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EDITORIAL FOCUS

Contact-free respiratory monitoring using bed wheel sensors: a valid respiratory monitoring technique with significant potential impact on public health

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Unexpected death from acute respiratory dysfunction is frequent and preventable. In the United States, opioid-related deaths now represent the highest cause for accidental mortality in adults (8). In infants, the Sudden Infant Death Syndrome is the third leading cause for mortality (8). In the institutional patient care setting, respiratory dysfunction is the most underlying noncardiac cause for cardiac arrest (9) and the second highest cause of death in nursing facilities (4).

What Is Needed to Prevent Unexpected Respiratory Catastrophes?

Early diagnosis of critical respiratory events is important to prevent unexpected death from acute respiratory dysfunction such that the appropriate treatment of the respiratory failure can be provided. Survival rates of cardiac arrest are doubled on hospital wards when continuous respiration monitoring is used (9), and an increased frequency of patient monitoring on the hospital ward decreases mortality. As a single physiological variable, respiratory rate is a relevant early marker of predicting respiratory deterioration and cardiac arrest (3).

Sadly, respiratory rate may be the most poorly monitored vital sign in the general hospital ward (7). In this issue of the *Journal of Applied Physiology*, Isono et al. (5) provide important new information indicating that respiratory rate can reliably be assessed in a wide range of patients with a high risk of respiratory arrest who do not carry respiratory measurement equipment. Many preventable deaths occur when patients are resting in their beds. The beauty of the new method lies in the integration of four pairs of strain-gauge load sensors under the bed legs, tracking the weight shift of the abdominal organs during respiration along the longitudinal axis of the bed. The authors have validated their method in 16 healthy subjects of normal body weight; they examined a wide range of respiratory rates and positions (supine and left and right lateral as well as 30, 45, and 60° sitting). Comparing a total of 4,633 breaths measured by the Isono method (5) and pneumotachography, the authors applied linear regression analysis and Bland-Altmann plots. A bias of 0.17 (95% confidence interval 0.12; 0.22) breath/min was identified, which is likely not clinically meaningful. Importantly, bias and precision were not modified by changes in body position to the 60° elevated upper position, although the signal along the longitudinal axis of the bed is decreased when the patient is sitting, suggesting a high sensitivity of the method.

Additional data will demonstrate whether the bed sensor technology can be used as a surveillance device in patients at high risk of respiratory arrest. Analysis of data from patients with a wide range of body weights and heights will help identify a reliable minimum detectable weight shift. Furthermore, patients with obstructive sleep apnea will have to be examined; obstructive sleep apnea is hard to identify by any method that is based on analysis of chest movement. Disease entity-based alarm thresholds may then be implemented and tested to address the issues of high-alarm frequency and alarm fatigue.

How Does the Isono Method Compare with Other Available Methods?

Alfred Fleisch presented the pneumotachograph in 1925 (3a); his method is still considered the "gold standard" of respiratory monitoring. However, the technique requires a well-trained examiner and high patient compliance. In 1978, measurement of end-tidal carbon dioxide concentration by capnography was introduced in the US, a method initially used to distinguish esophageal from tracheal intubation. In patients who are not tracheally intubated, pneumotachography and end-tidal CO_2 monitoring are vulnerable to artifacts, and ideally, both methods require a sealed full-face or nasal mask interface or, at the very minimum, a gas inlet in proximity to the patient's nostrils or mouth such that respiratory rate can be measured. Chest wall impedance or diameter can also be used to assess respiratory rate either via ECG electrodes (2), a respiratory belt containing strain gauge sensors, or a piezoelectric sensor (6). Finally, photoplethysmography (2) and oscillometry (signal acquisition via a blood pressure cuff) as well as acoustic analysis of breathing (10) have been used.

The Isono bed sensor method adds value since patients do not feel any discomfort and may not even recognize monitoring of their breathing, whereas other validated respiratory monitoring methods require a cooperative patient who accepts the attached interfaces. Impaired cognitive function and hyperactive delirium are common in patients who present with high risk of respiratory death; patients often remove the measurement equipment attached to their body to increase respiratory safety. Acoustic respiratory monitoring methods may not need to be directly attached to a patient's body, but the method is

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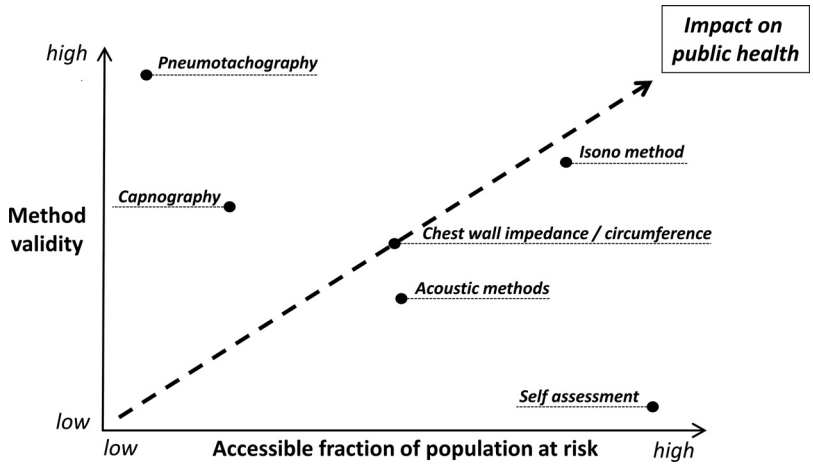

Fig. 1. Potential impact of respiratory function monitoring strategy on public health. Potential impact of a respiratory monitoring technique on public health is a function of the fraction of the targetable population at risk for respiratory abnormalities and the physiological validity of the method (black dashed line).

sensitive to high background noise levels, which limits its clinical use.

Because of the inevitable conflict between accuracy and invasiveness of respiratory monitoring techniques (1), there are only a few methods that allow for respiratory function monitoring outside of an acute care setting, where respiratory rate surveillance has a high impact on public health (see Fig. 1). Because the Isono method requires a minimum level of patient cooperation, measurements can be obtained in skilled nursing facilities, patient homes, and hospices.

In summary, the bed sensor method used by Isono et al. (5) to assess respiratory rate has a high potential impact on public health. Its applicability to a large population at risk for respiratory dysfunction combined with a high validity in comparison with pneumothachography warrants further examination in disease entity-based subgroups of patients with respiratory diseases.

DISCLOSURES

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AUTHOR CONTRIBUTIONS

M.S.S. and M.E. drafted, edited, and revised the manuscript, prepared figures, and approved the final version of the manuscript..

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