Notice to CNE enrollees:
A closed-book, multiple-choice examination following this article tests your understanding of the following objectives:

1. Discuss nursing recommendations for patients with a neurological diagnosis and end-tidal carbon dioxide level/intracranial pressure (ETCO₂/ICP) changes.
2. Describe the physiological stress response to clustered nursing interventions in neurological patients receiving mechanical ventilation.
3. Discuss the importance of clustering nursing activities to minimize increased ICP and ETCO₂ changes.

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Background
Guidelines recommend rest periods between nursing interventions for patients with a neurologic diagnosis but do not specify a safe number of interventions.

Objectives
To examine the physiological stress response to clustered nursing interventions in neurological patients receiving mechanical ventilation.

Methods
Prospective, comparative, descriptive design to examine effects of clustered interventions (≥6 interventions in a single nursing interaction) versus nonclustered interventions on patients’ stress. Stress response was defined as a 10% change in end-tidal carbon dioxide from before the interaction to (1) 5 and 10 minutes after the start of the interaction, (2) at the end of the interaction, and (3) 15 minutes after the interaction.

Results
The mean percent change in end-tidal carbon dioxide at 5 minutes differed significantly between patients with clustered interventions and patients with nonclustered interventions (6.7% vs -0.2%; P = .001). Patients with clustered interventions were significantly more likely than patients with low clustering to exhibit a stress response at 5 minutes (24.3% vs 0%; P = .01).

Conclusions
Neurologic patients receiving mechanical ventilation who experienced 6 or more clustered nursing interventions showed a higher mean change in end-tidal carbon dioxide than did patients who received fewer than 6 clustered interventions. These findings suggest that providing fewer interventions during 1 nursing interaction may minimize induced stress in neurologic patients receiving mechanical ventilation. (American Journal of Critical Care. 2013;22:239-245)
Priority nursing management for patients with a primary diagnosis of brain disease includes minimizing and/or eliminating all activity that increases intracranial pressure (ICP). Physiological stress increases metabolism and raises the level of carbon dioxide, which acts as a vasodilator and thus can increase ICP. Patients with an acute neurologic diagnosis experience an induced hypermetabolic state due to the cerebral injury, hyperthermia, and increased central nervous stimulation and muscle tone. This hypermetabolic state results in increased resting production of carbon dioxide.

The partial pressure of arterial carbon dioxide (PaCO₂) can affect cerebral blood flow, cerebral blood volume, and therefore ICP. End-tidal carbon dioxide level (ETCO₂), monitored by clinicians via a capnograph, is a proxy for PaCO₂ under normal ventilation/perfusion matching in the lungs and is the partial pressure of carbon dioxide in the airway at the end of expiration. Researchers have demonstrated that subclinical fluctuations in ETCO₂ are associated with clinically significant fluctuations in ICP and have suggested that these fluctuations could be eliminated or reduced if patients’ ventilation and carbon dioxide levels were more tightly controlled.

Nurses cluster patient care interventions to allow patients to get maximal rest between interactions where they are receiving nursing care. Nursing guidelines have recommended allowing such rest periods without specifying whether the nurse should do a multitude of interventions in a concentrated period of time or limit the number of interventions per interaction to permit rest between episodes of nursing care. However, data are not sufficient to provide specific practice guidelines at this time. In addition, the studies are old and have not examined newer and more novel technologies available to examine the physiological effect of nursing interventions in patients with a neurologic diagnosis.

Changes in ETCO₂ level as measured by capnography may help to determine the number of interventions a patient with a primary neurologic diagnosis who is receiving mechanical ventilation can tolerate before cerebral blood flow is affected. The purpose of this study was to examine if physiological stress caused by nursing activities results in additional carbon dioxide production that is reflected in the ETCO₂. The purpose of this study was also to examine the effect of clustering of nursing interventions on physiological stress as indicated by changes in ETCO₂ in neurologic patients receiving mechanical ventilation.

**Methods**

A prospective, comparative, descriptive design was used to examine the physiological stress response to clustering of nursing interventions in neurologic patients receiving mechanical ventilation. The study was approved by the institutional review board at Allina Hospitals and Clinics, Minneapolis, Minnesota. Consent was obtained from each patient’s legal representative, as all enrolled patients were sedated and neurologically injured. Before enrolled patients transferred out of the intensive care unit (ICU), they were assessed by the nurse researcher if they were able to give consent. If the consent was not obtained from the patient, a letter was sent to their home explaining the study with additional contact information. No patients contacted the research team for follow-up.

**Setting and Sample**

From July 2009 through March 2010, a convenience sample (n = 15) of adult ICU patients in a 30-bed medical/surgical/neurological, Beaconsfield ICU at Abbott Northwestern Hospital in Minneapolis, Minnesota, were studied. Patients included in the study had a primary diagnosis of brain disease (eg, ischemic stroke, tumor, status epilepticus, intracranial hemorrhage, subdural hematoma, and/or subarachnoid hemorrhage) and had been receiving mechanical ventilation for less than 48 hours. Exclusion criteria were lung disorder.

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**About the Authors**

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(eg, chronic obstructive pulmonary disease, asthma, lung cancer, pneumonia, acute respiratory distress syndrome), age less than 18 years, and/or pregnancy. Non-English speaking adults were also excluded because of the lack of financial resources to hire interpreters for this nonfunded study.

**Data Collection Methods**

Patients’ characteristics (age, sex, diagnosis) were collected from each patient’s electronic health record and entered into the data form by the research nurse. All other data were collected for 4 to 6 nursing interactions within a 24-hour period for each patient participating. An interaction was defined as the discrete period of time that a nurse was providing care for 1 patient. Education was provided for nurses delivering care for patients enrolled in the study either by a face-to-face interaction or through written materials.

**Nursing Interaction and Nursing Interventions.** A study-specific data collection form was created on which the start and stop times of the entire nursing interaction and the types of nursing interventions performed were noted. Nursing-specific interventions included assessment, administering medications, suctioning, repositioning, hygiene, oral care, bath, shampoo, shave, incontinence care, wound care, range-of-motion exercises, linen change, weighing, application of splints or binders, and/or other.

**ETCO**

A noninvasive Infinity Microstream pod with Oridion’s Microstream technology (Siemens Medical Solutions USA Inc) was used to measure expired carbon dioxide. The ETCO sensor was attached to the endotracheal tube and the ETCO was displayed on the bedside General Electric monitor screen both as a visual waveform and a numerical value. Vital signs (heart rate, respiratory rate, blood pressure, arterial oxygen saturation) and ETCO were measured in 5-minute increments starting 5 minutes before interventions began and continuing until 15 minutes after the interventions had been completed. Additionally capnogram printouts were collected at baseline, once during each interaction, and 15 minutes after each interaction.

**Analytic Measures**

The dependent variables were measures of stress response at several different time points. The stress response was measured at multiple time periods because little is known about when patients experience the highest levels of stress while undergoing care. The time points considered were (1) from baseline to 5 minutes after beginning the interventions, (2) from baseline to 10 minutes after beginning the interventions, (3) from baseline to the end of the nursing interaction, and (4) from baseline to 15 minutes after the nursing interaction was completed. For each time interval, the percent change in ETCO from baseline was calculated. The percent change was used to classify whether a patient exhibited a stress response at each of the time points. A stress response was defined as a 10% or greater change in ETCO from baseline. The independent variable was clustered interventions (ie, number of interventions) status. For each nursing interaction, interventions were classified as clustered or nonclustered. Clustered interventions were defined as 6 interventions or more occurring in 1 nursing interaction. The threshold of 6 interventions per interaction was chosen because it represented the mean and the median of the frequency of the distribution of the number of interventions per nursing interaction.

**Statistical Analysis**

Data analysis took place in 2 phases. The first phase was a patient level analysis, and the second phase was a nursing interaction level analysis. The interaction level analysis examined patients’ stress responses to clustered versus nonclustered nursing interventions. Characteristics of the patients and the nursing interactions were summarized by using means and percentages. Student t tests with unequal variance were used to test for significant differences in mean ETCO change by intervention status. Significant differences in the percentage of patients exhibiting a stress response by intervention status were evaluated by using χ² tests. All analyses were conducted by using Stata statistical software (version 11).

**Results**

**Patients’ Characteristics**

The sample population consisted of 15 patients, of which 7 were males (47%) and 8 were females (53%). The mean age of patients was 54.3 years (SD, 21.7) and ranged from 18 to 92 years. The majority of patients (53%) had an intracranial hemorrhage; the other patients (47%) had tumors, status epilepticus, or multiple neurologic diagnoses (Table 1). Patients experienced a mean of 4.8 nursing interactions (SD, 0.83; range, 4-6).

**Characteristics of Nursing Interactions**

The interaction-level analysis was conducted by using the 60 nursing interactions for which complete...
The mean number of interventions per nursing interaction was 6.1 (SD, 1.5; range, 3-10). Nursing interactions lasted from 10 to 80 minutes (mean, 32.8 minutes; SD, 15.6 minutes). Overall, 62% of nursing interactions were classified as clustered interventions. Table 2 shows the frequency of each type of intervention performed during nursing interactions by clustering status.

**ETCO₂ Changes**

Percent change in ETCO₂ differed significantly between patients with clustered interventions and patients without clustered interventions (Table 3). From baseline to 5 minutes into the interaction, patients with clustered interventions had a 6.7% mean change in ETCO₂, whereas patients without clustered interventions had a -0.2% change in ETCO₂ level ($P = .001$). Similarly, from baseline to the end of the interaction, patients with clustered interventions experienced a 5.5% change in ETCO₂, while patients without clustered interventions experienced a 0.2% change in ETCO₂ ($P = .03$). Although the mean percent change in ETCO₂ was less than the 10% threshold used to define a stress response, some nursing interactions did in fact have a percent change greater than 10%. Moreover, patients with clustered interventions were significantly more likely than those without clustered interventions to exhibit a stress response (Table 4). From baseline to 5 minutes into an interaction, 24.3% with clustered interventions exhibited a stress response compared with 0.0% of patients without clustered interventions ($P = .01$).

**Discussion**

Although nursing guidelines are ambiguous regarding the clustering of interventions, our results demonstrate that the mean percent change in ETCO₂ data were available. The mean number of interventions per nursing interaction was 6.1 (SD, 1.5; range, 3-10). Nursing interactions lasted from 10 to 80 minutes (mean, 32.8 minutes; SD, 15.6 minutes). Overall, 62% of nursing interactions were classified as clustered interventions. Table 2 shows the frequency of each type of intervention performed during nursing interactions by clustering status.

**Table 1**

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intracranial hemorrhage</td>
<td>8 (53)</td>
</tr>
<tr>
<td>Status epilepticus</td>
<td>2 (13)</td>
</tr>
<tr>
<td>Tumor</td>
<td>3 (20)</td>
</tr>
<tr>
<td>Multiple neurologic diagnoses</td>
<td>2 (13)</td>
</tr>
</tbody>
</table>

**Table 2**

<table>
<thead>
<tr>
<th>Activity</th>
<th>% Clustered (n=37)</th>
<th>% Nonclustered (n=23)</th>
<th>Total % of interactions (n=60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessments</td>
<td>100</td>
<td>91</td>
<td>97</td>
</tr>
<tr>
<td>Medications</td>
<td>65</td>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td>Suctioning</td>
<td>97</td>
<td>96</td>
<td>97</td>
</tr>
<tr>
<td>Positioning</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Hygiene</td>
<td>81</td>
<td>35</td>
<td>63</td>
</tr>
<tr>
<td>Oral care</td>
<td>97</td>
<td>96</td>
<td>97</td>
</tr>
<tr>
<td>Bath</td>
<td>32</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>Shampoo</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Shave</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Incontinence care</td>
<td>16</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Wound care</td>
<td>3</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Range-of-motion exercises</td>
<td>51</td>
<td>4</td>
<td>33</td>
</tr>
<tr>
<td>Linen change</td>
<td>38</td>
<td>9</td>
<td>27</td>
</tr>
<tr>
<td>Weighing</td>
<td>19</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Applying splint</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 3**

<table>
<thead>
<tr>
<th>Timing</th>
<th>% Change Clustered (n=37)</th>
<th>% Change Nonclustered (n=23)</th>
<th>Difference %</th>
<th>SE</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Minutes into interaction</td>
<td>6.7</td>
<td>-0.2</td>
<td>-6.9</td>
<td>2.4</td>
<td>-3.421</td>
<td>.001</td>
</tr>
<tr>
<td>10 Minutes into interaction</td>
<td>5.6</td>
<td>2.5</td>
<td>-3.1</td>
<td>4.4</td>
<td>-0.795</td>
<td>.43</td>
</tr>
<tr>
<td>Beginning to end of interaction</td>
<td>5.5</td>
<td>0.2</td>
<td>-5.3</td>
<td>2.8</td>
<td>-2.184</td>
<td>.03</td>
</tr>
<tr>
<td>15 Minutes after interaction</td>
<td>3.8</td>
<td>0.7</td>
<td>-3.1</td>
<td>2.2</td>
<td>-1.609</td>
<td>.11</td>
</tr>
</tbody>
</table>
differed significantly between patients who received 6 or more clustered interventions compared with patients who received fewer than 6 interventions during a nursing interaction. These findings suggest that providing fewer interventions at 1 nursing interaction may minimize induced stress.

Research has been conducted that examines the relationship between the patient’s ICP and an individual routine nursing intervention such as suctioning, turning, bathing, oral hygiene, neurologic assessment, and tube manipulation. The nursing interventions resulted in minimal to significant increases in ICP that were at times sustained for 10 minutes. However, no researcher has examined changes in ET Co2 associated with these nursing activities.

Bruya6 reported no significant differences in ICP between patients with known or suspected intracranial hypertension who had rest periods incorporated between nursing interventions and patients who did not. In contrast, our results demonstrate that the increased number of nursing interventions did increase the stress experienced by patients as measured by ET Co2. It could be that ET Co2 provides a more immediate reflection of stress experienced by the patient than ICP does.6

Kim et al3 reported that some subclinical changes in ET Co2 resulted in increased ICP. For ventilator patients with a neurologic diagnosis who do not have a monitored ICP, measurement of ET Co2 is an inexpensive, noninvasive way to gather information to help nurses determine if the number of interventions or a specific intervention being provided is causing an increase in stress. Nurses could then more proactively plan on when and how many interventions to provide at a time. For example, nurses may decide they need to pre-treat the patient with medication to decrease pain and/or an antianxiety medication.

For patients with traumatic brain injury, PaCO2 and ET Co2 are maintained from 30 to 35 mm Hg in an attempt to control cerebral blood flow and therefore ICP.9 However, no recommendations are available for ventilator patients with neurologic conditions, and future research should examine optimal patient-specific ET Co2 goals.

The definition of stress for this study was based on the American Association for Critical-Care Nurses’s determination that a 10% change in ET Co2 from baseline is a reportable condition and that ET Co2 changes on the basis of metabolism.10 Carbon dioxide is found in the blood and cerebral tissue as the end product of cell metabolism and is the most potent mediator influencing cerebral blood flow.1

However, it is not known at what point the change in ET Co2 is detrimental to a patient’s condition. Could it be that a 5% change may actually start to cause or facilitate adverse outcomes?

Suctioning of a patient’s endotracheal tube is known to cause an increase in ICP,11 and suctioning was done 95% of the time during clustering of interventions. Because suctioning also occurred when there was no significant change in ET Co2, is there a particular approach to suctioning that does not create as much stress? Does all suctioning affect ET Co2, or does the number of times a patient is suctioned within 1 interaction affect ET Co2? In future studies, researchers should examine not only suctioning but the number of times a patient is suctioned per interaction.

This study also identified the types of interventions performed most often during a nursing interaction. Positioning of patients was completed in 100% of the interactions, followed by assessment (97%), suctioning (97%), and oral care (97%). These interventions were usually completed in both the patients who received clustered interventions and patients who did not. One should question whether it is the number of interventions, the duration of the interaction, or the type of care that is causing the changes in ET Co2. Hugo,7 Rising,11 and Snyder4 all reported that the greatest increases in ICP were associated with respiratory care and repositioning in patients with a neurologic diagnosis. Snyder4 and Hugo7 recognized that these interventions were often simultaneous or were performed in quick succession with other interventions, so it was challenging to attribute the increases in ICP specifically to the respiratory care and/or repositioning. Future research should examine changes with specific types of care to provide nurses with data so that they can plan interventions in a manner that causes the least amount of stress to the patient.

Table 4 Percentage of nursing interactions with stress response at selected time points by intervention clustering status

<table>
<thead>
<tr>
<th>Timing</th>
<th>% Change</th>
<th>Clustered (n = 37)</th>
<th>Nonclustered (n = 23)</th>
<th>χ2</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Minutes into interaction</td>
<td>24.3</td>
<td>0.0</td>
<td>6.582</td>
<td>.01</td>
<td></td>
</tr>
<tr>
<td>10 Minutes into interaction</td>
<td>24.3</td>
<td>13.0</td>
<td>1.128</td>
<td>.34</td>
<td></td>
</tr>
<tr>
<td>Beginning to end of interaction</td>
<td>24.3</td>
<td>4.4</td>
<td>4.075</td>
<td>.07</td>
<td></td>
</tr>
<tr>
<td>15 Minutes after interaction</td>
<td>13.5</td>
<td>4.4</td>
<td>1.324</td>
<td>.39</td>
<td></td>
</tr>
</tbody>
</table>

Providing fewer interventions at 1 nursing interaction may minimize induced stress.
Limitations

First, because of our small sample size, some substantial, clinically relevant differences that would have been significant with a larger sample may not have been statistically significant in this study. Second, a convenience sample was used, and the patients in this study may not be representative of all neurologic patients receiving mechanical ventilation. Third, 10 interactions in our study were eliminated because they had incomplete data. Finally, the issue of confounding variables must be considered. The analyses do not account for differences in interactions between the group that received clustered interventions and the group that did not. These differences may explain the changes in ETCO₂ and the increased prevalence of the stress response in the group with clustered interventions. Vital signs and ETCO₂ during interactions were not compared.

Implications for Practice

Because of the small sample size, we are limited in making recommendations for practice. These results provide the beginning of an evidence base for how and what interventions nurses provide for patients with a neurologic diagnosis who are receiving mechanical ventilation.

Conclusions

Neurologic patients receiving mechanical ventilation who had 6 or more clustered interventions experienced a higher mean change in ETCO₂ than did patients who received fewer than 6 interventions. Ambiguous nursing guidelines offer no concrete recommendations regarding clustered interventions, but the findings of this study suggest that providing fewer interventions in 1 nursing interaction may minimize induced stress. Future research should include a larger sample size, other populations of patients, specification of which nursing interventions cause more stress, and other measures of the stress response such as biomarkers.

FINANCIAL DISCLOSURES

None reported.

eLetters

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