on the rapid transfer of heat from the body’s core to the skin and from the skin to the environment.9

The most important determinant in an EHS outcome is the amount of time that patients’ core body temperature is above the threshold (38.6°C) for cellular damage.45 Reducing the $T_{\text{core}}$ to less than 40°C within 30 minutes or less is critical.9 When in doubt, the maxim “cool first, transport second” should be employed to ensure rapid treatment.

The fastest way to decrease $T_{\text{core}}$ is to remove restrictive clothing and equipment and immerse the body (trunk and extremities) in a pool or tub of cold water (approximately 1°C-14°C, or 35°F-57.2°F).46 Once the patient is immersed in cold water, aggressive stirring or continuous water motion will replace warmed water at the skin with cold water. Additionally, wrapping a cold, wet towel...
around the top of the head will enhance rapid cooling further.\textsuperscript{45} It is recognized that cold water is not always available in remote areas. One alternative, when resources are limited, is to douse the victim with immediately available water. This method can reach a cooling rate of 0.1°C to 0.2°C per minute.\textsuperscript{47} Cooling rates for the most common cooling methods are presented in Figure 2.\textsuperscript{9}

**Civilian Nursing Implications**

Heat exposure is one of the most deadly natural hazards in the United States. The Centers for Disease Control and Prevention\textsuperscript{48} estimates that between 1992 and 2006, heat stroke claimed the lives of 423 Americans, more than hurricanes, lightning, floods, tornados, and earthquakes combined. These injuries require aggressive clinical treatments consisting of rapid cooling and supportive nursing care, such as fluid resuscitation to preserve organ function. Therefore, although this article is focused on Navy critical care nursing, the concepts of rapid recognition and cooling are universal and apply to any critical care nurse caring for a heat stroke victim.

**Conclusion**

EHS requiring critical care nursing intervention represents a substantial risk of morbidity and mortality to Navy and Marine Corps personnel. With military EHS rates at high levels despite scientific advances, never before has it been so clinically important to recognize and rapidly treat potential EHS casualties. EHS rates in the Marine Corps, for instance, were more than 5 times higher than the rates in other military branches in 2011.\textsuperscript{49} Data also suggest that military heat stroke survivors have twice the mortality risk from cardiovascular, kidney, and liver failure within 30 years of initial hospitalization compared with military survivors of nonheat injuries.\textsuperscript{21} According to the best evidence available, ice-water or cold-water immersion is the most effective cooling treatment and is recommended as the definitive treatment.\textsuperscript{46} If this method is unavailable, case reports demonstrate that continual water dousing combined with fanning is a practical alternative until advanced treatment is available. Practical resources for the implementation of EHS prevention and emergency procedures can

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**Figure 2** Relative cooling rates by heat stroke nursing intervention. Optimal cooling rates (>0.155°C/min), acceptable cooling rate (>0.079°C/min and <0.154°C/min), or unacceptable cooling rates (<0.078°C/min).  
Abbreviation: IVF, intravenous fluids.  
Adapted with permission from Pryor et al.\textsuperscript{9} ©2013 with permission from Elsevier.
be found in multiple locations (Table 4). The evidence underscores the need for prompt identification of potential EHS victims and aggressive cooling measures in the field as key critical care nursing actions. CCN

Acknowledgments
The views expressed are those of the authors and do not reflect the official policy or position of the US Marine Corps, the Department of Defense, or the US government.

Financial Disclosures
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More
To learn more about military critical care nursing, read “Tales From the Sea: Critical Care Nurses Serving Aboard the USNS Mercy” by Faulk and Hanly in Critical Care Nurse, August 2013;33:61-67. Available at www.ccnonline.org.

References

Table 4 Military and civilian resources for exertional heat illness guidelines

<table>
<thead>
<tr>
<th>Resource</th>
<th>Website</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniformed Services University, Consortium for Health and Military Performance</td>
<td><a href="http://champ.usuhs.mil">http://champ.usuhs.mil</a></td>
<td>Clinical consultation for exertional heat illness and related conditions such as exertional rhabdomyolysis</td>
</tr>
<tr>
<td>US Army Research Institute of Environmental Medicine</td>
<td><a href="http://www.usariem.army.mil">http://www.usariem.army.mil</a></td>
<td>Army clinical and educational resources regarding heat physiology, acclimation, and related operational issues</td>
</tr>
<tr>
<td>US Army Medical Department</td>
<td><a href="http://www.cs.amedd.army.mil">http://www.cs.amedd.army.mil</a></td>
<td>Provides a link to Medical Aspects of Harsh Environments, Volume 1</td>
</tr>
<tr>
<td>American College of Sports Medicine</td>
<td><a href="http://www.acsm.org">www.acsm.org</a></td>
<td>Civilian guidelines and consensus regarding exertional heat illness</td>
</tr>
</tbody>
</table>
Extracorporeal cardiopulmonary resuscitation (ECPR) remains a promising treatment for pediatric patients in cardiac arrest unresponsive to traditional cardiopulmonary resuscitation. With veno-arterial extracorporeal support, blood is drained from the right atrium, oxygenated through the extracorporeal circuit, and transfused back to the body, bypassing the heart and lungs. The use of artificial oxygenation and perfusion thus provides the body a period of hemodynamic stability, while allowing resolution of underlying disease processes. Survival rates for ECPR patients are higher than those for traditional cardiopulmonary resuscitation (CPR), although neurological outcomes require further investigation. The impact of duration of CPR and length of treatment with extracorporeal membrane oxygenation vary in published reports. Furthermore, current guidelines for the initiation and use of ECPR are limited and may lead to confusion about appropriate use of this support. Many ethical concerns arise with this advanced form of life support. More often than not, the dilemma is not whether to withhold ECPR, but rather when to withdraw it. Although clinicians must decide if ECPR is appropriate and when further intervention is futile, the ultimate burden of choice is left to the patient’s caregivers. Offering support and guidance to the patient’s family as well as the patient is essential. (Critical Care Nurse. 2015;35[1]:60-70)

It is only fitting that the first neonate to be supported by extracorporeal membrane oxygenation (ECMO) was named Esperanza, which when translated from Spanish means hope.1 Indeed, to the more than 50 000 patients who have survived because of ECMO, this revolutionary treatment has provided hope where there was none before.2 In the past 5 decades, the use of artificial oxygenation and perfusion has revolutionized the care of critically ill patients, both in the operating room and in the intensive care unit. Use of artificial oxygenation and perfusion has evolved from bypass during cardiac surgery to advanced life support, to complex extracorporeal cardiopulmonary resuscitation (ECPR). Within the past 20 years, ECPR has been initiated when traditional resuscitation methods have failed and has proven its effectiveness with a survival to discharge rate of approximately 40%.3-13 However, the appropriate use of this therapy and delineated criteria for initiating and withdrawing this therapy have yet to be defined. Furthermore, implementation of this
extraordinary therapy introduces many ethical dilemmas concerning advanced life support. This article addresses the use of ECMO during CPR, as well as the ethical problems we face with the continued advancement of end-of-life care.

**Extracorporeal Cardiopulmonary Resuscitation**

ECPR is considered the initiation of ECMO, following refractory cardiac arrest unresponsive to conventional cardiopulmonary resuscitation (CPR). During the initiation of ECPR, traditional resuscitation measures are continued, including chest compressions and emergency administration of medication. Practitioners initiating this treatment should aim to maximize cardiac output and flow to optimize outcomes. While traditional resuscitation continues, surgeons place the ECMO cannulas in large arterial and venous vessels. Location of cannula placement is based on the type of ECMO that the patient will receive. There are 2 forms of ECMO, venovenous and venoarterial. During venovenous ECMO, blood is drained from the right atrium, oxygenated through the circuit, then perfused back into the right atrium where the heart pumps it to the rest of the body, bypassing only the lungs. However, this form of ECMO requires adequate cardiac function, which is always severely impaired or absent in ECPR patients.14 Therefore, venoarterial extracorporeal support is initiated for ECPR patients. In this technique, 1 cannula is placed for venous drainage, similar to venovenous ECMO, but the oxygenated blood is returned to the aorta, bypassing both the lungs and heart (see Figure). Placement of the cannulas is dependent on the ease of access and the size of the patient.14 If access to intracardiac placement is available, such as with postoperative cardiac patients, this method is usually preferable, with direct cannulation of the right atrium and aorta. Other methods include the cannulation of the femoral artery and vein. However, this use is restricted to adolescents and adults because the size of their vessels is large enough to support adequate drainage and reinfusion.14 Still, the most common method of cannulation is venous access through the internal jugular vein directly into the right atrium and arterial access through the right carotid artery into the aorta.3

Once a patient is successfully cannulated, the patient is immediately connected to the ECMO circuit. For this reason, most centers have developed a “rapid deployment system,” in which a circuit is preprimed with a crystalloid solution or is able to be primed with blood products within a very short period, usually 10 to 20 minutes.15 Although a large immediate infusion of crystalloid solution can be tolerated by older children and adolescents, some centers are reluctant to administer such an infusion to a neonate because of the significant hemodilution.15 However, the

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benefits of immediate end-organ perfusion often outweigh the risks of low hematocrit, which can be resolved with blood transfusions once the circuit has been established.\textsuperscript{15}

**The Benefits of ECPR**

The postresuscitation phase in pediatric patients remains a high-risk period, complicated by significant myocardial dysfunction, hyperthermia, hyperglycemia, impaired autoregulation of blood pressure, and ischemia/reperfusion response.\textsuperscript{14-16} Upon return of spontaneous circulation and reperfusion, a decrease in contractility of the heart, known as myocardial stunning, often occurs. Decreased function of the heart can lead to hypotensive shock, with further damage arising from increased production of inflammatory mediators and nitric oxide.\textsuperscript{16} Treatment of hypotension and myocardial dysfunction often requires aggressive hemodynamic support with fluid resuscitation and vasoactive agents including epinephrine, dobutamine, and dopamine.\textsuperscript{16}

In contrast, mechanical circulation via ECMO allows the body a period of hemodynamic stability and the possibility of resolution of underlying disease processes.\textsuperscript{15,16} Perfusion of organs with fully oxygenated blood via the ECMO circuit allows decreased myocardial oxygen demand, generally without the use of high-dose vasoconstrictors and inotropic agents.\textsuperscript{15} This stability in the postresuscitation period may further improve survival rates.\textsuperscript{17}

Large, multi-institutional studies\textsuperscript{16-18} show that overall survival to discharge rates in pediatric patients resuscitated with conventional CPR remains at approximately 25% to 27%. However, survival statistics for ECPR are more encouraging, with a general rate of success of near 40% to 60%.\textsuperscript{2,5,7,10,19-22} Multi-institutional data obtained in 2012 from the Extracorporeal Life Support Organization (ELSO), an international registry and database of ECMO treatment, demonstrated that ECPR was successful for 934 out of 2236 neonatal and pediatric patients, with survival to discharge of 39% for neonates and 40% for children. Other retrospective, single-institution studies have shown survival rates as high as 72% to 80%.\textsuperscript{2,5,27,29} The Table provides more detailed information from the current studies of ECPR in pediatric patients. Critical analysis of this information is imperative when determining the utility of ECPR.

Most studies rate ECPR’s success solely on survival to discharge statistics; only a few studies address neurological outcome. A void remains in the literature as far as addressing quality of life after ECPR. Furthermore, “good neurological outcome” is often a subjective measure, with terminology varying among researchers. Some studies have shown that ECPR patients have an increased likelihood of central nervous system complications developing compared with patients treated with ECMO without CPR.\textsuperscript{4} Other studies examining ECPR patients have shown favorable neurological outcomes, as measured by the Pediatric Cerebral Performance Category Scale, with a score of 2 or less in most patients.\textsuperscript{8,9,10,20,22} Further investigation into long-term neurological sequelae is needed and should be included in future studies.

**When to Initiate Therapy?**

In 2005, the American Heart Association recommended the use of ECPR for in-hospital patients in cardiac arrest when the duration of no-flow arrest is brief and the condition leading to the cardiac arrest is reversible.\textsuperscript{15} This broad recommendation does not offer a definition of “brief,” nor does it differentiate between time of no-flow arrest and duration of traditional CPR. More recent recommendations from the 2010 International Consensus on Cardiopulmonary Resuscitation\textsuperscript{15} specifies that ECPR is appropriate for patients with heart disease that is “amenable to treatment or heart transplantation,” where the cardiac arrest occurs in the intensive care unit in a facility with the personnel, equipment, and training to provide ECPR. Use of ECPR is indicated in only 1 situation after out-of-hospital cardiac arrest, which is in cases of environmentally induced severe hypothermia (<30°C), again, only if the appropriate equipment and expertise are available.\textsuperscript{36} Medical institutions providing ECPR should have established protocols for its implementation and use. Often centers lacking these resources are unable to offer ECPR at all.

The advantages of ECPR after prolonged conventional resuscitation remain a source of controversy. Despite the large number of studies performed regarding ECPR use, no criteria or guidelines for timing of initiation of this therapy have been clearly established. The International Consensus on Cardiopulmonary Resuscitation recognizes that evidence is insufficient for establishing...
Table  Retrospective pediatric studies of extracorporeal membrane oxygenation (ECMO) in cardiopulmonary resuscitation

<table>
<thead>
<tr>
<th>Reference</th>
<th>Population of patients</th>
<th>No. of patients</th>
<th>No. (%) of survivors to discharge</th>
<th>Duration of cardiopulmonary resuscitation, min</th>
<th>Duration of ECMO therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aharon et al28</td>
<td>Postoperative, cardiac</td>
<td>10</td>
<td>8 (80)</td>
<td>Mean (range), 42 (5-110) &gt; 30 min associated with poor survival</td>
<td>Not reported</td>
</tr>
<tr>
<td>Alsoufi et al21</td>
<td>Postoperative, cardiac</td>
<td>48</td>
<td>23 (46)</td>
<td>Not reported</td>
<td>Not reported</td>
</tr>
<tr>
<td>Alsoufi et al30</td>
<td>ICU and cardiac</td>
<td>80</td>
<td>27 (34)</td>
<td>Median (range) Survivors: 46 (14-95) Nonsurvivors: 41 (19-110)</td>
<td>4 days for both survivors and nonsurvivors</td>
</tr>
<tr>
<td>Cengiz et al4</td>
<td>ELSO registry</td>
<td>161</td>
<td>64 (40)</td>
<td>Not reported</td>
<td>Mean (SD) Survivors: 4.7 (3.5) days Nonsurvivors: 4.4 (6.4) days</td>
</tr>
<tr>
<td>Chan et al9</td>
<td>ELSO registry of cardiac patients</td>
<td>492</td>
<td>208 (42)</td>
<td>Not reported</td>
<td>Median (IQR) Survivors: 87 (51-137) hours Nonsurvivors: 87 (37-171) hours</td>
</tr>
<tr>
<td>Conrad et al7</td>
<td>ELSO registry</td>
<td>151 Neonatal 65 (43)</td>
<td>282 Pediatric 111 (39)</td>
<td>Not reported</td>
<td>Not reported</td>
</tr>
<tr>
<td>de Mos et al14</td>
<td>ICU</td>
<td>5</td>
<td>2 (40)</td>
<td>Range All: 31-77 Survivors: 35-48</td>
<td>Not reported</td>
</tr>
<tr>
<td>Del Nido23</td>
<td>Cardiac</td>
<td>11</td>
<td>6 (55)</td>
<td>Mean (SD): 65 (9)</td>
<td>Mean (SD): 112 (18) hours</td>
</tr>
<tr>
<td>Delmo Walter et al11</td>
<td>ICU</td>
<td>42</td>
<td>17 (40.4)</td>
<td>Mean (SD) Survivors: 35 (1.3) Nonsurvivors: 46 (4.2)</td>
<td>Mean (SD) Survivors: 4.0 (2.2) days Nonsurvivors: 6.0 (0.9) days</td>
</tr>
<tr>
<td>Duncan et al22</td>
<td>Cardiac</td>
<td>11</td>
<td>6 (55)</td>
<td>Median (range) 55 (20-103)</td>
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<tr>
<td>Huang et al13</td>
<td>Pediatric</td>
<td>54</td>
<td>25 (46)</td>
<td>Mean (SD) Survivors: 39 (17) Nonsurvivors: 52 (45)</td>
<td>Not reported</td>
</tr>
<tr>
<td>Huang et al8</td>
<td>Pediatric</td>
<td>27</td>
<td>11 (41)</td>
<td>Median (IQR) Survivors: 45 (25-50) Nonsurvivors: 60 (37-81)</td>
<td>Median (IQR), range Survivors: 102 (68-135), 43-419 hours Nonsurvivors: 89.2 (26.9-221), 6-637 hours</td>
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<tr>
<td>Joffe et al19</td>
<td>Meta-analysis</td>
<td>762</td>
<td>361 (49)</td>
<td>Not reported</td>
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<tr>
<td>Kane et al20</td>
<td>Cardiac</td>
<td>172</td>
<td>88 (51)</td>
<td>Median (interquartile range) Survivors: 32 (25-41) Nonsurvivors: 36 (21-45)</td>
<td>Median (interquartile range) Survivors: 84 (52-118) hours Nonsurvivors: 119 (57-183) hours</td>
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<tr>
<td>Kelly and Harrison31</td>
<td>Pediatric and cardiac</td>
<td>31</td>
<td>7 (23)</td>
<td>Median Survivors: 40 Nonsurvivors: 47</td>
<td>Mean Survivors: 4 days Nonsurvivors: 6 days</td>
</tr>
<tr>
<td>Kumar et al12</td>
<td>Postoperative, cardiac</td>
<td>29</td>
<td>12 (41)</td>
<td>Mean (SD) Survivors: 42 (8) Nonsurvivors: 51 (10)</td>
<td>Not reported</td>
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</tbody>
</table>

Continued
any specific threshold for CPR duration beyond which survival is unlikely.36

A substantial amount of debate can be found in published reports about when ECPR should be initiated and when further intervention would be futile. Several pediatric studies have shown increased mortality rates for patients cannulated after 30 minutes of conventional CPR.7,11,28,34 However, other retrospective studies8-10,12,20,26,27,29,31,32 of pediatric patients have shown positive outcomes with median CPR duration of 30 to 50 minutes. Even more interesting are the multiple case reports24,27,30,32,37 of successful cannulation and survival to discharge in patients receiving CPR of up to 90 to 220 minutes.

Other research has focused on parameters that may act as predictors for positive outcome. ECPR patients with a preexisting diagnosis of cardiac illness have shown improved survival outcomes, when compared with patients with noncardiac illnesses.5,6,8,30,32 Perhaps patients with cardiac illness have less multiorgan dysfunction before cardiac arrest and therefore are more likely to

<table>
<thead>
<tr>
<th>Reference</th>
<th>Population of patients</th>
<th>No. of patients</th>
<th>No. (%) of survivors to discharge</th>
<th>Duration of cardiopulmonary resuscitation, min</th>
<th>Duration of ECMO therapy</th>
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</thead>
<tbody>
<tr>
<td>Morris et al32</td>
<td>ICU</td>
<td>64</td>
<td>21 (33)</td>
<td>Median (range) Survivors: 50 (5-105)</td>
<td>Median (range) Survivors: 55 (2-359) hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Non survivors: 46 (15-90)</td>
<td>Non survivors: 64 (1-506) hours</td>
</tr>
<tr>
<td>Paden et al2</td>
<td>ELSO registry</td>
<td>Neonatal: 784</td>
<td>Neonatal: 304 (39) Pediatric: 630 (40)</td>
<td>Not reported</td>
<td>Not reported in ECPR group</td>
</tr>
<tr>
<td>Polimenakos et al26</td>
<td>Cardiac single ventricle, neonates</td>
<td>14</td>
<td>8 (57)</td>
<td>Mean (SD) Survivors: 38.6 (6.3)</td>
<td>Median (IQR) Survivors: 4 (3-6.5) days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Non survivors: 42.1 (7.7)</td>
<td>Non survivors: 8 (5-11.5) days</td>
</tr>
<tr>
<td>Prodhan et al8</td>
<td>ICU, cardiac</td>
<td>32</td>
<td>24 (72)</td>
<td>Median (range) Survivors: 43 (15-142)</td>
<td>Median (range) Survivors: 122 (41-816) hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Non survivors: 60 (20-76)</td>
<td>Non survivors: 59 (7-905) hours</td>
</tr>
<tr>
<td>Raymond et al8</td>
<td>AHA/NRCPR</td>
<td>199</td>
<td>87 (44)</td>
<td>Median (range) Survivors: 46 (26-68)</td>
<td>Not reported</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Non survivors: 57 (38-71)</td>
<td></td>
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<tr>
<td>Shah et al32</td>
<td>Cardiac</td>
<td>27</td>
<td>9 (33)</td>
<td>Not reported</td>
<td>Mean (SD) Survivors: 79.3 (40.7) hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Non survivors: 128.6 (193.3) hours</td>
<td></td>
</tr>
<tr>
<td>Sivarajan et al34</td>
<td>Cardiac</td>
<td>37</td>
<td>14 (38)</td>
<td>Median (range) Survivors: 15</td>
<td>Not reported</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Non survivors: 40</td>
<td></td>
</tr>
<tr>
<td>Thiagarajan et al8</td>
<td>ELSO registry</td>
<td>682</td>
<td>261 (38)</td>
<td>Not reported</td>
<td>Median (interquartile range) Survivors: 88 (51-140) hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Non survivors: 66 (26-157) hours</td>
<td></td>
</tr>
<tr>
<td>Tajik and Cardarelli7</td>
<td>Meta-analysis</td>
<td>288</td>
<td>114 (39.6)</td>
<td>Not reported</td>
<td>Median (range) 4.3 (0.03-90) days</td>
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<tr>
<td>Wolf et al34</td>
<td>Cardiac</td>
<td>90</td>
<td>50 (55.5)</td>
<td>Survivors: 42 (16-98)</td>
<td>Median (range) Survivors: 3 (1-20) days</td>
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<td>Non survivors: 43 (20-75)</td>
<td>Non survivors: 5 (1-21) days</td>
</tr>
<tr>
<td>Thourani et al31</td>
<td>Cardiac</td>
<td>15</td>
<td>11 (73.3)</td>
<td>Not reported</td>
<td>Median (range) 66 (18-179)</td>
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Abbreviations: AHA/NRCPR, American Heart Association/National Registry of Cardiopulmonary Resuscitation; ELSO, Extracorporeal Life Support Organization; ICU, intensive care unit; IQR, interquartile range.
survive after treatment with ECPR. Few published data support preexisting measurements as indicators for survival. Arterial blood gas values have been postulated to be predictive variables in several studies, with pH less than 7.2 associated with higher mortality. However, Thiagarajan et al noted that although pre-ECMO arterial pH less than 6.9 was strongly associated with negative outcome, 12% of children who survived after ECPR use had a pre-ECMO pH less than 6.9. Multiple studies have shown that preexisting renal insufficiency and metabolic electrolyte abnormalities are associated with worse survival to discharge.

This discordance in published results is of extreme importance to practitioners initiating ECPR in pediatric patients. The absence of clearly defined parameters and inconsistencies in published reports may lead some clinicians to initiate ECPR when attempts may be futile, but also may inhibit its use when there is the possibility of success.

**When to Withdraw ECMO?**

Transition from ECPR to standard ECMO care occurs once the child is cannulated and placed on the ECMO circuit. Further management of the patient focuses on treatment of underlying disease processes. The use of artificial oxygenation and perfusion in this time allows the child a period of hemodynamic stability and decreased myocardial oxygen demand, during which vital organ function may return. However, the precise amount of time it takes the organs to regain adequate function to support the body remains unknown. Several studies of duration of ECMO after CPR show similar amounts of time on the circuit for both survivors and nonsurvivors. Historically, data in pediatric patients indicate that ECMO for cardiac failure after cardiothoracic surgery continued beyond 3 to 6 days results in poor outcomes, and ECMO beyond 2 weeks may not improve respiratory failure. However, a recent review of ELSO data in cardiac ECMO patients shows no significant difference in survival to discharge between patients who receive ECMO for 14 to 20.9 days (25% survival) and patients who received ECMO for 21 to 27.9 days (23% survival); but, survival decreased significantly after 28 days to 13%. In pediatric patients receiving ECMO for acute respiratory failure, review of ELSO data showed survival rates were inversely related to duration of ECMO. Patients receiving ECMO support for 3 weeks or longer had a survival to discharge rate of 38%, significantly decreased from the rate of survival of patients who received ECMO support for 2 weeks or less (61%).

If separation from the ECMO circuit is not possible because of ongoing cardiac or pulmonary failure, then transition to other modes of mechanical support may be an option. Patients with prolonged pulmonary failure but recovery of cardiac function may be transitioned to venovenous extracorporeal support, potentially decreasing the risk of oxygenator-associated thrombi. Patients with continued cardiac dysfunction may be converted to a ventricular assist device to act as a bridge for transplant. To date, only 2 ventricular assist devices are approved for pediatric use, the Berlin Heart and HeartWare. However, no current research supports the use of a ventricular assist device in children after cardiac arrest.

The only clear indicator for withdrawal of ECMO support is neurological devastation evidenced by brain death, in which termination of all life support is warranted. Other clear criteria for withdrawal of ECMO include hemorrhagic stroke or intraventricular hemorrhage in which anticoagulation must be discontinued to prevent worsening intracranial bleeding. Other indicators for termination of ECMO include worsening end-organ dysfunction. Renal insufficiency following ECPR is a poor prognostic factor. Acute renal injury can occur during cardiac arrest and resuscitation as a result of hypoperfusion of the kidneys. Again, the question of how long it will take for these organs to recover, or if recovery is possible at all, has yet to be answered.

**Ethical Considerations**

The judicious use of ECPR in pediatric critical care is complicated by a vast number of factors, including the high cost of care, questionable effectiveness, and intensified emotions of families and providers caring for a critically ill child. ECPR is an advanced form of life support, so its use in patient care must be in accordance with the principles of medical ethics. The first principle is beneficence, which requires that practitioners offer care that is beneficial to their patients. Unnecessary surgical
procedures and unauthorized research are common problems that arise when addressing beneficence. The second principle is nonmaleficence, meaning do no harm. This principle requires that the benefits of a treatment must outweigh the potential negative aspects such as overburdensome pain and unavoidable suffering. When discussing the continued use of ECMO, practitioners must decide if prolonged therapy to enhance the possibility of survival prevails over the risk of unnecessary discomfort and extended suffering of the child. The third ethical principle is autonomy, which refers to the patient’s right to decide what is appropriate in their care. In critically ill pediatric patients, a dependent child’s autonomy is delegated to the surrogate decision maker, most often the parents. Their values and judgments must be respected by practitioners and incorporated into decision making at every level.

The fourth principle is justice, which is often a source of controversy in modern medicine. This principle demands that therapies be provided equally to all patients despite differences in socioeconomic status, race, gender, and so on. However, medical resources are not limitless, and societies must strive to ensure appropriate distribution of health care. Median hospital charges of ECPR patients has been quoted at $310,824, which is significantly greater than charges for propensity-matched conventional CPR patients, which are $147,817. Financial burdens of ECMO support may far exceed reimbursement from insurance companies and may place the hospital at financial risk. Offering excess treatment in one patient may conceivably lead to a decrease in resources for another patient.

Taking into account the ethical principles of medicine, practitioners in the intensive care unit must be acutely aware of the potential for benefit and the medically futility of the therapies they provide. Most often, such awareness means that advanced life support is initiated and removed appropriately depending on the patient’s chance of survival and the desires of the patient’s family. These concepts are more commonly known as initiating, withholding, and withdrawing treatment.

Ethical guidelines have determined that, withholding and withdrawing life support are no different. However, many professionals recognize that a psychological difference clearly exists. Based on this assumption, the President’s Commission on Ethical Problems in Medicine concluded that, contrary to widespread feelings on the matter, withdrawing treatment was preferable to withholding treatment for 2 reasons. Primarily, withdrawing allows a time-limited trial of therapy in which the patient’s status can be reassessed and prognosis determined. Second, a traditional reluctance to withdraw treatment had led many practitioners to forgo lifesaving therapies altogether for fear of eventual “failure.” For this reason, most intensivists now offer advanced life support to their patients with the hope that therapies will be successful, or at the very least “buy some time.”

Withholding ECPR is often a debate between physicians involved in the patient’s care. Most families are not aware of ECPR and would not know to request that their child be treated with ECPR. Often ECPR is recommended by a physician, and therefore withholding ECPR may come to mean simply not offering it. Withholding ECPR often becomes an intraprofessional dilemma, where the effectiveness of treatment is controversial. As discussed previously, the lack of parameters to guide physicians is detrimental to evidence-based practice, and decisions in this scenario are often based on personal reasoning, experience, and values. In these difficult situations, practitioners most often decide to treat, possibly against their better judgment. Solomon et al examined perceptions of physicians and nurses caring for critically ill children and reported that 80% of critical care attending physicians agreed that “sometimes I feel we are saving children who should not be saved,” whereas only 8% agreed that “sometimes I feel we give up on children too soon.”

The ethical dilemma of ECPR is therefore most often not whether to withhold it, but when to withdraw it. Again, the literature does not support a definitive timetable for withdrawal of ECMO. Obviously, neurological devastation as evidenced by brain death is a definitive indicator for withdrawal of treatment. But no other parameters exist, and the decision to withdraw is often at the recommendation of the provider. Maintaining ethical principles at this time is essential for practitioners as they address the medical futility of further treatment. There must be a level of assurance that prolonged time on ECMO will enhance patients’ outcomes and that this possibility outweighs the risks of further suffering and discomfort for the child.
The Final Decision

Although clinicians must decide if ECMO is appropriate and when further intervention is futile, the ultimate burden of choice is left to the patient’s parents. As practitioners, we must be aware of, and respect, the tremendous responsibility of this decision. ECPR is initiated as the most advanced form of life support available to patients, when death without ECMO is most certainly imminent. Furthermore, many patients remain alive purely through the use of ECMO and cannot be supported with traditional medicine. Removal of the pump often equates to death.

In 2003, Curley and Meyer examined parental experiences with ECMO and reported that 61% of parents felt that they had no other choice but to consent to treatment, since death was the only other option. In the study, most parents understood that ECMO was an extraordinary intervention, even in the technologically dominant intensive care unit environment.

As practitioners, we must be aware of our communication with parents in this very difficult and anxious time. Honesty concerning the many complications and uncertainties of ECMO is paramount to effective discussions. Furthermore, when a decision is made to treat a child with ECMO, parents must be cautioned that its use involves a time-limited trial. Reasonable expectations of length of duration and outcome must be clear to parents. Finally, all members of the team must be prepared to answer questions and provide support throughout the use of ECMO. The importance of offering support and guidance can never be underestimated in this setting, where parents are very aware that every moment with their child may be their last.

Nursing Implications

The use of ECMO during CPR is a technologically advanced and complex treatment that requires extensive knowledge from every member of the health care team. Bedside nurses should be well educated on the physiology of the patient, as well as the mechanical aspects of the ECMO pump. Centers providing this treatment must offer educational programs to train nurses in rapid deployment of the ECMO circuit. Familiarity with the circuit and experience with the cannulation procedure will ensure a smooth transition from cardiopulmonary resuscitation to artificial circulation.

Once the patient is cannulated, highly skilled nurses are needed to manage daily treatment. Nursing care of ECMO patients is both physically and mentally demanding. These patients require frequent laboratory and physical assessments, as well as frequent neurological checks. Neurological injury is common in ECMO patients owing to the acuity of their illness and the risk of cerebral vascular injury from stroke or hemorrhage. Daily ultrasound imaging of the head are routine in most centers, and continuous electroencephalographic monitoring is also implemented with concerns for subclinical seizure activity. Because of the immense workload associated with ECMO patients, 2 nurses are generally needed to care for these acutely ill children. One nurse is tasked with the care of the patient, while the other nurse tends to the needs of the ECMO pump. Most centers have implemented the use of perfusionists and specially trained respiratory therapists to manage the ECMO circuit in an effort to reduce the strain on nursing staffing.

Furthermore, the bedside nurse is often depended on to provide support to patients’ families. This responsibility is difficult and challenging, and it requires a large amount of dedication. Most intensive care nurses are well versed in end-of-life care and must continue to use this skill during ECMO trials. Although the physical care of these patients can be burdensome, bedside nurses must strive to ensure that time is allocated for family support. When needed, nurses should be aware of the resources available for patients’ families, including palliative care teams, social workers, and chaplain services. These services can help by offering assistance to family members during periods of critical illness and end of life.

The Future of ECPR

Use of ECMO as a final therapy during CPR in the care of critically ill patients remains promising. As providers continue to broaden the boundaries of use of ECMO, it is imperative that judicious decision making be maintained in the clinical setting. Further data and research are needed to create guidelines and parameters for withholding and withdrawing ECMO. It is essential that clinicians providing this treatment be thoroughly educated and knowledgeable about the literature, so that decisions are based on evidence.
Finally, as with all end-of-life care, it is essential that all members of the health care team be aware of parental presence and concern. Support must be provided to patients’ families on a constant basis to ensure that their needs are met. It is very easy for physicians and nurses to become overwhelmed by the technical aspects of caring for these critically ill patients and focus solely on maintaining life. However, a holistic approach to care should remain a focus, with appropriate support of the patient as well as the patient’s family.

References


CNE Test  Test ID C151: Extracorporeal Membrane Oxygenation for Pediatric Cardiac Arrest

Learning objectives: 1. Determine the difference between venovenous and venoarterial extracorporeal membrane oxygenation (ECMO). 2. Describe the benefits of extracorporeal cardiopulmonary resuscitation. 3. Discuss the ethical considerations related to management of patients undergoing ECMO.

1. Venoarterial extracorporeal membrane oxygenation (ECMO) is the preferred extracorporeal support for extracorporeal cardiopulmonary resuscitation (ECPR) patients over venovenous ECMO because of which of the following?
   a. Risk of hemodilution in neonates
   b. Absence of adequate cardiac function
   c. Impaired renal function
   d. None of the above

2. Complications in the postresuscitation phase in pediatric patients include all except which of the following?
   a. Impaired autoregulation of blood pressure
   b. Myocardial dysfunction
   c. Increased contractility of the heart
   d. Hyperglycemia

3. Benefits of mechanical circulation via ECMO include which of the following?
   a. Decreased risk of hypotensive shock
   b. Decreased risk of aggressive vasoactive resuscitation
   c. Promotion of autoregulation of blood pressure in the initial resuscitation period
   d. Promotion of hemodynamic stability

4. ECPR is recommended for use in which of the following types of patient settings?
   a. Heart transplant surgery
   b. Brief no-flow cardiac arrest in the hospital setting
   c. Severe hyperthermia
   d. Prolonged cardiopulmonary resuscitation with spontaneous return of circulation

5. Which of the following preexisting measurements can help determine survival potential?
   a. Preexisting diagnosis of cardiac illness has shown to improve survival outcomes
   b. A pre-ECMO pH of less than 7.2 is associated with higher mortality
   c. A pre-ECMO pH of less than 6.9% is associated with negative outcomes
   d. All of the above

6. Which of the following is the only clear indicator for withdrawal of ECMO support?
   a. Neurological deterioration
   b. Ongoing cardiac dysfunction
   c. Ongoing pulmonary failure
   d. Oxygenator-associated thrombi

7. The use of ECPR in pediatric critical care is complicated by all except which of the following?
   a. High cost of care
   b. Questionable effectiveness
   c. Intensified emotions of families and providers
   d. Absence of standardized clinical guidelines for withdrawal

8. Which of the following is the term for the concept of initiating and removing advanced life support?
   a. Initiating
   b. Withholding
   c. Withdrawing
   d. All of the above

9. Nursing care of patients receiving ECMO include which of the following?
   a. Neurologic assessment
   b. Highly skilled nursing care
   c. Early mobility
   d. A and B

10. Which of the following can help nurses assist families with emotional support during hospitalization?
    a. Child life specialists
    b. Palliative care, social workers, and chaplain services
    c. Physician support
    d. Leadership support

11. Studies examining parents’ experiences with ECMO report which of the following?
    a. Parents felt they had no other choice as death was the only other option.
    b. ECMO is one of several treatments available to improve their child’s condition.
    c. Parents preferred optimistic reports on their child’s condition over reasonable prognosis.
    d. Parents relied heavily on the physicians to guide them through the daily stressors of having a child undergoing supportive measures.

12. Which of the following statements is true regarding treatment of neonates with ECPR?
    a. Large immediate infusion of crystalloids is a standard of care for neonates.
    b. Immediate infusion with crystalloids is well tolerated by neonates.
    c. Benefits of immediate end-organ perfusion often outweigh the risks of low hematocrit.
    d. Hemodilution is not a significant risk with neonates.

Test answers: Mark only one box for your answer to each question. You may photocopy this form.

1.  a  2.  a  3.  a  4.  a  5.  a  6.  a  7.  a  8.  a  9.  a  10.  a  11.  a  12.  a
   a  b  c  d  a  b  c  d  a  b  c  d

Test ID: C151 Form expires: February 1, 2018 Contact hours: 1.0  Pharma hours: 0.0  Fee: AACN members, $0; nonmembers, $10  Passing score: 9 correct (75%)
Synergy CERP Category A  Test writer: Tina Cronin

Program evaluation

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The American Association of Critical-Care Nurses is accredited as a provider of continuing nursing education by the American Nurses Credentialing Center’s Commission on Accreditation. AANC has been approved as a provider of continuing education in nursing by the State Boards of Nursing of Alabama (#ABNP0062), California (#01036), and Louisiana (#ABN12). AACN programming meets the standards for most other states requiring mandatory continuing education credit for relicensure.
Thirty years ago this month (February 1985) I took the CCRN exam. Achieving and maintaining my critical care certification is one of the accomplishments, in my 34 years as a critical care nurse, of which I am most proud. Many of the nurses who are reading this column were not yet born when I became certified. My efforts to help others prepare for and achieve this coveted certification is exciting and humbling. The recent changes that have occurred in the eligibility criteria have allowed more nurses to obtain and maintain their CCRN certification. Now all nurses who affect the care of critically ill patients and their families, whether electronically (CCRN-e), in the classroom, at the bedside, or from an administrative office (CCRN-K), can proudly wear the CCRN credential. I feel honored to be a member of this group. Please join me in celebrating my anniversary and remember to celebrate your own!

Adult CCRN Practice Questions

1. Following a craniotomy, a patient has a decreased serum sodium level. Which other laboratory findings would lead the nurse to suspect syndrome of inappropriate antidiuretic hormone (SIADH)?
   A. High serum osmolality and low urine sodium
   B. Low serum osmolality and high urine sodium
   C. High urine specific gravity and high urinary output
   D. Low urine specific gravity and low urinary output

Test plan topic: Endocrine, 6% of the CCRN questions

2. A multiple trauma patient has received 4 L of normal saline and 2 units of packed red blood cells but continues to be hypotensive. Which recent assessment finding of this patient would best reflect improving tissue perfusion?
   A. Increasing creatinine level
   B. Increasing hematocrit
   C. Decreasing heart rate
   D. Decreasing lactic acid levels

Test plan topic: Multisystem, 8% of the CCRN questions

3. A patient who continues to experience full-body tonic-clonic
Test plan topic: Cardiovascular, 20% of the CCRN questions

Correct Answers and Rationales for Adult CCRN Practice Questions

1. Correct Answer: B
Rationale
SIADH or diabetes insipidus (DI) can develop after craniotomy. The posterior lobe of the pituitary gland, which is regulated by the hypothalamus, releases antidiuretic hormone (ADH). In SIADH, increased release of ADH causes fluid retention. The fluid retention causes the patient to have a low urinary output, low serum osmolality, low serum level of sodium, high specific gravity of urine, and high sodium level in the urine.

Source

2. Correct Answer: D
Rationale
The best indicator of improved oxygen delivery to the cells during resuscitation is a decreasing level of lactic acid, which is a byproduct of anaerobic metabolism. Creatinine and hematocrit are not good indicators of oxygenation at the cellular level, and a decrease in heart rate can reflect adequate resuscitation, but is not as specific an indicator of tissue perfusion as are lactic acid levels.

Source

3. Correct Answer: C
Rationale
Status epilepticus is a seizure that is continuous for a prolonged period of time and typically does not respond to single/initial administration of antiepileptic medication and benzodiazepine. Simple and partial complex seizures last only 5 to 7 minutes. Myoclonic seizures are associated with hypoxic brain injury and have a single jerklike presentation, not full-body involvement.

Sources
4. Correct Answer: D

Rationale
The most common cause of autonomic dysreflexia is obstruction of the urinary catheter, so irrigation might correct the problem. The head of the bed (A) should be elevated, not lowered. Although C5-level quadriplegics must be monitored carefully for airway and pulmonary issues, assisting the patient with effectively coughing (B) will not help to treat the current problem. Fever (C) is not a symptom of autonomic dysreflexia.

Sources

5. Correct Answer: A

Rationale
Increasing the epinephrine infusion would further increase α- and β-receptor stimulation to increase heart rate, contractility, and blood pressure. Decreasing the norepinephrine (B) could further decrease the blood pressure. The CVP and the PAOP are both high, indicating that more volume (C) is not needed at this time. No need to pace for a heart rate of 65/min.

Source

Pediatric CCRN Practice Questions
1. A 13-year-old is now permanently disabled after a motor vehicle collision (MVC) in which the mother was driving. What is an effective way for the nurse to promote coping for this patient and family?
   A. Instruct the parents to recognize how different the child will be from their peers.
   B. Discourage expression of feelings of anger by the patient toward the mother.
   C. Provide information about other children in similar situations who are doing well.
   D. Do not include the child in discussions or decisions about care.

Test plan topic: Professional Caring and Ethical Practices, 20% of the pediatric CCRN questions

2. A 3-week-old infant is newly admitted to the pediatric intensive care unit (PICU) with a heart rate of 246/min. The parents report the baby has refused feeding for 8 hours and is difficult to console. The infant is pale and sweating. What intervention will be tried first?
   A. Digoxin
   B. Applying ice to the face
   C. Synchronized cardioversion
   D. Intravenous (IV) adenosine

Test plan topic: Cardiac, 14% of the pediatric CCRN questions

3. An 11-year-old admitted for bacterial meningitis has complained of headache and abdominal pain for the past 4 hours and is now febrile, tachycardic, and vomiting. The nurse contacts the physician immediately because the nurse suspects:
   A. Acute adrenocortical insufficiency
   B. Appendicitis
   C. Hyponatremia
   D. Cushing syndrome

Test plan topic: Neurological, 14% of the pediatric CCRN questions

4. A 6-kg infant is in the PICU after 6 days of having bloody diarrhea, vomiting, and fever at home. Urine output in the past 12 hours is 10 mL and is amber in color. Blood pressure is 110/85 mm Hg. What diagnostic test do you expect to evaluate these new symptoms?
   A. Liver function tests
   B. Magnetic resonance imaging
   C. Renal scan
   D. Echocardiogram

Test plan topic: Renal, 6% of the pediatric CCRN questions

5. An 8-year-old recovering from an open femoral fracture is moved from the medical-surgical unit to the PICU because of signs of infection. What symptom of osteomyelitis may be masked by treatment of the primary injury?

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A. Local signs infection
B. Fever
C. Dehydration
D. Pain

Test plan topic: Multisystem, 11% of the pediatric CCRN questions

Correct Answers and Rationales for Pediatric CCRN Practice Questions

1. Correct Answer: C
Rationale
Fostering hopefulness (C) may help improve the patient’s sense of well-being. It is important to promote normalization by emphasizing abilities, rather than focusing on differences (A). If the child is not allowed to express anger (B), this family will not be able to develop a nurturing environment. Allowing the patient to participate in decisions (D) will encourage a positive self-image.

Source

2. Correct Answer: B
Rationale
This patient has clinical signs of supraventricular tachycardia (SVT). A vagal maneuver, like applying ice to the face, can immediately reverse SVT. IV adenosine (D) may be used in the emergency setting when vagal maneuvers fail. Digoxin (A) is first-line medical management for chronic SVT. Synchronized cardioversion (C) can be used to treat SVT in the ICU setting if cardiac output is compromised.

Source

3. Correct Answer: A
Rationale
Although rare, acute adrenocortical insufficiency can be caused by damage of the adrenal gland from meningococcemia. Early symptoms include headache, diffuse abdominal pain, nausea, and vomiting. Although abdominal pain and vomiting can be symptoms of appendicitis (B), classic signs include anorexia and periumbilical pain followed by nausea and pain in the right lower quadrant. Hyponatremia (C) should always be considered in patients with central nervous system infection and can be a result of adrenal insufficiency. Cushing syndrome (D) is rare in children and most often caused by steroid therapy.

Source

4. Correct Answer: C
Rationale
Oliguria, amber urine, and hypertension are clinical manifestations of hemolytic-uremic syndrome (HUS), the leading cause of acute renal failure in infants and young children. HUS generally follows an episode of gastroenteritis. A renal scan to assess renal perfusion is an expected diagnostic procedure.

Source

5. Correct Answer: D
Rationale
Because the patient is most likely receiving pain medication for the fracture, increased pain and tenderness may not be perceived. The nurse should monitor for signs of acute infection and alterations in thermoregulation while continuing to provide pain-relief measures.

Source

AACN Certcorp publishes a study bibliography that identifies the sources from which items are validated. The document may be found in the AACN Certification exam handbook. The contributor of each question written for this column has listed the source used in developing each item. CCN
Is it prudent to correlate noninvasive blood pressure (NIBP) measurements with arterial blood pressure measurements? My understanding is that the accuracy of arterial blood pressure measurements is assessed by doing the square-wave test and leveling, not by correlating the arterial measurements with the NIBP values. However, I observe the practice of correlating with the NIBP values so often, it makes me wonder if I have misunderstood my previous training on arterial catheters.

Barbara McLean, RN, MN, CCNS-BC, NP-BC, CCRN, replies:

Many critically ill patients are monitored with continuous blood pressure measurements, which provide clinicians with the important measures of systolic blood pressure (reflecting the change of pressure in the artery related to ventricular stroke volume) and diastolic blood pressure (related to vascular tone), as well as the calculated mean arterial pressure and pulse pressure. The physiology of blood pressure monitoring is quite complex, and the meanings of the different values are often misunderstood. Although most providers use target end points for pressure monitoring and intervention, little evidence supports the use of a single blood pressure target. When measuring noninvasively, the points of measure are static, versus the invasive measures, which are dynamic (beat to beat). The complexity of variables requires a physiological appreciation of a constellation of signs and symptoms, not just the blood pressures or the mean pressure.¹

In 1896, the mercury sphygmomanometer was designed and then adopted and disseminated in part by Harvey Cushing. In 1905, Korotkoff developed methods for auscultating Korotkoff sounds, which were related primarily to diastolic pressures. The clinical techniques of direct measurement of blood pressure by intra-arterial cannula were initially developed in the 1930s but were not used effectively until the 1950s. These measurements were soon accepted as representing true systolic and diastolic pressures.² Since that time, a significant amount of research and engineering has produced a variety of invasive and alternative indirect methods of measuring blood pressure. Following a brief summary of the current methods of evaluating blood pressure, a simple overview of validation of invasive arterial blood pressure will simplify the comparisons.

Providers can indirectly monitor blood pressure by using a number of techniques, most of which describe the external pressure...
applied to block flow to an artery distal to the occlusion. These methods actually detect the effects of blood flow, not intra-arterial pressure. These differences in what is actually measured are the major points of discrepancy between direct and indirect measurements. Five methods are currently used for noninvasive monitoring of blood pressure: Doppler flow, infrasound, oscillometry, the volume clamp technique, and arterial tonometry.

**Doppler Flow**

Systems that operate on the Doppler principle take advantage of the change in frequency of an echo signal when there is movement between 2 objects. Doppler devices emit brief pulses of sound at a high frequency that are reflected back to the transducer. In an uncompressed artery, the small amount of motion of the artery wall does not cause a change in frequency of the reflected signal. The compressed artery exhibits a large amount of wall motion when flow first appears in the vessel distal to the inflated cuff, which changes the frequency of the signal, causing what is known as a Doppler shift. The first appearance of flow in the distal part of the artery represents systolic pressure. When the Doppler shift in the echo signal disappears, that represents diastolic pressure.

**Infrasound**

Infrasound devices use a microphone to detect low-frequency (20-30 Hz) sound waves associated with the oscillation of the arterial wall. These sounds are processed by a minicomputer, and the processed signals are usually displayed in digital form.

**Oscillometry**

Most automated NIBP devices are based on oscillometry. Oscillometric devices operate on the same principle as manual oscillometric measurements. The cuff senses pressure fluctuations caused by vessel wall oscillations in the presence of pulsatile blood flow. Maximum oscillation is seen at mean pressure, whereas wall movement greatly decreases below diastolic pressure. As with the other automated methods described, the signals produced by the system are processed electronically and displayed in numeric form. In oscillometry, variations in cuff pressure resulting from arterial pulsations during cuff deflation are sensed by the monitor and used to determine arterial blood pressure values. The pressure at which the peak amplitude of arterial pulsations occurs corresponds closely to directly measured mean arterial pressure, and values of systolic and diastolic pressure are derived from proprietary formulas that examine the rate of change of the pressure pulsations. Consequently, systolic and diastolic values obtained with this technique are less reliable than mean arterial pressure values.

Indirectly measured pressures vary depending on the size of the cuff used. Cuffs of inadequate width and length can provide falsely elevated measurements. Bladder width should equal 40% and bladder length at least 60% of the circumference of the extremity measured. When a cuff is slowly deflated and blood first begins to flow through the occluded artery, the artery’s walls begin to vibrate. This vibration can be detected as an oscillation in pressure and has served as the basis for the development of several automated devices for monitoring blood pressure. The disadvantages include the inability to measure diastolic pressure, poor correlation with directly measured pressures, and lack of utility in situations in which Riva-Rocci (auscultation) measurements are also unobtainable.

**Volume Clamp Technique**

The volume clamp method avoids the use of an arm cuff. A finger cuff is applied to the proximal or middle phalanx to keep the artery at a constant size. The pressure in the cuff is changed as necessary by a servocontrol unit strapped to the wrist. The feedback in this system is provided by a photoplethysmograph that estimates arterial size. The pressure needed to keep the artery at its unloaded volume can be used to estimate the intra-arterial pressure.

**Arterial Tonometry**

Arterial tonometry provides continuous noninvasive measurement of arterial pressure, including pressure waveforms. It slightly compresses the superficial wall of an artery (usually the radial artery). Pressure tracings obtained in this manner are similar to intra-arterial tracings. A generalized transfer
function can convert these tracings to an estimate of aortic pressure. This method has not yet achieved widespread clinical use.

In summary, automated non-invasive measurement of blood pressure is a major component of modern critical care monitoring. Oscillometric and Doppler-based devices are adequate for frequent blood pressure checks in patients without hemodynamic instability, in patient transport situations where arterial catheters cannot be easily used, and in patients with severe burns, in whom direct arterial pressure measurement would be associated with an unacceptably high risk of infection. Automated NIBP monitors have a role in following trends of pressure change; however, the averaging over time is the value-laden data, not the single measure, or its comparison to invasive arterial pressure. In general, such automated devices have significant limitations in patients with rapidly fluctuating blood pressures, and blood pressure values obtained with such devices may differ substantially from directly measured intra-arterial pressures.

Given these limitations, critical care practitioners should be wary of relying solely on NIBP measurements in patients with rapidly changing hemodynamics or in whom very exact measurements of blood pressure are important. It is vital to remember that regardless of the method by which blood pressure is measured, it is a poor surrogate for the true value of concern, that is, the stroke volume that forces itself (via cardiac ejection) into the resistant arteries. For most trials conducted in humans or animals, blood pressure measures obtained by using a wide variety of methods correlate poorly with invasive arterial pressure measurements, particularly in patients with edema, who are receiving vasoactive medications, or who have significant hypoperfusion.

In the clinical environment, monitoring of direct arterial pressure uses an underdamped catheter-transducer system. The arterial response to ventricular ejection is a frequency response, that is, the stroke volume bolus of blood goes into the artery, generating a vibration column that emits many responses (arterial wall oscillations) that are averaged into the systolic pressure. These frequencies transmit into the system, which transmits the frequencies through the fluid-filled tubing and transducer. Nowadays, monitors offer internal calibration, filtering of artifacts, and printouts of the display. The digital display shows an average of values over time and thus does not show beat-to-beat variability accurately. Beat-to-beat differences in amplitude can be measured precisely by freezing the monitor display with on-screen calibration, allowing assessment of the effect of ectopic beats on blood pressure, variations in pulse pressure or systolic pressure, and the severity of pulsus paradoxus.

Direct measurement of arterial blood pressure requires that the pressure waveform from the cannulated artery be reproduced accurately on the bedside monitor. The displayed pressure signal is markedly influenced by the measuring system, including the arterial catheter, extension tubing, stopcocks, flush devices, transducer, amplifier, and recorder.

Zeroing and leveling are common procedures for most providers, but the importance of the dynamic response to fluid flush is not generally well understood or used to test the accuracy of the system. The length, width, and compliance of the tubing all affect the system’s response to change. Small-bore catheters are preferable because they minimize the mass of fluid that can oscillate and amplify the pressure. The compliance of the system (the change in volume of the tubing and the transducer for a given change in pressure) should be low. In addition, bubbles in the tubing can affect measurements in 2 ways. Large amounts of air in the measurement system damp the system response and cause the system to underestimate the pressure. Large amounts of air are usually easily detectable. Small air bubbles cause an increase in the compliance of the system and can markedly amplify the reported pressure.

Testing the Accuracy of the Monitoring System

Zero Reference

When pressure measurements seem inaccurate or differ markedly from indirect measurements, the system’s accuracy can be checked quickly. The most likely source of error is improper zeroing of the
system, which can be caused either by a change in the patient’s position or by zero drift. Opening the transducer stopcock to air and aligning the transducer with the midaxillary line should confirm that the monitor displays zero (a transducer that is below the zero reference line will result in falsely high measurements and vice versa). The monitor should be zeroed whenever the patient’s position changes, when blood pressure changes significantly, and routinely every 6 to 8 hours because of zero drift. Disposable pressure transducers are standardized and do not require calibration. If zero referencing is correct, a fast-flush test can be done to assess the system’s dynamic response.\textsuperscript{10,11}

**Square-Wave Test**

Two major factors affect the validity of pressures measured: resonant frequency response, the vibration of the fluid column in response to a change in the system (eg, flush), and the damping coefficient, evaluating the end of the vibrations.

Overdamped tracings are usually caused by problems that are correctable, such as air bubbles, kinks in tubing, clots, overly compliant tubing, loose connections, a deflated pressure bag, or anatomical factors that affect the catheter. An underdamped tracing results in systolic overshoot and can be due to excessive tubing length or patient-related factors such as increased inotropic or chronotropic state, as the vessel wall is more rigid and oscillates at a higher level. Many monitors can be adjusted to filter out frequencies above a certain limit, which can eliminate frequencies in the input signal that are causing ringing, although elimination of important frequencies will result in inaccurate measurements.\textsuperscript{10}

Although other techniques can be used, the easiest way to test the damping coefficient and resonant frequency of a monitoring system is by doing a fast-flush test (also known as a square-wave test). This test is performed at the bedside by briefly opening and closing the continuous flush device, producing a square-wave displacement on the monitor followed by a return to baseline, usually after a few smaller oscillations. Visual inspection is usually sufficient to ensure a proper frequency response. An optimal fast-flush test causes an undershoot followed by a small overshoot, then settles back into the patient’s waveform (Figure 1). When air is present in the tubing, a clot is on the tip of the catheter, or the catheter is not properly positioned, the waveform will

![Figure 1](image_url)
appear more rounded and less defined. When the square-wave flush is applied, no resonance is seen (Figure 2). Finally, when the system is underdamped, the tubing is too long, or the catheter is the wrong size, multiple oscillations are apparent after the square-wave test is applied (Figure 3).

Dynamic response validation by fast-flush test should be performed frequently: at least every 8 hours, with every significant change in the patient’s hemodynamic status, after each opening of the system (zeroing, blood sampling, tubing change), and whenever the waveform appears damped.

Components of the monitoring system are designed to optimize the frequency response of the entire system. The 18- and 20-gauge catheters used to gain vascular access are not a major source of distortion but can become kinked or occluded by thrombus, resulting in overdamping of the system. Standard, noncompliant tubing is provided with most disposable transducer kits and should be as short as possible to minimize signal amplification (overdamping). Air bubbles in the tubing and connecting stopcocks are a notorious source of overdamping of the tracing and can be cleared by flushing through a stopcock.

Despite technical problems, direct arterial pressure measurement offers several advantages. Arterial catheters actually measure the end-on pressure propagated by the arterial pulse. In contrast, indirect methods report the external pressure necessary either to obstruct flow or to maintain a constant transmural vessel pressure. Arterial catheters can also detect pressures at which Korotkoff sounds are either absent or inaccurate. Arterial catheters provide a continuous measurement, with heartbeat-to-heartbeat blood pressures.

**Problems With Comparing Noninvasive and Invasive Pressure Monitoring**

Indirect methods of measuring blood pressure estimate the arterial pressure by reporting the external pressure necessary to either obstruct flow or maintain a constant transmural vessel size. A recently published meta-analysis of 28 studies involving 919 patients concluded that inaccuracy and imprecision of continuous noninvasive arterial pressure monitoring devices are larger than what was defined as acceptable. This may have implications...
for clinical situations where continuous noninvasive arterial pressure is being used for patient care decisions.

Direct arterial catheters measure the end-on pressure propagated by the arterial pulse with every beat. They are not measuring the same end points as indirect methods measure. Rigorous validation of the accuracy of the monitoring system can be done with the square-wave flush test, but that does not ensure the value of the blood pressure measurements, just the accuracy of the system.11

Direct arterial pressure measurement offers several advantages in many but not all patients. Although an invasive catheter is required, the reported risk of complications is low. Arterial catheters provide a heartbeat-to-heartbeat measurement, can detect pressures at which Korotkoff sounds are either absent or inaccurate, and do not require repeated inflation and deflation of a cuff. Regardless of the method used, the mean arterial pressure should generally be the value used for decision making in most critically ill patients, because it is the most stable (least affected) measurement (calculation) across all methods of blood pressure monitoring.

So to answer the first question, “Is it prudent to correlate NIBP measurements with arterial blood pressure measurements?” No. Most noninvasive methods provide an average calculation for systolic and diastolic blood pressures, based on a measured mean pressure. Compare the mean pressures and consider the tested and zeroed invasive arterial pressure to be the true measure whether you like the numbers or not. These 2 types of measurements evaluate something quite different: direct pressure monitors beat-to-beat pressure pulse, whereas the commonly used noninvasive methods measure peak oscillations related to blood flow. Especially in patients treated with vasopressors, inotropic agents, and vasodilators, these measurements may differ significantly.

The second question was, “My understanding is that the accuracy of arterial blood pressure measurements is assessed by doing the square-wave test and leveling, not by correlating the arterial measurements with the NIBP values. However, I observe the practice of correlating with the NIBP values so often, it makes me wonder if I have misunderstood my previous training on arterial catheters.”

Leveling and square-wave testing provide an evaluation of the system and validation of system acceptability. Neither test validates the patient’s arterial pressure, but the tests validate the integrity of...
the monitoring system that measures the pressure. If zeroing is performed and the square-wave test is passed, you can rest assured that the direct pressure is being monitored correctly. When invasive arterial pressure monitor is zero referenced, leveled, and passes the frequency response test, then the invasive pressure is what should be monitored. At the very best, correlation can be made between noninvasive and invasive measurements at the mean pressure measure only.

Remember that the primary role of the circulation is to provide tissues with dissolved and bound oxygen as well as other energy substrates, so it is always best to correlate pressure readings with indicators of tissue perfusion, no matter what method(s) you choose for monitoring. Recommendations for pressure targets must take into consideration the site and method of measurement as well as the true value of blood pressure versus oxygen adequacy. Trends in blood pressure and the relationship to metabolic measures are the most important measures in today’s critical care environment. CCN

Financial Disclosures
None reported.

References
In Our Unit

Implementation of Early Exercise and Progressive Mobility: Steps to Success

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Erin Kreppel, PT, MPT

A new bundle of interventions to improve the care of critically ill patients receiving mechanical ventilation has been identified. This bundle incorporates performance and coordination of spontaneous awakening trials and spontaneous breathing trials; careful selection of sedatives; assessment, prevention, and management of delirium; and early exercise with progressive mobility. In collaboration with the Institute for Healthcare Improvement, and as a part of a critical care collaborative, our hospital had implemented many parts of the bundle, but early exercise and progressive mobility had not yet been incorporated into care. In this article, we share our process for literature review, appraisal, and synthesis along with protocol development. An evidence-based performance improvement (EBPI) model was used to plan, implement, and disseminate the change. High-fidelity human simulation boosted confidence and teamwork and also underscored important safety aspects before implementation. Unit champions and daily multidisciplinary rounding assisted with culture change.

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Literature Review, Appraisal, and Synthesis

Electronic databases searched for evidence included Cochrane, PubMed, and CINAHL. Key words included mechanical ventilation, critically ill, critical illness, early mobilization protocol, delirium, intensive care unit, early mobility, sedation, physical rehabilitation, and physical therapy. In CINAHL, limits included research, English, human, and all adults. Related citations were reviewed in PubMed with limitations of clinical trials, human, English, and publication between 2007 and 2012. References from key articles were reviewed to search for additional evidence. Articles were included in the appraisal if content focused on early mobility in critically ill patients receiving mechanical ventilation.

Articles were rated by strength of evidence. Level 1 evidence, that established by meta-analysis or systemic review (and also the highest level of evidence) was not found. No Cochrane reviews or national practice guidelines that were related to the subject had been published between 2007 and 2012. Since that time, a clinical practice guideline related to pain, agitation, and delirium in the critically ill has
been published. Seven keeper articles were identified.\textsuperscript{5-11}

The articles were shared and discussed with our multidisciplinary team. From these articles, the team determined that early activity had been demonstrated to be safe and feasible\textsuperscript{5-8} and that early mobility was associated with an increase in both delirium-free days and ventilator-free days.\textsuperscript{9,10} Some studies noted that the implementation of early mobility contributed to decreases in length of stay in both intensive care units (ICUs) and hospitals.\textsuperscript{5,10} An additional article\textsuperscript{11} discussed barriers and facilitators to implementation of early mobility. Barriers included sedation, decreased level of consciousness, and agitation. Factors that facilitated change were the presence of a protocol and the presence of unit champions.\textsuperscript{11} The multidisciplinary team decided that the evidence was sufficient for us to implement the practice of early mobility for our patients.

Planning for Change

While our team was planning implementation of early mobility, we elected to be a part of an expedition on early mobility sponsored by the Institute for Healthcare Improvement. The expedition was a series of webinars that included presentations of the science surrounding early mobility and assisted with protocol development and implementation planning. We invited various departments (respiratory therapy, physical and occupational therapy, pharmacy) and our medical director to attend the webinars. We ensured that ICU nursing staff, who would act as unit champions, could attend. The webinar communicated the importance of early mobility and the evidence supporting the change.

Our early mobility protocol (Figure 1) was developed after careful reading of 2 key articles: a randomized controlled trial and a descriptive study that detailed the intervention arm of that same trial.\textsuperscript{14} The protocol was reviewed by the multidisciplinary team and by several critical care intensivists. The protocol included contraindications to initiating early mobility designated by a yellow text box indicating caution. Once the patient had no contraindications, preparation of early mobility would begin, designated by a green text box indicating that the patient was ready to go. Preparing for early mobility would include assessing and securing all devices, stopping tube feeding, and moving all catheters, intravenous pumps, and the urinary catheter drainage bag to the side of the bed with the ventilator. Activity would progress from active range-of-motion exercises to bed mobility exercises (lateral rolling, move from semicumbent to upright), sitting on the edge of the bed, sitting to/from standing and bed to/from chair transfers, and finally ambulation. An additional red box was included in the protocol that delineated contraindications to continuing early mobility.

If the patient experienced physiological changes such as hemodynamic instability, or oxygen desaturation, activity would be stopped.

An additional flowchart (Figure 2) was created to visualize and teach others how early mobility would fit into our process of coordination of spontaneous awakening trials and spontaneous breathing trials.

Our plan for implementation was written and reviewed by our hospital’s Human Institutional Review Committee and the university’s institutional review board. We wanted to collect patient data during the implementation of our project to monitor process and outcomes and wanted to ensure the safety of that data collection and dissemination of results.

The final aspects of planning for practice change included creating an aim statement. Using our EBPI model, an aim statement would help us to know whether we had reached a short-term goal in our implementation. Working with our medical director, we determined that our aim statement would be:

By month 3 of the project, early mobility would be incorporated into the care of 25% of patients receiving mechanical ventilation (as appropriate). The implementation steps in accordance with our EBPI model are listed in Table 1.

Practicing With High-Fidelity Human Simulation

One of our physical therapists had read an article about the use of high-fidelity human simulation to teach physical therapy students. Training with simulation helped improve the students’ confidence before they started getting clinical experience in an actual ICU.\textsuperscript{15} The physical therapist expressed a desire to try our protocol by using simulation first so that the team could practice together to ensure that the protocol was easy to understand and that safety concerns were addressed. Her main concern was related to accidental extubation of a patient, and she wanted us to plan the steps of how we would care for a patient who experienced that serious adverse event. We developed 3
simulation scenarios (see Table 2 for examples):

- Assessment of the patient to determine whether any contraindications for beginning early mobility were present.
- Preparation of the patient and beginning activity with recognition of changes in condition that would require stopping activity.
- Inadvertent extubation during activity.

The project leader/clinical nurse specialist worked with the personnel in the simulation laboratory to prepare for practice. Intravenous pumps, a tube feeding pump, a sequential compression device, a ventilator, a manual resuscitation bag, a cardiac monitor, a walker, and a transport ventilator were transported to the laboratory. The simulation laboratory was set up with the appropriate equipment to look like one of our ICU rooms. Nursing unit champions, physical therapists, occupational therapists, and respiratory therapists participated. The clinical nurse specialist reviewed the draft protocol, including the sections on contraindications for early mobility, preparation of the patient, progression of activity, and when to stop activity if the patient’s condition changed. Additionally, the flowchart of how early mobility

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**Figure 1** Early mobility protocol.
would be incorporated into our current process was reviewed and discussed.

The simulation began and the group focused on how to begin to move the patient. Discussion was intense, with brainstorming about the roles and responsibilities of each of the team members. When the patient needed to move from sitting at the edge of the bed to standing or transferring to a chair, a team member was substituted for the patient simulator so that the team could practice standing the patient at the bedside and ambulation in the hallway. Proper body mechanics and safe handling of patient were emphasized. The group thoroughly enjoyed the simulation and found that the “hands-on” approach boosted confidence.

Four priorities were identified for implementation of the protocol with a “real” patient:

- The nurse caring for the patient could begin to prepare all tubes and catheters anticipating the other team members’ arrival.

Doing so decreased the preparation time for the other disciplines, thereby increasing the number of other patients that they were able to see in their work day.

- One person should be designated to communicate with the patient and provide direction to the team during early mobility. The physical therapist or occupational therapist was positioned immediately.

Figure 2 Incorporation of early mobility into our current process.
in front of the patient while the patient was moving and the group determined that this team member would direct the patient and lead communications for the team. The goal was to help the patient understand what to do next and to decrease confusion for team members.

• Additional roles were delineated. The respiratory therapist would be responsible at all times for monitoring endotracheal tube security and oxygenation status. The nurse would monitor other tubes and catheters as well as vital signs. The physical and occupational therapists would assess and monitor motor strength, balance, and tolerance of activity. The decision to stop the intervention and return the patient to a supine position would be a team decision led by the nurse. The patient also could stop the activity.

• Specific equipment would be helpful for mobilization. A reclining-back manual wheelchair would be positioned behind the patient when walking in the hall in the event of change of condition. This specific type of wheelchair would allow supine positioning for ease in transferring the patient back into the bed. The transport ventilator would be used when the patient was ambulating in the hall.

Implementation

Small tests of change were used to begin the implementation. After each test, the multidisciplinary team reviewed how things went. The protocol flowed well and was easily understood. The team, having gained confidence through the use of simulation, worked well together and the patients were safe. Next steps involved teaching others about early mobility and disseminating the practice. The physical medicine and rehabilitation department conducted several in-service training sessions with their staff and added written and oral competencies to ensure staff knowledge and patient safety. Nurses and respiratory therapists conducted training during staff meetings as well as special educational conferences focused on the bundle. We used a slogan of “Mobility Is Medicine” and provided slogan buttons to those staff members who had cared for a patient during early mobility. We also purchased cookies shaped like feet and emphasized “Feet to the Floor.” This added fun and helped create some excitement regarding the change. Daily multidisciplinary rounding helped to determine which patients were ready for early mobility and supported staff during implementation. The team met every 2 weeks in conjunction with the medical director. Problems encountered with the practice change were discussed and methods to improve implementation were developed. Constant communication with all the specialties involved was done through staff meetings, electronic mail, bulletin boards, and departmental publications.

The patient’s experience was also explored. One patient whom we interviewed after he had been extubated indicated that he enjoyed being up while connected to the ventilator. He had severe chronic obstructive disease and had received mechanical ventilation before. He felt that he was ready to move before the team was ready, and when he began to ambulate out of his room, he felt that he could have walked much further but the team was “nervous.” He walked the next day around the whole perimeter of the ICU. He stated that “it felt good to get out and walk because there is nothing else to do in the ICU” and “it made it more interesting.” The exercise made him feel like he was improving.

Table 1  Plan for implementing the evidence-based performance improvement model

| 1. Describe the problem: Need for implementation of early mobility into practice. |
| 2. Formulate focused clinical question: What is the effect of an early mobility protocol on delirium and length of stay in the intensive care unit over the course of 3 months? |
| 3. Search for evidence. |
| 4. Appraise and synthesize evidence. |
| 5. Develop aim statement: By month 3 of project, early mobility will be incorporated into care of 25% of patients receiving mechanical ventilation (as appropriate). |
| • Ensure safety: high-fidelity human simulation |
| • Ensure safety and reproducibility: protocol refinement |
| 7. Disseminate practice to all staff and patients. |
| 8. Utilize plan-do-study-act process to monitor/evaluate implementation of new practice. |

a Based on information from Levin et al.3
Sustaining Practice

Creating organizational memory and knowledge reservoirs were important mechanisms in our hospital to help with sustaining practice.14 In our electronic medical record, we were able to create files to hold resource documents. Our early mobility protocol was placed

### Instructor content
Patient is improving. Yesterday patient was able to sit and dangle legs at bedside, sit to stand with 2-person assist. Gait was steady. Plan for today is to march in place, weight shift, and determine if patient can ambulate in room.

### Expectations of student group
Verbalize the contraindications to initiating early mobility. Examine patient and infusions. Review ventilator settings and vital signs.

### Important learning considerations
Have chart of contraindications for early mobility available for team to review.

Note that patient has no contraindications.

Have chart of items for consideration for planning for early mobility.

Discuss roles and responsibilities of different personnel.

**Respiratory therapist:** responsible for endotracheal tube and tubing to ventilator. Setup of portable ventilator.

**Nurse:** responsible for intravenous poles and intravenous catheters. Cardiac monitor onto walker.

**Patient care technician:** remove sequential compression device, and move urinary drainage bag to side of bed by ventilator. Attach to walker. Emphasize maintaining drainage bag below level of bladder.

**Physical/occupational therapist:** apply gait belt, instruct patient. Assess trunk stability, balance. Assist to sit at side of bed. Determine whether may sit to stand, march in place, begin ambulation in room.

### Simulate Critical Care Nursing in Your Own Practice

**Inadvertent endotracheal tube removal, patient is anxious, tachypneic.**

**Indications that patient may need reintubation:**
- Tachypnea, decreased oxygen saturation, circumoral cyanosis, tachycardia, hypotension.

**Resources for reintubation:** nurse practitioner, physician, or anesthesiologist.
in these files for ease of reference at each computer terminal. We revised our mechanical ventilator order set (computer physician order entry) to include prechecked orders for early mobility as well as consultation with physical and/or occupational therapists for evaluation and treatment. Then when the patient met criteria for initiation of early mobility, the appropriate orders were there. We also used documents called standards of nursing practice. These documents were a blend of nursing art and science that helped to delineate the important aspects of nursing care for a specific type of patient. They were used to help with orientation of new staff. Our standard of nursing practice for patients receiving mechanical ventilation was updated to include concepts related to early mobility. Lectures for critical care class also were updated to include early mobility.

Lessons Learned

After 3 months, we were excited that we had met our aim. More than 25% of critically ill patients receiving mechanical ventilation in that third month had received early mobility. No serious adverse events had occurred. Staff were not only readily identifying patients who were appropriate for early mobility but also were obtaining orders for physical and occupational therapy for patients who were not receiving mechanical ventilation. A physical therapist and an occupational therapist were assigned to the ICU daily. We had collected data related to incidence and duration of delirium and found a problem with the flow-sheet design in our electronic medical record. Additional changes were made to add detail to the 4 features of the Confusion Assessment Method-ICU (CAM-ICU) to support critical thinking and accuracy of documentation. We also noted problems with sedation and analgesia practices and are in the process of implementing a nonverbal pain assessment tool and an analgesia-first approach. As always, change continues.

Summary

Our purposeful approach to the implementation of early mobility by using an EBPI model resulted in sustained improvement over the practice a year later. Critical appraisal and synthesis of the literature resulted in a good protocol for early mobility. High-fidelity human simulation built confidence with working together, and this translated to experiences with early mobility in actual patients. Lessons learned from others related to the use of unit champions and multidisciplinary rounding to help support the practice change. We continue to find opportunities to improve our practice related to the care of patients receiving mechanical ventilation.

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None reported.
Becoming Nursey

Reviewed by Mary Pat Aust, RN, MS

The decision to become a nurse is a long-term commitment that sends nursing students on a potentially confusing and frightening journey. The transition between the safety and structure of nursing school and becoming a licensed health care provider in a hospital never seems long or structured enough to avoid the inevitable fear and anxiety associated with it. In her book, *Becoming Nursey*, Kleber covers topics such as getting through school, transitioning to working as a nurse in a hospital, and transitioning from the acute care medical-surgical unit to a neuro/trauma intensive care unit.

Kleber's confident, compassionate, and witty demeanor is evident throughout the book, as she discusses combining the technical and emotional work of nursing and how to find your place along the continuum. She offers tips for conquering studying for the NCLEX exam and strategies for landing a job. She calls out some of the most frightening things about being a new nurse (eg, calling physicians, rounding with physicians, giving and receiving report from colleagues, and assessing patients) and provides very practical, actionable tips.

Kleber offers advice on some common areas where new nurses stumble, such as time management, shift work, and, the ultimate in stress, the code blue. With wit and wisdom, she shares stories from her own experiences. She also shares her perspective on the work-life balance, which is essential to becoming a resilient nurse.

As a nurse with more than 30 years of experience, I had 3 wishes after reading this book. First, I wish I had this book all those years ago when I was becoming nursey so I would not have been so surprised by how different working as a nurse, responsible and accountable for the care of really sick patients, was from what I learned in school. Second, I have had some great preceptors through the years and I wish Kati Kleber had been one of them. Third, I wish this book was available to give to all new nurses who crossed my path. It will make them feel as though they are not alone, prepare them for what is to come, and allow them to make informed choices as they move from school to becoming nursey.

Mary Pat Aust is a clinical practice specialist at the American Association of Critical-Care Nurses in Aliso Viejo, California.

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Anatomy of Research for Nurses

This book is part of the Anatomy series, published by Sigma Theta Tau International, that uses the concept of anatomical structure and function to develop the content. The foundation of the book rests on distinguishing research from quality improvement and evidence-based practice, with additional discussion about where these 3 components intersect.
Many well-known names in the world of nursing research have authored chapters in this book. Their contributions are significantly supported by the inclusion of a medical librarian who coauthored the chapter on conducting the literature search and review. In addition to the process of conducting research, the book includes legal and ethical aspects, research involving special and vulnerable populations, where to find funding, and the impact of the Internet and social media on the conduct of research.

**Foundations of Clinical Nurse Specialist Practice**

*2nd edition*

*Fulton JS, Lyon BL, Goudreau KA, eds.*


This book is both a text for educating new clinical nurse specialists (CNSs) and for the benefit of CNSs in practice to continue their professional development journey. While giving the history and context of the role, this edition reaches into the present and future opportunities within the health care system for the unique contributions of the CNS. As health care continues to change, so do the ways in which a CNS affects patients and families, nurses, and systems in the 3 spheres of influence.

The authors also discuss entrepreneurship, billing and reimbursement, and regulation of practice. Finally, short exemplar chapters demonstrate how the CNS role can be implemented to achieve positive outcomes in multiple settings.

**Palliative Care Nursing: Quality Care to the End of Life**

*4th edition*

*Matzo M, Sherman DW, eds.*


This statement in the preface of the 4th edition truly describes the role and function of palliative care:

Unlike hospice care, palliative care is not dependent on prognosis and can be provided in the context of curative treatments, curing what can be cured, but with the concurrent attempt of alleviating symptoms caused by disease or its treatment.

**Palliative Care Nursing** describes the ethical and legal aspects of palliative and end-of-life care, and presents the process of providing that care within the framework of the whole person (including family and caregivers). Provision of nursing care is divided into 2 sections: (1) addressing the physical aspects of dying for particular diagnoses and (2) addressing symptom management for all patients. Palliative care nursing is a crucial aspect of providing care across patients’ life span, whether faced with congenital issues, chronic disease, or aging. CCN
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*Date:* February 20-21, 2015. *Place:* Nova Southeastern University. *Address:* 8585 SW 124th Ave, FL 33183. *Keynote Speaker:* Mary Ann “Cammy” Fancher. *Sponsor:* Greater Miami Area Chapter of AACN. *Contact:* Joe Falise. *Phone:* (954) 594-1427. *E-mail:* jfalise@med.miami.edu. *Fee:* Members, $140; nonmembers, $170; groups of 3 or more, $130/person; 1-day course (all attendees), $100. *Credits:* 14 CEUs

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Jacqueline Kramer, RN, is a staff nurse in the ICU/Burn Unit at Detroit Receiving Hospital in Detroit, Michigan.

Why did you become a nurse?
I was made to be a nurse. It is in my nature to care for, assess, troubleshoot, reassure, and encourage patients. Being a nurse is all I have ever wanted to do.

What about your job as a nurse makes you happy?
Seeing my patients make progress and recover makes me happy. The patients I care for are burn victims and they are very close to death. When these patients take a turn for the better by just opening their eyes for the first time in the unit, it is nothing short of a miracle. As a nurse, I can be a change agent and I can bring hope to the hopeless, deliver healing to the resistant, encourage and teach the noncompliant, and see miracles happen at the bedside. This is why I am so excited about my job.

Tell us about an extraordinary experience you’ve had as a critical care nurse.
I cared for a very ill, severely burned, and heavily sedated patient for months. While caring for her, I used to get close to her ear and whisper, “You can do it. I’m here for you. I’m praying for you.” She slowly improved and one day, when she was able to sit up in bed, she said, “Thank you for encouraging me. I heard everything you said.” It felt incredible to find out that she heard me all those times when I whispered reassuring words to her. To be able to make a positive difference in the life of someone who is suffering is truly a blessing.

What are the challenges you encounter and how do you overcome them?
Fear of failing to do my very best as a nurse is the greatest challenge I face every day. I turn to God for strength and I pray diligently that He continues to use me to help improve patients’ lives.

What has your journey as a nurse been like?
My journey as a nurse has been a beautiful educational experience and a true blessing. There have been (and will continue to be) challenging days when I have done all I can do and nothing helps, but knowing I did my best gives me some satisfaction.

At the end of a busy day, how do you find balance in your life?
I find balance in my faith and belief in God. I try to live my life and treat others as I want to be treated.

What would we be surprised to know about you?
I am a vegetarian!

How has AACN played a role in your career?
AACN has played a major role in my career. I look to AACN for standards and resources, and I use the continuing nursing education to evolve and learn as a nurse. AACN mandates excellence and I accept the challenge to uphold, meet, and exceed this mandate. CCN

I Am a Critical Care Nurse features the extraordinary in a critical care nurse’s ordinary experiences. To be featured in this department, contact Critical Care Nurse via e-mail at ccn@aacn.org.
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