MRSA Colonization and Infection Control

Temperature and Mortality in ARDS

Manual vs Automated Lateral Rotation

Predictors of Physical Recovery in the ICU

Measuring Height in Recumbent Patients

Delirium Monitoring and Patient Outcomes

Head-of-Bed Elevation and Patient Outcomes

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Mangusan and colleagues assess outcomes associated with postoperative delirium after cardiac surgery.

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2014

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An Official Publication of the American Association of Critical-Care Nurses
Viral Outbreaks in an Age of Global Citizenship

By Cindy L. Munro, RN, PhD, ANP, and Richard H. Savel, MD

The 2014 West Africa Ebola outbreak is the most recent highly publicized viral outbreak to challenge the health care community, but Ebola Viral Disease (EVD) has not been our first challenge and it will not be the last. Infectious diseases have always carried risks for health care providers, and there have always been dedicated healers ready to face the fight.

A roadside marker near Elliston, Virginia, testifies that neither outbreaks nor their effects on those who bravely step forward to care for the sick are new. The marker’s inscription reads, “Near here stood Montgomery White Sulphur Springs, popular resort area of 19th century America. During the Civil War the resort was converted into a military hospital staffed by Catholic nuns. Several hundred victims of smallpox including nurses and soldiers are buried nearby.”

Today, we might do well to take a moment to contemplate the sacrifices of contemporary health workers on the West African frontlines who also have been buried alongside patients they sought to save.

As we rise to meet present challenges, a pragmatic reflection on previous outbreaks can assist health care providers to react more effectively to these and future challenges. Of course, these kinds of outbreaks are of particular concern to critical care providers because a relatively large proportion of patients affected have become critically ill. Caring for these patients involves risk of exposure and transmission to others.

Viral Disease in the Global Village

In the previous decade, health care providers worldwide have wrestled with several viral diseases that posed potentially serious threats, including Middle Eastern Respiratory Syndrome (MERS), Severe Acute Respiratory Syndrome (SARS), and the 2009 H1N1 influenza pandemic. To date there have been relatively small numbers of EVD, MERS, or SARS patients treated in the United States, but the H1N1 influenza pandemic taught us that viral diseases do not respect international boundaries. The Table illustrates how quickly diseases that originate elsewhere can affect the United States. It behooves us to pay attention to global health care problems and to be ready to respond. We are global citizens, and we cannot view illnesses as geographically distinct problems that don’t concern us.

Two imported cases of MERS, in health care providers who were infected while working in Saudi Arabia, were documented in the United States in...
May 2014.3,4 These were the first reports of MERS in the United States, but MERS has received much less publicity than EVD. Unlike EVD, MERS did not spread to the health care workers who treated the 2 imported cases, and did not generate widespread concern among the public.

SARS caused a global outbreak in 2003, and although no deaths occurred in the United States, 29 states reported probable cases.4,5 Breaches in the use of personal protective equipment were linked to infections in health care providers. SARS subsided as mysteriously as it began, and there have been no known cases of SARS anywhere in the world since 2004.

Our familiarity with seasonal influenza may make us less likely to think about pandemic influenza as a serious risk. However, the CDC estimated that the 2009 pandemic influenza outbreak involved approximately 60.8 million cases and more than 12,000 deaths in the United States alone.6 In a review of the 2009 influenza pandemic, Fineberg stated, “In terms of persistence, versatility, potential severity, and speed of spread, however, few viruses rival influenza virus.”7(p1335)

**Table**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Viral cause</th>
<th>Index case</th>
<th>First imported US case</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Africa Outbreak: Ebola Viral Disease,</td>
<td>Ebola virus (family Filoviridae,</td>
<td>Guinea, December 2013</td>
<td>September 2014</td>
<td>8, 9, 11</td>
</tr>
<tr>
<td>Ebola Hemorrhagic Fever</td>
<td>genus Ebolavirus)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle Eastern Respiratory Syndrome (MERS)</td>
<td>MERS-corona virus (MERS-CoV)</td>
<td>Saudi Arabia, June 2012</td>
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<td>3, 4</td>
</tr>
<tr>
<td>H1N1 Pandemic influenza</td>
<td>Influenza A (H1N1)</td>
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<td>6, 7</td>
</tr>
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<td>Severe Acute Respiratory Syndrome (SARS)</td>
<td>SARS-associated coronavirus</td>
<td>Asia, November 2002</td>
<td>March 2003</td>
<td>4, 5</td>
</tr>
</tbody>
</table>

**Ebola Outbreaks in Africa**

The first reported outbreak of Ebola occurred in 1976, and thus far all EVD outbreaks have originated in Africa.³ The 2014 West African outbreak is the largest ever reported, and it occurred concurrently with an unrelated Democratic Republic of Congo outbreak. At the end of October 2014, the World Health Organization reported more than 10,000 probable, confirmed, and suspected cases in West Africa, with almost 5000 deaths, and the reported number of cases was doubling every 15 to 20 days in Liberia.⁵

In September 2014, the Centers for Disease Control and Prevention (CDC) published an Ebola Response modeling tool to estimate the potential number of future cases and how additional control measures might affect the number of cases.¹⁰ Extrapolating from existing data, they estimated that if no additional interventions to control the spread were instituted, Liberia and Sierra Leone would have approximately 550,000 EVD cases (and an estimated 1.4 million cases when corrected for underreporting) by January 2015. Further modeling predicted that if 70% of EVD cases were treated under conditions that limited transmission (including safe burial of patients who succumb to EVD), the outbreak would be nearly over by the end of January 2015. These astonishing figures highlight the importance of interrupting transmission.

**New Pathogens Are Unpredictable**

Because outbreaks involve novel pathogens, they challenge our thinking. Although experience serves as an initial rough guide for responses to outbreaks, novel pathogens are unpredictable and often defy conventional wisdom. Research is difficult to conduct during an outbreak. Resources are scarce, and the focus is appropriately on the urgent needs of reducing the spread of disease and providing
supportive care to victims. Despite the difficulties, research to develop novel diagnostic strategies, therapies, and vaccines is crucial and offers broad potential benefit to future patients. Interestingly, all of the viral pathogens in Table 1 have zoonotic connections. Research that improves our understanding of animal sources and zoonotic transmission, as well as surveillance of viral pathogens in animals, is underdeveloped and underfunded, but it is vital to prevention of future outbreaks.

Outbreaks reinforce the importance of critical care knowledge, skill, and teamwork in uncertain situations. Prevention and supportive therapy, which seem simple, require high levels of infrastructure and of provider knowledge and skills. These elements are already part of the critical care tool kit, but outbreaks highlight the importance of the basics as a foundation for clinical practice. For example, infection control practices are one of the first skill sets that nurses and physicians learn, but they are also some of the most difficult skills to perform well and consistently.

Containing the spread of EVD, MERS, SARS, and influenza requires standard and contact precautions. Airborne infection isolation is recommended for MERS, SARS, and influenza; although EVD is not spread by airborne transmission, it can be spread by aerosolized secretions. In order to be effective, infection control measures must begin at the first point of contact with a potentially infected person. The recent Ebola outbreak reminds us that hand washing, personal protective equipment, and pristine technique are essential. Practice makes perfect. Safety requires both individual effort and exceptional teamwork, including taking accountability for helping each other adhere to infection control protocols.

Knowledge Mitigates Risk
The very nature of clinical care brings nurses, physicians, and other members of the health care team into close proximity with patients at the most infectious period of their illness. Today’s risks are mitigated by better understanding of pathogenesis and transmission, by the availability of personal protective equipment, and by the exceptional knowledge and skills of critical care providers. But caring for outbreak victims will never be completely free of risk. Our duty is to use all our knowledge and skills to protect ourselves, our patients, and the public, and to be ready for the next challenge. History has shown there will always be dedicated health care providers ready to take evidence-based practice and basic human compassion to the frontlines of these battles. The statements and opinions contained in this editorial are solely those of the coeditors.

REFERENCES

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Head-of-Bed Elevation’s Effect on Gastric Reflux, Aspiration, and Pressure Ulcers

A head-of-bed (HOB) elevation greater than 30° is recommended to prevent ventilator-associated pneumonia and reduce the risk of aspiration. Yet, risk for pressure ulcers is considered higher with HOB greater than 30°. Schallom and colleagues compared the effect of HOB elevations of 30° and 45° on aspiration and pressure ulcer development. They identified the following:

- Most patients tolerated higher elevations, but 3 patients requested HOB lowered from 45°.
- No pressure ulcers were identified during the study or 48 hours after.
- Overall 44% of oral and 62% of tracheal secretions were positive for pepsin.
- As sedation deepened, the percentage of pepsin-positive oral secretions increased.
- As the mean HOB angle decreased, the percentage of pepsin-positive oral secretions increased.

The authors suggest HOB elevation greater than 30° is acceptable to reduce risks in gastric-fed patients using mechanical ventilation. However, these results are based on a sample of 11 patients over a 36-hour period and further testing with pepsin measured (vs presence) is recommended.

—Elisabeth George, RN, PhD

Acute Respiratory Distress Syndrome and Fever

Clinicians may think of fever as “bad” and would consider interventions to reduce a patient’s elevated temperature. Schell-Chaple and colleagues conducted a secondary analysis of temperature using patients from the ARDS Network and found the following:

- Body temperature alterations were present at baseline in 28% of the study sample.
- Body temperature at baseline and on the second day of the study predicted 90-day mortality.
- Surprisingly, those with the highest baseline temperatures showed a decrease in 90-day mortality.
- The favorable outcome with fever may be due to the body’s ability to mount an appropriate acute phase response, although it is unclear whether permissive fever or aggressive fever suppression influences mortality.

Thus, fever may serve a purpose in some patient populations. Fever suppression in patients with acute respiratory distress syndrome and other populations deserves further examination to determine if it is helpful, harmful, or nontherapeutic.

—Rochelle Armola, RN, MSN, CCRN

Manual vs Automated Lateral Rotation in Patients on Mechanical Ventilation

Previous studies that compared manual with automated turning lacked rigorous control over the manual turning process, and suggested that automated turning may be more efficacious than manual turning. Hanne-man and colleagues conducted a pilot study to test the efficacy and safety of 2-hour manual turning compared with continuous, automated bed turning for intensive care patients on mechanical ventilation. The authors compared preventable pulmonary complications (PPCs), turning-related adverse events, mechanical ventilation duration, intensive care unit length of stay, and mortality between the 2 groups. They found the following:

- Most patients were not eligible for the study due to factors such as pulmonary comorbidity, medical instability, excessive weight, or previous intubation.
- No difference between groups for any outcome above was found.
- Automated turning showed modest efficacy over manual turning for reduction, but not prevention, of PPCs.

Serious turning-related adverse events occurred with both groups, reiterating the need for safety practices and close patient monitoring.

—Alethea Sment, RN, BSN, CCRN-CSC

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**Nasal Colonization and Lower Respiratory Tract Infections with Methicillin-Resistant Staphylococcus Aureus**

By Belen Tilahun, PharmD, Andrew C. Faust, PharmD, BCPS, Phyllis McCorstin, APRN, CNS, and Anthony Ortegon, MD

**Background** Methicillin-resistant *Staphylococcus aureus* is a cause of lower respiratory tract infections, particularly health care– and ventilator-associated pneumonia. Although many health systems use nasal screening for this microorganism for infection control, correlation between nasal carriage of the organism and development of infections due to it is not clear.

**Methods** Records of patients admitted to medical intensive care between January 1, 2011, and December 31, 2012, were reviewed retrospectively. Patients’ data were included if the patients were 18 years or older, satisfied clinical criteria for pneumonia, and had both nasal swabbing and culturing of respiratory specimens within 24 hours of admission.

**Results** A total of 165 patients met the inclusion criteria. Most had either community-acquired or health care–associated pneumonia. Of the 28 patients with a nasal swab positive for methicillin-resistant *S. aureus*, 8 (4.8%) also had respiratory tract cultures positive for the microorganism. Among the 165 patients, 2 (1.2%) had negative nasal swabs but positive respiratory cultures. Sensitivity and specificity of nasal colonization with methicillin-resistant *S. aureus* for subsequent infection with the pathogen were 80% and 87.1%, respectively; positive and negative predictive values were 28.6% and 98.5%, respectively.

**Conclusions** Nasal screening for methicillin-resistant *S. aureus* may be a valuable tool for de-escalation of empiric therapy targeted to the organism, especially in patients admitted for severe community-acquired or health care–associated pneumonia. The high negative predictive value suggests that patients with a negative nasal swab most likely do not have a lower respiratory tract infection caused by the organism. *(American Journal of Critical Care. 2015;24:8-12)*

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doi: http://dx.doi.org/10.4037/ajcc2015102
MRSA nasal colonization is a risk factor for bacteremia, pneumonia, and skin infection.

Methods

This investigation was a retrospective cohort study of patients at Texas Health Presbyterian Hospital of Dallas, an 898-bed community teaching hospital with a 24-bed medical ICU in Dallas, Texas.

Sample

All patients admitted to the unit between January 1, 2011, and December 31, 2012, were identified from the unit’s patient log, and their data were screened for inclusion criteria by using electronic medical records. Patients’ data were included in the study if the patients were at least 18 years old, met clinical criteria for pneumonia, and had both nasal swabbing for MRSA and culturing of specimens from the lower respiratory tract for MRSA within 24 hours of admission to the ICU. Clinical criteria for pneumonia were defined as new or progressive radiographic changes; at least 1 set of laboratory findings that included fever, leukopenia, or leukocytosis; and at least 2 signs and symptoms that included new onset of purulent sputum, worsening of respiratory status, or worsening gas exchange. Patients were excluded from the study if they had previously received treatment for a MRSA infection 24 hours to 30 days before ICU admission or if they had a primary infection other than an LRTI.

Outcomes and Data Collected

The primary outcome of the study was the correlation between MRSA nasal swab results and MRSA LRTI. Baseline data collected included age, race, sex, type of respiratory tract culture, underlying lung disease, and risk factors for health care–associated pneumonia (HCAP).
Results

A total of 1753 patients had nasal swab screening for MRSA during the study period. Of these patients, 1588 were excluded from the study either because a respiratory tract culture was not obtained within 24 hours of admission or the clinical criteria for pneumonia were not satisfied. The mean age of the 165 patients included in the study was 63 years; 59% of the sample were men. Only 32.7% had an underlying comorbid condition of chronic obstructive pulmonary disease, congestive heart failure, or asthma (Table 1). The most common type of specimen obtained from the respiratory tract for culturing was a tracheal aspirate or suctioned sputum (65.4%). Of the 165 patients, 74 (44.8%) had a risk factor for HCAP. The risk for HCAP did not differ significantly between patients who had nasal swabs positive for MSRA and those who had nasal swabs negative for the pathogen, although numerically more patients with positive nasal swabs had risk factors for HCAP (Table 2).

A total of 28 patients (17%) had a nasal swab positive for MRSA. Among the entire sample, both the nasal swab and lower respiratory tract culture were positive for MSRA in 8 patients (4.8%). Only 2 patients (1.2%) had a negative nasal swab but a positive respiratory culture (Table 3). Only 1 of these 2 patients had a risk factor for HCAP. The sensitivity, specificity, and positive and negative predictive values of a nasal swab result for subsequent LRTI with MRSA are listed in Table 4.

Discussion

We evaluated the correlation between MRSA nasal colonization and MRSA LRTI, primarily community-acquired pneumonia and HCAP, in patients admitted to the medical ICU. Currently, many institutions use MRSA nasal screening as a tool as part of a broader infection prevention policy.14 Patients with MRSA nasal colonization are treated by using barrier isolation to help mitigate the transmission of disease, although the efficacy of this practice has been questioned.15 However, our results indicate the value of a nasal screen negative for MRSA from the perspective of antimicrobial stewardship. Because it is relatively noninvasive and has a greater than 95% negative predictive value for LRTI caused by MSRA, nasal screening should be considered a tool to help narrow empiric antibiotic therapy away from MRSA-specific medications for LRTIs.

Results similar to ours were recently obtained in a prospective observational study16 of 388 medical and surgical ICU patients with ventilator-associated pneumonia (VAP). In that study, 37 patients had

Table 1
Characteristics of study patients (n = 165)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%) of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical history</td>
<td></td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>35 (21.2)</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>21 (12.7)</td>
</tr>
<tr>
<td>Asthma</td>
<td>11 (6.7)</td>
</tr>
<tr>
<td>None</td>
<td>111 (67.3)</td>
</tr>
<tr>
<td>Type of specimen for respiratory culture</td>
<td></td>
</tr>
<tr>
<td>Tracheal aspirate or sputum obtained by suctioning</td>
<td>108 (65.4)</td>
</tr>
<tr>
<td>Expectorated sputum</td>
<td>22 (13.3)</td>
</tr>
<tr>
<td>Induced sputum</td>
<td>27 (16.4)</td>
</tr>
<tr>
<td>Bronchoalveolar lavage fluid</td>
<td>8 (4.8)</td>
</tr>
<tr>
<td>Risk factorsa for health care–associated pneumonia</td>
<td>74 (44.8)</td>
</tr>
</tbody>
</table>

a Hospitalized ≥2 days within 90 days, nursing home or long-term care facility, home infusion, dialysis within 30 days, home wound care, immunosuppressive disease or therapy.

Table 2
Presence of risk factorsa for health care–associated pneumonia among patients with nasal swabs positive and negative for methicillin-resistant Staphylococcus aureus (MRSA)

<table>
<thead>
<tr>
<th>Nasal swab</th>
<th>Risk factors present, No. (%) of patients</th>
<th>Risk factors absent, No. (%) of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRSA positive (n = 28)</td>
<td>15 (53.6)</td>
<td>13 (46.4)</td>
</tr>
<tr>
<td>MRSA negative (n = 137)</td>
<td>59 (43.1)</td>
<td>78 (56.9)</td>
</tr>
</tbody>
</table>

a Hospitalized ≥2 days within 90 days, nursing home or long-term care facility, home infusion, dialysis within 30 days, home wound care, immunosuppressive disease or therapy.

Table 3
Results of nasal cultures for methicillin-resistant Staphylococcus aureus (MRSA) compared with results of respiratory cultures

<table>
<thead>
<tr>
<th>Nasal cultures</th>
<th>Respiratory cultures</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MRSA positive</td>
<td>MRSA negative</td>
</tr>
<tr>
<td>MRSA positive</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>MRSA negative</td>
<td>2</td>
<td>135</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>155</td>
</tr>
</tbody>
</table>

Table 4
Sensitivity, specificity, positive predictive value, and negative predictive value of nasal colonization with methicillin-resistant Staphylococcus aureus for subsequent lower respiratory tract infection due to the pathogen

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percentage</th>
<th>95 % CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>80.0</td>
<td>44.2-96.5</td>
</tr>
<tr>
<td>Specificity</td>
<td>87.1</td>
<td>80.5-91.8</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>28.6</td>
<td>14.0-48.9</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>98.5</td>
<td>94.3-99.7</td>
</tr>
</tbody>
</table>
VAP caused by MRSA, and 54 patients had MRSA colonization before VAP developed. The high specificity (92%) and negative predictive value (96.7%) in the study by Chan et al\textsuperscript{14} suggest that a negative surveillance culture can accurately exclude MRSA as the causative organism of VAP, thereby affording more judicious use of MRSA-specific therapy.

Several researchers\textsuperscript{9,17,18} examined MRSA colonization as a predictor of subsequent MRSA infections. In a nest-case control study, Ramarathnam et al\textsuperscript{17} identified 426 patients colonized with MRSA during a 19-month period. A subsequent MRSA infection developed within 3 months of admission in 36 of these patients (8.5%); most of the patients (3.8% of the total cohort) had pneumonia. In our study, in which all patients met criteria for pneumonia, MRSA pneumonia developed in 28.6% of the patients who had nasal MRSA colonization. In a retrospective study of 355 patients admitted to the trauma ICU, Croft et al\textsuperscript{18} compared the rate of occurrence of MRSA infection between patients who had nasal swabs positive for MRSA and those who had swabs negative for the pathogen. Sites of MRSA infections included the lungs (pneumonia), urinary tract, bloodstream, skin and soft tissue, intra-abdominal locations, and multiple sites. MRSA infections developed in 21 of the 319 patients (6.6%) in the non-colonized group and in 12 of the 36 patients (33.3%) in the colonized group (\textit{P}<.001). In this study,\textsuperscript{18} compared with patients who were not colonized with MRSA at admission, patients who were colonized had a significantly higher rate of MRSA infections regardless of the site of infection.

Sarikonda et al\textsuperscript{9} evaluated the accuracy of nasal MRSA screening as a predictor of ICU-acquired infections, including LRTI and BSI. Of 749 patients, 164 had tests positive for MRSA colonization at the time of ICU admission, and MRSA colonization developed in 19 patients during the ICU stay. A total of 100 patients (56.2%) had MRSA LRTI and 58 (32.6%) had MRSA BSI. A total of 20 patients (11.2%) had both MRSA LRTI and MSRA BSI. Among the 120 patients with MRSA LRTI, 76 had VAP (55.8%). In this prospective cohort analysis of patients,\textsuperscript{9} the occurrence of LRTI and BSI caused by MRSA was similar for patients with (27.4%) or without (22.7%) MRSA nasal colonization (\textit{P} = .21). Sarikonda et al\textsuperscript{9} concluded that nasal colonization with MRSA is a poor predictor of MRSA LRTI and BSI requiring antimicrobial treatment.

Dangerfield et al\textsuperscript{19} conducted a study similar to ours, although they used polymerase chain reaction to identify MRSA carriage. Those authors reported similar results to our study and also concluded that the high negative predictive value (99.2%) can be used to guide antibiotic deescalation.

Our study is one of the few studies in which MRSA nasal colonization was correlated with MRSA LRTI. The strength of our study is the strict selection of patients according to the clinical criteria for pneumonia, a requirement that led to the exclusion of a majority of patients. However, the study was retrospective and done at a single center, characteristics that can limit uniform application of the results. Additionally, the use of chromogenic culture instead of a polymerase chain reaction to detect MRSA in our institution may have limited the sensitivity in detecting MRSA colonization, as polymerase chain reaction is more sensitive than chromogenic cultures for detecting MRSA colonization.\textsuperscript{19}

**Conclusion**

MRSA nasal screening is currently used in many centers as part of infection control. Our results indicate that routine MRSA nasal screening may have value for management of antibiotic therapy for LRTIs. The high negative predictive value (98.5%) of MRSA-negative nasal screening for subsequent development of MRSA LRTI suggests that patients with a negative nasal swab most likely will not have an LRTI caused by MRSA. Because of the poor positive predictive value of nasal swabbing, patients with MRSA nasal colonization should not necessarily be started on MRSA-targeted therapy merely because the nasal swab is positive for MSRA. Therefore, the value of MRSA nasal swabs lies in the ability to potentially discontinue empiric MRSA-targeted therapy when nasal swabs are negative for MRSA.


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Although health care systems routinely use MRSA nasal screening for infection control, there is limited evidence that MRSA nasal screening is associated with the occurrence of a MRSA-related lower respiratory tract infection. To address a gap in the literature, this study reports on the association between MRSA nasal colonization and lower respiratory tract infections among critically ill patients admitted to a medical intensive care unit (MICU).

The study's authors conducted a retrospective review of the electronic medical records to identify eligible patients. A total of 165 critically ill patients who had MRSA nasal and lower respiratory cultures with 24 hours of admission to the MICU were included. Patients were excluded from this study if they had received treatment for a MRSA infection within 24 hours to 30 days prior to admission or had a primary infection that did not affect the lower respiratory tract.

This study confirmed a high negative predictive value (98.5%) of MRSA nasal screening associated with patients without a MRSA infection of the lower respiratory tract. From a clinical perspective, this result highlights that the value of MRSA nasal screening lies in its ability to correctly identify patients who do not have a lower respiratory tract infection caused by MRSA. This evidence is clinically useful for critical care clinicians because it can be used to inform decisions about antibiotic therapy for critically ill patients with a lower respiratory tract infection but test negative for MRSA nasal colonization.

Staphylococcus aureus is a common pathogen recovered from critically ill patients with lower respiratory tract infections. More than half of S. aureus isolates nationwide are methicillin-resistant (MRSA). Although health care systems routinely use MRSA nasal screening for infection control, there is limited evidence that MRSA nasal screening is associated with the occurrence of a MRSA-related lower respiratory tract infection. To address a gap in the literature, this study reports on the association between MRSA nasal colonization and lower respiratory tract infections among critically ill patients admitted to a medical intensive care unit (MICU).

The study's authors conducted a retrospective review of the electronic medical records to identify eligible patients. A total of 165 critically ill patients who had MRSA nasal and lower respiratory cultures with 24 hours of admission to the MICU were included. Patients were excluded from this study if they had received treatment for a MRSA infection within 24 hours to 30 days prior to admission or had a primary infection that did not affect the lower respiratory tract.

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EVIDENCE-BASED REVIEW AND DISCUSSION POINTS

Evidence-Based Review (EBR) is the journal club feature in the American Journal of Critical Care. In a journal club, attendees review and critique published research articles: an important first step toward integrating evidence-based practice into patient care. General and specific questions such as those outlined in the “Discussion Points” box aid journal club participants in probing the quality of the research study, the appropriateness of the study design and methods, the validity of the conclusions, and the implications of the article for clinical practice. When critically appraising this issue’s EBR article, found on pp 8-12, consider the questions and discussion points outlined in the “Discussion Points” box. Visit www.ajcconline.org to discuss the article online.

INVESTIGATOR SPOTLIGHT

Andrew Faust, PharmD, BCPS, is a critical care pharmacist at Texas Health Presbyterian Hospital in Dallas, Texas. He and his coauthors take a multidisciplinary approach to quality and research projects related to pharmacologic strategies to optimize the care of the critically ill patient.

According to Faust, collaborations with coauthors, Belen Tilahun, PharmD, and Phyllis McCorstin, APRN, CNS, were essential to the conceptualization and conduct of this study. “Each year, the pharmacy preceptors of our residency program generate ideas for medication-related projects and Dr. Tilahun elected to work with me on this project,” he says. Coauthor, Phyllis McCorstin, and I had collaborated on prior studies and I knew she would play vital role on this project commented Faust. “Thankfully, we had the luxury of residents and other trainees to assist with reviewing more than 1700 charts, which is a significant time commitment,” he says.

The first step for any investigator is to start with an answerable question, says Faust. This study grew out of the researchers’ desire to address the question, “If patients do not have respiratory cultures, could MSRA nasal screening serve as a valid surrogate indicator for the cause of a lower respiratory tract infection?”

Based on their results, Faust and coauthors concluded that MRSA nasal screening should be considered as a tool to help focus empiric antibiotic coverage. Faust says that at his institution, “We have seen a reduction in duration of vancomycin therapy, which then reduces costs associated with the time spent adjusting doses and assessing serum levels of vancomycin.”

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The next step I envision for research in this area is to evaluate the impact of MRSA nasal screening on patient-centered outcomes,” he says.

Discussion Points

A. Description of the Study
- What populations of hospitalized patients are vulnerable to methicillin-resistant *Staphylococcus aureus* (MRSA) infections of the lower respiratory tract?
- Why should critical care clinicians be concerned about MRSA in critically ill patients?

B. Literature Evaluation
- What has been cited in the literature about the relationship between MRSA nasal colonization and the occurrence of a MRSA associated lower respiratory tract infection?
- What is the current state of the science on MRSA nasal screening as a tool for targeted antibiotic therapy?

C. Sample
- What patients were eligible to participate in this study?
- How did the investigators determine if a patient met criteria for a lower respiratory tract infection (eg, pneumonia)?

D. Methods and Design
- How did the investigators screen and collect data on eligible patients?
- What is the definition of positive and negative predictive value?

E. Results
- How many of the eligible patients had a risk for a lower respiratory tract infection?
- What were the main findings of this study?

F. Clinical Significance
- What are the implications of this study for clinical practice?
- Why do the investigators recommend cautious interpretation and application of a negative MRSA nasal culture result to a patient’s clinical management?

About the Author
Ronald L. Hickman is an assistant professor, Case Western Reserve University, and an acute care nurse practitioner at University Hospitals Case Medical Center, Cleveland, Ohio.
BODY TEMPERATURE AND MORTALITY IN PATIENTS WITH ACUTE RESPIRATORY DISTRESS SYNDROME

By Hildy M. Schell-Chaple, RN, MS, Kathleen A. Puntillo, RN, PhD, Michael A. Matthay, MD, Kathleen D. Liu, MD, PhD, and the National Heart, Lung, and Blood Institute Acute Respiratory Distress Syndrome Network

Background Little is known about the relationship between body temperature and outcomes in patients with acute respiratory distress syndrome (ARDS). A better understanding of this relationship may provide evidence for fever suppression or warming interventions, which are commonly applied in practice.

Objective To examine the relationship between body temperature and mortality in patients with ARDS.

Methods Secondary analysis of body temperature and mortality using data from the ARDS Network Fluid and Catheter Treatment Trial (n = 969). Body temperature at baseline and on study day 2, primary cause of ARDS, severity of illness, and 90-day mortality were analyzed by using multiple logistic regression.

Results Mean baseline temperature was 37.5°C (SD, 1.1°C; range, 27.2°C-40.7°C). At baseline, fever (≥38.3°C) was present in 23% and hypothermia (<36°C) in 5% of the patients. Body temperature was a significant predictor of 90-day mortality after primary cause of ARDS and score on the Acute Physiology and Chronic Health Evaluation III were adjusted for. Higher temperature was associated with decreased mortality: for every 1°C increase in baseline temperature, the odds of death decreased by 15% (odds ratio, 0.85; 95% CI, 0.73-0.98, P = .03).

When patients were divided into 5 temperature groups, mortality was lower with higher temperature (P for trend = .02).

Conclusions Early in ARDS, fever is associated with improved survival rates. Fever in the acute phase response to lung injury and its relationship to recovery may be an important factor in determining patients’ outcome and warrants further study. (American Journal of Critical Care. 2015;24:15-23)
The relationship between body temperature alterations (both hypothermia and fever) in critically ill patients and outcomes is not well understood, despite the fact that clinicians often intervene to achieve normothermia in these patients.1-6 Fever is common in critically ill patients and occurs as an adaptive response to inflammation that results from injury or infection.7,9 Fever is defined as a regulated increase in body temperature above the normal thermal set point in response to injury and inflammation.10 Studies that have examined the relationship between fever and mortality in critically ill patients have yielded disparate results.1,7,9,11-13 High fever, typically defined as 39.5°C or greater, has been associated with increased mortality in critically ill patients.7,9,12

A large multinational observational study evaluating the relationship between temperature and mortality in critically ill patients with and without infection showed a reduced risk of in-hospital mortality with fever relative to normothermia in critically ill patients with infection.11 The noninfection group from this study also had reduced risk of mortality with elevated temperatures up to 39°C, after which mortality increased. Hypothermia was associated with increased mortality in both infection and noninfection groups. In another recent multisite observational study,9 the presence of fever on admission to the intensive care unit (ICU) had no significant association with ICU case-fatality among patients in medical and surgical ICUs.

In a large, randomized, double-blind, placebo-controlled trial evaluating the effects of ibuprofen on outcomes in critically ill patients with sepsis, body temperature was significantly reduced in the febrile group that received ibuprofen.14 However, despite the significant reductions in fever, heart rate, lactate levels, and oxygen consumption values in the treatment group, no differences in oxygen delivery, organ failure-free days, or mortality were found. In a recent observational trial,1 researchers investigated the association of fever and antipyretic interventions with mortality in critically ill patients with and without sepsis. In the cohort with sepsis, fever was an independent predictor of decreased mortality and use of acetaminophen and ibuprofen was an independent predictor of increased mortality. In the cohort without sepsis, only high fever (≥39.5°C) was independently associated with increased mortality, and no associations were found with use of antipyretic medication and mortality. Thus, robust evidence to guide management of fever in critically ill patients is lacking. Nonetheless, the use of antipyretic medications and physical cooling interventions to treat fever is widespread in clinical practice.14

Acute respiratory distress syndrome (ARDS) is one of several forms of critical illness characterized by the presence of the acute phase response, a series of complex neuroimmunologic reactions that include stimulation of fever and the release of cytokines and other immunologically activated proteins in response to injury or infection in an attempt to reestablish homeostasis.15,16 The acute phase response stimulates leukocytosis, complement activation, coagulation activation, opsonization, cytotoxicity, vascular permeability, and chemotaxis of monocytes, neutrophils, and T cells.17 Fever is a hallmark sign of the acute phase response to infectious and noninfectious sources of tissue injury, so one would expect fever to be common in patients with ARDS. However, little is known about the incidence of fever in patients with ARDS and whether body temperature has an association with the trajectory of illness and recovery.

Thus, a better understanding of the impact of body temperature on outcomes for ARDS patients can inform future research. Specifically, because the relationship between body temperature and patients’ outcomes is unknown, it is unclear whether temperature-altering interventions are beneficial, detrimental, or neutral in patients with ARDS. The purpose of this study was to examine the relationship between body temperature in early ARDS and mortality.

About the Authors
Hildy M. Schell-Chaple is a clinical nurse specialist and PhD candidate at the University of California, San Francisco (UCSF) School of Nursing. Kathleen A. Puntillo is a professor emerita at the UCSF School of Nursing. Michael A. Matthay is a professor of medicine and anesthesia and Kathleen D. Liu is an associate professor at the UCSF School of Medicine.

Corresponding author: Hildy M. Schell-Chaple, RN, MS, 505 Parnassus Avenue, Box 0210, San Francisco, CA 94143 (e-mail: hildy.schell@ucsfmedctr.org).

High fever has been associated with increased mortality in critically ill patients.
Methods

We conducted a secondary analysis of body temperature by using data from the National Heart, Lung and Blood Institute (NHLBI) ARDS Network Fluid and Catheter Treatment Trial.18,19 This multicenter factorial study randomized patients with acute lung injury for 48 hours or less to receive either liberal or conservative fluid management strategies per protocol.15-21 The institutional review boards of participating centers and the NHLBI approved the original study. Written consent was obtained from the patient participants or their legal surrogates in the original study. Certification from the institutional review board at the investigators’ center was obtained for this secondary analysis.

Adult patients who met the American-European Consensus criteria for acute lung injury for 48 hours or less were eligible for study enrollment. With the exception of 0.2% of this study’s sample, patients met the recently published criteria for the Berlin definition of ARDS.16 Exclusion criteria included presence of ARDS for more than 48 hours, presence of a pulmonary artery catheter before study enrollment, presence of chronic conditions that could influence compliance with the study protocol or ventilator weaning, and terminal conditions with estimated 6-month mortality of greater than 50%. Because of missing data on body temperature and score on the Acute Physiology and Chronic Health Evaluation (APACHE) III, 31 patients were excluded from the original sample of 1000 patients.

Measurement of Variables

The sources of baseline measurements of body temperature in the original study included rectal, tympanic, and axillary sites. Baseline temperature was obtained from the 4-hour period preceding randomization, which occurred immediately after consent was obtained. Body temperature was measured at the same time each day from rectal, tympanic, axillary, or pulmonary artery catheter sites and recorded for up to 7 days. Temperature ranges used to create 5 groups were selected on the basis of definitions of moderate to deep hypothermia (<34°C), mild hypothermia (34°C-35.9°C), normothermia (36°C-38.2°C), fever (38.3°C-39.4°C), and high fever (≥39.5°C).9,20-22

Patients were followed up for 90 days after study enrollment or until death, whichever occurred first. The APACHE III score was calculated from patients’ baseline data.23 One of the following causes of primary lung injury was selected for each patient: trauma, sepsis, multiple transfusions, pneumonia, aspiration, or other causes.

Statistical Analysis

An independent-samples t test was conducted to compare baseline temperatures for survivors and nonsurvivors. In order to control for potential confounding variables, multiple logistic regression was performed to assess the impact of 3 factors on the likelihood of mortality at 90 days in patients with ARDS. The 3 factors in the model were baseline temperature, primary cause of ARDS, and severity of illness, measured by the APACHE III score. These variables were included because of their potential physiological and clinical significance as well as their significant association with mortality in univariate analyses. In addition, as a sensitivity analysis to explore whether hypothermia influenced the results of the study, the multiple logistic regression was repeated with exclusion of patients with body temperatures less than 36°C. Multiple logistic regression was also repeated using temperature from day 2 of the study in place of baseline temperature to determine whether the relationship was sustained at another time point early in the ARDS trajectory.

To better understand the relationship between body temperature and mortality, we used 5 categories of baseline temperature (moderate to deep hypothermia, mild hypothermia, normothermia, fever, and high fever) and used logistic regression to test for a trend in the mortality among the temperature groups. Baseline characteristics were compared among the 5 temperature groups by using 1-way analysis of variance for continuous variables and χ² analysis for categorical variables.

Because temperature is part of the APACHE III score calculation, correlation analyses and collinearity diagnostics of the independent variables were completed, and low correlations ruled out concern about multicollinearity issues. The Hosmer-Lemeshow test was used to assess the goodness of fit of the model.24 Odds ratios and 95% confidence intervals were calculated. Statistical tests were 2-sided and differences were considered significant at P less than .05. Data were analyzed with SPSS computer software, version 21 (SPSS, Inc).

Results

Characteristics of the 969 participants with baseline temperature data available are presented by temperature group in Table 1. Mean body temperature at baseline was 37.5°C (SD, 1.1°C; range, 27.2°C-40.7°C). Mean body temperature on day 2 was
At baseline, fever was present in 227 patients (23%) and hypothermia in 48 patients (5%). The overall 90-day mortality rate of the sample was 267/969 (28%). Baseline temperatures were compared between survivors (n = 702) and nonsurvivors (n = 267). Mean body temperature showed a modest but statistically significant difference between survivors and nonsurvivors (37.6°C [SD, 1°C] vs 37.3°C [SD, 1.2°C], P < .001).

As shown in Table 2, multiple logistic regression showed that baseline temperature and APACHE III score made significant contributions to the model. Baseline temperature was a significant predictor of mortality when the cause of ARDS and APACHE III score were controlled for. Remarkably, for every 1°C increase in temperature, the odds of death at 90 days decreased by 15% (odds ratio, 0.85 per 1°C increase in temperature; 95% CI, 0.73-0.98, P = .03).

To test whether the hypothermic patients significantly influenced our finding, we performed a sensitivity analysis with those patients excluded from the logistic regression. When patients with hypothermia (< 36°C, n = 48) were excluded from the analysis, baseline temperature remained a significant predictor of mortality after the cause of ARDS and the APACHE III score were controlled for, with higher baseline temperature being associated with decreased mortality (odds ratio, 0.82 per 1°C increase in temperature; 95% CI, 0.69-0.98, P = .03).

Similarly, our findings were unchanged when the data were analyzed without the participant who had an extremely low body temperature (27.2°C).

To test whether the relationship between body temperature and mortality was significant at another early time point in the ARDS trajectory, we repeated the multiple logistic regression analysis using temperature from the second study day (Table 3). Body temperature on study day 2 was also a significant predictor of mortality, when APACHE III score and the cause of ARDS were controlled for (odds ratio, 0.82 per 1°C increase in temperature; 95% CI, 0.69-0.98; P = .03).

### Table 1
Baseline patient characteristics by body temperature group

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Moderate-deep hypothermia (n = 3)</th>
<th>Mild hypothermia (n = 45)</th>
<th>Normothermia (n = 694)</th>
<th>Fever (n = 200)</th>
<th>High fever (n = 27)</th>
<th>P&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>59 (19)</td>
<td>48 (15)</td>
<td>50 (16)</td>
<td>47 (15)</td>
<td>47 (15)</td>
<td>.06</td>
</tr>
<tr>
<td>Male sex</td>
<td>67</td>
<td>49</td>
<td>52</td>
<td>60</td>
<td>63</td>
<td>.26</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>33</td>
<td>60</td>
<td>64</td>
<td>62</td>
<td>70</td>
<td>.22</td>
</tr>
<tr>
<td>Black</td>
<td>0</td>
<td>29</td>
<td>22</td>
<td>20</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>67</td>
<td>11</td>
<td>14</td>
<td>18</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Cause of ARDS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.48</td>
</tr>
<tr>
<td>Trauma</td>
<td>0</td>
<td>2</td>
<td>7</td>
<td>10</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Sepsis</td>
<td>33</td>
<td>29</td>
<td>23</td>
<td>21</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Multiple transfusion</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Pneumonia</td>
<td>33</td>
<td>51</td>
<td>47</td>
<td>48</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>Aspiration</td>
<td>33</td>
<td>11</td>
<td>17</td>
<td>10</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>7</td>
<td>5</td>
<td>9</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>APACHE III score, mean (SD)</td>
<td>123 (28)</td>
<td>103 (30)</td>
<td>94 (31)</td>
<td>91 (28)</td>
<td>96 (27)</td>
<td>.09</td>
</tr>
</tbody>
</table>

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; ARDS, acute respiratory distress syndrome.
<sup>a</sup>Moderate-deep hypothermia, body temperature < 34°C; mild hypothermia, body temperature 34°C-35.9°C; normothermia, body temperature 36°C-38.2°C; fever, body temperature 38.3°C-39.4°C; high fever, body temperature ≥ 39.5°C.
<sup>b</sup>Values are percentage of patients unless indicated otherwise.
<sup>c</sup>P < .05 for statistical significance.

### Table 2
Baseline body temperature, cause of acute respiratory distress syndrome, and APACHE III score as predictors of 90-day mortality

<table>
<thead>
<tr>
<th>Predictor variable</th>
<th>Odds ratio (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline body temperature&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.85 (0.73-0.98)</td>
<td>.03</td>
</tr>
<tr>
<td>APACHE III score&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.03 (1.02-1.03)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Primary cause of lung injury&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trauma vs aspiration</td>
<td>0.51 (0.20-1.26)</td>
<td>.14</td>
</tr>
<tr>
<td>Sepsis vs aspiration</td>
<td>1.27 (0.76-2.13)</td>
<td>.37</td>
</tr>
<tr>
<td>Multiple transfusion vs aspiration</td>
<td>1.89 (0.44-8.07)</td>
<td>.39</td>
</tr>
<tr>
<td>Pneumonia vs aspiration</td>
<td>1.16 (0.72-1.86)</td>
<td>.55</td>
</tr>
<tr>
<td>Other causes vs aspiration</td>
<td>0.84 (0.38-1.83)</td>
<td>.65</td>
</tr>
</tbody>
</table>

Abbreviation: APACHE, Acute Physiology and Chronic Health Evaluation.
<sup>a</sup>Hosmer-Lemeshow goodness of fit P = .55.
<sup>b</sup>Per 1°C increase in body temperature.
<sup>c</sup>Reference category for analysis was the aspiration group.

37.4°C (SD, 0.9°C; range, 34.5°C-40.6°C). At baseline, fever was present in 227 patients (23%) and hypothermia in 48 patients (5%). The overall 90-day mortality rate of the sample was 267/969 (28%). Baseline temperatures were compared between survivors (n = 702) and nonsurvivors (n = 267). Mean body temperature showed a modest but statistically significant difference between survivors and nonsurvivors (37.6°C [SD, 1°C] vs 37.3°C [SD, 1.2°C], P < .001).

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As shown in the Figure, a significant trend toward lower mortality in the fever and high fever groups was apparent (23% and 19%, respectively) compared with in the normothermia (29%) and mild hypothermia group (36%) and the moderate to deep hypothermia group (67%; P for trend = .02).

Although patients in the moderate to deep hypothermia group were older and had higher APACHE III scores, no statistically significant differences in baseline characteristics were found among the 5 temperature groups as shown in Table 1.

**Discussion**

The presentation of body temperature alterations, both fever and hypothermia, and the impact on physiologic and recovery outcomes in patients with ARDS are not well understood. This study adds to the literature on temperature abnormalities in critically ill patients with ARDS and is 1 of 2 new studies to investigate the association between temperature and mortality in this subgroup of critically ill patients. Netzer et al recently published findings from their secondary analysis of 450 patients from the Improving Care of Acute Lung Injury Patients study cohort. The frequency of temperature alterations in their study was higher than in ours. They found at least 1 febrile day (≥38.0°C) in the first 3 days of ARDS onset in 65% of their sample, and 46% of their sample had at least 1 hypothermic day (< 36°C). Febrile days in early ARDS in their study were not associated with increased in-hospital mortality in their multivariable model, yet 2 or more days of hypothermia were found to be associated with increased risk of in-hospital mortality. The incidence of body temperature alterations in our sample is more similar to the incidence reported in an observational study of 493 medical and surgical critical care patients, of whom 28% had fever and 9% had hypothermia as defined using the same temperature thresholds used in our study. However, similar to our findings, in that study, hypothermia, rather than fever, was associated with an increased risk of death.

Laupland et al prospectively studied temperature on admission and outcomes in 10962 patients (75% medical and 25% surgical admission types) from French ICUs in 10 years. Body temperatures at admission were hypothermia (16%), normothermia (55%), fever (26%), and mixed hypothermia and fever (3%). Although it is unclear whether ARDS was present, in the patients who required mechanical ventilation (n = 5019), 27% had fever and 23% had hypothermia at admission. After severity of illness and other confounders were controlled for, fever was not associated with increased ICU mortality.

Indeed, hypothermia was a significant independent predictor of ICU mortality in the medical subgroup. These findings are consistent with the increased odds of mortality as body temperature decreased that we are reporting here. Similar to our study, their study also lacked evaluation of temperature-altering interventions (antipyretics and warming), limiting interpretation of their potential confounding effects.

In a study by Bernard et al, administration of ibuprofen did not significantly alter the rates of organ failure and mortality in a large sample (n=455) of patients with sepsis, of whom 29% had ARDS. They evaluated whether this cyclooxygenase inhibitor
The importance of fever in the acute response to infection may be underestimated.

Affected fever and the increased metabolic demands of sepsis. That study included febrile and hypothermic patients and excluded patients with normothermia. A significant reduction in body temperature was achieved in the ibuprofen group compared with the placebo group. However, the use of acetaminophen and physical cooling methods for fever reduction was not controlled for, and patients in both placebo and treatment groups received acetaminophen before and during the study.

Using data presented in the original study by Bernard et al., we calculated mortality rates in the subgroup of febrile patients in the 2 arms of the study: mortality in the ibuprofen and placebo groups was the same at 35%. Although the study intervention was not targeted to fever suppression, these results suggest that at a minimum there is no mortality benefit to fever suppression. Furthermore, the 54% mortality rate of the ibuprofen-treated hypothermic subgroup was significantly lower than the 90% mortality in the placebo-treated hypothermic subgroup (P = .02), although both mortality rates were higher than the mortality rates in the febrile patients. The finding that mortality rates were lower in patients who had a fever rather than hypothermia at admission is consistent with our results, where mortality was lowest in the febrile group. In our study, this association remained significant, even after severity of illness and primary cause of ARDS were adjusted for.

In a large (n = 1425), multisite observational study, findings for fever and mortality and for antipyretic intervention use and mortality differed between the cohort with sepsis and the cohort without sepsis. Those researchers reported that fever is an independent predictor of decreased mortality in patients with sepsis but is not a predictor in patients without sepsis. This result suggests that future investigations evaluate the risk and use of antipyretic interventions with respect to the cause of the fever. Although ARDS was not a specified patient characteristic in that study, a large number of patients received mechanical ventilation (67%) and had respiratory/thoracic disease as the reason for admission (38%). In our study, 71% of the sample had sepsis (n = 228) or pneumonia (n = 458) as the primary cause of their ARDS. Therefore, the importance of fever in the acute phase response to infection, which is often associated with acute lung injury, and its relationship to recovery may be underestimated.

Researchers who have examined the relationship between fever and outcomes including mortality in critically ill patients have reported mixed results. However, experimental animal studies suggest that febrile-range hyperthermia in lung injury models worsens lung function and increases mortality, although the mechanisms are not well understood. Induced hypothermia has been used as a therapeutic strategy in critically ill patients after cardiac arrest and with acute liver failure to optimize outcomes. A recent randomized controlled trial compared the effects of fever suppression using external cooling versus no cooling for 48 hours on vasopressor dose reduction in febrile patients with septic shock. In that study, in which 70% had pneumonia as the primary source of infection, there was a significantly higher occurrence of a 50% reduction in vasopressor dose from baseline to 12 hours in the cooling group, but significance was not sustained to their primary end point of 48 hours. Although the study was not powered to detect significant differences in mortality, they reported a lower 14-day mortality rate in the cooling group but that rate was no longer significant at ICU or hospital discharge.

Earlier, in the first known study examining the relationship of mortality to body temperature in ARDS patients, Villar and Slutsky reported an association between induced hypothermia and survival. They conducted a case-controlled prospective trial to evaluate whether induced hypothermia affected clinical outcomes in 19 patients with moribund sepsis and ARDS. In contrast to our results, they found a significant increase in survival in the hypothermia intervention group as well as reductions in intrapulmonary shunt, heart rate, and oxygen tension–based indices. Interestingly, they found no difference in oxygen consumption between the groups, and whether induced hypothermia initiated a protective mechanism is unclear.

In spite of the positive results, their study had several limitations, including small sample size, the moribund condition of the sample, the potential for historical bias, and the lack of a standard evaluation of severity of illness. Furthermore, it is important to distinguish between induced hypothermia and spontaneous hypothermia as well as induced normothermia when reviewing publications on thermoregulation. Mechanisms of spontaneous hypothermia include impaired heat production, excessive heat loss, and/or impaired thermoregulation and may be the result of exposure or metabolic/endocrine, neurologic, or toxic disease states. It is unclear whether the occurrence of hypothermia in early ARDS is a sign of disease severity or of discordant thermoregulatory...
response to severe inflammation, and/or if the hypothermia adversely affects lung recovery and patients’ survival.

A prospective clinical trial comparing infection and mortality rates in 85 critically ill trauma patients randomized to permissive fever or aggressive fever suppression groups was stopped after an interim analysis because more deaths were occurring in the aggressive fever suppression group. Although the target sample size was not achieved, this raises the question of whether clinicians should routinely intervene to suppress fever in critically ill patients. Along the same lines, our study, which shows an association of lower mortality with higher baseline and day 2 body temperatures, supports the rationale for a randomized clinical trial that compares the effects of permissive fever versus the common practice of fever suppression on the recovery and outcomes of critically ill patients including patients with ARDS.

Our analyses had some limitations. The lack of standardized body temperature measurement methods could have resulted in patients being incorrectly categorized into the temperature groups used in our analysis of the 5 temperature groups. Although 51% of the sample had temperature measured by a pulmonary artery catheter for the study day 2 analysis, the rectal, tympanic, or axillary methods of measurement have varying levels of agreement with core temperature measured with a pulmonary artery catheter. Data on temperature-altering interventions such as antipyretic medications, external cooling, and warming measures were not collected. We also did not have information regarding unit-based protocols or unit routines for managing hypothermia and fever, which can vary. These factors limit the interpretation of whether the study results are related to spontaneous body temperatures or temperatures altered by fever suppression or warming interventions. Nonetheless, the results suggest that, despite frequent use of antipyretic interventions in critically ill patients, there may be equipoise in support of a randomized clinical trial of such interventions to determine if they have any benefit.

Although not specific to the ARDS population, studies of the impact of fever and fever-suppression interventions on outcomes in critically ill patients are underway. In effort to evaluate the safety and feasibility of studying aggressive versus permissive temperature control and its effects on mortality and inflammatory biomarkers in critically ill patients with no neurologic injuries, a pilot randomized clinical trial was recently conducted in Canada. Results of that pilot study indicated no difference in mortality or safety outcomes between the aggressive and permissive treatment groups, but they concluded the study with less than 50% of their targeted sample size because of enrollment challenges that informed their feasibility aim. The HEAT trial (permissive Hyperthermia Through avoidance of paracetamol in known or suspected infection in ICU trial), a multisite, randomized clinical trial to compare the effect of intravenous acetaminophen and placebo on survival, body temperature reduction, and organ injury in febrile critically ill patients with infection recently concluded enrollment of participants in Australia and New Zealand.

Finally, because fever is a biomarker of the acute phase response, it is difficult to determine whether the favorable outcome of patients with fever is due to their ability to mount an appropriate acute phase response or is related to the fever response itself. Furthermore, it is unclear whether there is an ideal target temperature range that is optimal for lung recovery or that is protective against further lung injury in patients with ARDS. Therefore, the design of future studies evaluating temperature and outcomes should include measurement of temperature-altering interventions and biologic markers of the acute phase response such as cytokines and acute phase proteins, to optimize interpretation and testing of our results.

This study had the largest cohort of patients with ARDS ever used to evaluate alterations in body temperature. Fever was present in 23% of the sample at baseline, and a smaller proportion of patients had hypothermia early in their ARDS trajectory. Although fever was associated with improved survival even after severity of illness and cause of ARDS were accounted for, we cannot conclude that permissive fever or aggressive fever suppression influences mortality because of the aforementioned limitations of our study. The routine practice of fever suppression in patients with ARDS requires further research to test whether fever suppression has a harmful, helpful, or neutral effect on patients’ outcomes. Well-designed randomized controlled trials are warranted to test the therapeutic value of treating or not treating fever in patients with ARDS.

ACKNOWLEDGMENTS
We thank Steve Paul, PhD, for his valuable assistance in the statistical analysis. Participants in the National Heart, Lung, and Blood Institute ARDS Network at the National Institutes of Health are listed here. Members of steering committee are indicated by an asterisk. Cleveland Clinic Foundation, Herbert P. Wiedemann, MD,* Alejandro C. Arroliga,

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Manual vs Automated Lateral Rotation to Reduce Preventable Pulmonary Complications in Ventilator Patients

By Sandra K. Hanneman, RN, PhD, Gary M. Gusick, RN, PhD, Shannan K. Hamlin, RN, PhD, ACNP-BC, CCRN, Sheryln J. Wachtel, RN, PhD, Stanley G. Cron, MSPH, Deborah J. Jones, RN, PhD, and Sandra A. Oldham, MD

Purpose
To estimate effect sizes for a trial to compare preventable pulmonary complications (PPCs), turning-related adverse events, mechanical ventilation duration, intensive care unit (ICU) length of stay, and ICU mortality between patients randomized to 2-hourly manual or continuous automated lateral rotation.

Methods
Randomized controlled trial pilot study with 15 patients selected randomly from eligible medical-surgical ICU patients from 2 tertiary hospitals and assigned randomly to the manual-turn or automated-turn protocol for up to 7 consecutive days. A radiologist blinded to group and site assessed serial chest radiographs for PPCs. Repeated-measures analysis with linear mixed models was used to estimate change in PPC score, and Wilcoxon rank sum or Fisher exact test was used to compare group differences in the secondary outcomes.

Results
Of 16 patients enrolled, 12 (75%) completed the study. Data from 15 patients, 7 manual turn and 8 automated turn, were analyzed. Between-group differences in PPC incidence (67% overall), change in PPC score ($\beta = 0.15$, manual turn and $\beta = -0.44$, automated turn), and secondary outcomes were not significant ($P > .05$). Standardized effect sizes were small to moderate for the outcome variables. A sample size of 54 patients would be needed to detect statistically significant between-group differences in PPC over time.

Conclusions
The incidence of PPCs in adult patients receiving mechanical ventilation in a medical-surgical ICU was high. Automated turning decreased PPCs with time but had little effect on secondary outcomes. Safety outcomes were not substantially different between groups. A modest efficacy effect supported reduced PPCs with automated turning to the lateral position. (American Journal of Critical Care. 2015;24:24-32)
Evidence suggests that ICU patients are not turned every 2 hours\textsuperscript{10-13} for a variety of reasons, including patients' medical instability and/or discomfort and other demands competing for nursing staff time. Specialty beds that provide continuous, automated lateral rotation theoretically avoid stimulation of the sympathetic nervous system by an abrupt change in position and relieve staff from regular turning. Consistent evidence, albeit of variable rigor, has demonstrated that automated turning reduces PPCs, but this mechanical therapy adds to ICU cost of care and thus is used selectively. Furthermore, up to 39\% of patients do not tolerate automated turning\textsuperscript{14-16} and require termination of the therapy or use of sedation to promote tolerance.

Automated turning has been tested in randomized controlled trials with medical-surgical ICU patients who are receiving mechanical ventilation,\textsuperscript{14,16-22} and researchers in all but 2 studies\textsuperscript{17,20} reported a significant reduction in PPCs. Researchers in 2 studies\textsuperscript{16,22} reported shorter ICU stays in patients receiving automated turning, and researchers in another study\textsuperscript{16} also reported decreased duration of mechanical ventilation. None of the trials demonstrated differences in mortality. Research design limitations, however, have prevented a legitimate comparison of automated and manual turning for efficacy and safety.\textsuperscript{23} A particular concern is the lack of control over manual turning, which has served as the control group intervention in studies of turning with a specialty bed; consequently, there is no evidence that automated turning is as effective or more effective than 2-hourly manual turning.

Neither the safety of manual turning nor the safety of automated turning has been studied systematically, and turning-related adverse events can influence adherence to turning protocols. We conducted a pilot study for a randomized controlled trial to test the efficacy and safety of 2-hourly manual and continuous, automated turning. The purpose of the pilot study was to estimate effect sizes to determine the sample size needed for the randomized controlled trial to compare PPCs, turning-related adverse events, duration of mechanical ventilation, length of stay in the ICU, and ICU mortality in medical-surgical ICU patients receiving mechanical ventilation who were randomized to manual or automated lateral rotation.

Materials and Methods

Study Design and Participants

This parallel-group, completely randomized, experimental pilot study (ClinicalTrials.gov NCT00542321) was conducted in 2 ICUs at 2 tertiary, nonprofit, teaching hospitals after approval by the institutional review boards of the university and hospitals. Study units were an 18-bed...
medial-surgical ICU and a 24-bed medical ICU. In most cases, the patient’s legally authorized surrogate signed the informed consent form. Reconsent for continued study participation was elicited daily from those patients who were able to provide it.

All patients admitted to a study unit intubated and receiving mechanical ventilation or intubated after ICU admission were assessed by a nurse investigator for study eligibility. Demographic information was entered into a site-specific enrollment log. By using a spreadsheet with computer-generated sequences of random numbers, eligible patients were randomly selected to approach for study participation. If selected to approach, the care provider verified that the patient could accept random assignment to a turning intervention and informed consent was sought. When informed consent was obtained, the randomization spreadsheet was used to assign the patient to intervention group: 2-hourly manual turn (standard-of-care control group) or automated turn (experimental group).

Eligible patients were at least 18 years of age and had received mechanical ventilation through an orotracheal tube for 8 hours or less before protocol activation. Patients were excluded for any of the following: pulmonary mass, pneumothorax, hemothorax, pleural effusion, or other potential source of compression atelectasis at the time of assessment as determined by chest radiograph, radiology report, or physician communication; systolic blood pressure less than 90 mm Hg with vasopressor support; injuries requiring immobilization; head injury requiring intracranial pressure monitoring; intubation within the preceding 2 weeks; and weight 159 kg or greater (a limitation of the automated turning bed). Patients participated in the study until 1 of the following occurred: 7 consecutive days on protocol, discontinuance of mechanical ventilation, death, transfer from study unit, or consent revoked. Follow-up continued until ICU discharge.

Turning Interventions

Manual Turn. Patients were turned manually every 2 hours from the back to the left side to the back to the right side. Salient aspects of the protocol included a lateral turn of at least 45° to promote drainage of secretions; elevation of the head of the patient’s bed at least 30° to reduce risk of aspiration in the lateral and back positions; use of dedicated nurses to ensure frequency, angle, and duration of turn; and tracking of compliance with the intervention protocol and adverse events associated with turning. Study nurses assessed adherence to the manual turn protocol every 10 minutes; they measured and recorded angle of turn and repositioned the patient as needed and/or documented the reason for protocol violation.

Automated Turn. The Triadyne Proventa (Arjo-Huntleigh) bed was used for automated turning. Adjustable body packs were used to support the head, arms, and legs of the patient during rotation. The rotation angle was programmed to 45° in the lateral positions. Salient aspects of this protocol included lateral rotation to the maximum angle; essentially continuous rotation (rotation was paused for short periods as needed for care and diagnostic tests); elevation of the head of the patient’s bed at least 30° to reduce risk of aspiration; built-in timer to monitor bed movement in the programmed positions; and tracking of compliance with the intervention protocol and adverse events associated with turning. The acclimation mode, which provides a gradual increase in the degree of rotation over several hours from 25° to the maximum lateral angle, was used to help the patient adjust to automated turning. Thereafter, rotation was programmed at the maximum angle for the duration of time on protocol.

Study Procedures

Study nurses remained at the bedside throughout the manual-turn patient’s lateral rotation time and continuously when an automated-turn patient was on protocol. Demographic, clinical, and Acute Physiology and Chronic Health Evaluation (APACHE) II25 data were collected from the medical record by 2 investigators independently for assessment of interrater reliability.

A mini-bubble protractor (KCI, Inc) was placed on the patient’s chest at the second anterior intercostal space to measure angle of turn and at the lowest portion of the back upper bed frame to measure the angle at which the head of the bed was elevated. Turn time, position, and angle (manual-turn group); adverse events; head-of-bed angle; daily reconsent; and comments were entered directly into a spreadsheet on the study site computer.

A battery-powered angle sensor (SMARTTOOL Smart Level, M-D Building Products) was added to the base of the mattress at the head of the Proventa bed. The signal was captured every 1 second, and angle sensor output (0-5 V) was converted to angle of turn in degrees.
At the completion of follow-up for each patient, digital chest radiographs were deidentified, labeled with code number, and uploaded to the radiologist’s computer for interpretation. PPCs were operationally defined as radiographic evidence of atelectasis or pneumonia. The radiologist completed a PPC coding sheet (Figure 1) for each radiograph by checking boxes for lung zone(s) involved and extent and type of infiltrate. If the patient had more than 1 radiograph per day, the image with the greatest pathology score was used. Severity of PPCs was determined by the product of the extent and lung zone of abnormality, with possible scores varying from 0 (no PPCs) to 18 (lobar PPCs in 6 lung zones). One chest radiologist, blinded to study site and treatment group, interpreted selected radiographs twice, 4 months apart, for assessment of intrarater reliability of coding. Estimates for validity and reliability of the PPC coding sheet in a previous study included a content validity index of 0.93 and intrarater and interrater reliabilities of 0.95 or higher.

### Outcome Measures

The primary outcome was the incidence and progression or resolution of PPCs, assessed by interpreting serial chest radiographs taken before, during, and after study participation. Incidence was defined as presence of PPCs on any chest radiograph during the study when the prestudy chest radiographs showed none. Progression or resolution of infiltrate was determined by change from one chest radiograph to the next; higher severity defined progression of PPCs and lower severity defined resolution of PPCs. Secondary outcomes were turning-related adverse events, duration of mechanical ventilation, ICU length of stay, and ICU mortality rate. Nonserious turning-related adverse events were defined as changes in medical condition that are life-threatening and require intervention. Duration of mechanical ventilation was defined as number of days the patient received mechanical ventilation in the ICU, ICU length of stay as number of days in the study unit, and ICU mortality rate as the percentage of study patients who died from any cause while in the ICU.

### Statistical Analysis

Variables were compared by the Pearson $\chi^2$ or Wilcoxon rank sum (2-sided) test with SAS software (version 9.3, SAS Institute Inc). Interrater reliabilities were estimated with percentage agreement, with 90% agreement or greater considered acceptable. Intrarater reliability for PPC coding was estimated with the Cohen $\kappa$ coefficient, with 0.60 or greater considered acceptable. To assess compliance with the manual-turn protocol, time lying on the right and left sides was calculated and divided by total time on protocol to derive the percentage of time spent in the lateral position. Complete fidelity to
Results

Participant Flow

We assessed 511 patients for eligibility in 8.6 months of recruitment, and 495 (97%) were excluded for the reasons shown in Figure 2. Most patients assessed (n = 325) were not eligible for study participation. Sixteen patients were enrolled, and 12 (75%) completed the study protocol. Reasons for not completing the study protocol included the following: could not keep patient positioned (manual turn), clinicians objected to the experimental bed (automated turn), experimental bed malfunction (automated turn), and protocol never activated because of cardiac arrest and death (manual turn). The latter patient was dropped from the analysis; the others were included in the intention-to-treat analysis based on group assignment. Of the demographic and clinical characteristics, only endotracheal tube size ($P = .007$) and sex ($P = .04$) were different.
between study sites; therefore, the sites were combined for further analyses.

The 16 enrolled patients were evenly divided by site and turning group assignment. Of the patients on protocol, 7 (47%) were from one site and 8 (53%) from the other. Seven patients (47%) were randomized to the manual-turn group and 8 (53%) to the automated-turn group. Patient characteristics by group are shown in Table 1. All patients had respiratory failure as the primary or secondary diagnosis.

**Protocol Conduct and Data Quality**

Assessment parameters of protocol conduct and data quality are shown in Table 2. A total of 148 chest radiographs were coded for PPCs, with a mean of 10 radiographs per patient. Of those chest radiographs, 50 (34%) were randomly selected for repeat interpretation by the study radiologist.

**Efficacy Outcome**

PPC prevalence was 79% before the study, 93% during the study, and 79% after the study. The incidence of PPCs was 67%, with no statistically significant difference between groups. The rates of change per day in PPC score (slopes) were \( \beta = 0.15 \) for the manual-turn group and \( \beta = -0.44 \) for the automated-turn group; the differences were not significant (effect size of time by group interaction \( \beta = 0.39 \), \( \sigma = 0.39 \), \( df = 1, 9.56 \); \( P = .16 \)). Based on the standardized effect size of time by group interaction \( (d = 0.39) \), a sample size of 54 patients (one per patient) would be needed to detect this effect on PPC score as significant with 80% power and an \( \alpha \) of 0.05.

**Secondary Outcomes**

We found no statistically significant differences between groups in turning-related adverse events, duration of mechanical ventilation, ICU length of stay, or ICU mortality; standardized effect sizes were 0.12, 0.17, 0.53, and 0.09, respectively. ICU length of stay was affected by an extreme outlier in the automated-turn group who stayed in the ICU for 90 days. Twelve serious adverse events occurred in 7 patients (47%), and 2 of those events (17%) were probably or possibly related to turning: dysrhythmia, inadvertent extubation, and ventilator malfunction in the manual-turn group and death, dysrhythmia, hypoxemia, hypertension, and ventilator disconnect in the automated-turn group. Overall, duration of mechanical ventilation was positively correlated with APACHE II score \( (r = 0.56, P = .04) \); ICU length of stay was positively, but not significantly, correlated with APACHE II score \( (r = 0.33, P = .22) \).

**Discussion**

The findings from this pilot study suggest that automated turning may confer a modest efficacy advantage over manual turning for reducing the frequency of PPCs over time in adult patients receiving mechanical ventilation in medical-surgical ICUs. Our pilot study addressed limitations of previous randomized controlled trials by use of a completely randomized experimental design, rigorous testing of both the manual and automated turning protocols, blinding of the outcome assessor, and estimation of the reliability of chest radiographic interpretation. Others have noted that less rigorously controlled trials than ours tend to show a greater effect for automated turning. Similar to McIntyre and colleagues, we chose PPC as our dependent variable rather than only pneumonia because (1) the 2 conditions are

**Table 1**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Manual-turn group (n = 7)</th>
<th>Automated-turn group (n = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>54 (12)</td>
<td>58 (11)</td>
</tr>
<tr>
<td>Sex, No. (%) of patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>3 (43)</td>
<td>4 (50)</td>
</tr>
<tr>
<td>Female</td>
<td>4 (57)</td>
<td>4 (50)</td>
</tr>
<tr>
<td>Race/ethnicity, No. (%) of patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>6 (86)</td>
<td>6 (75)</td>
</tr>
<tr>
<td>Black</td>
<td>1 (14)</td>
<td>1 (12)</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>0 (0)</td>
<td>1 (12)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>2 (29)</td>
<td>1 (12)</td>
</tr>
<tr>
<td>Fraction of inspired oxygen, mean (SD)</td>
<td>0.71 (0.32)</td>
<td>0.65 (0.24)</td>
</tr>
<tr>
<td>Pao2, mean (SD), mm Hg</td>
<td>146 (114)</td>
<td>105 (34)</td>
</tr>
<tr>
<td>Systolic blood pressure, mean (SD), mm Hg</td>
<td>127 (34)</td>
<td>118 (13)</td>
</tr>
<tr>
<td>Surgery, No. (%) of patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>5 (72)</td>
<td>5 (62)</td>
</tr>
<tr>
<td>Abdominal</td>
<td>1 (14)</td>
<td>1 (12)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (14)</td>
<td>2 (25)</td>
</tr>
<tr>
<td>COPD comorbid, No. (%) of patients</td>
<td>4 (57)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Enteral feeding, No. (%) of patients</td>
<td>5 (71)</td>
<td>4 (50)</td>
</tr>
<tr>
<td>APACHE II score, mean (SD)</td>
<td>27 (9)</td>
<td>24 (5)</td>
</tr>
<tr>
<td>Days on study protocol, mean (SD)</td>
<td>3.7 (2.3)</td>
<td>3 (2.3)</td>
</tr>
<tr>
<td>Days of mechanical ventilation, mean (SD)</td>
<td>5.2 (4.3)</td>
<td>6 (5)</td>
</tr>
<tr>
<td>Days in ICU, median (interquartile range)</td>
<td>8.2 (3.6-14.9)</td>
<td>11.1 (5.4-23.4)</td>
</tr>
<tr>
<td>ICU mortality, No. (%) of patients</td>
<td>2 (29)</td>
<td>2 (25)</td>
</tr>
</tbody>
</table>

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; COPD, chronic obstructive pulmonary disease; ICU, intensive care unit.  
\( ^{a} \) Percentages may not total 100 because of rounding.  
\( ^{b} \) Significant difference \( (P \leq .05) \).  
\( ^{c} \) APACHE II score can vary from 0 to 71, with higher score associated with greater disease severity and risk of death; modified Glasgow Coma Scale was used to compute APACHE II score.
report the actual turn angle. Thus, turn angle may affect outcome(s). Although automated-turn rotation time exceeded our threshold, mean angle of turn did not. Such factors as the patient’s body weight, anthropometrics, and position in bed affect the turn angle.\(^{31}\) In routine practice, turn angles achieved with automated turning are likely to fall short of \(45^\circ\).

Maintaining time in and angle of lateral rotation was a challenge with patients who were confused, able to self-turn, or sedated lightly. Despite the use of turning wedges and pillow supports for the manual turn, patients “slipped out” of the turn angle to a position more representative of a quarter-turn. Without dedicated turning staff to readjust the turn angle, many patients are unlikely to benefit optimally from secretion mobilization during manual lateral rotation.

The serious adverse events associated with both manual and automated turning suggest that lateral rotation in ICU patients receiving mechanical ventilation is not a benign intervention, and close monitoring of patients is indicated regardless of turning method. Our pending detailed analysis of nonserious adverse events may inform secondary interventions to promote patients’ tolerance of lateral rotation.

It is notable that most patients had PPCs before study enrollment; indeed, pulmonary disease most likely contributed to the need for intubation and mechanical ventilation. Increased prevalence of PPCs during the study, despite turning, reinforces the high risk for pulmonary morbidity with intubation and mechanical ventilation. Some resolution of PPCs occurred, particularly in the automated-turn group, as the PPC prevalence after the study was either equivalent to (manual turn) or less than (automated turn) the during-study level. Nonetheless, PPC rates were high before, during, and after study participation, making a strong argument for further research on ways to reduce PPCs in ICU patients receiving mechanical ventilation.

The major limitation of this pilot study is reliance on changes detected on chest radiographs for determination of PPC. Previous lateral rotation study reports did not address reproducibility of chest radiographic interpretation. Others\(^{32,33}\) have noted the low sensitivity of chest radiographs in the assessment of PPCs; we found only fair agreement by a lone expert\(^b\) thoracic radiologist with repeated assessment. Previous reliability testing of the PPC coding sheet\(^a\) was done by abstraction of PPC data from radiology reports rather than reinterpretation of the radiographs. Although the study radiologist had access to serial radiographs for each patient, she did not

---

**Table 2**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocol deviations, No. of participants</td>
<td>1</td>
</tr>
<tr>
<td>Failure to abort turning when stopping rule should have been invoked</td>
<td>1</td>
</tr>
<tr>
<td>1.25-hour delay in manual turn per physician request to evaluate serial ventilator adjustments</td>
<td>1</td>
</tr>
<tr>
<td>Patient enrolled with exclusion criterion</td>
<td>2</td>
</tr>
<tr>
<td>Patient turned with head of bed flat for 12 hours after lumbar puncture</td>
<td>2</td>
</tr>
<tr>
<td>Compliance with measurement of turn angle, mean (SD), %</td>
<td>92 (11)</td>
</tr>
<tr>
<td>Manual turn</td>
<td>100 (0)</td>
</tr>
<tr>
<td>Automated turn</td>
<td>100 (0)</td>
</tr>
<tr>
<td>Compliance with turn angle (\geq 45^\circ), mean (SD), %</td>
<td>87 (11)</td>
</tr>
<tr>
<td>Manual turn</td>
<td>33 (24)</td>
</tr>
<tr>
<td>Automated turn</td>
<td>33 (24)</td>
</tr>
<tr>
<td>Compliance with time in the lateral position, mean (SD), %</td>
<td>94 (5)</td>
</tr>
<tr>
<td>Manual turn</td>
<td>91 (4)</td>
</tr>
<tr>
<td>Automated turn</td>
<td>91 (4)</td>
</tr>
<tr>
<td>Angle of turn, mean (SD), degrees</td>
<td>51 (5.1)</td>
</tr>
<tr>
<td>Manual turn</td>
<td>34 (5.0)</td>
</tr>
<tr>
<td>Automated turn</td>
<td>34 (5.0)</td>
</tr>
<tr>
<td>Reproducibility of demographic, clinical, APACHE, and outcome data</td>
<td>90% (intrarater reliability, percentage agreement)</td>
</tr>
<tr>
<td>Reproducibility of PPC coding(^b)</td>
<td>0.41 (intrarater reliability, K coefficient)</td>
</tr>
</tbody>
</table>

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; PPC, preventable pulmonary complication.

\(^{a}\) \(P \leq .01\).

\(^{b}\) Indicates fair agreement.\(^a\)

difficult to differentiate on physical examination and chest radiographs and (2) atelectasis frequently leads to pneumonia, suggesting that they are parts of a continuum that moves from noninfectious to infectious complication.

Compared with manual turning, automated turning appears to better reduce progression/accelerate resolution of, but not prevent, PPCs. The modest efficacy effect size is consistent with the findings of previous studies wherein investigators found a reduction in noninfectious (eg, atelectasis)\(^{14,21}\) and/or infectious (eg, pneumonia)\(^{16,18,19,22}\) PPCs in adult patients receiving mechanical ventilation in medical-surgical ICUs. In the 2 studies\(^{17,20}\) with no significant reduction, the mean turn angle was 25° or less, compared with 34° in the present study; other trials in this population of patients did not
have access to patients’ demographic or clinical information or consultation with others. Therefore, misclassification of PPCs was a potential threat in this study, albeit a threat equally applied to both groups.

Conclusions and Implications

Results of this pilot study suggest that continuous automated turning may be more efficacious than manual turning every 2 hours for reducing PPCs in adult patients receiving mechanical ventilation in medical-surgical ICUs. The incidence of PPCs in this population was high. The number of adverse events, mechanical ventilation duration, ICU length of stay, and ICU mortality were not substantially different between turning methods. The standardized effect size indicates that 54 patients would be needed to test the hypothesis that automated turning has greater efficacy than manual turning when the turning interventions are maximized. Our pilot data support the conclusions of previous trials with little control over the turning interventions that automated turning may confer an advantage for reducing PPCs in ICU patients receiving mechanical ventilation.

ACKNOWLEDGMENTS

The authors thank Audrius Brazdeikis, PhD, for assistance with programming acquisition of automated bed-turn angle and Preshant Bhagat, BSN, for assistance with coding the adverse events.

FINANCIAL DISCLOSURES

This study was supported by a grant from the Texas Medical Center Howell Nursing Research Fund, the Society of Critical Care Medicine Norma J. Shoemaker Nursing Research Grant, an American Association of Critical-Care Nurses mentorship grant, and a nursing research grant from the American Association of Critical-Care Nurses Houston-Gulf Coast Chapter.

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REFERENCES

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PHYSICAL RECOVERY IN INTENSIVE CARE UNIT SURVIVORS: A COHORT ANALYSIS

By Leanne M. Aitken, RN, PhD, Elizabeth Burmeister, RN, BN, MSc, Sharon McKinley, RN, PhD, Jennifer Allison, Dip Phsy, MSc, PhD, Madeleine King, BSc(Hons), GradDipMedStat, PhD, Gavin Leslie, RN, PhD, and Doug Elliott, RN, PhD

Background Some survivors of critical illness experience poor physical recovery, but which patients experience the most compromise during recovery is unknown.

Objective To identify factors associated with physical recovery by using the 6-minute walk test in adult survivors of critical illness 26 weeks after discharge from the hospital.

Methods A total of 195 adult survivors of a critical illness were enrolled in a multicenter trial of physical rehabilitation after discharge from the hospital. The 6-minute walk test, the 36-Item Short Form Health Survey, and sleep rated on a 5-point scale were completed at weeks 1 and 26. Clinical and demographic data were obtained from patient records.

Results A total of 145 patients completed the 26-week test. Of these, 94 (65%) increased the distance walked in 6 minutes by at least 75 m from the 1-week value and were therefore considered to have improved on the test. Factors associated with improvement included moderate to severe sleeping problems in week 1, moderate to vigorous exercise in week 26, and higher vitality in week 26. Conversely, respiratory problems and higher social functioning in week 1 were associated with less improvement in the distance walked.

Conclusion Multiple factors are associated with physical recovery after critical illness. Interventions to target multidimensional aspects of recovery such as sleep and exercise may result in improved physical function after critical illness. (American Journal of Critical Care. 2015;24:33-40)
Survival after a critical illness that requires admission to an intensive care unit (ICU) is common and occurs in approximately 90% of patients discharged from the hospital in Australia. For some survivors, recovery may be characterized by marked compromise of physical and psychological health after discharge from the hospital. Physical compromise often is manifested as generalized muscle weakness leading to an inability to perform simple activities of daily living. Currently, the muscle deterioration that patients experience during critical illness and the lengthy recovery period that these patients require are widely recognized.

Numerous observational studies have indicated the range and extent of physical compromise that patients experience after a critical illness, but exploration of the factors predictive of this compromise has been limited. Physical function can be assessed by using self-report instruments such as the Short-Form 36 (SF-36) or objective measures such as the distance walked in 6 minutes (6MWD).

Concurrently, survivors of critical illness may experience both psychological compromise, in the form of anxiety, depression, and symptoms of posttraumatic stress disorder, and cognitive compromise.

Recognition of compromise after critical illness has prompted a range of small, usually single-center, studies of the factors associated with recovery. Factors identified include age, socioeconomic status, sex, severity of illness, primary diagnosis, and length of ICU stay (including duration of interventions such as mechanical ventilation). A major limitation of the research to date is that many of the factors associated with recovery cannot be modified. Identification of potentially modifiable factors associated with recovery may allow development of interventions tailored to overcome specific limitations or to address specific factors and may lead to greater improvement in function for survivors of a critical illness. The aim of this substudy analysis was to examine the factors associated with physical recovery by using the 6MWD in adult survivors of critical illness during a period of 26 weeks after hospital discharge.

**Methods**

**Design**

Patients in this cohort analysis were enrolled in a multicenter randomized controlled trial that tested the effects of an 8-week home-based rehabilitation program on health-related quality of life and physical function for survivors of critical illness. The study protocol and primary results for the trial have been published previously.

**Patients and Centers**

Patients were recruited from ICUs in 12 hospitals in Sydney, Brisbane, and Perth, Australia (6 teaching, 5 district, and 1 private hospital). Patients were eligible for enrolment if they were 18 years or older; had an ICU length of stay of 48 hours or longer; received mechanical ventilation for 24 hours or longer; were discharged home to self-care or a caregiver (noninstitutional care); resided within the hospitals’ local geographic areas (to enable home visits; approximately 50-km radius); had no neurological, spinal, or skeletal dysfunction preventing participation in physical rehabilitation; were not receiving palliative care; had no organized rehabilitation related to ongoing management of a chronic disease (eg, pulmonary rehabilitation, cardiac rehabilitation); and were cognitively able to complete the self-report...
measures and comply with the instructions for physical testing.

The sample size was based on the primary aim of the original trial to determine the effect of a physical rehabilitation program on physical function: a hypothesized effect of a 10-point difference on the physical function domain of the SF-36.16,17

**Procedures**

After the study was approved by the human research ethics committee of each research site, patients were approached about participating in the study after ICU discharge; informed consent was obtained either at that time or after the patient agreed to be contacted at home after discharge from the hospital. The graded, individualized endurance and strength training that patients received in the primary trial has been described elsewhere.16,17 Blinded assessments in patients’ homes at weeks 1, 8, and 26 after hospital discharge included examination of physical functioning, health-related quality of life, and psychological well-being. The 2 groups (control and interventional) did not differ significantly in physical function, 6MWD, or overall health-related quality of life as indicated by scores on the SF-36. Data from both groups were therefore combined for this analysis to identify factors associated with physical recovery in ICU survivors.

**Outcome Measures**

**Primary Outcome.** The primary outcome for this analysis was physical function as measured by the 6-minute walk test (6MWT). Specifically, the outcome was the improvement in patients’ physical function from week 1 to week 26. Patients whose 6MWD improved by 75 m or more during the 26 weeks of the study were categorized as “improved 6MWD”; this distance was based on 95% CI of the standard error of measurement of the week-1 test. Currently, no agreed-upon minimal clinically important difference for the 6MWD in survivors of a critical illness exists. For patients with chronic obstructive pulmonary disease,18 the estimated minimal clinically important difference is 35 m; therefore, an improvement of 75 m is considered a clinically important improvement in survivors of critical illness.

The 6MWT was performed in the patient’s home or environs by trained assessors. The assessors were registered nurses or physiotherapy students who were trained by the physiotherapist investigator (J.A.) to conduct the 6MWT according to the guidelines of the American Thoracic Society.4 The course for the walk test was measured and mapped on paper, and the same course was used for the 1-, 8-, and 26-week tests. The test was performed twice at each assessment, to account for any learning effect, and the best result was recorded for analysis.19 During the 6MWT, patients were directly observed and monitored continuously by the assessor via a portable pulse oximeter (to measure pulse rate and oxygen saturation). Patients’ exertion levels were assessed and documented during the test by using the Borg Perceived Exertion Scale.20

**Other Measures.** Psychological well-being was assessed by using the Depression Anxiety Stress Scales21 and the Impact of Event Scale.22 Quality of sleep was assessed by using an item from the 15D instrument of the health-related quality of life, with a 5-point scale ranging from no problems to severe sleeplessness.23 Clinical and demographic data were obtained from ICU and hospital records. Data on incidental exercise were obtained by telephone interview with patients at each time point; the exercise was categorized as none, mild, moderate, or vigorous. Moderate exercise was exercise that the patients thought caused a moderate increase in heart rate or breathing; vigorous exercise caused a large increase in heart rate or breathing.

**Data Analysis**

Stata 11 software (StataCorp LP) was used for all analysis of data. Data were cleaned and checked for missing and outlying values. Descriptive characteristics of the population were explored, and the variables were checked for normal distribution.

Baseline variables, including demographic details (age, sex); hospital details (diagnosis, duration of mechanical ventilation, ICU and hospital length of stay, scores on the Acute Physiology and Chronic Health Evaluation II); and week-1 scores for the SF-36, Depression Anxiety and Stress Scales, the Impact of Event Scale, and sleeping instruments; and the amount of incidental exercise were assessed by using univariate analysis to determine if relationships with the outcome existed. Multiple logistic regression modeling included all variables significant at the .10 level on univariate analysis when the backward elimination method was used. After removal of each nonsignificant variable, the model was assessed by using likelihood-ratio tests and Wald statistics. The fit of the final logistic model was assessed by using the Pearson goodness-of-fit $\chi^2$ statistic and the area under the receiver operating...
Results

Flow of Patients

In total 5980 patients were screened, and 195 were enrolled between 2005 and 2008 (see Figure). Patients were a mixed medical and surgical group of ICU patients with a mean age of 57 years; 30% were female (Table 1). A total of 145 patients (74%) completed the 6MWT at 26 weeks. Those who completed the test at 26 weeks did not differ significantly in age, sex, diagnosis, and length of stay in the ICU and the hospital from patients who did not complete the 6MWT.

Prediction of 6MWD

Of those patients who completed the 26-week 6MWT, 94 (65%) increased their distance walked by at least 75 m from the 1-week test and were therefore categorized as improved 6MWD. The mean distance at week 1 after hospital discharge was 307 m (SD, 137 m); this value increased to 435 m (SD, 156 m) for patients who completed the test at week 26, an increase of 42%. For those 143 patients who completed both the week-1 and week-26 6MWT, the mean difference was 121 m (SD, 20 m).

Table 1
Characteristics of the 195 participants in the study

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>6-min walk distance</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Improved (n = 94)</td>
<td>Not improved (n = 51)</td>
</tr>
<tr>
<td>Age, mean (SD), y</td>
<td>56 (16.4)</td>
<td>59 (15.2)</td>
</tr>
<tr>
<td>Female sex, No. (%)</td>
<td>34 (36)</td>
<td>23 (45)</td>
</tr>
<tr>
<td>Day 1 APACHE II score, mean (SD)</td>
<td>20.6 (12.4)</td>
<td>18.0 (5.7)</td>
</tr>
<tr>
<td>6-min walk distance, mean (SD), m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week 1</td>
<td>302 (121)</td>
<td>340 (130)</td>
</tr>
<tr>
<td>Week 26</td>
<td>482 (141)</td>
<td>349 (146)</td>
</tr>
<tr>
<td>Operative admissions, No. (%)</td>
<td>47 (50)</td>
<td>21 (41)</td>
</tr>
<tr>
<td>ICU admission diagnosis, a No. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>20 (21)</td>
<td>10 (20)</td>
</tr>
<tr>
<td>Respiratory</td>
<td>11 (12)</td>
<td>19 (37)</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>30 (32)</td>
<td>14 (27)</td>
</tr>
<tr>
<td>Other</td>
<td>31 (33)</td>
<td>8 (16)</td>
</tr>
<tr>
<td>Duration of mechanical ventilation, median (IQR), h</td>
<td>92 (46-223)</td>
<td>75 (45-145)</td>
</tr>
<tr>
<td>Days in ICU, median (IQR), d</td>
<td>5 (4-10)</td>
<td>6 (4-12)</td>
</tr>
<tr>
<td>Days in hospital, median (IQR), d</td>
<td>20 (12-31)</td>
<td>14 (11-30)</td>
</tr>
</tbody>
</table>

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; ICU, intensive care unit; IQR, interquartile range.

a Admission diagnosis based on APACHE III diagnostic codes.
Univariate relationships (P < .10) existed between an improved 6MWD and several factors: diagnostic group; quality of sleep; scores on the SF-36 domains of social role functioning, vitality, physical function, role—physical and physical component summary at week 1; score on the stress subscale of the Depression Anxiety Stress Scales at week 1; scores on the SF-36 domains of vitality, physical function, role—physical and physical component summary at week 26; and amount of incidental exercise at week 26.

After backward stepwise removal of factors that were not significant in the multivariable model, logistic regression (Table 2) indicated that moderate to severe sleeping problems in week 1 (log odds coefficient, 0.80; 95% CI, 0.11-1.48), moderate to vigorous exercise at week 26 (log odds coefficient, 2.44; 95% CI, 1.04-3.84), and higher vitality at week 26 (log odds coefficient, 0.06; 95% CI, 0.02-0.09) were associated with an improved 6MWD. Conversely, respiratory diagnosis (log odds coefficient, -2.24; 95% CI, -4.06 to -0.41), higher scores on the SF-36 social functioning domain at week 1 (log odds coefficient, -0.03; 95% CI, -0.05 to -0.01), and greater 6MWD at week 1 (log odds coefficient, -0.01; 95% CI, 0.01-0.00) were associated with no improvement in the 6MWD. The final model was an excellent predictor of improvement in 6MWD, with an area under the curve of 0.88 and a Pearson χ2 of 82.7, P = .95.

### Discussion

In this study, we sought to identify factors independently associated with improvement in physical function during a 26-week period in survivors of critical illness treated in an ICU who returned home. Patients were considered to have improved physical function if they increased their distance walked on the 6MWT from 1 week to 26 weeks after hospital discharge by 75 m or more. Two-thirds of patients had an increase in their 6MWD; the mean distance increased by more than 40%.

Improvement in 6MWD by 75 m or more was independently associated with moderate to severe sleeping difficulties at week 1 and moderate to vigorous incidental exercise and higher vitality at week 26. A lack of improvement in physical function was independently associated with admission to the ICU because of a respiratory diagnosis, higher social functioning, and greater 6MWD in the first week after hospital discharge.

Physical function, as reflected by the 6MWD, has rarely been measured in cohorts of ICU survivors. Herridge and colleagues followed up 109 survivors of acute respiratory distress syndrome for 5 years. A total of 83 patients walked approximately 280 m 3 months after hospital discharge, 400 m at 6 months, 420 m at 12 months, and 440 m at 5 years. Similar improvements were noted by Wright et al in 31 patients with pancreatitis, who walked approximately 350 m at 3 months and 420 m at 12 months. In a study by McWilliams et al, 38 general ICU patients walked approximately 280 m at 1 week and 440 m 6 weeks later. We found no other reports of factors associated with improved 6MWD. Thus, our results are only the second description of factors associated with improved walking distance in the general ICU population, and our sample had markedly more patients than did the only previous report.

In our cohort of ICU survivors, moderate to severe sleeping difficulties 1 week after hospital discharge were associated with greater improvement in physical function. Poor sleep quality in the ICU is well recognized, but examination of whether compromised sleep continues after hospital discharge has been limited. In our study, 50% of patients reported moderate to severe problems sleeping at week 1, and the percentage remained greater than 30% at weeks 8 and 26. These findings are consistent with those of a study in which 50% of 40 ICU patients with acute lung injury reported insomnia 6 months after discharge and with the results of study in which 7 of 109 survivors of acute respiratory distress syndrome who reported persistent changes in sleep quality had abnormal sleep architecture on polysomnography 6 months or more after hospital discharge. A similar relationship...
between sleep problems after hospital discharge, physical function, and quality of life was also found in former ICU patients.\textsuperscript{31}

The meaning of such relationships is unclear. Possible explanations include that as the patients’ sleep improved, their physical function also improved, or that the physiological aspects that resulted in a short 6MWD at week 1 also affected sleep quality and quantity. The latter explanation is consistent with our finding that patients who improved their distance walked in 6 minutes had a lower mean 6MWD at week 1 than did patients whose 6MWD did not improve. Regardless, this finding suggests that strategies to improve sleep may also improve other aspects of recovery after critical illness.

Not unexpectedly, moderate to vigorous incidental exercise independent of the study intervention and higher self-reports of vitality were associated with longer 6MWDs. Moderate to vigorous incidental exercise was exertion that patients thought caused a moderate or large increase in their heart rate or breathing. However, the direction of the relationships between incidental exercise, self-reported vitality, the study intervention, and the 6MWD are not clear. Incidental exercise may have resulted in improved 6MWD, or alternatively the study intervention may have contributed to the patients’ ability to undertake moderate to vigorous incidental exercise. Similarly, the higher sense of vitality may have led patients to feel capable of pushing themselves to walk farther on the 6MWT, or alternatively the longer 6MWD may have contributed to a high sense of vitality. Regardless of the direction of these relationships, moderate to vigorous incidental exercise and a high self-rating of vitality appear to assist physical function. In the context of this finding, and because the study intervention was not associated with improvement in 6MWD, possibly a more intense or prolonged exercise intervention would be required to elicit improvements in the 6MWD. Such an intervention might commence earlier in recovery, last for longer than 8 weeks, or consist of more frequent or intense episodes of exercise. Since the current study intervention was designed, several studies have been done to test the feasibility and efficacy of early exercise interventions, both within the ICU\textsuperscript{22} and after ICU discharge but before discharge from the hospital,\textsuperscript{13} and to determine the effectiveness of a more intense home-based exercise intervention.\textsuperscript{26}

Patients with a primary respiratory diagnosis experienced less improvement in the 6MWD than did patients with other diagnoses. Herridge et al\textsuperscript{10} reported minimal increase in 6MWD after 6 months in patients with acute respiratory distress syndrome; the patients’ mean 6MWD was only 440 m 5 years after hospitalization. This finding may indicate that ongoing pathological damage to the lungs resulting in limited physical function may require more intense rehabilitation, such as provided in pulmonary rehabilitation programs.\textsuperscript{14}

The role of social functioning in recovery is unclear. Higher social functioning soon after discharge was associated with less improvement in physical function. Possibly patients who felt their social functioning was adequate were not motivated to increase physical activity to interact with friends and family, although the rationale for such an association is not obvious.

### Strengths and Limitations

This analysis incorporated results from a multisite study of 195 survivors of critical illness, representing a larger cohort than any other examination of 6MWD in this population of patients. Control for a wide range of factors that might affect improvement in physical function was incorporated in the study design.

Limitations include the low number of patients, only 195 of the almost 6000 patients screened, who were enrolled in the study, raising questions about the representativeness of this cohort when the wider ICU population is considered. Further, 143 of the 195 patients enrolled completed the 6MWT at both 1 and 6 months, but the baseline characteristics of those who completed the test were similar to those of patients who did not complete the assessment.

In conclusion, various factors affected recovery after critical illness. These factors probably did not occur in isolation; most likely an interaction occurred between physical, psychological, and cognitive health.\textsuperscript{3} Exploration of the effects interventions designed to improve recovery have on all of these elements is essential. Further, the most effective interventions may target more than one aspect of recovery.

### ACKNOWLEDGMENTS

Trial registration: Australian and New Zealand Clinical Trials Register ACTRN12605000166673.

### FINANCIAL DISCLOSURES

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1. Which of the following is a major limitation for current research on physical recovery in intensive care?  
   a. Interventions that are tailored to overcome specific limitations can improve functionalities in survivors.  
   b. Many of the factors associated with recovery cannot be modified.  
   c. Survival after critical illness is not common enough to warrant large, multicenter research trials.  
   d. Survivors of critical illness exhibit symptoms of both physiological and psychological compromise.

2. Which of the following criteria disqualified patients for enrollment in this study?  
   a. Ability to complete the self-report measures  
   b. Discharged to noninstitutional care  
   c. Ability to follow instructions  
   d. Organized rehabilitation related to a chronic disease process

3. A relationship among sleep problems after hospitalization, physical function, and quality of life suggests which of the following?  
   a. Strategies to improve sleep may also improve other aspects of life after critical illness.  
   b. There is no relationship between sleep, critical illness, and a decline in physical recovery.  
   c. Sleep quality and quantity have no relationship to the distance walked in 6 minutes (6MWD).  
   d. Higher reports of vitality were associated with longer 6-minute walk tests (6MWTs).

4. How were patients categorized as improved using the 6MWT?  
   a. The standard error of measurement from week 1 based on a confidence interval of 90%.  
   b. Improvement in the patient’s ability to comply with instructions for physical testing  
   c. Significant increase in the Short-Form 36 quality of life scores  
   d. Increased walking distance of 75 meters or more from baseline

5. Exertion levels for study patients were assessed using which of the following?  
   a. Moderate Exercise vs Vigorous Exercise Criteria Scale  
   b. Borg Perceived Exertion Scale  
   c. Impact of Event Scale  
   d. Stress Exertion Scale

6. Social functioning and its role in recovery:  
   a. Showed that inadequate social function was related to increased physical activity  
   b. Showed that more physical improvement was seen in patients with higher social function  
   c. Was associated with more improvement in physical function  
   d. Is unclear

7. Which of the following percentages of patients was categorized as improved based on the 6MWT?  
   a. 26%  
   b. 84%  
   c. 65%  
   d. 75%

8. Which of the following factors exhibited a univariate relationship with an improved 6MWD?  
   a. Decreased quality of sleep  
   b. Physical component summary at week 26  
   c. Physical component summary at week 8  
   d. Score on the Depression Anxiety Stress Scales at week 8

9. Which of the following diagnostic groups had the greatest increase in 6MWD?  
   a. Cardiovascular  
   b. Respiratory  
   c. Gastrointestinal  
   d. Oncologic

10. Improvement in the 6MWD by 75 meters or more was independently associated with which of the following?  
    a. Moderate to severe sleeping difficulties at week 8  
    b. Moderate to vigorous exercise at week 8  
    c. Higher vitality at week 26  
    d. Admission to the ICU because of a respiratory diagnosis

11. Which of the following percentages of patients was able to complete the 26-week test?  
    a. 65%  
    b. 100%  
    c. 74%  
    d. 45%

12. Physical compromise after critical illness is often manifested by which of the following?  
    a. Changes in physical but not psychological health  
    b. Inability to perform simple activities of daily living  
    c. Decreased recovery period  
    d. Changes that occur in isolation

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**Program evaluation**

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<td>To complete this program, it took me ______ hours/minutes.</td>
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Measuring Height in Recumbent Critical Care Patients

By Diane M. Dennis, BAppSc (Physiotherapy), PhD, Emily E. Hunt, BND, MDiet, and Charley A. Budgeon, BSc (Hons) Applied Statistics

Background
Estimates of the height of patients in the intensive care unit are required to adhere to clinical guidelines for drug dosages, ventilatory support, and nutrition. The gold standard of standing height cannot be used because these patients are often unconscious and recumbent. The ability of physiotherapists or dietitians to measure height in unconscious, recumbent patients has not been evaluated.

Objectives
To compare the accuracy of physicians, physiotherapists, and dietitians in estimating the height of recumbent critical care patients by using existing practice methods.

Methods
A total of 35 patients were recruited from the cardiothoracic preadmission clinic, where standing height is routinely measured by a physiotherapist. After surgery, in the intensive care unit, 1 physician, 2 physiotherapists, and 2 dietitians measured each recumbent patient’s height. Three methods were used: observation, whole-body measurement, and height estimated by using length of the forearm and the British Association for Parenteral and Enteral Nutrition normative chart. Difference from standing height was measured from zero and was compared across professions and methods, with zero indicating no difference.

Results
Overall, 17 physicians, 4 dietitians, and 9 physiotherapists consented to measure patients. After adjustments for method, measurements by physiotherapists did not differ significantly from the gold standard ($P = .59$), whereas those of physicians ($P = .02$) and dietitians ($P < .001$) did.

Conclusions
Physiotherapists’ measurements of supine height of recumbent critical care patients, obtained by using a nonrigid measuring tape, are more accurate than measurements obtained by physicians and dietitians. (*American Journal of Critical Care*. 2015;24:41-47)
N umerous calculations are required in the intensive care unit (ICU) to adhere to clinical guidelines such as those for drug dosages, ventilatory support, and nutrition. Height estimates are specifically required for calculations of ideal or adjusted body weight and for those involving body surface area, such as cardiac and body mass index. Lung capacity, for example, correlates best with lean body mass,¹ which is a function of height rather than of actual body mass. In a study of estimates of tidal volume, Diacon et al² concluded that every ventilator in the ICU should be equipped with a measuring tape to measure height for the prescription of tidal volumes; however, to date no guidelines have been provided on how the height should be measured and by whom.

Standing height is considered the gold standard for accurate measurement of height;² self-reported height is second best.¹ Neither of these methods can be used in ICU patients admitted under emergency circumstances who are unconscious and recumbent.

Although actual measurement of height is better than visual estimates,³⁴ questions remain about how accurate the measurements are, the best technique to use, and which personnel are most suitable for obtaining the measurements. In the ICU at Sir Charles Gairdner Hospital, Perth, Australia, according to the usual clinical practice, physiotherapists (for ventilatory reasons) and dietitians (for estimation of nutritional requirements) formally measure height in recumbent patients, and physicians visually estimate height. However, most research on the measurement of height in recumbent ICU or emergency department patients has used physicians and nurses with variable critical care experience, and the accuracy of the measurements has varied.¹³⁴ No investigators, to our knowledge, have evaluated the ability of physiotherapists or dietitians to measure height in recumbent ICU patients.

In older patients, measurement of other body segments for estimations of height may be preferable, because these patients may have kyphosis or mobility problems that make accurate standing-height measurement difficult. Forearm length is sometimes used because it is a reliable predictor of height,⁵⁶ is easily obtained in bedfast patients, and, compared with standing height, is less affected by the aging process. The forearm is most accessible in terms of patients’ positioning in the ICU, and only 2 bony landmarks (olecranon and ulnar styloid) are required.

The aim of this study was to compare the accuracy of physicians, physiotherapists, and dietitians in estimating the height of recumbent critical care patients by using existing practice methods. The null hypotheses were that physicians, physiotherapists, and dietitians would be able to measure height accurately and that actual measurements would be more accurate than would visual estimates.

Methods

Setting and Patients

This study took place at Sir Charles Gairdner Hospital, a 600-bed tertiary university hospital where postoperative cardiothoracic patients are routinely transferred to the mixed medical-surgical, 23-bed ICU. Between December 2011 and March 2012, prospective patients for the study were recruited from the cardiothoracic outpatient preadmission clinic, where standing height is routinely measured by the attending senior cardiothoracic physiotherapist. The study had no exclusion criteria; all patients were eligible. Patients were presented with information about the study, and they provided written consent to participate in it. On each patient’s admission to the ICU after surgery, the patient’s attending physician, physiotherapist, and dietitian were also presented with information about the study, and they provided their written consent to participate.

About the Authors

Diane M. Dennis is a senior physiotherapist, Physiotherapy Department, and Emily E. Hunt is a dietitian, Nutrition and Diet Therapy Department, Sir Charles Gairdner Hospital, Perth, Western Australia. Charley A. Budgeon is a biostatistician, Centre for Applied Statistics, University of Western Australia, Perth, Western Australia.

Corresponding author: Diane Dennis, Physiotherapy Department, Sir Charles Gairdner Hospital, Hospital Avenue, Nedlands, Perth, 6009, Western Australia (e-mail: Diane.Dennis@health.wa.gov.au).

Numerous calculations are required in the intensive care unit (ICU) to adhere to clinical guidelines such as those for drug dosages, ventilatory support, and nutrition. Height estimates are specifically required for calculations of ideal or adjusted body weight and for those involving body surface area, such as cardiac and body mass index. Lung capacity, for example, correlates best with lean body mass,¹ which is a function of height rather than of actual body mass. In a study of estimates of tidal volume, Diacon et al² concluded that every ventilator in the ICU should be equipped with a measuring tape to measure height for the prescription of tidal volumes; however, to date no guidelines have been provided on how the height should be measured and by whom.

Standing height is considered the gold standard for accurate measurement of height;² self-reported height is second best.¹ Neither of these methods can be used in ICU patients admitted under emergency circumstances who are unconscious and recumbent.

Although actual measurement of height is better than visual estimates,³⁴ questions remain about how accurate the measurements are, the best technique to use, and which personnel are most suitable for obtaining the measurements. In the ICU at Sir Charles Gairdner Hospital, Perth, Australia, according to the usual clinical practice, physiotherapists (for ventilatory reasons) and dietitians (for estimation of nutritional requirements) formally measure height in recumbent patients, and physicians visually estimate height. However, most research on the measurement of height in recumbent ICU or emergency department patients has used physicians and nurses with variable critical care experience, and the accuracy of the measurements has varied.¹³⁴ No investigators, to our knowledge, have evaluated the ability of physiotherapists or dietitians to measure height in recumbent ICU patients.

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as measurers. The study was approved by the hospital’s ethics committee.

**Process**

After surgery, patients were in the ICU resting in bed. During this time they received all usual care. Baseline data, including standing height, age, diagnosis, number of attachments (ie, number of drains, catheters, and leads that might make measurement of height difficult), and estimated time resting in bed when measurements were undertaken, were collected by the principal investigator (D.M.D.), who did not obtain any measurements of height in recumbent patients. Each patient’s height while he or she was recumbent was measured as soon as possible after ICU admission by the patient’s attending physician, 2 physiotherapists, and 2 dietitians. Because this study was a pragmatic one, members of different professions used different methods of measurement according to each member’s usual clinical practice. No additional training related to any of the measurements of height in recumbent patients was provided before data collection.

Patients were not repositioned for measurements, and all measurements were obtained by using a nonrigid measuring tape. All personnel who obtained measurements first estimated the patient’s height on the basis of observation. The attending physician then measured from the top of the patient’s head to the plantar surface of the calcaneus (whole body). Dietitians measured forearm length (olecranon tip to tip of ulnar styloid) and then estimated height by using the British Association for Parenteral and Enteral Nutrition normative values, the current clinical practice. Physiotherapists measured height by using both techniques (whole body and forearm length). All measurers had no knowledge of the preadmission standing height and obtained measurements independent of each other.

For the purpose of this study, a difference from zero greater than 2 cm between gold-standard standing height and any other height measurement was considered clinically significant, in line with accurate calculation of body mass index. That is, a difference of more than 2 cm can result in an error in calculating body mass index that will alter the tidal-volume prescription for mechanical ventilation.

**Statistical Power**

The mean difference between standing and supine height estimates in a previous study was 0.73 cm. Power calculations indicated that a sample size of 35 patients would have 80% power to detect a clinically significant difference of 2 cm, with a conservative estimate of 4 cm for the standard deviation.

**Statistical Analysis**

Measurement data were compared with the measurement of standing height obtained by using the gold standard for each patient, and the difference from zero was compared across professions and methods of measurement, with zero indicating no difference. The differences from the gold standard were analyzed by using a linear mixed model. All tests were 2-sided with a significance level of .05.

**Results**

A total of 35 patients consented to be measured in the study, and 17 medical staff, 4 dietitians, and 9 physiotherapists consented to measure patients. No patients were excluded, and none withdrew from the study. The majority of the patients were men (71%), and most of the patients had undergone valve replacement surgery (54%). Demographic and surgical characteristics of the sample are described in Table 1.

All measurements were obtained within 24 hours of ICU admission, and although in most instances the patient remained unconscious and intubated, 6 patients (17%) had become conscious by the time all measurements were completed.

---

**Table 1** Patient demographic and surgical data (n = 35)*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, median (interquartile range), y</td>
<td>65 (60-84)</td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
</tr>
<tr>
<td>≤ 65</td>
<td>18 (51)</td>
</tr>
<tr>
<td>&gt; 65</td>
<td>17 (49)</td>
</tr>
<tr>
<td>Male sex</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25 (71)</td>
</tr>
<tr>
<td>Surgery</td>
<td></td>
</tr>
<tr>
<td>Coronary artery bypass grafting</td>
<td>8 (23)</td>
</tr>
<tr>
<td>Valve replacement</td>
<td>19 (54)</td>
</tr>
<tr>
<td>Combination coronary artery bypass grafting and valve replacement</td>
<td>6 (17)</td>
</tr>
<tr>
<td>Other</td>
<td>2 (6)</td>
</tr>
<tr>
<td>No. of attachments at time of first measurement, median (interquartile range)</td>
<td></td>
</tr>
<tr>
<td>Endotracheal tube</td>
<td>33 (94)</td>
</tr>
<tr>
<td>Central venous catheter</td>
<td>35 (100)</td>
</tr>
<tr>
<td>Arterial catheter</td>
<td>35 (100)</td>
</tr>
<tr>
<td>Balloon pump</td>
<td>3 (9)</td>
</tr>
<tr>
<td>Electrocardiographic leads</td>
<td>35 (100)</td>
</tr>
<tr>
<td>Indwelling catheter</td>
<td>35 (100)</td>
</tr>
<tr>
<td>Pacing wires</td>
<td>12 (34)</td>
</tr>
<tr>
<td>Pulmonary artery sheath</td>
<td>17 (49)</td>
</tr>
<tr>
<td>Femoral catheter</td>
<td>4 (11)</td>
</tr>
</tbody>
</table>

* Data are No. (%) of patients unless indicated otherwise.
Table 2
Mean difference from zero (centimeters), all methods by profession

<table>
<thead>
<tr>
<th>Profession</th>
<th>Estimated mean</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dietitian</td>
<td>2.86</td>
<td>1.46 to 4.31</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Physician</td>
<td>1.95</td>
<td>0.26 to 3.64</td>
<td>.02</td>
</tr>
<tr>
<td>Physiotherapist</td>
<td>0.37</td>
<td>-0.97 to 1.71</td>
<td>.59</td>
</tr>
</tbody>
</table>

Table 3
Difference between each method and standing height measurement (centimeters) by profession

<table>
<thead>
<tr>
<th>Profession</th>
<th>Estimated mean</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physician Observation</td>
<td>-0.14</td>
<td>-1.72 to 1.43</td>
<td>.86</td>
</tr>
<tr>
<td>Physician Whole body, head to toe</td>
<td>1.05</td>
<td>-1.34 to 3.43</td>
<td>.38</td>
</tr>
<tr>
<td>Physiotherapist Observation</td>
<td>-0.17</td>
<td>-1.75 to 1.40</td>
<td>.83</td>
</tr>
<tr>
<td>Physiotherapist Whole body, head to toe</td>
<td>1.43</td>
<td>-0.15 to 3.00</td>
<td>.08</td>
</tr>
<tr>
<td>Physiotherapist Forearm and normative chart</td>
<td>2.54</td>
<td>0.69 to 4.39</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Dietitian Observation</td>
<td>3.23</td>
<td>1.38 to 5.08</td>
<td>.008</td>
</tr>
<tr>
<td>Dietitian Forearm and normative chart</td>
<td>2.54</td>
<td>0.69 to 4.39</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Table 4
Mean difference from zero (centimeters), all methods by profession, age stratified

<table>
<thead>
<tr>
<th>Profession</th>
<th>≤65 (Estimated mean (95% CI))</th>
<th>P</th>
<th>≥65 (Estimated mean (95% CI))</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dietitian</td>
<td>2.35 (0.09 to 4.60)</td>
<td>.04</td>
<td>3.46 (1.79 to 5.13)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Physician</td>
<td>0.43 (-2.16 to 3.02)</td>
<td>.74</td>
<td>3.56 (1.44 to 5.69)</td>
<td>.001</td>
</tr>
<tr>
<td>Physiotherapist</td>
<td>-0.38 (-2.52 to 1.77)</td>
<td>.73</td>
<td>1.16 (-0.36 to 2.68)</td>
<td>.13</td>
</tr>
</tbody>
</table>

Overall the measurements differed significantly between professions (Table 2). Measurements obtained by physiotherapists did not differ significantly from the gold standard (P = .59), whereas those of physicians (P = .02) and dietitians (P < .001) did.

A comparison of the measurement methods for each profession (Table 3) indicated that the difference between the measurements obtained by observation and those obtained by using the gold standard was smallest for physiotherapists (0.14 cm lower, P = .86) but did not differ significantly from either the whole-body measurement or measurements based on the forearm length. For the physicians, the difference between the whole-body method and the gold standard did not differ significantly from zero (1.05 cm higher, P = .38); however, the difference from zero between the observed method and the gold standard was significant (2.61 cm higher, P = .03). Although these differences did not differ significantly from each other, the difference from zero between the observed method and the gold standard did not exceed the difference that is considered clinically significant. Within the dietitians, the differences between measurements based on the length of the forearm and measurements obtained by using the gold standard were significantly different from zero (2.54 cm higher P < .001), as were differences between measurements based on observation and those obtained by using the gold standard (3.23 cm higher, P = .008). Neither of these differences from zero matched the difference that is considered clinically significant.

When patients were stratified by age (≤65 years and >65 years; Table 4), for the younger age group, the differences between the measurements and the gold standard did not differ significantly from zero for the physiotherapists (0.38 cm lower, P = .73) or the physicians (0.43 cm higher, P = .74). However, the corresponding difference for dietitians was significant (2.35 cm higher, P = .04). In addition, when the differences from the gold standard were considered, neither physiotherapists and physicians (P = .42) nor dietitians and physicians (P = .08) differed from each other, but physiotherapists differed from dietitians (P = .001).

Overall in the older group, for physiotherapists, differences between the measurements and the gold standard did not differ significantly from zero (1.16 cm higher, P = .13), whereas differences from zero were significant for physicians (3.56 cm higher, P = .001) and dietitians (3.46 cm higher, P < .001). In addition, both physiotherapists and physicians (P = .02) and physiotherapists and dietitians (P = .005) differed significantly from each other, but physicians did not differ from dietitians (P = .92).

Table 5 indicates which method of measurement was best for each profession when measurements were stratified for age. Physiotherapists had no significant difference between methods for the younger cohort (P = .07). Differences between the measurements obtained by using the gold standard and those obtained by using the other 3 methods were not significant; however, whole-body measurements had the smallest difference (0.49 cm lower). In the older cohort, differences between the 3 methods were not significant (P = .32), and none of the 3 methods produced measurements that differed significantly from measurements obtained by using the gold standard. The whole-body measurements had the smallest difference (0.16 cm).
Physician’s measurements of the younger cohort were equally accurate for the observation method and the whole-body method ($P = .19$). However, measurements obtained by using the whole-body method differed the least from measurements obtained by using the gold standard (0.74 cm lower). In the older cohort, the difference between the observation method and the gold standard was significantly different from zero (4.16 cm; $P = .02$). The difference between the whole-body method and the gold standard was not significantly different from zero ($P = .09$), but the estimated mean difference did exceed the difference that is considered clinically significant (2.94 cm).

For dietitians, in the younger cohort, the differences from zero between measurements obtained by using the gold standard and those obtained by using the other 2 methods were significant, but the measurements obtained by the other methods did not differ from each other ($P = .89$). Even so, the mean difference between the observation method and the gold standard was the closest to zero (2.28 cm). In the older cohort, measurements obtained by using the observation method and by using the forearm-length method differed significantly from measurements obtained by using the gold-standard method. The observation method had a 4.24-cm ($P = .002$) difference from the gold standard, which was not statistically different from the 2.68-cm ($P = .04$) difference between the forearm method and the gold-standard method.

All measurements by any of the caregivers obtained by using any method were within 11.5% of the standing-height measurement (Table 6). Overall, the mean percentage difference from the gold standard was 2.95%; measurements obtained by the physiotherapists had the smallest percentage difference (2.71%) from the gold standard.

### Discussion

The main aim of this study was to compare the accuracy of physicians, physiotherapists, and dietitians in estimating height in recumbent patients by using existing practice methods. We found that physiotherapists were most consistently able to measure recumbent height closest to the gold-standard standing height and with lower standard error for any technique and across both age cohorts. Further, measurements obtained by the physiotherapists had the lowest estimated mean difference in both age groups of patients when the whole-body method was used. These findings are perhaps not surprising. The undergraduate training of physiotherapists includes studies of body-surface anatomy, anthropomorphic measurements, and range of movement. Although physicians receive similar training, they are perhaps less practiced in true objective clinical measurement and arguably more likely to estimate height. Dietitians have limited training in body-surface anatomy and anthropomorphic measurements. Anecdotally, in our ICU dietitians measure height only when no one else has already done so and nutritional requirements must be estimated. Although statistically measurements obtained by dietitians had the largest differences from zero, in a clinical sense, larger measurement errors may be acceptable when used for a nutritional prescription. A difference in height of up to 4 cm corresponds to a difference of approximately 24 cal/d when the Pennsylvania State (Mifflin) 2003 equation, the standard energy calculation in our ICU, is used. This difference would lead to a change in feeding rate of only 1 mL/h in a continuous 2-hour standard feeding regimen.

Overall, in terms of which method of measurement was the most reliable, the whole-body method

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**Table 5**

<table>
<thead>
<tr>
<th>Profession</th>
<th>≤65</th>
<th>≥65</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimated mean (95% CI)</td>
<td>$P$</td>
</tr>
<tr>
<td>Physician</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observation</td>
<td>1.15 (-2.32 to 4.62)</td>
<td>.49</td>
</tr>
<tr>
<td>Whole body, head to toe</td>
<td>-0.74 (-4.21 to 2.74)</td>
<td>.65</td>
</tr>
<tr>
<td>Physiotherapist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observation</td>
<td>-1.75 (-4.27 to 0.77)</td>
<td>.17</td>
</tr>
<tr>
<td>Forearm and head to toe</td>
<td>-0.49 (-3.01 to 2.03)</td>
<td>.70</td>
</tr>
<tr>
<td>Dietitian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observation</td>
<td>1.11 (-1.41 to 3.63)</td>
<td>.38</td>
</tr>
<tr>
<td>Forearm and normative chart</td>
<td>2.28 (-0.461 to 5.02)</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td>2.42 (-0.461 to 5.02)</td>
<td>.08</td>
</tr>
</tbody>
</table>

**Table 6**

<table>
<thead>
<tr>
<th>Profession</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dietitian</td>
<td>140</td>
<td>3.18</td>
<td>2.65</td>
<td>0</td>
<td>11.11</td>
</tr>
<tr>
<td>Physician</td>
<td>66</td>
<td>3.24</td>
<td>2.44</td>
<td>0</td>
<td>9.64</td>
</tr>
<tr>
<td>Physiotherapist</td>
<td>210</td>
<td>2.71</td>
<td>2.17</td>
<td>0</td>
<td>9.88</td>
</tr>
<tr>
<td>Overall</td>
<td>416</td>
<td>2.95</td>
<td>2.39</td>
<td>0</td>
<td>11.11</td>
</tr>
</tbody>
</table>
was better than the observation method for both physiotherapists and physicians. Whether dietitians would also be most accurate when using this method was beyond the scope of the study and could be explored in the future.

The difficulty in measuring any supine patient may be compounded in the ICU by the presence of numerous attachments (eg, ventilator circuits, drains, monitoring cables). Our cohort of patients who had cardiac surgery may not have reflected the general ICU population for predictability of course and length of stay, but the patients had a high number of attachments. The impact of the number of attachments on individual measurers is unknown. Although all the measurers worked in the ICU during the study period, no data were collected about their ICU experience. Perhaps some measurers or professional groups were more comfortable moving and manipulating attachments, and that ease might have influenced both the ability to measure and the accuracy of the measurement.

Despite these attachments, and despite professional differences already alluded to, all measurements were within 11.5% of those obtained by using the gold-standard method, and the overall mean difference from zero was 2.95%. These results reflect greater accuracy by our measurer cohort, particularly physiotherapists, than the accuracy reported elsewhere. Our results are also well within the 20% difference that Coe et al\(^6\) reported would give rise to clinically significant errors.

Whatever the method, the measurement tool may also be important. In a recent Australian study,\(^3\) a rigid 3-m metal measuring tape combined with a head board and a foot board (bookend method) was used. Although it was specifically designed for that study, most likely the device is nonconforming and relies on having the patient lie flat and potentially be repositioned for measurement in order to standardize alignment of body parts and body positioning. We prefer a nonrigid conforming measuring tape used by personnel specifically trained in surface anatomy and measurement.

**Limitations**

All measurers were recruited on the day of measurement as the staff in each profession allocated to look after the patients on that day. Thus, although our results were significant, we had access to only a relatively small number of dietitians in the measurer cohort. The unequal number of individual measurers per specialty may have introduced a bias, whereby one dietitian who was particularly inaccurate in his or her measurements may have unduly influenced the overall accuracy of measurements obtained by dietitians as a group. Conversely, because a larger number of medical staff obtained measurements, estimations of height by this group may have most accurately reflected the accuracy of the population of physicians as a whole.

No data were collected on the number of times individual measurers were asked to measure a patient, potentiating measurement "practice" or "training" whereby informed measurers might improve as the study continued. This potential training effect was minimized by providing no feedback to the measurers about their accuracy after each measurement was obtained.

The ability of nursing staff to measure height was not assessed because measuring height is not a normal clinical practice in our ICU. This factor may limit the extent to which our results can be extrapolated to other units where nurses do measure height.

**Conclusion**

Physiotherapists’ measurements of the supine height of recumbent ICU patients obtained by using a nonrigid measuring tape are more accurate than measurements obtained by physicians and dietitians. This difference may reflect the undergraduate training of physiotherapists in body-surface anatomy, anthropomorphic measurements, and range of movement. However, in the context of clinically meaningful difference, the larger measurement errors in the dietitian group may be acceptable in nutritional prescription.

**ACKNOWLEDGMENTS**

We gratefully acknowledge physiotherapists Steven Cindric (subject recruitment), Natalie Tran, and Rachel Mullins (coordination of data collection). We also thank all multidisciplinary staff who participated as measurers.

**FINANCIAL DISCLOSURES**

None reported.

**REFERENCES**


To purchase electronic or print reprints, contact the American Association of Critical-Care Nurses, 101 Columbia, Aliso Viejo, CA 92656. Phone, (800) 899-1712 or (949) 362-2050 (ext 532); fax, (949) 362-2049; e-mail, reprints@aacn.org.
By Lois Andrews, RN-BC, DNP, CCRN, ACNS-BC, Susan G. Silva, PhD, Susan Kaplan, RN, PhD, and Kathie Zimbro, RN, PhD

Background Use of an evidence-based tool for routine assessment for delirium by bedside nurses in the intensive care unit is recommended. However, little is known about patient outcomes after implementation of such a tool.

Objective To evaluate the implementation and effects of the Confusion Assessment Method for the Intensive Care Unit as a bedside assessment for delirium in a general intensive care unit in a tertiary care hospital.

Methods Charts of patients admitted to the unit during a 3-month period before implementation of the assessment tool and 1 year after implementation were reviewed retrospectively. Patient outcomes were incidence of delirium diagnosis, duration of mechanical ventilation, length of stay in the intensive care unit, and time spent in restraints.

Results The 2 groups of patients did not differ in demographics, clinical characteristics, or predisposing factors. The groups also did not differ significantly in delirium diagnosis, duration of mechanical ventilation, length of stay in the intensive care unit, or time spent in restraints. Barriers to use of the tool included nurses’ lack of confidence in performing the assessment, concerns about use of the tool in patients receiving mechanical ventilation, and lack of interdisciplinary response to findings obtained with the tool.

Conclusions No change in patient outcomes or diagnosis of delirium occurred 1 year after implementation of the Confusion Assessment Method for the Intensive Care Unit. Lessons learned and barriers to adoption and use, however, were identified. (American Journal of Critical Care. 2015;24:48-56)
We examined the effects of implementation of the CAM-ICU as a bedside assessment for delirium completed by ICU nurses at least once a shift (every 12 hours) in a general ICU. Specifically, we addressed the following questions: (1) What are the effects of implementing the CAM-ICU assessment on diagnosis of delirium, duration of mechanical ventilation, ICU length of stay, and time spent in restraints? and (2) What are the barriers to performing this assessment in the clinical setting?

Methods

A 2-group pretest-posttest design was used for this performance improvement project. The project was approved by the appropriate hospital and university review boards, with a waiver for informed consent.

Setting

The project was conducted in Sentara Norfolk General Hospital, Norfolk, Virginia, a 525-bed tertiary care Magnet facility. The 16-bed open general ICU (which received a Silver Beacon Award in August 2013) admits patients to the critical care and trauma teaching services as well as to private intensivist and surgical practices.

Implementation of the CAM-ICU assessment began in 2011 when an interdisciplinary critical care team proposed that bedside assessment for delirium be performed by the ICU nurses. The choice of a tool was delegated to the nursing staff. At that time, a sedation scale and a protocol for daily interruption of sedation were in place. The staff chose the CAM-ICU on the basis of previous exposure to the tool, its support in the literature, and its availability in the electronic record. The hospital converted to use of the Richmond Agitation-Sedation Scale (RASS) at the same time the CAM-ICU was adopted.

Implementing the new delirium screening procedure and sedation scale in the general ICU began in late 2011 and included a 1-hour mandatory education session designed by a multidisciplinary team for the nursing staff. Content included the consequences of delirium, identification of risk factors for delirium, and use of the RASS and the CAM-ICU. Videos demonstrating patient assessments with the CAM-ICU were used. Pocket cards with the RASS and CAM-ICU were distributed to staff as a reference.

Evaluation of initial use of the delirium tool indicated a lack of consistency in performance and documentation. Staff constructed detailed flow sheets with rows for the CAM-ICU results. Additional training procedures incorporated competency assessments, 1-on-1 training, short educational sessions, random checks of accuracy, and compliance reports.

Delirium goes undetected in 72% of cases when routine monitoring is not in place.
Clinical characteristics identified as contributing to the development of delirium\textsuperscript{1,5,10,20-23} were noted as absent or present in the before and after groups. In addition, data on demographics and use of medications during hospitalization were extracted from the charts by using a data collection form.

**Measures**

*Confusion Assessment Method for the Intensive Care Unit.* Ely et al\textsuperscript{11} adapted the Confusion Assessment Method for use in nonverbal ICU patients receiving mechanical ventilation. The validity of the CAM-ICU has been demonstrated in patients admitted to adult medical and coronary ICUs\textsuperscript{17,24}.

*Patient Outcomes.* Patients in both groups were categorized as delirious if their charts contained diagnostic codes for delirium from the International Classification of Diseases, Ninth Revision. Proxy measures for delirium in physicians’ documentation were altered mental status, confusion, decreased mental status, and delirium. For the group assessed after implementation, scores on the CAM-ICU and the RASS were recorded once a shift (once every 12 hours), and patients were classified as delirious if they had at least 1 CAM-ICU score indicative of delirium during the ICU stay. Duration of mechanical ventilation and length of stay in the ICU were calculated on the basis of data in the electronic medical records. Duration of mechanical ventilation was recorded as the length of time a patient received the treatment while in the ICU. Admission and discharge times were used to calculate ICU length of stay for patients who were intubated before ICU arrival or who were still receiving mechanical ventilation when discharged from the ICU. The use of restraints was recorded, and the duration of use was measured in hourly increments.

*Adherence and Fidelity to the Intervention.* The CAM-ICU was to be used at least once per 12-hour shift. Adherence, defined as the percentage of time performed (number of shifts the planned assessment was completed/number of shifts the CAM-ICU should have been completed per the protocol) during the general ICU stay, was recorded. The precision of the CAM-ICU scores obtained by bedside nursing staff was assessed by the clinical nurse specialist and the pharmacist, who obtained paired CAM-ICU scores independently within 1 hour of the nurse. Results were compared by using the \( \kappa \) statistic.

*Barriers to Implementation.* Staff were interviewed via an electronic survey to determine factors that interfered with implementation of and adherence to the CAM-ICU and to identify obstacles to performing the assessment (Table 1).

### Table 1

**Nursing staff questionnaire about the Confusion Assessment Method for the Intensive Care Unit (CAM-ICU)**

<table>
<thead>
<tr>
<th>Question number</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Did you receive education on delirium assessment using the CAM-ICU?</td>
</tr>
<tr>
<td>2</td>
<td>Was this education enough?</td>
</tr>
<tr>
<td>3</td>
<td>What other preparation would help you perform the CAM-ICU?</td>
</tr>
<tr>
<td>4</td>
<td>Do you find it difficult to perform a CAM-ICU on your patient at least every 12 hours?</td>
</tr>
<tr>
<td>5</td>
<td>If you answered yes to question 4, what would make it easier to perform the CAM-ICU every 12 hours?</td>
</tr>
<tr>
<td>6</td>
<td>If you answered no to question 4, what made it easy to adopt this change?</td>
</tr>
<tr>
<td>7</td>
<td>In general, what are your thoughts on including the CAM-ICU in the nursing assessment?</td>
</tr>
</tbody>
</table>

With the RASS and the CAM-ICU on a patient to the clinical nurse specialist by September 15, 2012.

**Sample**

Charts of all patients 18 to 89 years old admitted to the general ICU during the 3 months before (September 15 to December 15, 2011) implementation of the new delirium screening procedure and sedation scale and a 3-month period after implementation (September 15 to December 15, 2012) were considered for inclusion in the sample. Patients 90 years or older were excluded because of consent constraints imposed by the institutional review board. The same time of year for the before period and the after period was chosen to decrease seasonal variance between the samples. Exclusion criteria were based on published studies\textsuperscript{3,8,10,17-20} Patients were excluded if they transferred in from another hospital or from another ICU during the current admission, remained in the ICU less than 24 hours, died before transfer out of the ICU, remained in a persistent comatose state, had a history of psychiatric or neurologic disease, were unable to communicate, or had a diagnosis of alcohol withdrawal syndrome or alcohol-induced delirium.

**Data Collection**

Charts of patients in the before and after groups were reviewed retrospectively. Reports compiled by the information technology department isolated data on patients admitted to the general ICU during the before and after periods and eliminated patients on the basis of the exclusion criteria. The remaining charts were reviewed manually.
Data Analysis

Descriptive statistics were used to summarize the demographic and clinical characteristics of the patients in the 2 groups. Nondirectional tests with the significance level set at .05 were conducted by using SAS 9.3 software (SAS Institute Inc). Independent group t tests, for continuous measures and χ² tests for binary outcomes (alternatively, the Fisher exact test) were used to test for differences between the 2 groups in demographics, clinical characteristics, and outcomes.

Results

A total of 640 patients were admitted to the general ICU during the observation periods, 229 of these remained after the exclusion criteria were applied (see Figure). The exclusion criteria eliminated 64% of the eligible charts, decreasing the power of the study. Specifically, 22.8% of records were eliminated on the basis of 1 or more of the mental health diagnoses in the exclusion criteria. The 2 groups of patients (before and after implementation) did not differ significantly in demographic and clinical characteristics (Table 2) or the presence of predisposing factors (Table 3).

Analysis of Patient Outcomes

The primary patient outcomes were the diagnosis of delirium, duration of mechanical ventilation, ICU length of stay, and time in restraints. No patients were identified as delirious on the basis of the codes for delirium in the International Classification of Diseases, Ninth Revision. When the proxy terms for delirium were used, 18 patients (14.1%) in the before-implementation group and 11 (10.9%) in the after-implementation group were classified as delirious; however, the difference between the 2 groups was not significant (χ² = 0.5; df = 1; P = .47). After implementation of the procedure, 10 of the 101 patients (9.9%) had delirium according to scores
on the CAM-ICU. Among these 10 patients, 4 (40%) also had altered mental status noted by a physician.

Table 4 presents the ICU length of stay, duration of mechanical ventilation, and time in restraints for patients in 2 groups. A natural logarithm transformation procedure was used to normalize the skewed data distribution for these outcomes. The 2 groups did not differ significantly in mean ICU length of stay ($t = 0.27; df = 227; P = .79$), duration of mechanical ventilation ($t = -0.06; df = 74; P = .96$), or time in restraints (for the 54 patients who were restrained; $t = 0.24; df = 52; P = .81$).

After implementation, outcomes for the subgroup of patients who did not have delirium according to scores on the CAM-ICU were compared with the outcomes of the subgroup whose scores indicated delirium. Statistical significance was not determined because of the small number of patients (n = 10) in the group with CAM-ICU scores indicative of delirium.
Adherence and Fidelity to the Intervention

Nurses used the CAM-ICU to screen for delirium 76.1% of the time expected (at least once per shift) during the 3-month period. RASS scores were recorded 83% of the time. Of the total RASS scores recorded, 85.3% were -1 to +1, and 5.4% were less than -3 (comatose). Paired observations were performed on 4 randomly chosen patients by the clinical nurse specialist and the pharmacist every other week during the 3-month period, yielding a sample of 21 (3 patients chosen were out of the unit during one of the observations). Precision of interobserver agreement was measured by calculating the κ statistic. The results indicated substantial agreement between the ICU nurses and the clinical nurse specialist (κ = 0.86), the ICU nurses and the pharmacist (κ = 0.71), and clinical nurse specialist and the pharmacist (κ = 0.78).

Barriers to the Intervention

An electronic survey on preparation to perform the assessment and implementation of the CAM-ICU into practice (Table 1) was sent to the staff (n = 42), and 20 (48%) responded. Among those who responded, 90% reported that performing the assessment every 12 hours was not difficult. Pooled reasons staff gave for easy adoption of the change included the education provided, the location of the assessment within the charting flow sheet, and the availability of the note cards. Identified barriers to adopting the CAM-ICU included lack of confidence in performing the assessment, difficulty of use in patients receiving mechanical ventilation, and lack of response to the findings.

Discussion

In this performance improvement project, we sought to describe and summarize the effects that implementing the CAM-ICU for detection of delirium by bedside ICU nurses had on patient outcomes in a sample of patients in a general ICU. We found no statistically significant differences before and after implementation.

For this project, we used a retrospective chart review with strict exclusion criteria developed on the basis of confounding diagnoses from other studies. Many of these studies were prospective, allowing assessment of the extent of mental health disorders and the ability of the patient to cooperate with assessment. Delirium is more common in patients with a history of mental disorders than in the general population, and elimination of the subgroup reduced the overall incidence of delirium in our study. In future investigations, patients with mental health disorders should be identified as a subgroup rather than eliminated.

In our sample, the incidence of delirium identified by physicians was low (10.9% before implementation of the CAM-ICU and 14.1% after implementation) compared with the incidence rates in recent studies (22%-38.8%). Using a patient’s diagnoses or problem list without a specific tool to detect delirium is a method that leads to underestimation of the presence of delirium. The lower than expected rate of delirium detected in our patients after implementation of the CAM-ICU may reflect the lack of multidisciplinary education and physicians’ adoption of delirium screening and assessment. Using the proxy terms as markers for delirium introduced inaccuracy, because these terms can be related to a pathological condition. However, 40% of the patients in the group after implementation of the CAM-ICU who had been identified as having altered mental status had CAM-ICU scores indicative of delirium. Conversely, 60% of patients who had CAM-ICU scores indicative of delirium had no mention of delirium in the physicians’ summaries. Whether these patients were not delirious, did not have indications of delirium during observation by a physician, or were delirious but the condition was not noticed by the physician is undetermined.

The incidence of delirium identified by the physicians was low compared with other recent studies.

### Table 4

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Before implementation</th>
<th>After implementation</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive care unit length of stay</td>
<td>4.2 (0.7) (n = 128)</td>
<td>4.2 (0.7) (n = 101)</td>
<td>.79</td>
</tr>
<tr>
<td>Duration of mechanical ventilation</td>
<td>3.4 (1.2) (n = 41)</td>
<td>3.4 (1.2) (n = 35)</td>
<td>.96</td>
</tr>
<tr>
<td>Total time in restraints</td>
<td>3.5 (1.3) (n = 30)</td>
<td>3.4 (1.1) (n = 24)</td>
<td>.81</td>
</tr>
</tbody>
</table>

a All values are mean (SD) of the natural logarithm transformed applied to all 3 outcomes.

b Determined by t test.
The compliance rate was low compared with the findings of previous studies, in which rates were greater than 80% or greater than 90%. Several factors may have contributed to our lower rate. We extracted compliance data from the charts retrospectively; the data were not reported or trends determined during the 3-month study period after implementation of the CAM-ICU. In the study by Scott et al, tracking and displaying performance during the adoption phase produced steady improvement in compliance rates. Additionally, untrained temporary staff in our ICU (nurses from other ICUs or from the resource pool) may have affected the compliance rate.

Implementing change in a unit is not a quick or easy task. The CAM-ICU was introduced in our unit at the end of 2011, with modifications and reeducation occurring during the 12 months between the before and after periods. Despite continued refinement of the process and support for the staff, the change apparently was not adopted universally. Outcomes will not change until a process has become part of the routine in the unit.

The ICU staff received ongoing training and support to perform the assessment accurately. Accuracy was evaluated, but the evaluation was random and included a low percentage of the staff. Real-time and ongoing chart reviews and continued surveillance by on-shift experts would increase the accuracy and adoption of the CAM-ICU. Staff nurses who had consultations with the clinical nurse specialist and other experts were able to validate assessments and clear up misconceptions. Consultations did not include all staff nurses regularly. Despite the low number of patients in the sample after implementation of the CAM-ICU, those who had scores indicative of delirium had characteristics of delirium more like those reported in the literature than did the patients whose scores were not indicative of delirium. Compared with patients who did not have delirium, patients who did had a longer mean length of stay in the ICU (137.3 hours vs 80.8 hours), longer duration of mechanical ventilation (159.6 hours vs 46.9 hours), greater usage of restraints (80% vs 24.8%), and longer duration of restraints (150.8 hours vs 37.9 hours).

Among the nurses who responded to the questionnaire, most (85%) thought that performing the CAM-ICU every 12 hours was not difficult. However, because the survey was voluntary, nurses who were not comfortable with the assessment may have chosen not to participate, as reflected in the low response rate (48%; N = 42). Although all staff nurses were required to perform an assessment with the clinical nurse specialist, some expressed concern over performing the assessment correctly. McNicoll et al found greater sensitivity with the CAM-ICU in verbal patients than in nonverbal patients, and concern has been expressed about the influence of sedation on CAM-ICU scoring. The nurses in our study reported they had difficulty using the tool with intubated patients, possibly explaining the unexpectedly high number of patients (60%) documented as “unable to assess” with the CAM-ICU whose RASS scores were greater than or equal to -3. Lack of success in identifying the hypoactive form of delirium in patients in our sample might have been a factor; 80% of the patients with CAM-ICU scores indicative of delirium were in restraints.

Implications for Future Practice

A prospective study design is superior to a retrospective design when a new process such as the CAM-ICU is implemented. Patients can be evaluated accurately by using inclusion and exclusion criteria. With prospective enrollment of patients, exclusion criteria could be evaluated accurately, and compliance with the scoring protocol could be tracked. Accuracy of scoring could also be assessed. Independent evaluations based on the CAM-ICU scores or criteria of the Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition) can validate each bedside evaluation. The accuracy of assessments can be measured and questionable results verified by using repeat evaluations by experts. Finally, compliance rates can be followed and reported to influence improvement. Using the electronic medical record to produce reports makes the process more efficient.

Nurses’ ability to perform the assessment accurately and consistently is critical. Continuing educational opportunities must be available. Expert coaching with real patients and scenarios highlighting unusual situations can help staff incorporate the new skill. Ongoing training must be readily available for staff new to the unit. Using a computerized learning system with follow-up demonstrations provides ongoing education efficiently. Universal adoption of the CAM-ICU throughout the facility decreases variation, and partnering with other unit councils to provide consistency between units is also helpful.

A multidisciplinary approach should be used for complex problems such as delirium. In many patients, delirium is an early indication of a disease-induced...
condition requiring medical treatment. Delirium must be seen and recognized by a patient’s physician. Ensuring that nurses’ CAM-ICU scores are available to physicians is vital, and the assessment should be included in the bedside rounds for all patients. The lack of a treatment algorithm for patients with CAM-ICU scores indicative of delirium may have contributed to the lack of change in the outcomes after implementation of the CAM-ICU. Not incorporating CAM-ICU results in a patient’s treatment plan was a barrier in both our study and other studies.14,15,21,27,29 In our study, initial education on delirium was conducted solely with the nursing staff. In other projects, a multidisciplinary approach was used.28,29 The CAM-ICU score documented by the nurses in our study did not become available on physicians’ reports until shortly before the observation period. The open general ICU environment, with multiple specialties and residents providing care, does not promote consistency in physicians’ practices. Information on the CAM-ICU and pocket cards have been incorporated only into the monthly orientation of residents in internal medicine. The adoption of delirium screening by physicians may be lagging behind that of the nursing staff and warrants further study; however, assessment of physicians’ practices was not part of our investigation.

Finally, many of the iatrogenic (administration of medications, sedation level) or environmental (noise, lighting, mobility) causes of delirium are influenced by nursing care. Developing nursing bundles or protocols for recognizing and treating the precipitating factors of delirium should be a priority for unit practice councils. Through application of evidence into practice, the incidence and duration of delirium can be reduced and better patient outcomes realized.

Conclusion

Delirium is a serious consequence of ICU care that increases morbidity and mortality in critical care patients. The CAM-ICU is a valid and reliable tool for detecting the presence of delirium when used by specially trained research nurses. Effective performance of the CAM-ICU by bedside staff requires a multidisciplinary plan with continued reinforcement and education.

FINANCIAL DISCLOSURES

None reported.

REFERENCES


SEE ALSO

For more about delirium monitoring and management, visit the Critical Care Nurse Web site, www.ccnonline.org, and read the article by Balas et al, “Management of Delirium in Critically Ill Older Adults” (August 2012).


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Notice to CNE enrollees:
A closed-book, multiple-choice examination following this article tests your understanding of the following objectives:
1. Describe the risks and benefits of head-of-bed elevation.
2. Identify the findings at 30° and 45° head-of-bed elevation.
3. Discuss the early outcomes regarding head-of-bed elevation.

To read this article and take the CNE test online, visit www.ajcconline.org and click “CNE Articles in This Issue.” No CNE test fee for AACN members.

Background  Guidelines recommending head of bed (HOB) elevation greater than 30° to prevent ventilator-associated pneumonia conflict with guidelines to prevent pressure ulcers, which recommend HOB elevation less than 30°.

Objectives  To examine the feasibility of 45° HOB elevation and describe and compare the occurrence of reflux, aspiration, and pressure ulcer development at 30° and 45° HOB elevation.

Methods  A randomized 2-day crossover trial was conducted. HOB angle was measured every 30 seconds. Oral and tracheal secretions were analyzed for pepsin presence. Skin was assessed for pressure ulcers. Wilcoxon signed rank tests and Kendall τ correlations were conducted.

Results  Fifteen patients were enrolled; 11 completed both days. Patients were maintained at 30° (mean, 30°) for 96% of minutes and at 45° (mean, 39°) for 77% of minutes. No patients showed signs of pressure ulcers. A total of 188 oral secretions were obtained, 82 (44%) were pepsin-positive; 174 tracheal secretions were obtained, 108 (62%) were pepsin-positive. The median percentage of pepsin-positive oral secretions was not significantly higher ($P = .11$) at 30° elevation (54%) than at 45° elevation (20%). The median percentage of pepsin-positive tracheal secretions was not significantly higher ($P = .37$) at 30° elevation (71%) than 45° elevation (67%). Deeper sedation correlated with increased reflux ($P = .03$).

Conclusions  HOB elevation greater than 30° is feasible and preferred to 30° for reducing oral secretion volume, reflux, and aspiration without pressure ulcer development in gastric-fed patients receiving mechanical ventilation. More deeply sedated patients may benefit from higher HOB elevations.

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Positioning of gastric-fed patients receiving mechanical ventilation is an important nursing intervention to decrease gastroesophageal reflux, aspiration, and ventilator-associated pneumonia. In supine patients, the esophagus is positioned horizontally. With 45° head-of-bed (HOB) elevation, the esophagus is above horizontal and reflux of gastric contents is counterbalanced by gravity. To reduce the risk of aspiration, many organizations’ guidelines recommend 30° to 45° HOB elevation for patients receiving mechanical ventilation. The guidelines are based on several studies that indicated that aspiration or rates of ventilator-associated pneumonia were lower when HOB elevation was at or near 45° compared with having the patient supine or the HOB elevated less than 30°. However, several studies demonstrated that patients are usually maintained at HOB elevations less than 30°. Rose et al stated that maintaining patients at 45° HOB elevation may not be clinically feasible.

Risk of pressure ulcer development is considered higher with HOB elevation greater than 30° because of the increased load on pressure points when patients are in semirecumbent or lateral positions. Guidelines for preventing pressure ulcers recommend HOB elevation of 30° or less. Based on these conflicting guidelines and difficulty maintaining higher HOB elevations, a study was needed to compare the outcomes of reflux, aspiration, and pressure ulcers simultaneously. The objectives of this study were (1) to determine the feasibility of achieving an HOB angle of at least 30°, (2) to describe and compare the occurrence of reflux (pepsin-positive oral secretions), aspiration (pepsin-positive tracheal secretions), and pressure ulcer development (per National Pressure Ulcer Advisory Panel guidelines) at HOB elevations of 30° and 45°, (3) to determine the association between lowered HOB and reflux, and (4) to determine the association between patients’ characteristics and reflux.

Methods
A 2-day crossover trial was conducted with random assignment to HOB elevation sequences. The HOB was elevated at 30° for 12 hours on day 1 and at 45° for 12 hours on day 2 or the HOB was elevated at 45° on day 1 and 30° on day 2. A 12-hour night-time washout period allowed elimination of the effects of the first day’s HOB elevation. The nurse positioned the patient per clinical needs and the patient’s preference during the washout period. HOB elevation at 30° was considered the standard of care (control). The experimental intervention was 45° HOB elevation. The hospital’s institutional review board approved the study, and informed consent was obtained from surrogates.

The research nurse documented when the HOB elevation differed from the assigned angle because of the patient’s request or because clinicians had lowered the HOB. Management of the ventilator and extubation were performed by the multidisciplinary team in the intensive care unit (ICU).

Setting and Sample
Patients were recruited from a medical and surgical ICU of a large Midwestern university-affiliated hospital. A screening filter identified patients with tube feeding orders in the electronic medical record. Major inclusion criteria were (1) confirmed gastric location of feeding tube, (2) ventilated per endotracheal tube, (3) at least 18 years of age, (4) approval to randomize patient to 45°, and (5) anticipated mechanical ventilation and tube feeding duration of 48 hours. Exclusion criteria are listed in the Figure.

About the Authors
Marilyn Schallom is a clinical nurse specialist/research scientist for the Department of Research for Patient Care Services, Barnes-Jewish Hospital, St Louis, Missouri. Betsy Dykeman is a nurse educator in the surgical intensive care unit at Barnes-Jewish Hospital. Norma Metheny is the Dorothy A. Votsmier Endowed Chair in Nursing at St Louis University School of Nursing, St Louis, Missouri. John Kirby is an associate professor at Washington University Medical School and medical director of the wound healing program at Barnes-Jewish Hospital. Janet Pierce is the Christine A. Hartley Endowed Professor of Nursing at the University of Kansas School of Nursing, Kansas City.

Corresponding author: Marilyn Schallom, Barnes-Jewish Hospital, 4901 Forest Park Avenue, 7th Floor, Mail Stop 90-75-594, St Louis, MO 63108 (e-mail: mes4143@bjc.org).
Device was moved throughout the oral cavity until no further secretions were obtained. No saline was used to rinse the suction device. Tracheal secretions were obtained via the endotracheal tube with an inline suction catheter (Ballard Medical) as the patient’s condition warranted, typically every 2 to 3 hours. No saline was instilled into the endotracheal tube. Saline was used to rinse tracheal secretions into the sputum trap.

A Western blot immunologic analysis was used to measure pepsin in secretions as described elsewhere. Results were interpreted by a biochemist blinded to HOB assignment. The assay was interpreted as positive if pepsin was detected in a concentration of 1.5 μg/mL or higher. The extent of reflux and aspiration were computed as the percentage of pepsin-positive oral and tracheal secretions, respectively.

Skin was assessed by the principal investigator at pressure points (sacrum/coccyx, buttocks, and bilateral trochanters) for skin redness, discoloration area compared with surrounding skin color, and

**Data Collection and Procedures**

Before study recruitment, nurses received education on the study and on operation of the HOB gauge. All data were collected by 1 of 2 nurses (principal investigator or ICU research nurse). An electronic HOB gauge (Nextronics Patient Position Monitoring System) placed on the undersurface of the bed frame recorded HOB angle every 30 seconds, with a range from -20° to +90°. A second device placed near the recording device also had a digital display component placed on the side rail of the bed. The HOB angle in degrees was displayed when a button on the digital display was pushed. Nurses were instructed to use the display when repositioning patients. The research nurse assisted with repositioning of patients. A sign with HOB assignment was suspended above the patient’s bed. The signs were removed during the night. At the end of the 36 hours, HOB data were downloaded.

Oral secretions were obtained hourly or when of sufficient volume to clear the Argyle Rigid Yankauer (Kendall, Covidien) suction device. The Yankauer device was moved throughout the oral cavity until no further secretions were obtained. No saline was used to rinse the suction device. Tracheal secretions were obtained via the endotracheal tube with an inline suction catheter (Ballard Medical) as the patient’s condition warranted, typically every 2 to 3 hours. No saline was instilled into the endotracheal tube. Saline was used to rinse tracheal secretions into the sputum trap.

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Skin was assessed by the principal investigator at pressure points (sacrum/coccyx, buttocks, and bilateral trochanters) for skin redness, discoloration area compared with surrounding skin color, and
other assessment parameters per the staging criteria of the National Pressure Ulcer Advisory Panel.22 Each time a patient was repositioned, the pressure area relieved from the dependent position was examined. Patients’ charts were reviewed 48 hours after study completion to document pressure ulcers. Study variables are summarized in Table 1.

### Analysis

HOB data were downloaded to Excel (Microsoft Corporation). Data were entered for analysis into SPSS 18 (IBM Corporation). Nonparametric statistical tests were used because of the small sample size. Median differences were examined with Wilcoxon signed rank tests. A 2 x 12 (condition x hour) repeated-measures Friedman test was used to analyze changes over time on number of minutes lowered and mean HOB angle when lowered. Kendall τ correlations were used for association analyses.

### Results

A total of 143 patients with gastric tube feeding orders were screened for a final convenience sample of 17 patients (see Figure). Two patients who were extubated before enrollment were not randomized. Eleven patients completed the 36-hour data collection period. Four patients were extubated early and had partial data included in the analysis.

### Characteristics of Patients

Patients’ characteristics and the interventions used are shown in Table 2. No patient received prokinetic agents. Three patients were overweight according to their body mass index (BMI, calculated as weight in kilograms divided by height in meters squared; overweight, 25-29.9), 7 patients were obese (BMI, 30-39.9), and 2 patients were obese class III (BMI > 40).26 A total of 103 gastric residual volume (GRV) measurements were obtained and were less than 100 mL for 82% of measurements. Eight GRVs were 250 mL or greater. BMI, GRV, and score on the Acute Physiology and Chronic Health Evaluation (APACHE) II showed no significant relationships to the percentage of pepsin-positive oral secretions. A significant negative correlation was observed between scores on the Richmond Agitation-Sedation Scale (RASS) and reflux ($\tau = -0.429, P = .03$). As sedation deepened (higher negative RASS score), the percentage of pepsin-positive oral secretions increased.

### Feasibility of HOB $\geq 30^\circ$

HOB angle within 2° of the assigned elevation was considered achievement of the assigned HOB elevation because of potential variation in the angles reported by the measuring and display device. Minutes lowered, HOB angle when lowered, and overall mean HOB angle were all significantly different between HOB assignments (Table 3). Mean HOB during the night was 33.4°. The HOB angles were lowered 66 times during 30° hours and 76 times during 45° hours. Patients were placed in Trendelenburg position on 13 occasions, 11 for repositioning, once for placement of a central venous catheter, and once for removal of a central venous catheter. Minutes lowered and mean HOB angle when lowered were not significantly different over time for either 30° or 45° hours. Lowering the HOB to reposition a patient (moving toward HOB and turning) most often took 0.5 to 2 minutes and sometimes took up to 5 minutes. Reasons and frequency of lowering HOB at each assignment by clinicians, other than for repositioning, are outlined in Table 4.

No patients requested the HOB be lowered while the HOB was elevated at 30°. Two patients requested the HOB be raised higher for more comfortable breathing. Three patients requested the HOB be lowered from the 45° assignment for a combined total of 1230 minutes. One patient slid down in bed when the HOB was raised to 45° for a total of 240 minutes.

### HOB angles were lowered

- 66 times during 30° hours and
- 76 times during 45° hours.

---

**Table 1**

<table>
<thead>
<tr>
<th>Type of variable</th>
<th>Method of measurement</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent</td>
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<td></td>
</tr>
<tr>
<td>Head-of-bed elevation</td>
<td>Nextronics patient position monitoring system</td>
<td>Every 30 sec</td>
</tr>
<tr>
<td>Dependent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflux</td>
<td>Pepsin in oral secretions</td>
<td>Every 1-2 h (8 AM-8 PM)</td>
</tr>
<tr>
<td>Aspiration</td>
<td>Pepsin in tracheal secretions</td>
<td>Every 2-3 h (8 AM-8 PM)</td>
</tr>
<tr>
<td>Pressure ulcers</td>
<td>Observation of pressure points</td>
<td>8 AM and 8 PM and with reposition</td>
</tr>
</tbody>
</table>

**Predictor**

- Body mass index
- Gastric residual volume
- Level of sedation
- APACHE II score
- Braden Scale25

<table>
<thead>
<tr>
<th>Type of variable</th>
<th>Method of measurement</th>
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<td>Time of admission</td>
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<tr>
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<td>Syringe aspiration</td>
<td>Every 4 h (8-12-4-8)</td>
</tr>
<tr>
<td></td>
<td>Medical record</td>
<td>Every 4 h (8-12-4-8)</td>
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<tr>
<td></td>
<td>Medical record</td>
<td>Admission to intensive care unit</td>
</tr>
<tr>
<td></td>
<td>Medical record</td>
<td>8 AM</td>
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</tbody>
</table>

Abbreviation: APACHE, Acute Physiology and Chronic Health Evaluation.
patients had either a pepsin-positive oral \((n = 5)\) or tracheal secretion \((n = 7)\). When both specimens were available, 3 were both pepsin-positive (reflux and aspiration); 1 occasion resulted in a pepsin-positive \((\text{mean arterial pressure} < 60 \text{ mm Hg})\) and required initiation of vasopressor medications. Both patients experienced hypotension during 30º hours and were maintained near 30º with titration and discontinuation of the vasopressor infusion.

**Reflux and Aspiration Occurrence**

Initially, obtaining oropharyngeal secretions was planned. Low sedation scores per the RASS led to concern for elicitation of the gag reflex and induction of reflux. Therefore, secretions from the oral cavity were suctioned. Overall 44% of oral and 62% of tracheal secretions were positive for pepsin. Secretion results at each HOB assignment are detailed in Table 5.

**Pressure Ulcer Development**

All patients were identified as at risk for pressure ulcer development. 25 No patients had a pressure ulcer develop. All patients were on low-air-loss pressure-relieving mattresses (Hill-Rom Corporation). Use of pressure-relieving mattresses and turning patients every 2 hours is the standard of care for both ICUs. Each day resulted in 12 opportunities for repositioning. The total number of turn opportunities was derived from the number of patients with data collected at the start of each hour. Patients were turned on 154 of the 310 turn opportunities, demonstrating every 2-hour repositioning. Patients were positioned on their right side for 123 observations (36%), left side for 96 observations (28%), and back for 120 observations (36%).

**HOB Angle and Reflux**

Minutes that the HOB was lowered, the mean angle when lowered, and the overall mean angle were correlated with the percentage of pepsin-positive oral secretions for each HOB assignment. Kendall \(\tau\) correlations were not significant for minutes lowered at each HOB assignment \((P = .46 \text{ at } 30^\circ \text{ and } P = .67 \text{ at } 45^\circ)\). Correlations were also not significant for mean HOB when lowered at each HOB assignment \((P = .67 \text{ at } 30^\circ \text{ and } P = .96 \text{ at } 45^\circ)\). The overall mean HOB angle and the percentage of pepsin-positive oral secretions for each HOB assignment demonstrated a significant negative correlation \((\tau = -0.536, P = .008 \text{ at } 30^\circ \text{ and } \tau = -0.433, P = .03 \text{ at } 45^\circ)\).

**Trendelenburg Use**

The data were reviewed to determine pepsin results after use of the Trendelenburg position \((\text{HOB} < 0^\circ)\). On 4 occasions, patients had no secretions available the hour after Trendelenburg positioning. For 9 uses of the Trendelenburg position,

<table>
<thead>
<tr>
<th>Table 2: Characteristics of participants and interventions</th>
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<tr>
<td><strong>Characteristic</strong></td>
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<tr>
<td><strong>Age, y</strong></td>
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<td><strong>Sex</strong></td>
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<td>Female</td>
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<tr>
<td><strong>Race:</strong></td>
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<tr>
<td>Medical</td>
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<td><strong>Reason for admission</strong></td>
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<tr>
<td>Surgery</td>
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<tr>
<td>Sepsis</td>
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<tr>
<td>Respiratory failure</td>
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<tr>
<td>Liver failure</td>
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<tr>
<td><strong>Body mass index(^a)</strong></td>
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<tr>
<td><strong>APACHE II score</strong></td>
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<tr>
<td><strong>Score on Braden Scale(^b)</strong></td>
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<tr>
<td><strong>Gastric residual volume, mL</strong></td>
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<tr>
<td><strong>RASS score</strong></td>
</tr>
<tr>
<td><strong>Type of bed surface</strong></td>
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<tr>
<td>Envision</td>
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<tr>
<td>Sport</td>
</tr>
<tr>
<td>Total care bariatric</td>
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<tr>
<td>Synergy</td>
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<tr>
<td><strong>Feeding tube type</strong></td>
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<tr>
<td>Large-bore Salem sump</td>
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<td>Small-bore feeding tube</td>
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<td>Bolus every 4 hours</td>
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<td>10F</td>
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<td>12F</td>
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<tr>
<td><strong>Stress ulcer prophylaxis</strong></td>
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<tr>
<td>Esomeprazole intravenous</td>
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<tr>
<td>Esomeprazole per feeding tube</td>
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<tr>
<td>Famotidine per feeding tube</td>
</tr>
</tbody>
</table>

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; RASS, Richmond Agitation and Sedation Scale.
\(^a\) Calculated as weight in kilograms divided by height in meters squared.
oral secretion and a pepsin-negative tracheal secretion (reflux, no aspiration); 2 instances resulted in pepsin-negative oral secretions and pepsin-positive tracheal secretions (aspiration without detected reflux). The results were examined for conversion from negative to positive after use of the Trendelenburg position. Specimens were not available at the start of the hour for 5 uses of the Trendelenburg position. On 5 occasions, a negative specimen converted to a positive specimen after the Trendelenburg position was used. On 3 occasions, specimens were positive before use of the Trendelenburg position and remained positive afterward.

**Discussion**

Previous research demonstrated the difficulty with obtaining an HOB elevation of 30° to 45°. This study demonstrated that patients can maintain an HOB elevation of at least 30°. Maintenance at the assigned HOB elevation was achieved with the assistance of signs, the nurse researcher, and the digital display of the HOB angle. However, mean nighttime HOB elevation was greater than 30° without reminders. The gauge with HOB digital display remained on the bed rail. Beds with incorporated accurate digital measurement readings could provide a method to assist with HOB elevation of 30° or greater. Rose et al reported that a bed measurement device initially improved HOB elevation to 45°. However, the device did not sustain HOB elevation at 45° through a 6-month period. Maintenance of the HOB at 30° was sustained throughout the 6 months.

In a survey, ICU nurses identified the probability of the patient sliding down in the bed as the primary concern with HOB at 45°. In the current study, only 1 patient had problems with sliding at 45°. Helman et al also cited patients' discomfort at 45°. Three patients requested that the HOB elevation be decreased to less than 45° for comfort, but each patient tolerated HOB elevation higher than 30°. The other 2 reasons cited in the survey included concerns over skin breakdown and hemodynamic monitoring. No patients had any alteration in skin integrity. Turning patients regularly to prevent pressure ulcers has long been recommended. Pressure-relieving mattresses can prevent pressure ulcers in ICU patients. Despite the concern for pressure ulcer risk with HOB elevation greater than 30°, the current study demonstrated the safety of HOB elevation greater than 30° for 12 to 24 hours with pressure ulcer prevention measures.

In a descriptive study of cardiothoracic ICU patients, Ballew et al reported that use of vasoressor medications and a mean blood pressure of 64 mm Hg were the strongest factors associated with a mean HOB angle less than 20°. Vasopressor use

---

### Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD), median</th>
<th>30° assignment</th>
<th>45° assignment</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Minutes head of bed lowered</td>
<td>24 (21.9), 20.5</td>
<td>149.1 (199.5), 40</td>
<td>.04</td>
<td></td>
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<tr>
<td>Mean angle of head of bed when lowered, degrees</td>
<td>8.2 (3.4), 8.3</td>
<td>19.4 (2.6), 14.9</td>
<td>.008</td>
<td></td>
</tr>
<tr>
<td>Overall mean angle (includes measurements when lowered), degrees</td>
<td>30.2 (4.8), 28.7</td>
<td>38.6 (3.6), 39.2</td>
<td>.001</td>
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### Table 4

<table>
<thead>
<tr>
<th>Variable</th>
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<tbody>
<tr>
<td>Personal care</td>
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<tr>
<td>Bath with full linen change</td>
<td>7</td>
</tr>
<tr>
<td>Cleaning after stool incontinence</td>
<td>3</td>
</tr>
<tr>
<td>Cleaning and fecal containment device placement</td>
<td>0</td>
</tr>
<tr>
<td>Dressing change</td>
<td>1</td>
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<tr>
<td>Straight catheterization</td>
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</tr>
<tr>
<td>Bedside procedures</td>
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<tr>
<td>Bronchoscopy</td>
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<tr>
<td>Ultrasound</td>
<td>0</td>
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<tr>
<td>Radiograph</td>
<td>1</td>
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<tr>
<td>Central venous catheter placement</td>
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<tr>
<td>Central venous catheter removal</td>
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<tr>
<td>Clinician decision</td>
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<tr>
<td>Atrial fibrillation bedside cardioversion</td>
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<tr>
<td>Bedside dialysis</td>
<td>0</td>
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<tr>
<td>Travel to radiology for computed tomography</td>
<td>3</td>
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<tr>
<td>Total frequency</td>
<td>18</td>
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</table>

### Table 5

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD), median</th>
<th>30° assignment</th>
<th>45° assignment</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pepsin-positive oral secretions, %</td>
<td>48.4 (31.3), 54</td>
<td>32.3 (33.2), 20</td>
<td>.11</td>
<td></td>
</tr>
<tr>
<td>Pepsin-positive tracheal secretions, %</td>
<td>69.4 (33.8), 71</td>
<td>62.5 (34.5), 67</td>
<td>.37</td>
<td></td>
</tr>
<tr>
<td>No. of oral secretions obtained</td>
<td>8.5 (3.6), 9.5</td>
<td>5.7 (3.2), 5</td>
<td>.04</td>
<td></td>
</tr>
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</table>
In this study provides initial evidence that elevation at 30° can be maintained even while patients require vasopressor medication support. Further investigation is needed.

No previous studies have examined intermittently lowering the head of the bed or use of the Trendelenburg position and gastric reflux. The findings suggest that overall mean HOB angle is more important in preventing reflux than intermittently lowering HOB. A bariatric repositioning algorithm describes use of the Trendelenburg position when pulling the patient up in bed,35 which was the primary reason for Trendelenburg positioning that we observed. Use of the Trendelenburg position appears to lead to reflux and aspiration in gastric-fed patients. These initial results warrant further investigation of use of the Trendelenburg position.

Both reflux and aspiration occurred frequently. The lower percentage of pepsin-positive oral and tracheal secretions during the 45° hours is consistent with lower aspiration and pneumonia rates at higher HOB elevations compared with rates in supine patients.43-45 A larger sample size in the future may allow a significant difference to be detected.

One explanation for the high percentage of reflux and aspiration observed is the frequency with which secretions were obtained. In an animal study46 with forced aspiration, pepsin was detected for up to 6 hours at decreasing levels. Researchers in future studies should measure the concentration of pepsin in micrograms, not merely the presence of pepsin in order to describe new reflux and aspiration events.

The correlation of BMI with reflux was not significant. Patients with morbid obesity had transient relaxations of the lower esophageal sphincter at a rate similar to patients with known gastroesophageal reflux disease.47 Patients were expected to have a higher percentage of pepsin-positive oral secretions with increased BMI. The small sample size of predominantly overweight and obese patients most likely affected the BMI correlation results and the high percentage of reflux that we observed.

Previous research on GRV and aspiration yielded variable results because of the different methods used to detect aspiration and diagnose pneumonia.48-51 GRV measurement with the syringe method is highly variable.48-51 GRVs greater than 250 mL are associated with a higher rate of aspiration pneumonia.48 However, researchers in a recent study52 examined absence of GRV monitoring in gastric-fed patients receiving mechanical ventilation and reported no significant difference in the rate of ventilator-associated pneumonia. The low number of GRVs of 250 mL or greater in this study may have resulted in the nonsignificant findings. However, because of the controversy over the use of GRV, more accurate measures of GRV are needed.

Researchers in several studies53-55 reported that deeper sedation and a lower level of consciousness are risk factors for aspiration and ventilator-associated pneumonia due to diminished cough reflex with delayed or absent clearing of refluxed material. Gravity assists with clearance of reflux in upright positions.56 The lower frequency with which oral secretions were obtained during the 45° hours may reflect gravity having facilitated clearing of refluxed material independent of sedation level.

The major limitation of the study was the small sample size and the short duration of data collection. Although reflux and aspiration were lower at 45° hours, the sample was underpowered to detect a significant difference. Further research is needed with a larger sample and for a longer period of time.

The sample included mainly obese patients, which may have prevented detection of differences in patients’ characteristics and increased the frequency of reflux and aspiration. Last, the use of secretions from the oral cavity rather than the oropharynx was a limitation. Future studies should incorporate use of small, pliable suction catheters for oropharyngeal suctioning.

Implications for Practice

Despite the small sample size and the 36-hour study enrollment, several findings have implications for caring for gastric-fed patients receiving mechanical ventilation. First, patients can be maintained at HOB angles greater than 30° without sliding and without pressure ulcer development when turned regularly and maintained on low-air-loss mattresses. Most patients are comfortable with the higher HOB elevations. It is feasible to maintain patients at HOB angles greater than 30° for 12 to 24 hours. Although more research is needed, maintenance at 30° HOB elevation with use of vasopressor medications is achievable. Therefore, patients who require vasopressor medications should be assessed for blood pressure tolerance at higher HOB elevations rather than having their HOB automatically lowered because of administration of vasopressors or low blood pressure.

The association between higher mean HOB angles and decreased reflux at both 30° and 45°
implies that gastric-fed patients should be maintained at the highest HOB elevation that the patient finds comfortable. This study provides further evidence that HOB elevation greater than 30° is an easy intervention for nurses to implement to reduce reflux and aspiration.

The use of Trendelenburg positioning appears to be a risk for reflux and aspiration and should be limited in practice for repositioning. Mechanical lifts can assist with repositioning patients without injuring health care providers. Nurses should consider oropharyngeal suctioning, gastric volume measurement, and suctioning of gastric secretions before injuring health care providers. Nurses should consider oropharyngeal suctioning, gastric volume measurement, and suctioning of gastric secretions before using the Trendelenburg position for procedures.

Oral secretions were obtained more frequently at 30° HOB elevation; thus patients who cannot be elevated more than 30° most likely require more frequent suctioning or assessment for volume of secretions being obtained to determine frequency of need for suctioning. Last, patients who are moderately to deeply sedated would benefit from HOB elevations of at least 30° to decrease reflux and aspiration. In particular subsets of patients, such as patients with traumatic brain injury, tradeoffs may be realized between HOB elevation, vasopressor use, pneumonia rates, and pressure ulcer development. It appears to be safe and therapeutically valuable to examine these issues.

ACKNOWLEDGMENTS
The authors thank the nursing and medical leadership of each intensive care unit, the nurses who supported patients in the study, especially Sarah Whitten, RN, MSN, and Barbara Stewart, PhD, and Dean Klinkenberg, PhD, for statistical oversight.

FINANCIAL DISCLOSURES
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**REFERENCES**


To purchase electronic or print reprints, contact the American Association of Critical-Care Nurses, 101 Columbia, Aliso Viejo, CA 92656. Phone, (800) 899-1712 or (949) 362-2050 (ext 532); fax, (949) 362-2049; e-mail, reprints@aacn.org.
CNE Test  Test ID A152401: Head-Of-Bed Elevation and Early Outcomes of Gastric Reflux, Aspiration, and Pressure Ulcers: A Feasibility Study

Learning objectives: 1. Describe the risks and benefits of head-of-bed elevation.  2. Identify the findings at 30° and 45° head-of-bed elevation.  3. Discuss the early outcomes regarding head-of-bed elevation.

1. To reduce the risk of aspiration, guidelines recommend head-of-bed elevation to which of the following levels?
   a. 20° to 30°
   b. 30° to 45°
   c. 40° to 50°
   d. 50° to 60°

2. Guidelines for preventing pressure ulcers recommend which of the following head-of-bed elevations or lower?
   a. 30°
   b. 40°
   c. 45°
   d. 50°

3. The experimental intervention included which of the following head-of-bed elevations?
   a. 30°
   b. 40°
   c. 45°
   d. 50°

4. Head-of-bed elevation data were downloaded at the end of how many hours?
   a. 12
   b. 24
   c. 36
   d. 48

5. Which of the following secretions were obtained hourly or when of sufficient volume?
   a. Tracheal
   b. Gastric
   c. Nasal
   d. Oral

6. Skin was assessed at all of the following pressure points except which?
   a. Back
   b. Sacrum/coccyx
   c. Buttocks
   d. Bilateral trochanters

7. Pepsin analysis was interpreted as being positive if the concentration was which of the following?
   a. 1 μg/mL or higher
   b. 1.5 μg/mL or higher
   c. 2 μg/mL or higher
   d. 2.5 μg/mL or higher

8. As sedation deepened, the percentage of pepsin-positive secretions did which of the following?
   a. Remained the same
   b. Decreased
   c. Increased
   d. Were unable to be measured

9. Maintenance of the assigned head-of-bed elevation was achieved by all except which of the following?
   a. Bed alarm monitoring
   b. Assistance of signs
   c. The nurse researcher
   d. Digital display of the head-of-bed angle

10. This study provides initial evidence that elevation at 30° can be maintained even while patients require which of the following therapies?
    a. Continuous renal replacement
    b. Vasopressor medication support
    c. Left ventricular assist device support
    d. Intra-aortic balloon pump support

11. Oral secretions were obtained at a lower frequency when the head-of-bed was at which of the following elevations?
    a. 30°
    b. 35°
    c. 40°
    d. 45°

12. The authors found that a head-of-bed angle greater than 30° for 12 to 24 hours is which of the following?
    a. Contraindicated for most patients
    b. Uncomfortable for the patient
    c. Feasible
    d. Unable to be maintained

Test ID: A152401  Contact hours: 1.0; pharma 0.0  Form expires: January 1, 2018. Test Answers: Mark only one box for your answer to each question.

1. [ ] a  2. [ ] a  3. [ ] a  4. [ ] a  5. [ ] a  6. [ ] a  7. [ ] a  8. [ ] a  9. [ ] a  10. [ ] a  11. [ ] a  12. [ ] a

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<td>Objective 2 was met</td>
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<td>Objective 3 was met</td>
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<td>To complete this program, it took me _______ hours/minutes.</td>
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Fee: AACN members, $0; nonmembers, $10  Passing score: 9 correct (75%)  Category: CERP A  Test writer: Daniel N. Storzer, RN, MS, APRN, ACNPC, ACNP-BC, CNRN, CCRN, CCEMT-P

AMERICAN ASSOCIATION OF CRITICAL-CARE NURSES

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DIFFERENCES IN ALARM EVENTS BETWEEN DISPOSABLE AND REUSABLE ELECTROCARDIOGRAPHY LEAD WIRES

By Nancy M. Albert, RN, PhD, CCNS, CHFN, CCRN, NE-BC, Terri Murray, RN, MSN, James F. Bena, MS, Ellen Slifcak, RN, BA, Joel D. Roach, BA, Jackie Spence, RN, MSN, and Alicia Burkle, EMT-P

Notice to CNE enrollees:
A closed-book, multiple-choice examination following this article tests your understanding of the following objectives:
1. Compare and contrast the use of disposable and reusable electrocardiographic (ECG) lead wires and their effect on alarm events.
2. Describe effects of false ECG alarms on the patient and caregivers.
3. Identify additional research needed to further explore the effects of ECG alarm management.

CNE 1.0 Hour

To read this article and take the CNE test online, visit www.ajcconline.org and click “CNE Articles in This Issue.” No CNE test fee for AACN members.

Background  Disposable electrocardiographic lead wires (ECG-LWs) may not be as durable as reusable ones.
Objective  To examine differences in alarm events between disposable and reusable ECG-LWs.
Method  Two cardiac telemetry units were randomized to reusable ECG-LWs, and 2 units alternated between disposable and reusable ECG-LWs for 4 months. A remote monitoring team, blinded to ECG-LW type, assessed frequency and type of alarm events by using total counts and rates per 100 patient days. Event rates were compared by using generalized linear mixed-effect models for differences and noninferiority between wire types.
Results  In 1611 patients and 9385.5 patient days of ECG monitoring, patient characteristics were similar between groups. Rates of alarms for no telemetry, leads fail, or leads off were lower in disposable ECG-LWs (adjusted relative risk [95% CI], 0.71 [0.53-0.96]; noninferiority $P<.001$; superiority $P=.03$ and monitoring (artifact) alarms were significantly noninferior (adjusted relative risk [95% CI]: 0.88, [0.62-1.24], $P=.02$; superiority $P=.44$). No between-group differences existed in false or true crisis alarms. Disposable ECG-LWs were noninferior to reusable ECG-LWs for all false-alarm events (N [rate per 100 patient days], disposable 2029 [79.1] vs reusable 6673 [97.9]; adjusted relative risk [95% CI]: 0.81 [0.63-1.06], $P=.002$; superiority $P=.12$.)
Conclusions  Disposable ECG-LWs with patented push-button design had superior performance in reducing alarms created by no telemetry, leads fail, or leads off and significant noninferiority in all false-alarm rates compared with reusable ECG-LWs. Fewer ECG alarms may save nurses time, decrease alarm fatigue, and improve patient safety. (American Journal of Critical Care. 2015; 24:67-74)
D urability of electrocardiographic lead wires (ECG-LWs) may be an important factor in alarm fatigue. Cleaned, reusable ECG-LWs are used in multiple patients and are generally replaced when soiling is excessive, casings are fractured and wires are exposed, or signals are improper or lead to excessive alarms and interruptions in ECG monitoring. When ECG alarms are identified as false alarms due to excessive signal noise (artifact) or monitoring failures, inappropriate responses of nurses and patients may follow. Nurses may interrupt patient care or other activities to assess the patient’s status, diagnose the problem, and make treatment decisions, all of which may be inappropriate, unimportant, or wasteful in terms of time spent and may increase the cost of health care.

Leads-off alarms could be presumed to be low priority when there may actually be high-priority events in progress. False crisis alarms due to double counting of high-amplitude ECG complexes or failure to count low-amplitude QRS complexes prompt nurses to shift priorities away from the true needs of their patients. Frequent noise associated with ECG alarms may lead to nurse desensitization of alarms, also known as alarm fatigue, that compromises patient safety, especially if alarms are disabled or ignored. Further, alarm noise may surprise patients, leading to anxiety, especially when nurses are delayed in responding or alarms prevent rest and sleep.

The rate of false alarms and lead failures may be excessive in relation to the total number of ECG alarms. In one non–critical care observational study, 9 nurses were observed during routine patient care to identify responses to ECG alarms. After 54 hours of alarm monitoring, 205 alarm events were recorded, and of those, 9 (4.4%) were for artifact and another 27 (13.2%) were for LW failures. In another report involving patients on a telemetry unit, the mean number of alarms per patient during a mean monitoring period of 16.5 hours per patient was 69.7. In 30 patients who had critical alarms adjudicated, the number of false (artifact) alarms exceeded the number of true alarms (209 vs 119), leading to a 34% true alarm rate after accounting for uncertain alarms. In 5 hospitals, where the relevance of alarm monitoring was assessed in adult intensive care units, nearly 24% of alarms were due to staff manipulation and another 17.5% were due to technical issues, leading to a low 58% alarm specificity. Finally, in a study of monitor alarms in a 15-bed medical progressive care unit, a shocking 16,953 alarms involving a mean census of 12 patients monitored per day occurred in an 18-day period. After an intervention was implemented to improve management of alarms, the overall number of alarms decreased; however, the proportion of technical leads-fail alarms increased, serving as a reminder that solving one ECG alarm problem may herald new issues.

Signaling durability that affects the service life of ECG-LWs is not well understood. No peer-reviewed publications have included reports about signaling durability in reusable ECG-LWs and how often the wires should be discarded in order to optimize sensitivity and specificity of true alarms and minimize excessive signal noise. Disposable ECG-LWs are single-use, but durability, based on appearance (eg, width of LW, flexibility without crimping, and ease with which wires are exposed) and connectivity of ECG-LW tips (snaps) to sensing pad electrodes may vary by brand. It is unknown if reusable and disposable ECG-LW systems create the same numbers of false alarms that require nurse action. False-alarm issues can be grouped into the following categories: flat-line
waveforms that might resemble a true crisis from a cardiac arrest requiring emergent care or may simply be a disconnection of an LW from a sensor (no telemetry, leads fail, or leads off), signaling issues that cause false monitoring or nuisance alarms, for example, excessive signal noise from patient movement interference (artifact) or ECG configurations that lead to double counting or undercounting of QRS waveforms (false crises). Further, it is unknown if true crisis alarms (defined as emergent tachydysrhythmias, bradydysrhythmias, pauses, or flat-line alarm events that are true events) are identified at the same rate in reusable and disposable ECG-LWs. If durability of disposable ECG-LWs is below expectations, the cost to replace them during a patient’s admission may be prohibitive. The purposes of this study were to determine if differences exist in the frequency of false ECG alarm events (no telemetry, leads fail, or leads off; artifact; and false crises) and true crisis events between reusable and disposable ECG-LWs in patients who were capable of free movement and were encouraged to ambulate during the hospital episode of care.

Methods

This cluster randomized (randomization by telemetry units, not patients), controlled, blinded trial was a prospective, comparative effectiveness research project with a crossover design. One brand of reusable ECG cable and LW system (standard care) and the Kendall DL disposable cable and LW system with patented push-button design (intervention care) were used. This study was approved by the hospital’s institutional review board before the start of the study and was carried out following the ethical standards set forth in the Helsinki Declaration of 1975.

Setting and Sample

The study was conducted between September and December 2011 at Cleveland Clinic, a quaternary care medical center in northeastern Ohio that had more than 1200 beds. Four 24-bed postoperative cardiac surgical step-down/telemetry units that accepted cardiac medical overflow were randomly allocated to different types of ECG-LWs; thus, such patients were listed as a case in both groups.

enrollmentFrom424bedCardiacSurgicalStepDownTelemetryUnits.png

Figure 1 Flow diagram of patient enrollment in study of electrocardiographic lead wires (ECG-LWs).

- Excluded before analysis:
  - On study unit < 4 hours; n = 7
  - On study unit < 4 hours; n = 2

Sample size was based on false- or nuisance-alarm sightings and remote monitoring team crisis calls per month at the unit (not patient) level. In 2009, the adult cardiovascular telemetry unit census was approximately 550 patient days per month and the rate of false alarms was between 0.35 and 0.75 alarms per patient day per unit. It was assumed that false-alarm rates would be the same within groups, and that the aim was to show that the false-alarm rate in the disposable ECG-LW group was not higher than the rate in the reusable ECG-LW group. Completing statistical tests of noninferiority of the new product (disposable ECG-LWs) compared with the existing product (reusable ECG-LWs) was important because it would provide evidence of statistical and clinical similarity of disposable ECG-LWs and the unit. During the 4-month study period, the following schedule was followed: months 1 and 3, both groups received usual-care ECG monitoring; months 2 and 4, groups received reusable or disposable ECG-LWs, depending on assignments (see flow diagram, Figure 1).
Two units crossed over between reusable and disposable ECG wires on the first day of each month.

Intervention Implementation

Units allocated to the intervention group received a supply of disposable ECG cables and LWs with 6 leads for use during the crossover months. Nursing staff were oriented to disposable ECG-LW cable-to-monitor connection, patient connection, and supply storage sites. When patients assigned to the intervention group were discharged from units, their disposable ECG-LWs were discarded. On the intervention units, during the disposable ECG-LW monitoring months, reusable ECG cables and LW were removed from the units. One research nurse and 1 research coordinator made daily rounds to each intervention group unit to assess application of disposable ECG-LWs and ensure an adequate supply. For the 2 units that crossed over between reusable and disposable ECG-LWs, on the first day of each month, all patients in the unit had their ECG-LW switched at 7 AM, during a 30-minute period. An alarm-silencing feature of the monitoring system prevented an alarm signal during the disconnection and reconnection procedure.

Outcomes and Data Collection

Data on alarms associated with true and false crisis ECG events per unit, per month were collected by personnel completing usual job responsibilities on a remote monitoring team. The remote monitoring facility is located off campus and personnel were blinded to ECG-LW group assignment. Remote monitoring team personnel routinely report the 5 following categories of alarms: (1) no telemetry, leads fail, or leads off, (2) monitoring alarms (artifact), (3) false crisis alarms (apparent crisis that was not a crisis when the patient was assessed), (4) all false alarms (no telemetry, leads fail, or leads off + monitoring alarms + false crisis), and (5) true crisis alarms. Members of the remote monitoring team communicate with nursing staff while or after an alarm sounds to ensure that they are recording the event correctly. The remote monitoring team calls nursing personnel for all perceived or actual crisis alarms even if the alarm shuts off automatically. For noncrisis alarms, remote monitoring team members use clinical judgment to determine if self-terminating alarms warrant communication with the nursing team and are included as reportable alarms. The ECG electrode sensors used in this study were the usual care product in place at the time of study enrollment and did not vary between groups. In both groups, nurses and other members of the health care team completed usual-care procedures to prepare individual patients’ skin for ECG monitoring. Patients’ characteristics were provided from an administrative billing database.

Statistical Analysis Methods

Categorical factors were described by using frequencies and percentages; continuous measures were shown as mean (SD). Characteristics of patients in different cohorts were compared by using mixed models for continuous measures and logistic regression with generalized estimating equations for binary measures. Generalized linear mixed models were used to test for differences in superiority and noninferiority between disposable and reusable ECG-LWs. Noninferiority of the disposable LWs compared with reusable LWs used a 1-sided test and a noninferiority region of 25%. Superiority of the disposable ECG-LW compared with reusable ECG-LW used a 2-sided test. All models were weighted by the patient’s length of stay in the unit; alarm rates were described by using total counts and rate per 100 patient days. In analyses, no adjustment for multiple comparisons was performed. Models were fit by using the GLIMMIX procedure within SAS software (version 9.2). A P value less than .05 was considered statistically significant for most comparisons, and a 1-sided significance level of .025 was used for noninferiority testing.

Results

A total of 1611 unique patients had 2330 admissions (each of which counted as 1 case) to the 4 study units. By type of admission, 534 patients had 596 medical admissions and 1175 patients had 1734 surgical admissions. In total, 9385.5 days of ECG monitoring occurred, with 2566 days of disposable ECG-LW monitoring and 6819.5 days of reusable ECG-LW monitoring. Patients’ characteristics did not differ between ECG-LW monitoring groups. Mean (95% CI) age of patients allocated to reusable ECG-LWs was 65.03 (64.4-65.6) years and in those
allocated to disposable ECG-LWs was 64.64 (63.9-65.4) years ($P = .29$). Other characteristics of the entire sample are reported in Table 1. Patients’ characteristics were also assessed within the 2 units that switched back and forth between reusable and disposable ECG-LWs during the 4-month period and between units during the 2 months when patients received either disposable or reusable ECG-LWs, per randomization assignment. Patients’ characteristics did not differ within units or between units.

### Alarms Between ECG-LW Monitoring Groups

The percentage of false alarms relative to all alarms was 80% for disposable (2029 false alarms out of 2530 false alarms plus true crisis alarms) and 83% for reusable ECG-LW (6673 false alarms out of 8007 false alarms plus true crisis alarms; Figure 2). Among all patients studied, disposable ECG-LWs led to a 29% relative risk reduction (adjusted relative risk, 0.71; 95% CI, 0.53-0.96) in no-telemetry, leads-fail, and leads-off alarms (superiority $P = .03$) and showed statistical noninferiority in monitoring (artifact) alarms and all false alarms, defined as no-telemetry, leads-fail, and leads-off + monitoring (artifact) + false crisis alarms ($P = .002$). Importantly, true crisis alarms occurred at an equal rate in the disposable and reusable ECG-LW groups (Table 2). Within-unit comparisons of alarm rates among patients on the 2 units that switched between disposable and reusable ECG-LW were consistent with the overall comparisons; there was a 30% relative risk reduction (adjusted relative risk, 0.70; 95% CI, 0.49-0.99) in no-telemetry, leads-fail, and leads-off alarms (superiority $P = .04$); see Table 3 for all within-group alarm factors studied. In the comparison of between-unit alarm rates (comparisons between units just in the 2 months where both ECG-LW

### Table 1

Demographic characteristics of the 1611 patients in the study

<table>
<thead>
<tr>
<th>Measure</th>
<th>Proportion of group (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reusable leads</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>0.62 (0.58-0.65)</td>
</tr>
<tr>
<td>Female</td>
<td>0.38 (0.35-0.42)</td>
</tr>
<tr>
<td>Discharge</td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>0.65 (0.61-0.68)</td>
</tr>
<tr>
<td>Not home</td>
<td>0.35 (0.32-0.39)</td>
</tr>
<tr>
<td>Insurance</td>
<td></td>
</tr>
<tr>
<td>Government/self-pay</td>
<td>0.63 (0.60-0.67)</td>
</tr>
<tr>
<td>Commercial</td>
<td>0.37 (0.33-0.40)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>0.86 (0.83-0.88)</td>
</tr>
<tr>
<td>Nonwhite</td>
<td>0.14 (0.12-0.17)</td>
</tr>
</tbody>
</table>

### Table 2

Comparisons of alarms between disposable (n = 634) and reusable (n = 1808) electrocardiographic lead wire groups: all cases

<table>
<thead>
<tr>
<th>Alarm type</th>
<th>No. (rate per 100 patient days)</th>
<th>Adjusted relative risk (95% CI)</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disposable</td>
<td>Reusable</td>
<td></td>
</tr>
<tr>
<td>No telemetry, leads fail, leads off</td>
<td>764 (29.8)</td>
<td>2791 (40.9)</td>
<td>0.71 (0.53-0.96)</td>
</tr>
<tr>
<td>Monitoring</td>
<td>751 (29.3)</td>
<td>2242 (32.9)</td>
<td>0.88 (0.62-1.24)</td>
</tr>
<tr>
<td>False crisis</td>
<td>514 (20.0)</td>
<td>1640 (24.0)</td>
<td>0.90 (0.50-1.63)</td>
</tr>
<tr>
<td>All false</td>
<td>2029 (79.1)</td>
<td>6673 (97.9)</td>
<td>0.81 (0.63-1.06)</td>
</tr>
<tr>
<td>True crisis</td>
<td>501 (19.5)</td>
<td>1334 (19.6)</td>
<td>1.00 (0.63-1.58)</td>
</tr>
</tbody>
</table>

* Includes 112 patients who were counted as cases in both groups.
* Generalized linear mixed-effects models.
* Monitoring alarms, alarms caused by artifact.
* All false alarms include no telemetry, leads fail, leads off, monitoring (artifact), and false crisis alarms.
Discussion

In this study of patients treated on cardiovascular step-down/telemetry units, less than 20% of all alarms were due to true crises, reflecting a high rate of false alarms. When considering the totality of false alarms encountered during the study, concerns about alarm fatigue seem very plausible. Our results were similar to results of Gross et al,3 who also reported that false alarms outnumbered true alarms; however, the ratio of true to false alarms was much higher in our study, compared with other reports.2,3 In other reports, the patients had medical-surgical conditions, but not necessarily cardiac histories and acute cardiac conditions. Patients receiving telemetry on cardiac medical-surgical telemetry units may be more likely to have wide, bizarre QRS complexes, low-amplitude QRS complexes, or abnormally high-amplitude non-QRS complexes and waveforms that lead to false crisis alarms. Regardless of the cause of the false alarms, the high frequency of false alarms raises concerns related to interruptions of nurses who are providing patient care and cost of care related to nursing time. Further, remote monitoring team personnel must respond to each alarm. In responding, excess noise is created from ringing phones and patient care is further interrupted so that the nurse can communicate with remote monitoring personnel. Finally, fewer false alarms could be important in terms of patient satisfaction and patient stress.

Disposable ECG-LWs were statistically and clinically noninferior to reusable ECG-LWs for all false alarms and monitoring alarms and were superior to reusable ECG-LWs for no-telemetry, leads-off, or leads-fail alarms. Further, the groups did not differ in sightings of true crisis alarms. In this study, the adjusted relative risk reduction in all false alarms in the disposable ECG-LW group compared with the reusable ECG-LW group reflected nearly 1 fewer false alarm per 5 alarms encountered. The noninferiority statistical analysis and use of confidence intervals show the relative risk levels for which the disposable ECG-LWs could be considered noninferior to the reusable ECG-LWs. Disposable ECG-LWs were noninferior, so clinicians should have confidence that they would not be exposed to excess false alarms, above and beyond the noninferiority bound stated. Further, the disposable ECG-LW superiority in no-telemetry, leads-off, or leads-fail alarms may reflect direct cost savings related to ECG paper use, as well as the benefits described earlier.

Although it was not the purpose of this study to evaluate alarm fatigue or cost of nursing care related to false alarms, in one report,7 nurses were the responders to 46.8% of all ECG alarms. Further, when an alarm sounded, it took between 3 and 5 minutes to communicate telemetry alarm events to caregivers.7 Nursing time is expensive, and fewer false alarms could decrease costs of nursing care. When nonnursing staff (eg, remote monitoring personnel) are first responders, 2 people are automatically involved in alarm adjudication, increasing time and costs. Further research is needed to determine if more costly, disposable ECG-LWs are cost neutral or save costs compared with reusable ECG-LWs when indirect expenses associated with ECG monitoring are considered.

Loss of ECG signal due to no telemetry, leads off, or lead failures was improved with disposable ECG-LWs. False asystole crises may be due to many issues that involve patient and ECG monitoring systems. For one company’s monitoring system, electromagnetic interference was the culprit in a false asystole alarm.4 Other patient issues could be agitation, pulling of ECG-LWs against the electrode with activity, and sweaty or hairy skin that decreases

Table 3
Within-unit comparisons of alarms between disposable (n = 634) and reusable (n = 687) electrocardiographic lead wire groupsa

<table>
<thead>
<tr>
<th>Alarm type</th>
<th>No. (rate per 100 patient days)</th>
<th>Adjusted relative risk (95% CI)</th>
<th>ρb</th>
<th>Noninferiority</th>
<th>Superiority</th>
</tr>
</thead>
<tbody>
<tr>
<td>No telemetry, leads fail, leads off</td>
<td>764 (29.8)</td>
<td>1018 (42.6)</td>
<td>0.70 (0.49-0.99)</td>
<td>.004</td>
<td>.04</td>
</tr>
<tr>
<td>Monitoringc</td>
<td>751 (29.3)</td>
<td>792 (33.1)</td>
<td>0.88 (0.58-1.34)</td>
<td>.04</td>
<td>.47</td>
</tr>
<tr>
<td>False crisis</td>
<td>514 (20.0)</td>
<td>500 (20.9)</td>
<td>0.96 (0.40-2.28)</td>
<td>.24</td>
<td>.91</td>
</tr>
<tr>
<td>All falsed</td>
<td>2029 (79.1)</td>
<td>2310 (96.6)</td>
<td>0.82 (0.60-1.10)</td>
<td>.008</td>
<td>.15</td>
</tr>
<tr>
<td>True crisis</td>
<td>501 (19.5)</td>
<td>519 (21.7)</td>
<td>0.90 (0.47-1.74)</td>
<td>.13</td>
<td>.71</td>
</tr>
</tbody>
</table>

a Includes 112 patients who were counted as cases in both groups.

b Generalized linear mixed-effects models.

c Monitoring alarms, alarms caused by artifact.

d All false alarms include no telemetry, leads fail, leads off, monitoring (artifact), and false crisis alarms.

Types were in use, there were no differences between disposable and reusable ECG-LW groups.
the sensor’s contact with the skin. In this study, the disposable ECG-LW selected had a push-button design that could have led to the superior performance in no telemetry, leads off, or lead failures over the reusable ECG-LW system. When company researchers compared 3 brands of disposable LW connectors to determine the mechanical coupling retention force measured in pounds, the disposable ECG-LW used in the trial had significantly greater retention forces than did disposable products from 2 other companies, reflecting a decrease in the likelihood that ECG-LWs would be disengaged from ECG electrodes. Thus, not all disposable ECG-LW systems are the same, and differences in the electrode connector, housing connections, or the wires themselves could lead to different results with respect to false-alarm events. Further research is needed to compare the durability of different disposable ECG-LW systems in a busy hospital cardiac step-down and telemetry unit.

Limitations

This study was conducted at a single center and involved adult patients with cardiovascular surgical and medical diagnoses who required telemetry monitoring. Results may not be generalizable to other hospitals if patients’ characteristics differ from those of patients in this study or in nursing units with predominately noncardiac patient populations. Alarm level data were not analyzed at the patient level. Although it is known that some patients create more alarms than others, we were unable to determine the mean rate of alarms per patient. Data were obtained by remote monitoring personnel who recorded alarm event occurrence and type of events. Errors of omission (alarm not recorded) or errors in documentation (inaccurate event recording) could have occurred; however, personnel were experienced in their jobs.

It is unknown if all disposable ECG LWs have the same performance with respect to the frequency of alarm events. In this trial, only 1 brand of disposable ECG-LW was used. Systems used to attach ECG-LWs to electrode sensors vary. In this study, the ECG-LW tips had a patented push-button design that may have been a factor in the superior effectiveness found in no-telemetry, leads-fail, and leads-off alarms for disposable ECG-LWs compared with reusable ECG-LWs. Results are not generalizable to all disposable ECG-LWs.

Conclusion

Disposable ECG cables and LWs with a patented push-button design had superior effectiveness, leading to fewer no-telemetry, leads-fail, and leads-off alarms compared with reusable ECG-LWs. Disposable LWs were significantly noninferior in ECG alarm percentages for all false alarms (no-telemetry, leads-fail, and leads-off alarms, monitoring alarms, and false crisis alarms) and were similar to reusable ECG-LWs for identifying true crisis alarms. Disposable ECG-LWs that decrease false alarms could decrease nurse interruptions and limit unnecessary clinical assessment and decision making, thereby reducing nurse fatigue associated with alarm events. A reduction in alarm events reduces alarm fatigue and increases awareness of important alarms that require nurse action.

Research is needed to learn if a reduction in ECG-LW assessments and adjustments significantly reduces nursing and adjunct personnel costs related to unnecessary paper recordings. Less ECG-LW artifact/noise and other unnecessary alarms may improve the patients’ experience by decreasing noxious noise and stress associated with perceived ECG abnormalities. Research is needed to learn if patients’ anxiety is reduced when ECG-related alarms are reduced.

FINANCIAL DISCLOSURES

Covidien LP provided disposable electrocardiographic lead wires used by the intervention groups and funded data collection and study analysis. Other research processes were internally funded.

REFERENCES


To purchase electronic or print reprints, contact the American Association of Critical-Care Nurses, 101 Columbia, Aliso Viejo, CA 92656. Phone, (800) 899-1712 or (949) 362-2050 (ext 532); fax, (949) 362-2048; e-mail, reprints@aacn.org.
1. Which of the following best describes the objective of the study?
   a. Investigate the disparity in alarm events between disposable and reusable electrocardiographic lead wires (ECG-LW)
   b. Study differences in patient care outcomes between disposable and reusable ECG-LW
   c. Assess nurse satisfaction with work unit by disposable vs reusable ECG-LWs
   d. Analyze the cost and quality of disposable and reusable ECG-LWs

2. Which of the following was a key consideration for the outcome of this study?
   a. Alarm fatigue is a small concern for units that use reusable ECG-LWs.
   b. Responding to unnecessary alarms results in an unhealthy work environment.
   c. Fewer ECG alarms may result in improved patient safety.
   d. Reusable ECG-LWs had superior performance in reducing unnecessary alarms.

3. Based on a review of the literature, how often should reusable ECG-LWs be discarded to optimize sensitivity and specificity?
   a. After every patient use
   b. Frequency was unknown
   c. Every 96 hours
   d. Varies per manufacturer recommendations

4. Participant randomization was ensured by which of the following methods?
   a. Two nurse managers selected sealed envelopes with the unit ECG-LW assignments.
   b. Research nurses chose participants based on admission diagnosis and length of stay.
   c. Research nurses called a special phone number to learn the assigned group.
   d. Two nurse managers selected specific months that were preassigned to ECG-LW assignment.

5. The study used the 2009 adult cardiovascular telemetry unit census of approximately 550 patient days per month to determine sample size. Which of the following best describes the rate of false alarms?
   a. Between 0.35 and 0.75 alarms per patient day per unit
   b. Between 0.75 and 1.00 alarms per patient day by length of stay
   c. Between 0.75 and 1.25 per 100 days/per unit
   d. Between 0.35 and 0.75 alarms per patient, per 24 hours

6. During the study, 2 units changed from reusable to disposable ECG-LWs. Which of the following prevented false alarm signals during the transition time?
   a. ECG-LWs were activated from a remote location after changes were completed.
   b. Remote monitoring teams were oriented to ignore alarms during the change process.
   c. The monitoring system was preset to delete data associated with the change times.
   d. Nurses used the monitoring system alarm-silence feature during change times.

7. A mixed-model approach was used for continuous measures, and logistic regression with general estimating equation was used for binary measures. Which of the following factors provided a consistent denominator for all alarms assessed?
   a. Patient age on the day of unit admission
   b. A count of the number of sensors used per patient
   c. Patient consecutive length-of-stay days on the unit
   d. Nurses’ paper documentation of false alarm reports

8. To ensure nursing staff were consistent with study processes, which of the following was key?
   a. Orientation to reusable ECG-LWs and patient connection practices
   b. Education regarding ECG interpretation and interventions
   c. Education on ECG-LW cleaning and application
   d. Orientation to disposable ECG-LWs and supply storage sites

9. During the study, remote monitoring teams collected which of the following types of data?
   a. True and false crisis ECG events, per unit per patient
   b. Frequency of alarm silencing events, per unit per month.
   c. Causes of all (true and false) ECG events per patient
   d. True and false crisis and monitoring ECG events, per unit per month.

10. In this study, the difference in the rate of alarms (per 100 patient-days) for false crises between disposable and reusable ECG-LWs was which of the following?
    a. 18.8% more
    b. An 11% reduction
    c. An increase by 3.6%
    d. A decrease by 4%

11. The percentage of ECG alarms related to all ECG alarms was greatest for which of the following alarm types and groups?
    a. Monitoring alarms, reusable group
    b. No lead alarms, reusable group
    c. True crisis alarms, disposable group
    d. False crisis alarms, disposable group

12. Which of the following statements best describes the study findings?
    a. Disposable ECG cables and LWs with a patented push-button design had noninferior and superior effectiveness in causing fewer false alarms, compared with reusable ECG-LWs.
    b. Reusable ECG cables and LWs with a patented push-button design had superior effectiveness, in causing fewer true alarms, compared with disposable ECG-LWs.
    c. There were no notable differences between reusable and disposable ECG cables and LWs in the rate of false and true alarms.
    d. The rate of all false alarms was about 20% of all alarms and disposable ECG cables and LWs did not alter the rates of alarms.

Test ID: A1524012 Contact hours: 1.0; pharma 0.0  Form expires: January 1, 2018. Test Answers: Mark only one box for your answer to each question.

1. [ ] a  2. [ ] a  3. [ ] a  4. [ ] a  5. [ ] a  6. [ ] a  7. [ ] a  8. [ ] a  9. [ ] a  10. [ ] a  11. [ ] a  12. [ ] a

Fee: AACN members, $0; nonmembers, $10  Passing score: 9 correct (75%)  Category: CERP A  Test writer: Jean Shinners, PhD, RN-BC

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The intensive care unit is a work environment where superior dedication is crucial for optimizing patients’ outcomes. As this demanding commitment is multidisciplinary in nature, it requires special qualities of health care workers and organizations. Thus research in the field covers a broad spectrum of activities necessary to deliver cutting-edge care. However, given the numerous research articles and education activities available, it is difficult for modern critical care clinicians to keep up with the latest progress and innovation in the field. This article broadly summarizes new developments in multidisciplinary intensive care. It provides elementary information about advanced insights in the field via brief descriptions of selected articles grouped by specific topics. Issues considered include care for heart patients, mechanical ventilation, delirium, nutrition, pressure ulcers, early mobility, infection prevention, transplantation and organ donation, care for caregivers, and family matters. (American Journal of Critical Care. 2015;24:75-86)
Care for critically ill patients and their families requires insights into various aspects of caregiving, and, as such, a multidisciplinary approach is often needed. Research in the field involves a wide range of activities necessary to deliver state-of-the-art care. However, given the flood of research articles and education activities available, it is difficult for modern critical care clinicians to keep up with the latest progress and innovations in the field. The objective of this article is to summarize new developments in multidisciplinary intensive care as published in the past year in the American Journal of Critical Care. It provides basic information about advanced insights in the field by briefly describing selected articles grouped by specific topics. The objective is neither to provide extensive details of the individual articles nor to provide broad literature reviews. This article should be considered a rough summary of recent research in critical care and should encourage readers to go back to the original articles if they feel the need for more comprehensive information.

### Caring for Heart Patients

The 5 main diagnoses of patients admitted to intensive care units (ICUs) in US hospitals are, in decreasing order: respiratory insufficiency/failure, postoperative management, ischemic heart disorder, sepsis, and heart failure. Patients admitted because of cardiovascular issues therefore represent a substantial portion of the ICU population. Further, more and more patients who are admitted to the ICU for noncardiac reasons have comorbid cardiovascular conditions that are likely to alter clinical management and outcomes. Crago et al performed a retrospective study to compare the incidence of early cardiac problems between patients who reported using β-blockers and/or angiotensin-converting enzyme inhibitors before aneurysmal subarachnoid hemorrhage and patients who did not. Those authors did not find tangible proof that exposure to adrenergic blockade before aneurysmal subarachnoid hemorrhage provided protection from cardiac injury.

Looking more into additional comorbid conditions associated with cardiovascular issues, which definitely challenge delivery of critical care, Halm discusses the most accurate way of monitoring blood pressure in obese patients. Halm reviews relevant studies and notes that direct intra-arterial measurement of blood pressure should be used instead of auscultatory/oscillometric techniques, which are considered significantly inaccurate in obese patients. A second recommendation includes matching cuffs with the size and shape of the upper arm. Preferably at admission, health care personnel should measure the patient’s arm circumference midway between the shoulder and elbow and assess the shape of the upper arm. Based on anthropometric assessment, an appropriately sized cuff should be selected.

Approximately 30% to 60% of patients with heart failure experience depressive symptoms. Depressive symptoms are clinically relevant when managing these patients because they may affect the relationship between inflammation and physical signs and symptoms in patients with heart failure. Heo et al performed a prospective observational study in which they examined the association between soluble tumor necrosis factor receptor I and physical signs and symptoms and the effects of depressive symptoms on this relationship in patients with heart failure. Results show that both depressive signs and inflammation should be considered along with physical signs and symptoms in patients with heart failure, but further studies are needed to determine the exact relationship between these clinical elements.

Similarly, McGuire et al undertook a secondary analysis of 3 studies on depression and cardiovascular...
patients in the ICU. The goal was to identify symptom clusters associated with clinical depression in patients hospitalized with coronary heart disease. Three symptom clusters (cognitive/affective, somatic/affective, and somatic) were identified. After performing a hierarchical cluster analysis, the authors concluded that, compared with patients without cognitive/affective symptoms, patients with the cognitive/affective symptom cluster (anhedonia, dysphoria, guilt, suicidal symptoms, nervous irritability) had an odds ratio of 1.41 (P < .001; 95% CI, 1.223-1.631) for clinical depression. According to this study’s outcomes, clinicians should watch for clinical depression in hospitalized patients with coronary heart disease who have the cognitive/affective symptom cluster identified.

Ventilation and Sedation

Endotracheal intubation is a traumatic experience yet is often necessary during critical illness. Adequate sedation is pivotal but not always achieved. Smithburger et al assessed characteristics of patients that were associated with effectiveness of sedation by dexmedetomidine, an increasingly used sedative agent. Sedation by dexmedetomidine was prospectively evaluated in 38 patients and judged ineffective in 19 patients (50%), effective in 11 patients (29%), and not assessable because of clinical confounders in 8 patients. A lower severity of disease appeared to be associated with a higher chance of effective sedation.

In order to reduce the time spent intubated and thus reduce the risk of ventilator-associated pneumonia, a strategy of sedation breaks has become standard practice in many ICUs. Tanios et al evaluated whether the sedation strategy had an influence on the rate of unplanned extubations. A total of 92 unplanned extubations occurred in a 36-month study period in a 33-bed ICU. Patients receiving continuous sedation with daily interruption of sedatives had a significantly lower risk of unplanned extubations (1.5 events per 1000 ventilator days) than did patients receiving the intermittent sedation protocol (5 events per 1000 ventilator days) or patients without a sedation protocol (16 events per 1000 ventilator days). As such, the implementation of a straight sedation protocol can be recommended. Yet, based on a scoping review of qualitative studies, Rose et al reported several barriers that influenced weaning and adoption of weaning strategies. The most important factors that may influence weaning and adoption of weaning strategies and tools include balancing of weaning systematization against the needs of individual patients and combining subjective knowledge of the patient with objective clinical criteria.

Airway management includes a variety of practices, including oral care, endotracheal suctioning, and care of endotracheal tubes. An essential component of care of endotracheal tubes is maintaining the endotracheal tube cuff pressure within the target range of 20 to 30 cm H2O. Avoiding excessive pressure is necessary to prevent tracheal lesions, whereas insufficient cuff pressure results in inadequate sealing of the extraluminal airway and could increase the risk of microaspiration of subglottic secretions. Microaspiration is considered the main pathogenic mechanism for ventilator-associated pneumonia, yet only a few published studies demonstrate this mechanism.

In recent years, detection of pepsin and amylase levels in tracheal aspirates has been used in research as an indicator of microaspiration. Pepsin is a biomarker for gastric aspiration and amylase is an enzyme present in saliva and thus is an indicator of microaspiration of oral secretions. In a pilot study, Sole et al assessed the presence of pepsin and amylase in tracheal secretions in adult patients receiving mechanical ventilation. Of the 13 patients, 9 were intubated with a tube that allowed subglottic secretions to be drained, 10 received synchronized intermittent mandatory ventilation, and 11 received enteral feeding through a tube distally placed in the stomach. Paired samples were taken from oral and tracheal secretions at baseline and after 4 hours. Pepsin was present in oral secretions of 9 patients and in tracheal secretions of 7 patients. As could be expected, amylase was detected in all patients’ oral secretions, but it also was detected in tracheal secretions of 5 patients. These data illustrate that microaspiration remains common in intubated patients. Further research to optimize the sealing capacity of endotracheal tube cuffs is warranted. These studies should focus on absolute sealing capacity of cuffs as well as on solid clinical outcomes (eg, pneumonia) and the time cut-off at which the device becomes clinically advantageous.

The cuff pressure of an endotracheal tube varies according to patient-related factors, environmental circumstances, and therapeutic interventions. Factors leading to increased cuff pressure include positive-pressure ventilation, ventilation with nitrous oxide, altitude (eg, during helicopter transport), and pathologic processes such as bronchospasms. Factors that may decrease cuff pressure include sedation and neuromuscular blockade, decreased core temperature, and loss of intracuff volume over
time.\textsuperscript{21} Lizy et al\textsuperscript{24} investigated the effect of changes in patients’ body position on cuff pressure in 12 orally intubated and sedated adult patients. Patients were positioned in a neutral starting position (supine, head-of-bed elevation 30°, head in neutral position) and cuff pressure was set at 25 cm H\textsubscript{2}O. Thereafter patients were positioned in 16 different postures that are commonly used in daily practice. When the patient was correctly positioned, the cuff pressure was measured during an end-expiratory ventilatory hold. A significant deviation in cuff pressure occurred with all 16 positions. Forty-one percent of cuff pressure measurements exceeded the upper limit (30 cm H\textsubscript{2}O) and were considered clinically relevant. No cuff pressures beneath the lower limit were observed. Importantly, the investigators observed a high within-patient variability. These data illustrate the need for strict guidelines on cuff pressure monitoring practice.\textsuperscript{14,24-26}

Oral care is a clinical challenge in intubated patients. Many nurses find oral hygiene difficult and sometimes even frustrating as they have the impression that oral health worsens despite all the efforts taken.\textsuperscript{27} Nonetheless, most nurses are convinced that oral health is integrally linked with overall well-being and recognize the importance of thorough oral hygiene practices.\textsuperscript{27,28} One of the pillars of oral care in intubated patients is the use of antiseptic mouthwashes, although the optimal frequency, contact time, and antiseptic concentrations have yet to be determined.\textsuperscript{29} Another aspect of oral care is optimizing the patient’s oral health status before ICU admission or intubation. In case of elective major surgery, patients can be encouraged to brush teeth and rinse the oral cavity in the weeks preceding the surgical procedure. In a cohort of patients with esophageal cancer, a protocol of brushing teeth 6 times daily resulted in a significant reduction in the incidence of postoperative pneumonia.\textsuperscript{30} It remains uncertain, however, whether such an approach could reduce the rate of VAP in surgical patients. Bergan et al\textsuperscript{31} tried to reduce the rate of postoperative pneumonia in cardiac surgery patients by implementing a care bundle focused on optimizing oral health before surgery. Patients were taught how to brush teeth and tongue and how to clean their jugal and palatal membranes. Additionally, patients were asked to rinse the mouth with chlorhexidine 0.12% twice daily until surgery. In brief, the protocol succeeded in optimizing oral health in 92% of patients before surgery. The rate of postoperative pneumonia decreased from 32 events per 1000 ventilator days in the preintervention period to 10 events per 1000 ventilator days in the 6 months following the implementation phase. Of note, patients who had pneumonia develop were more likely to have had worse oral health before surgery. These data, although based on a noncontrolled study, call for more attention toward oral care in the preoperative period.\textsuperscript{32}

When traditional mechanical ventilation fails to achieve oxygenation goals, extracorporeal membrane oxygenation (ECMO) may offer the last chance for survival. The devastating flu epidemics of the past years have boosted the experience with ECMO in many centers.\textsuperscript{33,34} Guttendorf et al\textsuperscript{35} described discharge outcomes in patients receiving ECMO either for respiratory or cardiac indications. The authors had a cohort of 212 patients who received ECMO, 126 for cardiac indications and 86 for respiratory indications. Overall survival was 33%, with 50% survival in patients with a respiratory indication and 28% survival among patients with a cardiac indication. Patients with poor outcomes were generally older, were more likely to require cardiovascular support before ECMO, and had more transfusions and complications. In a study\textsuperscript{36} of 6 patients, ECMO combined with use of an intra-aortic balloon pump for acute respiratory distress syndrome might have provoked right ventricular failure. Following use of the balloon pump, inotropic support could be markedly reduced. Four patients survived. As survival figures are still grim, a scoring system to predict mortality in venovenous ECMO has been developed for research and quality control purposes.\textsuperscript{37,38}

**Agitation, Confusion, and Delirium**

Agitation is often considered a precursor to or the initial phase of delirium. This complication is often associated with intensive care and affects nearly 60% of patients within the first 5 days of ICU admission.\textsuperscript{39} Most patients become agitated within the first day following admission, after a mean stay in the unit of barely 12 hours. This observation reflects the overwhelming influence of an acute admission on patients’ emotional equilibrium. Early predictors of agitation include a history of psychiatric diagnosis, organ failure (particularly respiratory failure), many hours with restraints, pain, and presence of a urinary bladder catheter.\textsuperscript{40} The noise and the light levels in the ICU contribute to the risk of delirium by disturbing patients' sleep patterns.\textsuperscript{41,42} In a randomized controlled trial, Lytle and colleagues\textsuperscript{43} evaluated the effect of lavender aromatherapy on vital signs and perceived quality of sleep. Patients
in the intervention group had significantly lower blood pressures \( (P = .03) \) at night but their mean overall sleep scores were not significantly higher than the scores of patients in the nonintervention group \( (P = .12) \). Given the small size of this (pilot) study, these results seem promising and ask for further exploration on a larger scale.

External factors provoking agitation are relatively well known, but little is known about biological pathways facilitating this complication. Alexander and colleagues\(^4\) explored relationships between clinical delirium and serum levels of cytokines and apolipoprotein E. Patients experiencing delirium had fewer ventilator-free days, longer ICU stays, higher care needs at discharge, and higher mortality. They also demonstrated higher levels of interleukin 6 and apolipoprotein E genotype. However, patients with the E4 allele of apolipoprotein E had a shorter duration of delirium and lower mortality, illustrating that this lipoprotein plays a complex role in illness response and recovery. The causal relationship between apolipoprotein E genotype, brain dysfunction, and survival is a topic for future research.

Reliable assessment of delirium remains a challenge in ICU patients. The Confusion Assessment Method for the Intensive Care Unit (CAM-ICU) is a validated tool to diagnose delirium. The score yields 3 ratings: positive, negative, and unable to assess. The latter rating yields a potential of masking either underreporting or excessive reporting of delirium. Swan and colleagues\(^5\) demonstrated, however, that an educational intervention regarding the use of the CAM-ICU resulted in 41% fewer “unable to rate” scores (from 32% to 19%). This straightforward before-after study shows that careful implementation and instruction may not be overlooked, even with regard to rather simple tools.

**Nutrition and Glucose Control**

In the past decade, the importance of early enteral nutrition has grown steadily.\(^4\) Failure to administer the caloric needs results in worse outcomes. Furthermore, shortages in nutritional elements such as vitamin D, known to have immunomodulating properties, are also associated with higher mortality in patients with sepsis or critically ill patients in general.\(^47,48\) In order to minimize the chance of caloric deficits, nutrition support protocols have been developed. Careful implementation of such a protocol shortens time to achieve feeding goals.\(^49\)

Feeding tube verification is considered a standard practice for ICU nurses. Failure to detect respiratory placement of a feeding tube may result in serious harm. The American Association of Critical-Care Nurses developed a practice alert for the verification of feeding tube placement based on 4 practices: (1) use of a variety of bedside methods to predict tube location during insertion, (2) recognizing that auscultatory methods are unreliable, (3) obtaining radiographic confirmation of any blindly inserted tube before initial use, and (4) checking tube location every 4 hours once feeding has started. Bourgault et al\(^50\) assessed the extent of adoption of these practices by 370 ICU nurses. Fifty-five percent of the nurses were aware of the practice alert, and 45% had adopted it in daily practice. However, only 29% of the adopters had also implemented all 4 of the clinical practices on which the practice alert is based. The level of adoption or implementation of the practice alert was closely related to personal and organizational factors.

Dysglycemia puts patients at risk for a variety of postoperative complications such as infection, which itself is associated with deleterious outcomes.\(^51-54\) Consequently, strict adherence to a protocol for glycemic control is pivotal.\(^55\) The effect of an educational intervention on ICU nurses’ knowledge about glycemic control was assessed by means of a before-after study.\(^56\) Nurses completed a questionnaire to measure their knowledge of glycemic control. They demonstrated a significant increase in knowledge levels but, more importantly, the intervention was associated with an improvement in clinical outcomes: the incidence of hypoglycemia decreased from 2.1% to 0.2%, and 88% of all blood glucose measurements in the postintervention period were below the critical threshold of 180 mg/dL.

The use of arterial catheters for hourly collection of blood samples for glycemic control avoids frequent fingersticks and spares patients some discomfort. Returning the clearing volume may substantially decrease procedure-related blood loss.\(^57\) Raurell-Torredà and colleagues\(^57\) questioned whether arterial catheter setup influenced the rate of mechanical problems and catheter infection, and whether the glycemic values matched those obtained from venous samples. Patients were randomized to either the intervention group (equipped with a nonwaste needleless setup) or the control group (equipped with the nonwaste syringe setup). Two infectious episodes were observed in the control group versus none in the intervention group. Mechanical complications were rare in both groups. Glycemia detected from arterial samples was as effective as with laboratory results (venous samples) except when hematocrit values were less than 25%. The investigators
concluded that obtaining blood samples from arterial catheters to guide intensive insulin therapy is both safe and effective.

Pressure Ulcers

Guidelines for the prevention of ventilator-associated pneumonia generally include the recommendation of semirecumbent positioning, although the body of evidence supporting such positioning is rather moderate.\(^6^0\)\(^6^1\) It has been hypothesized, however, that semirecumbent positioning puts patients at risk for pressure ulcers. In an open, prospective, randomized cross-over trial, the interface pressure was measured over distinct body positions by using a pressure-mapping device.\(^5^2\) Interface pressure with patients supine at various angles of head-of bed elevation and during reverse Trendelenburg position was measured in 20 healthy volunteers. Four types of mattresses were evaluated as well: 2 different foam mattresses and 2 air suspension beds one of which had low-air-loss technology. Peak sacral interface pressure increased significantly only in the 45° semirecumbent position, whereas use of the reverse Trendelenburg position led to decreased peak pressures for all positions. The mattress with the low-air-loss system provided the lowest peak pressures at all angles. The authors concluded that a 30° head-of-bed elevation appears to be a fine compromise for preventing ventilator-associated pneumonia while preventing skin breakdown. In a controlled study, Behrendt et al\(^6^3\) evaluated the effect of a continuous bedside pressure mapping (CBDM) device on rates of pressure ulcers in a medical ICU. In a 2-month period, 442 patients were assigned to beds equipped with or not equipped with a CBDM device. All patients were turned every 2 hours while patients in the CBDM device group were repositioned to offload high-pressure points when required. Patients in the CBDM device group experienced significantly fewer hospital-acquired pressure ulcers (0.9% vs 4.8%; \(P = .02\)). A limitation of the study is that patients were not randomized but rather were arbitrarily assigned to a treatment group. Yet, the baseline risk profiles for pressure ulcer development were not different between the groups, although some risk factors were not considered in the risk profile assessment. For example, Hyun et al\(^6^4\) demonstrated that the risk for pressure ulcers was substantially higher among underweight patients and extremely obese patients (8.6% and 9.9%, respectively) than among normal weight and obese patients (5.5% and 2.8%, respectively). The Braden score was predictive of development of pressure ulcers, but adding the body mass index to the model did not substantially improve the model’s predictive value.

Early Mobility

Besides the prevention of pressure ulcers, early mobility and exercise play an important role in the rehabilitation phase of critically ill patients. Despite its obvious advantages, mobility appears to be difficult to implement in ICUs. Roberts et al\(^6^5\) evaluated and compared the efficiency, effectiveness, and safety of a mobility platform with standard equipment. Data collected from 71 patients and 238 activities indicated that a mobility protocol can be safely implemented in an ICU. Yet, standard equipment can be used as well. A favorable side effect of the study was the overall change in attitude and culture in daily practice regarding early mobility. This change is important as there are plenty of obstacles to early mobility in ICU patients. Yet, a case series by Brownback et al\(^6^6\) illustrates that mobility interventions are possible even in patients undergoing continuous renal replacement therapy as long as some limitations and points requiring attention are taken into account.

Infection Prevention and Control

Despite the distribution of international guidelines and all the efforts invested in prevention,\(^6^7\) health care–associated infection continues to pose a threat to patients’ outcomes,\(^6^8\)-\(^7^0\) not to mention the societal costs associated with this complication.\(^7^1\)-\(^7^5\) Prolonged mechanical ventilation is an obvious risk factor, and a proactive approach to extubate patients as early as possible on basis of daily sedation breaks has been demonstrated to reduce the risk of pneumonia. Trauma, neurologic conditions, cardiovascular failure, and metabolic issues are recognized risk factors for pneumonia in adults, whereas the use of vasoactive drugs and the presence of a nasogastric tube are risk factors in infants and children.\(^7^6\)-\(^7^9\) In the past few years, researchers in several studies have stressed that the simple distribution of guidelines for pneumonia prevention does not change practice. Nurses’ and clinicians’ knowledge of evidence-based recommendations is moderate to low in most studies.\(^6^0\)-\(^6^1\),\(^7^6\)-\(^7^9\) In addition, implementation of guidelines is a challenge. In a survey among ICU nurses from 8 hospitals, the most consistent facilitator of adherence to guidelines for the prevention of ventilator-associated pneumonia was nurses’ positive attitude toward the guideline.\(^8^2\)
A similar observation has been made earlier in a study exploring behavioral determinants of hand hygiene. Hand hygiene is a cornerstone in the prevention of contamination of the work environment and equipment. In turn, contaminated equipment may serve as a vector for bacteria to colonize and infect patients. Addison et al investigated the cleanliness of disposable versus reusable electrocardiography (ECG) lead wires in children. Cardiac surgery patients were randomized to either disposable or reusable ECG lead wires. Levels of contamination were assessed by the evaluation of adenosine triphosphate counts, which correlate with microbial cell counts. On the first day postoperatively, adenosine triphosphate counts on disposable ECG lead wires were significantly lower ($P < .001$) than on reusable ECG lead wires. On the second day postoperatively, this difference was no longer significant ($P = .06$). The authors suggested that this observation should encourage the use of disposable ECG lead wires in pediatric cardiac surgery patients in the first 2 days following surgery. However, in the absence of clinical outcomes, this advice should be interpreted with caution. In a large randomized controlled trial encompassing more than 7200 patients, Albert and colleagues could not demonstrate a difference in infection rate between ICU patients with disposable and reusable ECG lead wires.

In a recent systematic review and meta-analysis, the potential of quality improvement interventions to reduce the risk of central catheter–associated bloodstream infection (CLABSI) was assessed. The study clustered 41 before-after trials and demonstrated a significant reduction in the risk of CLABSI (odds ratio, 0.39; 95% confidence interval, 0.33-0.46). Importantly, the effect was bigger when quality improvement initiatives were based on care bundles or checklists. Another important element in quality improvement initiatives is education and training. Gerolemou et al evaluated the effect of simulation-based training for nurses on use of sterile techniques during central venous catheter insertion on rates of CLABSI. After completion of the training intervention, the mean infection rate in the unit decreased from 2.61 to 0.4 per 1000 catheter days.

**Challenges in Transplant and Organ Donation in the ICU**

Solid organ transplant remains a challenge for intensive care practitioners, patients, and patients’ families. On the one hand, some patients and their families who urgently require 1 or more organs to be transplanted are commonly admitted to the ICU needing complex vital support while transplant surgery does not occur. On the other hand, the donation process also involves complex decision making by both patients’ families and clinicians, as organs for transplant may come from donors who are still alive or from donors who have been declared dead for either neurologic (brain death) or cardiopulmonary reasons.

Lustbader explored the practical and ethical challenges that critical care professionals face regarding organ donation from cadaveric donors in the ICU. The author describes the main controversies and opportunities in donation after brain death and donation after circulatory death, concluding that ICU staff members are exceptionally qualified to preserve the opportunity for organ donation for patients and families that wish to do so, within a very complex grieving process.

However, and according to Powell, one of the burning issues may be that a significant number of health professionals do not have a clear grasp of the definition and assessment of brain death and that communication with families of brain-dead patients is far from adequate. The author suggests that clarifying the main concepts of brain death and communication strategies for patients’ families must be included in continuous development and training programs. Similarly, institutions must emphasize the national guidelines for accountability on the brain-death declaration.

While some families and patients struggle with end-of-life decisions regarding organ donation, others have to deal with difficult times while waiting for a transplant. Hansen et al performed a qualitative case analysis of 1 liver transplant patient, describing the experiences of the patient’s family while their relative was on the transplant list. Through evaluation of semistructured interviews, the author pooled family members’ perspectives into 3 phases that correspond to the progression of the patient’s clinical condition: dealing with crisis, confusion and frustration, and back on the road to transplant. These exploratory data are important, as they may provide a starting point for wider studies on how to prepare health care professionals for dealing with families of ICU patients on transplant lists. Bell suggests that there are some benchmarking notions that have to be taken into account when dealing with such complex situations. These notions include clarifying concepts concerning the transplant process with patients’ families, ensuring
A positive correlation exists between nurses’ shift length and rate of medical errors.

Care for Caregivers

Caring for critically ill patients can be extremely stressful. The ICU can be a tension-charged environment with many sources of conflicts. Furthermore, ICU nurses’ daily encounters with suffering, grief, and death make them prone to the development of psychological disorders such as depression, anxiety, burnout, and posttraumatic stress disorder.

Mealer et al stated that resilience training may be helpful to mitigate the development of maladaptive psychological symptoms, and they tested the feasibility and acceptability of a multimodal program in a randomized controlled 12-week intervention pilot study. In the intervention arm, 13 nurses followed a 2-day educational workshop, written exposure therapy, mindfulness-based stress reduction techniques, aerobic exercises, and event-triggered counseling sessions. No interventions were associated with the control arm. Implementation of the intervention was successful as demonstrated by very high levels of attendance and high acceptability and satisfaction scores. Nurses in the intervention arm had a significant reduction in symptoms of depression (P = .03), and participants in both treatment and control groups showed a significant decrease in posttraumatic stress disorder symptoms (intervention P = .01; control P = .02) and improved resilience scores (intervention P = .05; control P = .03). The latter finding may be due to a lack of treatment fidelity and intervention contamination as nurses of both groups worked together in the unit. Despite the promising results of this trial, a sufficiently powered randomized controlled trial is needed to determine the effect of a multimodal resilience program on enhancing psychological outcomes and individual nurses’ level of resilience.

In the ICU, timely and accurate completion of procedures is vital in ensuring good outcomes for patients. It is, however, also well known that there is a positive correlation between critical care nurses’ shift length and the rate of medical errors. As in situ simulation has been proposed as an innovative approach to investigate quality of care topics, Calhoun et al explored its use to study the relationship between critical care nurses’ time spent on the current shift and the efficient, accurate completion of tasks in a pediatric ICU. As such, 28 nurses performed in 3 assessments during a standard 12-hour shift using a high-fidelity pediatric simulator. Assessments took place at the beginning of each participant’s shift, 6 hours into the shift, and immediately after the shift. The mean time needed to complete all tasks was 17.9 minutes before the shift, 13.3 minutes at midshift, and 12.4 minutes at the end of the shift, with a mean total decrease of 5.5 minutes (P < .001). No significant changes in accuracy were found. The combination of these results suggest that nursing performance of simple tasks may improve during the course of a 12-hour shift.

Working long shifts may, however, influence nurses’ sleep patterns. Long shifts may reduce the time available for responsibilities at home and thus contribute to limiting opportunities for sleep. Sleep deprivation, in turn, may lead to reduced alertness and hamper work performance. Allen et al recruited a sample of 20 critical care nurses who completed a daily sleep and activity log and wore an actigraph (a wristwatch-like device with a motion sensor that allows differentiation of sleep from wakefulness) for 14 days in order to measure their sleep time objectively. They reported mean sleep times between consecutive work shifts of 6.79 hours between 2 day shifts and 5.68 hours between 2 night shifts. Nurses slept much more between nonworkdays (8.53 hours) and during the night between a day shift and a non-workday (8.93 hours), strongly supporting the suggestion that nurses catch up on their sleep loss during nonwork periods. Whether the degree of sleep deprivation identified may impair patient safety must be determined by further research.

Family Matters

Worldwide, awareness is growing that families of critically ill patients should no longer be considered as outsiders in the ICU. Within the context of promoting family-centered care, Schnell et al demonstrated that an open visiting policy in the ICU improved satisfaction among patients’ families. Moreover, opening the ICU was not associated with disturbances in care delivery and yielded a slight increase in perceived workload only. Numerous units, however, still hold on to traditional, restricted visiting policies.

Riley et al invited patients’ family members, nurses, and physicians from 5 ICUs with restricted visitation policies to participate in focus group meetings in order to explore their perceptions about patient-centered care. As a result, patients’ and their families’ expectations were found to be
directed toward a patient-centered care paradigm. Nurses’ and physicians’ communication, concern, compassion, closeness, and flexibility were identified as facilitators of patient-centeredness, whereas competing roles of control over the patient’s care were recognized as an important barrier. For units planning a change toward a patient-centered ICU culture with open visitation policy, these findings are crucial to guide the implementation process.100

ICU visitation policies in Athens, Greece, are still predominantly restricted.101 As evidence accumulates that flexible and open ICU visitation policies are beneficial for both patients and their families, Athanasiou et al100 surveyed 143 critical care nurses from 6 Athenian public hospitals to investigate their beliefs about the effects of visiting on patients, patients’ families, and staff, as well as their attitudes toward visitation. Strikingly, a large majority of participants were opposed to open visitation, with more than 94% not wanting an open policy in their unit. Despite nurses’ awareness that open ICU visitation is supportive for patients and their families, Greek nurses associate it with hampering of nursing care (75%) and an increased physical and psychological burden (87%). This negative attitude may be influenced by inadequate staffing levels, a high shift rotation, and a limited number of experienced nurses. Optimizing work conditions might help to initiate a change in Greek nurses’ perceptions about open ICU visitation.101

Besides open visitation policies, family presence during resuscitation (FPDR) is an emerging issue in the promotion of family-centered care. Although the evidence for its positive effects on patients’ families continues to increase, the practice is still under debate and its implementation remains inconsistent.102,103

Using a 63-item survey, Tudor et al104 conducted a monocentric study among a convenience sample of 154 nurses working in both inpatient and outpatient units to explore their experiences with resuscitation, perceptions of benefits and risks of family presence, and self-confidence in family presence during resuscitation. The latter was significantly greater in participants who had completed an advanced training program, were highly experienced in resuscitation, specialty certified, or a member of a professional organization. Concerns about family interference during resuscitation, lack of space, lack of support for or trauma to the family members, and performance anxiety were identified as barriers to allowing patients’ families to be present during resuscitation procedures. More experience with FPDR, educational initiatives dealing with its benefits, and the appointment of a designated team member to attend to the patient’s family during resuscitation are required to change current practice and to promote consistent implementation of FPDR.104

In pediatric critical care, family-centered care is largely implemented. However, when the child’s condition becomes unstable and resuscitation is needed, there is less agreement about family presence. To investigate the state of the science concerning family presence during resuscitation and invasive procedures in pediatric critical care, Smith McAlvin et al105 systematically reviewed articles published between 1995 and 2012. Of 113 articles identified, 6 were eligible for inclusion in the review. The authors reported that parents wish to be present during both invasive procedures and resuscitation, would be present again, recommend being present to others, and would not have changed anything about their presence experience. Parents had better coping and better adjustment to the death of their child when present. Parents not present displayed more distress than did parents who were present. Although the generalizability of these findings is hampered by gaps in the methods of the studies included, these results suggest that the presence of patients’ families during resuscitation and invasive procedures increases parents’ satisfaction and coping. Further research is, however, needed.

FINANCIAL DISCLOSURES
None reported.

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REFERENCES


Evidence-based practice and performance improvement have become familiar terms in developed health care settings over the past 2 decades. The major instigator for better quality health care was the Institute of Medicine’s (IOM’s) report in 2000, *To Err is Human*, proposing that medical errors are one of the leading causes of death in the United States. As a result, large organizations, both private and governmental, now encourage evidence-based care by setting specific quality and safety initiatives for health care providers to follow. Although cooperation is not always mandatory, failure to collect data and/or comply with these initiatives can result in loss in reimbursement. Outside these “mandated” initiatives, providers in individual hospitals and units—including the intensive care unit (ICU)—are also encouraged to identify measures important to their specific situations.

Improving care in the ICU should be a goal of every provider in the unit. Critically ill patients undergo extensive invasive testing, may have several monitoring devices, and can be receiving multiple medications. This situation often places them at a greater risk for potentially preventable conditions that can be associated with high morbidity and mortality such as iatrogenic injuries, hospital-acquired infections, pressure ulcers, and delirium. The nursing profession currently comprises the largest segment of the nation’s health care workforce and generally has the most immediate and most consistent patient contact. Critical care nurses often perform most of the care, patient assessments, and evaluations in the ICU, which places them in the perfect position to identify, initiate, evaluate, and sustain quality initiatives. Another IOM report, *The Future of Nursing: Leading Change, Advancing Health* stresses nurses’ fundamental role in transforming our health care system so that it “provides seamless, affordable, quality care that is accessible to all and leads to improved health outcomes.”

This paper will provide guidance in choosing appropriate measures for quality initiatives in an ICU setting, assuring accurate data collection, providing meaningful results, and implementing change. Specific focus will be placed on how nurses can partake in and lead these initiatives.

**Choose the Right Metric**

One of the first steps in developing a quality initiative is deciding what to measure. The metric must both accurately gauge the quality of care and be reliably measurable. Concrete outcomes such as mortality are common metrics used for quality initiatives but these metrics may not always be appropriate for initiatives in the ICU. For example, mortality in a patient with a severe stroke progressing to brain death does not necessarily give an accurate measure of quality of care. A more appropriate metric in this case may include use of end-of-life care such as palliative care or organ donation. Metrics should be relevant to the patient, those caring for the patient, and the health care organization. An example of one metric currently measured in the ICU that fulfills the above criteria is catheter-related urinary tract infections (CAUTIs). This metric is tracked and reported because CAUTIs are one of the most common health care–associated infections and are associated with increased morbidity, mortality, hospital cost, and length of stay. This measure is relevant to both the patient and the organization because decreases in CAUTI rates may improve...
Quality metrics can be divided into 3 broad categories: structural, process, and clinical or health outcomes.

First described by Donabedian in 1966 and recently applied to surgical outcomes by Birkmeyer and colleagues, quality metrics can be divided into 3 broad categories: structural, process, and clinical or health outcomes. Structural measures reflect the system or setting in which the health care is delivered. Examples of structural measures in a critical care setting include the level of training for ICU staff and physicians, staffing models, and open versus closed ICUs. Although they are not direct measures of care quality, such structural differences can be associated with high- or low-quality care. For example, studies have shown that patients in hospitals with better critical care nurse work environments and higher proportions of critical care nurses with a bachelor’s degree in nursing experienced significantly lower odds of death. Structural measures, such as nursing education, are often fairly easy to quantify. But, for some hospitals, the association between a structural measure and high quality care may not be obvious; moreover, financial and staff constraints may render collection of some structural data arduous.

The second category, process measures, describes the care that the patient actually receives. These measures evaluate adherence to various protocols and can be linked to outcomes. They are often used to compare one unit or hospital with another and are usually based on best available evidence such as randomized control trials and systematic reviews. Initiatives to improve CAUTI rates are examples of initiatives that often employ measurement of process metrics; such initiatives are a focus of quality improvement programs because decreasing CAUTI rates has a positive impact on outcome. The Centers for Disease Control and Prevention’s CAUTI guidelines cite multiple studies that have identified specific interventions that may reduce CAUTI rates. These include catheter insertion only for appropriate indications, maintenance of catheters only as long as needed, insertion by properly trained persons using aseptic technique and sterile equipment, and maintenance of unobstructed urine flow. There are difficulties with initiatives based on the measurement of process metrics, however. First, what is considered best practice today may not be considered best practice tomorrow due to the evolution of research. Second, having best-practice processes of care does not necessarily mean that the actual care delivered is of high quality (eg, the use of proper urinary catheter technique may not assure low CAUTI rates).

The last category is health or clinical outcome measures. The National Quality Measures Clearinghouse, a public resource for evidence-based quality measures and measure sets, defines a health or clinical outcome as “a health state of a patient resulting from health care.” Examples of these measures include mortality rates, complication rates, length of stay, readmission rates, patient satisfaction, functional health status, and other measures of health-related quality of life. Using the example of CAUTIs, the comparison of CAUTI rates among units and hospitals is an example of a clinical or health outcome. These rates are often publically reported and can be helpful when patients are choosing a specific health care entity such as a nursing home or surgeon. Caution must be used when interpreting these rates, however, because rates calculated for hospitals, units, or physicians with limited numbers of patients can be grossly inaccurate.

Birkmeyer and colleagues’ discuss a paradigm to help choose metrics based on the risk and the frequency of the procedure being studied. They propose that high-risk, low frequency procedures should be evaluated by structure based measures; low-risk, high-frequency procedures should be evaluated using process measures; and high risk, high-frequency procedures should be evaluated by outcome measures. Gershengorn and colleagues introduce a flow diagram to help select metrics...
When planning for data collection, it is important to consider who will be capturing the data and how data collection will affect their workload.

Optimize Data Collection

Once the measures are chosen, the next step is to determine how to accurately capture and record the data. Historically, patient data was written on paper and abstraction consisted of reading notes handwritten by health care providers. A chart abstractor would read the charts, decipher the handwriting, and attempt to pull out relevant data to be entered in a separate database. This form of data collection is resource intensive and often fraught with error. Wager and colleagues evaluated the accuracy and timeliness of physiologic

Figure Algorithm for appropriate metric identification.
data entry by technicians and nurses before and after electronic health record (EHR) implementation at a large tertiary hospital. They found that when using paper charting, the error rate approached 17% but when transitioned to data entry using an easily assesseable mobile device, error rates fell to < 6%.20

With the introduction of EHRs, data can be captured in real time at the bedside and either automatically entered into a database or manually entered into a computer using an interface.21 Bedside data includes variables such as physiologic data points, medication administration records, and assessments such as pain or Richmond Agitation-Sedation Scale.22 If this data is entered and saved using defined formats, it generally can be easily mined and analyzed. For example, when capturing a time of medication administration, if it is entered into a field defined and formatted as a standard unit of time (eg, mm/dd/yyyy or hh:mm), mining, analyzing, and displaying this data can be automated. However, if data is entered into an EHR using free text (daily progress or shift notes); searching for data is more difficult.23 The use of EHRs for data collection may eliminate data transcription errors,24-27 but may introduce new types of data entry inaccuracies. For example, equipment malfunction may result in erroneous data—some patient monitoring systems will automatically record all blood pressures taken even if the cuff is not connected to the patient, and this results in the collection of an inaccurate measurement. Additionally, the use of EHRs does not replace the need to be clear and precise about what data is to be collected. For example, “time zero” for sepsis patients means very different things to different individuals. For the emergency department nurse, this is often the time that the patient arrives at triage. For the ICU nurse, this may mean when the patient arrives to the ICU. No matter how the data is collected, without clarity on this issue, all data will be unreliable.

Although the implementation of EHRs has been an important step towards consistent and quality health care, EHRs have certainly created additional burdens on providers.28 Many providers complain that the EHR has taken away face time with patients and can often produce redundancy.29 Some institutions maintain mixed electronic and paper medical records due to the costs of implementing the EHR.30 Other systems have not yet maximized interoperability (connections between different software applications that make it possible for unaffiliated providers to directly communicate).31-35 These setups can produce not only redundancy and data errors, but also contempt among those entering duplicate data. When planning for data collection, therefore, it is important to consider who will be capturing the data and how data collection will affect their workload. For example, bedside nurses or technicians are already capturing many data points. In fact, some studies have shown nurses spend nearly 30% of their day documenting while only 7% of their time is spent assessing the patients.36

Studies have also shown an association between better patient outcomes and more nursing time per patient-day.37 Therefore, adding additional documentation time to already overloaded nurses can potentially have a negative impact on patient care. An alternative approach may be to utilize current technology to automate data transfer from patient devices such as patient monitors, smart beds, and infusion pumps.38 A 2003 study indicated that ICU nurses can save up to 30% of documentation time when physiologic data is automated.39 As the nurse is often the provider most aware of all that is happening with and for a patient, he or she may be the best-positioned person to advise on how data collection can be streamlined into usual care activities.

Disseminate Data

Once baseline data is collected and analyzed, the next step is dissemination to the team(s) involved. This step is important to keep the team engaged and can often be best accomplished by champions from different disciplines who have been involved in the project from its inception. Using charts and visual effects will strategically draw the viewer’s eye to the significant results. Ensure that values are clearly labeled on charts and legends are provided. The Table

Table

<table>
<thead>
<tr>
<th>Chart Type</th>
<th>Definition</th>
<th>Ideal use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run charts</td>
<td>Display observed data in an ordered sequence</td>
<td>Easily display trends, shifts, and stability of data</td>
</tr>
<tr>
<td>Control charts</td>
<td>Individual values are plotted in descending order on the x axis; line graph plots cumulative frequency</td>
<td>Focuses the reader’s eye on the factors that have the greatest impact and where an intervention is likely to produce the greatest benefit</td>
</tr>
<tr>
<td>Pareto charts</td>
<td>Bar chart that displays both positively and negatively influencing variables and their impact on the cumulative effect</td>
<td>Helps target both positive and negative influences on a product and easily display the magnitude of each effect</td>
</tr>
<tr>
<td>Scorecards and dashboards</td>
<td>Displays many different indicators together</td>
<td>Can be used to compare individual data with benchmarks. Are often are brightly colored and target areas of improvement</td>
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Empower Nurses

Because they make up the largest segment of the health care workforce and are on the frontline, nurses are well positioned to impact great change. Many critical care nurses only perform clinical duties in a single unit, thus they identify this unit as “home.” These nurses often feel motivated and empowered to improve care when possible. According to the 2004 IOM report, *Keeping Patients Safe: Transforming the Work Environment of Nurses*, “how well we are cared for by nurses affects our health, and sometimes can be a matter of life or death.”¹⁰ The IOM’s 2010 report addressing the future of nursing calls for nurses to be “full partners, with physicians and other health care professionals, in redesigning health care in the United States.”¹⁰

When leading quality initiatives, nurses have and will continue to play integral roles. For example, the recent randomized controlled trial evaluating checklists to decrease central-line–associated blood stream infections (CLABSIs), was initiated and led by nursing.¹¹ In this study, central venous catheters were placed in the intervention group using an infection prevention bundle previously described by Berenholtz et al.¹² The intervention group was found to have a 70% reduction in mean number of CLABSIs by the end of phase 1 compared to 21% in the control group.¹² Other studies striving to improve outcomes in preterm birth, enteral nutrition, and ventilator-associated pneumonia rates were all nurse-driven and had significant positive results.¹³⁻¹⁵ Providing multidisciplinary team-based clinical care in the ICU is known to improve outcomes and the Institute for Healthcare Improvement recommends implementation of multidisciplinary team rounds in the ICU.¹⁶ Large tertiary facilities, outreach organizations, as well as insurance companies have empowered nurses to improve patient care by enabling them to shape patients’ plans of care.¹⁷ There has been less overt advocacy around multidisciplinary team leadership, specifically for quality improvement initiatives. The current and future focus of health care is quality and patient safety. Nurses in general, and ICU nurses in specific,¹⁸ have often been described as patient advocates. Who better to lead initiatives to ensure high quality and safe care?

FINANCIAL DISCLOSURES
None Reported.

eLetters
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REFERENCES


34. Beaulieu-Volk D. EHRs’ interoperability challenge. HIE expansion aimed at helping providers exchange health information safely, but not all services created equally. Med Econ. 2014;91(6):763.


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HEART RATE INDUCED CONDUCTION DEFECTS

By Teri M. Kozik, RN, PhD, CNS, CCRN, Mary G. Carey, RN, PhD, CNS, Salah S. Al-Zaiti, RN, PhD, NP, and Michele M. Pelter, RN, PhD

Scenario: Below are 2 rhythm strips taken from resting 12-lead electrocardiograms (ECGs) for a 73-year-old man who came to the emergency department (ED) with complaints of a productive cough, shortness of breath, and chest discomfort for the past week. Leads II, V₁ and V₆ are shown below and were recorded on ED admission (left) and on the day of discharge (right). His temperature on admission was 103.1°F. He has a history of hypertension, hyperlipidemia, and coronary bypass graft surgery. He was admitted to the medical telemetry unit with pneumonia and treated with supplemental oxygen and antibiotic therapy.

Interpretation Questions:

1. Is the ECG properly calibrated (10 mm) and are leads properly placed?  □ Yes  □ No  □ NA
   If no, interpret cautiously.

2. Is this a sinus rhythm (one P wave preceding every QRS complex)?  □ Yes  □ No  □ NA
   If no, check for number of P waves in relation to QRS complexes.

3. Is the heart rate (R-R interval) normal (60-100 beats/min)?  □ Yes  □ No  □ NA
   If no, check for supra-ventricular or ventricular arrhythmias.

4. Is the QRS complex narrow (duration < 110 milliseconds [ms] in V₁)?  □ Yes  □ No  □ NA
   If no, check for bundle branch blocks (BBBs), pacing, or ventricular arrhythmia.

5. Is the ST segment deviated (> 2 mm in V₂-V₃, or > 1 mm in other leads)?  □ Yes  □ No  □ NA
   If yes, check for similar deviations in contiguous cardiac territories.

6. Is the T wave inverted in relation to the QRS (> 0.5 mV)?  □ Yes  □ No  □ NA
   If yes, check for ST deviation or conduction abnormalities.

7. Is the QT interval lengthened (> 450 ms [women] or > 470 ms [men])?  □ Yes  □ No  □ NA
   If yes, check for ventricular arrhythmias or left ventricular hypertrophy.

8. Is R- or S-wave amplitude enlarged (S wave V₁ + R wave V₅ > 35 mm)?  □ Yes  □ No  □ NA
   If yes, check for axis deviation or other chamber hypertrophy criteria.

Teri M. Kozik is a nurse researcher at St. Joseph’s Medical Center, Stockton, California. Mary G. Carey is associate director for clinical nursing research, Strong Memorial Hospital, Rochester, New York. Salah S. Al-Zaiti is an assistant professor at the Acute and Tertiary Care Department, University of Pittsburgh, Pennsylvania. Michele M. Pelter is an associate professor at the Orvis School of Nursing, University of Nevada, Reno.
Interpretation and Rationale

The ED admission ECG shows sinus tachycardia with LBBB. On the day of discharge, the ECG strip shows normal sinus rhythm. These ECGs demonstrate that this patient has a rate dependent LBBB (RD-LBBB). The ST-segment changes noted on ED admission are most likely secondary changes due to the presence of the LBBB.

Mechanism and Management

A RD-LBBB is defined as a LBBB that develops during an increase in heart rate. The rate at which a RD-LBBB occurs is called the critical heart rate. Interestingly, the critical heart rate that results in a RD-LBBB is often higher than the rate at which the RD-LBBB resolves.

This conduction defect occurs when one of the bundle branches (left BB in this case) has a prolonged refractory (recovery) period resulting in delayed depolarization of the myocardium. When the heart rate decreases, normal repolarization occurs, and the conduction defect disappears. Critical heart rates that result in RD-LBBB vary. In some patients, a minor heart rate change as little as 1 to 2 beats/min around the critical heart rate can result in a RD-LBBB. RD-LBBB is considered pathological. Prolongation of the refractory period in a BB was once thought to be due solely to intrinsic disease of the cardiac conduction system. However, other causes have been identified including hypertension, coronary artery disease, ischemia, aortic valve disease, and cardiomyopathies.

This patient’s RD-LBBB was caused by sinus tachycardia that was most likely caused by his fever. After successful management of his pneumonia and return to normal sinus rhythm, the RD-LBBB disappeared. Given this patient’s history of hypertension and coronary artery disease, evaluation by a cardiologist is warranted to rule out ischemia or other cardiac pathology.
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CCRN/PCCN Review Course
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 fees all attendees $100. Credits: 14 CEUs.

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SCRN (Stroke Certified Registered Nurse) Review Course
Date: February 20-21, 2015 Place: Nova Southeastern University. Address: 8585 SW 124th Ave, FL 33183. Keynote Speaker: Kendra Kent. Sponsor: Greater Miami Area Chapter of AACN. Contact: Ruth Salathe. Phone: (305) 586-4203. E-mail: ruthsalathe@gmail.com. Fee: Members, $150; nonmembers, $175; 1 day course fees all attendees $100; Groups of 3 $140/person (applies only if registration received together). Credits: 14 CEUs.

Plantation
40th Annual Spring Seminar
Date: April 18, 2015 Place: Renaissance Hotel. Address: 1230 South Pine Island, Plantation, FL 33324. Keynote Speakers: Teri Lynn Kiss, Kendra Menzies-Kent, Douglas Houghton, Mary Ann “Cammy” Fancher. Sponsor: Broward County Chapter of AACN. Contact: Patty Kelly. Phone: (954) 722-8020. E-mail: pattykelly7@att.net. Fee: Members, $75; nonmembers before April 1, 2015. Credits: 6.5 CEUs.

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January Acute and Critical Care Neuroscience Brunch
Date: January 24, 2015. Place: Par-A-Dice Hotel and Casino, East Peoria, IL. Keynote Speakers: Ruth Arms, Jan Boerke, Cindy Guede, Peter Cenek. Sponsor: Heart of Illinois Chapter of AACN. Contact: Gayle A. Lucas. Phone: (309) 256-8498. E-mail: galucas@att.net. Fee: $40. Credits: TBD.

Itasca
Midwest Conference
Date: March 23-24, 2015. Place: Eaglewood Resort and SPA. Address: 1401 Nordic Rd, Itasca, IL 60143. Keynote Speakers: TBA. Sponsor: Midwest Chicago Area Chapter of AACN. Contact: Jenny A. Zaker. Phone: (847) 309-0662. E-mail: zakerj46@gmail.com. Fee: TBA. Credits: TBD.

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