



NURSES' DETECTION OF INEFFECTIVE INSPIRATORY EFFORTS DURING MECHANICAL VENTILATION

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Background Patient-ventilator dyssynchrony is common and may influence patients' outcomes. Detection of such dyssynchronies relies on careful observation of patients and airway flow and pressure measurements. Given the shortage of specialists, critical care nurses could be trained to identify dyssynchronies.

Objective To evaluate the accuracy of specifically trained critical care nurses in detecting ineffective inspiratory efforts during expiration.

Methods We compared 2 nurses' evaluations of measurements from 1007 breaths in 8 patients with the evaluations of experienced critical care physicians. Sensitivity, specificity, positive predictive value, negative predictive value, and the Cohen κ for interobserver agreement were calculated.

Results For the first nurse, sensitivity was 92.5%, specificity was 98.3%, positive predictive value was 95.4%, negative predictive value was 97.1%, and κ was 0.92 (95% CI, 0.89-0.94). For the second nurse, sensitivity was 98.5%, specificity was 84.7%, positive predictive value was 70.7%, negative predictive value was 99.3%, and κ was 0.74 (95% CI, 0.70-0.78).

Conclusion Specifically trained nurses can reliably detect ineffective inspiratory efforts during expiration. (*American Journal of Critical Care*. 2012;21:e89-e93)

Patient-ventilator dyssynchrony (PVD) is highly prevalent in patients receiving mechanical ventilation,^{1,3} and it may influence their outcome. PVD increases the duration of mechanical ventilation and consequently the tracheostomy rate.^{1,4} PVD has also been implicated in respiratory muscle injury.^{1,4,5} Ineffective inspiratory efforts during expiration (IEE) and double triggering are the most common types of PVD.^{1,6} An IEE is defined as activation of inspiratory muscles without triggering of the ventilator. Nowadays, IEE detection is based on the careful observation of patients' inspiratory efforts and waveforms on mechanical ventilators.^{7,8} IEEs can be detected by identifying a sudden decrease in expiratory flow that is due to a reduction in expiratory driving pressure (alveolar pressure minus airway pressure) caused by the activity of inspiratory muscles (see Figure). Nevertheless, the clinical ability to recognize patient-ventilator dyssynchronies by visual inspection of flow and airway pressure tracings is generally quite low.⁹

Training nurses to detect PVD would have some advantages. First, it would help compensate for the lack of critical care physicians.¹⁰ Moreover, nurses spend more time with patients, so nurses could detect dyssynchrony earlier than other caregivers would.

We hypothesized that after specific training, critical care nurses would be able to detect IEE as accurately as critical care physicians could detect it.¹¹ Preliminary data from this study were presented at an international meeting.¹²

About the Authors

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Materials and Methods

The institutional ethics committee approved the study, waiving informed consent from the patients because the study was observational and investigators were not involved in any clinical decision, no extra effort for personnel and no change in usual treatment were required, and patients' anonymity was ensured by encryption software. All physicians and nurses participating in the study provided their consent.

Subjects

We studied airway flow and pressure recordings of 1024 breaths from 8 patients admitted to a general intensive care unit (ICU). We included patients who were at least 18 years old and had been undergoing mechanical ventilation for more than 24 hours with 1 of 2 ventilators: Evita 4 (Dräger Medical AG, Lubeck, Germany) or Servo-i (Maquet Critical Care, Solna, Sweden). The study subjects were the first 8 patients to undergo mechanical ventilation in the ICU of our hospital after the installation of the signal acquisition system (BetterCare, Sabadell, Spain). We decided to present approximately 1000 breaths to the study participants, a fair estimate of the number of breaths an expert or nurse can evaluate without getting tired or losing concentration. The signal acquisition system classified each breath into 4 categories as a function of the degree of deviation of the actual expiratory flow from a theoretical mono-exponential expiratory flow calculated from patient's respiratory mechanics. We selected the first 32 breaths in each deviation category from each of the 8 patients, and this yielded a data base of 1024 breaths for the study. A random-

Patient-ventilator dyssynchrony increases mechanical ventilation duration and consequently the tracheostomy rate

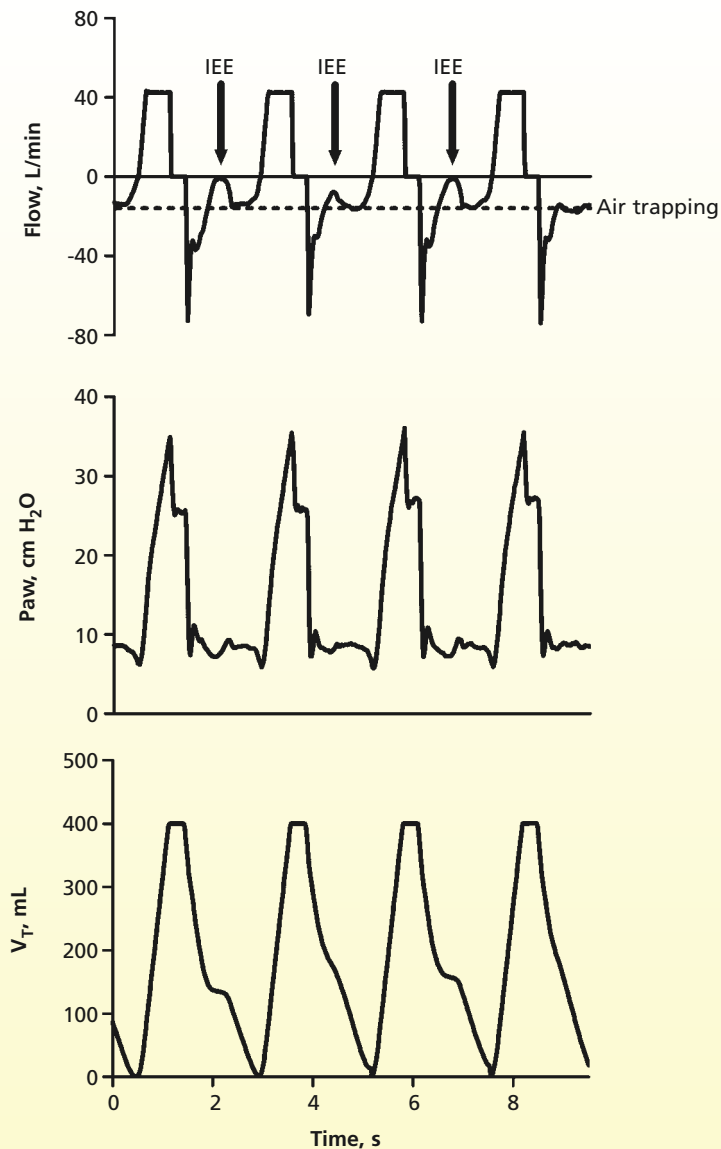


Figure Flow, airway pressure (Paw), and tidal volume (V_T) waveforms from a patient with obstructive lung disease receiving mechanical ventilation on assisted volume-controlled mode. Ineffective inspiratory efforts during expiration (IEE) can be observed in the flow tracing (arrows). IEE can be detected by identifying a sudden decrease in expiratory flow that is due to a reduction in expiratory driving pressure caused by inspiratory muscle activity followed by an increase in expiratory flow due to inspiratory muscle relaxation, and not followed by a ventilator breath. The most frequent reason for IEE is air trapping and associated auto-positive end-expiratory pressure.

ized sequence of the 1024 JPEG images showing airflow and airway pressure was presented to experts and nurses.

IEE Analysis by Experts

A computer program randomly presented each breath as a JPEG image depicting airflow and airway pressure to 5 intensivists with extensive experience

in mechanical ventilation. Individually, each expert, blinded to the others' response, categorized each selected breath as an IEE, not an IEE, or unknown (when he or she could not establish whether a breath was an IEE). At least 3 valid responses from the experts (not classified as unknown) were required to finally label a breath as IEE or not IEE. Breaths without 3 valid responses and those labeled unknown were evaluated in consensus. During consensus evaluation, these breaths were presented to all the experts on a big screen in a room and they were encouraged to discuss why they considered it an IEE or not. After discussion, the experts were again asked for a decision. Breaths in which at least 3 experts did not provide a valid response after discussion and breaths for which the winning decision did not achieve at least 4 votes were discarded from the analysis.

Nurses' Evaluation

We invited staff nurses from our ICU with more than 4 years' experience in general care of critically ill patients to participate in this study, and 2 of them agreed to be trained and to participate in the study. The breaths that had been categorized by the experts as IEE or not IEE were presented to these 2 specifically trained nurses, who were asked to categorize each breath as IEE, not IEE, or unknown.

Nurses' Training

The 2 participating nurses were provided with literature about patient-ventilator interaction and were then trained (2 hours/day for 20 days) to detect IEE by observing respiratory mechanics and pressure and flow measurements. During the training period, the nurses participated in mechanical ventilation rounds and received theoretical (lectures) and practical (measurement analysis) guidance.

Statistical Analysis

The opinion reached by consensus of the 5 critical care experts was considered the reference standard against which the nurses' opinions would be tested. Thus, a true-positive result was defined as a breath classified as an IEE by the experts and the nurse, a true negative as a breath classified as not an IEE by the experts and the nurse, a false positive as a breath classified as an IEE by the nurse but not by the experts, and a false negative as a breath classified as an IEE by the experts but not by the nurse. Standard formulas were used to calculate sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Agreement between (1) individual expert's assessment and the assessment

reached by consensus and (2) individual nurse's assessment and the assessment reached by consensus was analyzed with the Cohen κ statistic (SPSS 19.0 software, IBM, Armonk, New York). A κ between 0.41 and 0.75 was considered good, and a κ higher than 0.75 was considered excellent.¹³

Results

Experts failed to reach a consensus on 17 of the 1024 study breaths (1.7%), so these breaths were discarded from the analysis. Experts found 271 IEEs in the 1007 study breaths. The mean κ between individual experts' response and the consensus response was 0.85 (SD, 0.08).

The first nurse classified 22 breaths (2.2%) as unknown, and the second nurse classified 37 breaths (3.7%) as unknown. Results for the first nurse (n=985) were as follows: sensitivity, 92.5%; specificity, 98.3%; PPV, 95.4%; NPV, 97.1%; and κ , 0.92 (95% CI, 0.89-0.94). Results for the second nurse (n=970) were as follows: sensitivity 98.5%; specificity, 84.7%; PPV, 70.7%; NPV, 99.3; and κ , 0.74 (95% CI, 0.70-0.78).

Discussion

Our main findings are that experienced ICU nurses are able to detect IEEs after special training with similar accuracy to critical care experts in mechanical ventilation.

Although ventilator performance has improved in recent years, detecting PVD still requires highly trained personnel, which are scarce, so PVDs often go undetected.¹⁻³ This is an issue of concern because PVD may influence outcome. Thille et al¹ studied 62 patients receiving mechanical ventilation for more than 24 hours who were able to trigger all the ventilator's breaths during assisted-control ventilation. Patients with an asynchrony index (the number of asynchrony events divided by the total respiratory rate expressed as a percentage) higher than 10% required more time receiving mechanical ventilation (25 days vs 7 days), were more likely to require more than 1 week of mechanical ventilation (87% vs 49%), and had a higher rate of tracheostomies (33% vs 4%). Similarly, de Wit et al⁵ noted that patients with an ineffective triggering index of 10% had longer duration of mechanical ventilation, worse 28-day ventilator-free survival, and longer ICU and hospital stays. Moreover, one of the main aims of mechanical ventilation is to decrease the load on respiratory muscles, but PVD can actually increase the load on inspiratory muscles instead. Leung et al¹⁴ studied 11 patients (8 with chronic obstructive pulmonary disease) and reported that during IEE the diaphragmatic pressure-time product was 38% higher than during triggered breaths.

Many tasks traditionally performed by physicians can be done by nurses. For instance, Shum et al¹⁵ showed that specifically trained nurses can perform flexible sigmoidoscopy safely and effectively. Bambi et al¹⁶ reviewed the literature and found support for implementing advanced nurse practitioners in emergency departments to screen patients and reduce waiting times for patients with minor ailments. We found that, after specific training, nurses were able to detect IEE with similar accuracy to highly trained physicians, although the responses of the 2 nurses differed. In fact, we compared each nurse's ratings against the ratings of a board of physicians with extensive experience in mechanical ventilation, so our design could be considered biased against the 2 nurses. Nevertheless, the nurses' results were very good.

Colombo et al⁹ tested the accuracy of highly experienced ICU physicians and first-year ICU residents at detecting PVD against a reference standard of diaphragmatic electromyography. Neither experienced nor less experienced physicians were specifically trained in detecting PVD, and their results were very poor (although experienced physicians' results were slightly better) compared with the results of our specifically trained nurses. This finding suggests that specific training and the use of dedicated algorithms¹¹ could be more important than previous experience for detecting IEE. Training nurses to detect IEE could have a marked effect on patient care: because nurses usually spend more time at an individual patient's bedside than physicians, IEE could be detected and resolved earlier. Furthermore, this added responsibility might help increase critical care nurses' job satisfaction and reduce turnover.

Some limitations of this study must be mentioned. First, although the nurses participating in this study did not have previous specific training in mechanical ventilation, they did have extensive experience in critical care and were highly motivated to participate in this project. These factors could be an inherent bias of the study. Thus, it is uncertain whether the same results could be achieved with nursing staff who have less experience in critical care or who are less motivated in the project. Second, our design was intended to study only the ability of

Experienced intensive care unit nurses are able to detect ineffective inspiratory efforts after special training.

Ineffective triggering may increase respiratory muscle load and length of hospital stay.

trained nurses to detect IEE and says nothing about their ability to solve the problem; therefore, the effects on patients' outcomes remains speculative. Finally, we cannot exclude the risk of bias associated with testing nurses who were aware of the focus of the testing and the lack of similarity of this testing environment to clinical practice.

In conclusion, our study shows that specifically trained staff nurses can detect IEE by monitoring flow and pressure measurements with accuracy similar to the accuracy of highly trained physicians.

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