External validation in an intermediate unit of a respiratory decompensation model trained in an intensive care unit

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Background. *Preventing urgent intubation and upgrade in level of care in patients with subclinical deterioration could be of great utility in hospitalized patients. Early detection should result in decreased mortality, duration of stay, and/or resource use. The goal of this study was to externally validate a previously developed, vital sign-based, intensive care unit, respiratory instability model on a separate population, intermediate care patients.*

Methods. *From May 2014 to May 2016, the model calculated relative risk of adverse events every 15 minutes (*n *= 373,271 observations) for 2,050 patients in a surgical intermediate care unit.*

Results. *We identified 167 upgrades and 57 intubations. The performance of the model for predicting upgrades within 12 hours was highly significant with an area under the curve of 0.693 (95% confidence interval, 0.658–0.724). The model was well calibrated with relative risks in the highest and lowest deciles of 2.99 and 0.45, respectively (a 6.6-fold increase). The model was effective at predicting intubation, with a demonstrated area under the curve within 12 hours of the event of 0.748 (95% confidence interval, 0.685–0.800). The highest and lowest deciles of observed relative risk were 3.91 and 0.39, respectively (a 10.1-fold increase). Univariate analysis of vital signs showed that transfer upgrades were associated, in order of importance, with rising respiration rate, rising heart rate, and falling pulse-oxygen saturation level.*

Conclusion. *The respiratory instability model developed previously is valid in intermediate care patients to predict both urgent intubations and requirements for upgrade in level of care to an intensive care unit. (Surgery 2016;■:■-■.)*

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Since at least the 1970s, there has been an interest in the correlation between cardiorespiratory vital signs and severity of illness.[1] For the past 10 years, physicians have used decreasing heart rate variability as an indicator of increasing severity of illness and increasing likelihood of mortality in trauma patients.[2,3] While the ability to stratify patients is appealing, even more useful would be the prediction of adverse events hours earlier, providing lead time for interventions that may *prevent* morbidity and mortality.

Multiple, well-known aggregate weighted predictive models are available, such as the National Early Warning Score and Modified Early Warning Score for early identification of deterioration in an acute care ward and the Acute Physiology and Chronic Health Evaluation (APACHE) IV for predicting intensive care unit (ICU) mortality.[4-6] These scoring systems use various static collections of vital sign data and other parameters (such as serum electrolytes and blood counts) on ICU admission to predict which patients will be more likely to deteriorate.[6]

Another such model, developed by Póvoa et al,[7] uses intermittent data from biomarkers like serial C-reactive protein measurements to predict the development of ventilator-associated pneumonia (VAP) in mechanically ventilated patients. Static values from serum laboratory testing, however,

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are often not readily available and may pose a barrier to the utility of predictive models in dynamic patient populations.

An example of a *continuous* predictive model, which uses convenient and immediately available bedside monitoring data, is the heart rate characteristics index score in neonates. This model directs early diagnosis of sepsis and allows for early intervention.[8,9] A multicenter, randomized controlled trial demonstrated that simply displaying the heart rate characteristics index resulted in a decreased mortality for very low birth weight infants by >20%.[9]

The idea of predicting a preventable adverse event with continuous monitor data has since been implemented in the adult world. Politano et al,[10] analyzed vital sign data and waveforms (heart rate [HR], respiratory rate [RR], and pulse-oxygen saturation [SpO_2]) from 798 adult patients in the surgical intensive care unit in an attempt at early detection of respiratory decompensation. From these analyses, a multivariate model was developed and validated that predicts the risk of intubation in an ICU level patient in the next 8 hours.

Patients in ICUs are already at the highest level of care available within a given institution and enjoy the highest nurse-patient ratio and the most frequent observation. A great benefit of the respiratory instability model would be an ability to identify subclinically deteriorating patients within a *lower* acuity unit where personnel and opportunities for direct observation are scarcer.

In hospitals across the United States, ICUs differ from intermediate care units (IMU) in that the former often possess in-unit respiratory therapists and higher nurse-patient ratios (as high as 1:1). As such, lower acuity units are vulnerable to the factors that lead to preventable adverse events: poor and intermittent clinical monitoring, failure to appreciate clinical urgency, and resultant failure to initiate preventive therapies.[11,12] Therefore, the ability to generalize the respiratory instability model developed by Politano et al[10] to the IMU setting and identify patients at early stages of respiratory decompensation could allow for early interventions that prevent unplanned intubations and prevent upgrades in care.

We hypothesized that this model, which was developed and trained in an ICU population, could also be used to predict respiratory decompensation and a requirement for an upgrade in level of care for patients in an IMU.

METHODS

Study design. This retrospective study, spanning May 2014 through May 2016, was conducted in a tertiary-care level 1 trauma center with a 12-bed combined SIMU. All patients were managed by teams of board-certified surgical intensivists, residents, and nurse practitioners. All SIMU beds were connected to continuous physiologic monitoring systems and an electronic data warehouse that archives the complete medical record.

Primary end points were times of intubation for respiratory decompensation and times of transfer or discharge from the SIMU. Events and nonevents were automatically identified from records derived from the University of Virginia Data Warehouse. Individual patient records were then systematically reviewed, which allowed us to confirm documented episodes of respiratory decompensation requiring urgent, unplanned intubation.

We used the Transparent Reporting of a multivariable prediction model for Individual Prognosis or Diagnosis statement checklist in analyzing and reporting this study.[13] The University of Virginia Institutional Review Board approved this study with a waiver of informed consent.

Study populations and outcome definitions. Inclusion criteria were defined as any patient over age 17 who was admitted to the SIMU for at least 6 hours within the noted study period. Admissions without archived physiologic monitoring data due to technical complications were excluded.

We identified events such as urgent intubation, upgrade to ICU, and downgrade/discharge through chart reviews of individual patient electronic medical records (EMR) for a given hospital admission. The date, time, and urgency for intubation events were recorded, in addition to the time and location of bed transfer. Elective intubations occurring at the time of an elective procedure or within the operating room were not recorded as urgent intubation events. Previous episodes of urgent intubation occurring prior to SIMU monitoring were recorded but not taken into account in categorizing the upgrade. Tracheostomy placement events were also recorded but did not occur at time of upgrade and thus were not taken into account. Code status was noted for each patient within 24 hours of upgrade to identify Do Not Intubate (DNI) orders, but these patients were not excluded from analyses.

Physiologic data acquisition and predictors. All SIMU beds are connected to a GE Carescape Gateway continuous bedside monitoring system

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