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# The use of the pulse oximetric saturation to fraction of inspired oxygen ratio in an automated acute respiratory distress syndrome screening tool☆,☆☆,★

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ABSTRACT

*Purpose:* To determine the relationship between the pulse oximetric saturation to fraction of inspired oxygen (SF) ratio and the arterial partial pressure of oxygen to the fraction of inspired oxygen (PF) ratio, and to assess the usefulness of the SF ratio in an automated acute respiratory distress syndrome (ARDS) screening tool.
*Material and methods:* This was a retrospective cohort study using the Multiparameter Intelligent Monitoring in Intensive Care II database. The relationship was derived and validated in all patients ventilated for at least 24 hours.
*Results:* The total data set included 7544 paired measurements from 3767 intensive care unit admissions. The correlation between SF ratio and PF ratio in the whole data set was good (Spearman $\rho = 0.72$, $P < .001$). An automated ARDS diagnostic tool using the derived SF cutoff had excellent agreement with the same tool using the PF ratio of 300 ($\kappa = 0.87$).
*Conclusion:* The SF ratio may be an adequate substitute for the PF ratio in an automated ARDS screening tool.


## 1. Introduction

Acute respiratory distress syndrome (ARDS) is a condition that carries a mortality rate in excess of 30%. This condition affects approximately 190 000 people yearly and is associated with 74 500 deaths in the United States [1]. The mainstay therapy for ARDS is the use of low tidal volume ventilation, which reduces mortality by 28% and has a number needed to treat of 11 [1,2].

Diagnosis of ARDS relies on obtaining an arterial blood gasometry and calculating the relation between the partial pressure of oxygen ($Pa{O_2}$) and the fraction of inspired oxygen ($F{IO_2}$), known as *PF ratio* [3]. A review of the literature suggests that ARDS is underdiagnosed and low tidal volume ventilation is underused [4–6]. Some have speculated that a reluctance to obtain an arterial blood gasometry through an invasive procedure or an intraarterial catheter, which has inherent risks, may contribute to the underdiagnosis [7,8].

The ratio between the pulse oximetric saturation ($Sp{O_2}$) and $F{IO_2}$ (SF ratio) has been shown to have a good correlation with the PF ratio in patients with ARDS, pediatric intensive care unit (ICU) patients, and patients undergoing general anesthesia [9–11]. This correlation has not been examined in adult critically ill ventilated patients in the ICU who have not been previously diagnosed with ARDS. The SF ratio has also not been tested as part of a criteria to diagnose or screen for ARDS. We aim to derive and validate the correlation between SF ratio and PF ratio in an unselected population of mechanically ventilated ICU patients and to test the performance of an automated surveillance tool.

## 2. Materials and methods

This is a retrospective cross-sectional analysis of data from the Multiparameter Intelligent Monitoring in Intensive Care II database. Our institutional review board exempted the study. The database and its data acquisition process have been described previously in the literature [12]. In summary, the database contains demographic data; medications; drip rates; laboratory results; procedure codes; *International Classification of Diseases, Ninth Revision* codes; Diagnosis-Related Group codes; free-text notes; physiological data validated by a nurse and other directly uploaded by the bedside monitor; information entered on the chart such as ventilator settings; provider order entry; and other parameters commonly monitored in ICU. The current version includes 32 536 patients, spanning 7 years, from 2001 to 2008.

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### 2.1. Patients and measurements selection

We included all critical care patients in the Multiparameter Intelligent Monitoring in Intensive Care II database who were at least 18 years old and were mechanically ventilated, irrespective of diagnosis. We considered a patient to be mechanically ventilated if a "ventilation mode" was recorded in the patient's chart. When patients had more than one ICU admission, each admission was included as a separate observation.

The measurements used in this study are part of the physiological data automatically uploaded by the bedside monitor to a central database. Venous and arterial blood gases are labeled separately in the database. All $Pa_{O_2}$ measurements recorded were matched to the following: (1) the closest $Sp_{O_2}$ value recorded in the patient's chart within a maximum of 10 minutes, (2) the last $F_{IO_2}$ preceding each $Sp_{O_2}$ measurement occurring within 30 minutes and (3) the last positive end-expiratory pressure (PEEP) recorded before the $Pa_{O_2}$ measurement. The PF and SF ratios were calculated for each pair of matched $Pa_{O_2}$ and $Sp_{O_2}$ with the same $F_{IO_2}$. The $F_{IO_2}$ labeling separates oxygen delivered by the ventilator from others, like nasal cannula or facemask. By selecting only measurements obtained within 30 minutes of an $F_{IO_2}$ entry, we are ensuring that most of these were recorded during mechanical ventilation.

To better understand the accuracy of the SF ratio calculated from these measurements, we compared them with the SF ratio calculated from oxygen saturation reported on the paired gasometry reading (within 10 minutes).

Because the oxygen hemoglobin dissociation curve is flat after 97% saturation, $Sp_{O_2}$ values greater than that threshold were excluded. Also excluded were measurements taken when patients were on less than 5 cm $H_2O$ of PEEP (because this is the minimal amount of PEEP required to make the diagnosis of ARDS), values of $Sp_{O_2}$ less than 85% (because these were relatively rare events, are more likely to represent inaccurate measurements, and should prompt immediate interventions and confirmation with a more accurate measurement, namely, a blood gasometry study), and arterial blood gasometries with $Pa_{O_2}$ values less than 50 mmHg, which could represent mislabeled venous gasometries.

To detect possible ARDS, we used a previously validated automated tool, the "ALI Sniffer" [13]. In summary, to be detected as having ARDS, a patient needs to have both a PF ratio equal to or less than 300 and a chest radiograph showing bilateral opacities in a 24-hour period. To detect bilateral opacities, the free-text entry from the chest radiograph report is searched for (1) the word *edema* or (2) a combination of the words *bilateral* AND *infiltrate*.

### 2.2. Statistical analysis

We describe normally distributed continuous variables as means and standard deviations and nonnormally distributed variables as medians and interquartile ranges. Proportions and percentages were used to describe categorical variables. The patients were divided into 2 groups, on a 60/40 ratio, to create a derivation and a validation set, respectively. Correlations were analyzed by Spearman analysis for nonnormally distributed variables, and agreement was measured using Cohen $\kappa$.

As PF and SF ratios were not normally distributed, for the linear regression, they were transformed Log10(PF) and Log10(SF), respectively. The relationship of the transformed variables was analyzed using mixed-effects model to account for multiple measurements per patient. The cutoff values obtained from the mixed effects model were validated against all, the first, the last, and the worst measurement(s) for each subject. This approach was used to ensure that the test performed similarly when using multiple or only one measurement(s) per patient.

The agreement in the detection of possible ARDS applying a validated method for clinical database surveillance, the ALI Sniffer, using both PF and SF ratios was assessed [13]. The test characteristics (sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios) of the new method were defined using the previously validated method as the criterion standard. Again, the results were validated using all, the first, and the last measurement(s) and the worst $Pa_{O_2}$ measurement for each patient. Using the SF ratio cutoffs equivalent to 200 and 100 of PF ratio, we calculated the mortality in each of the severity groups defined in an effort to test the prediction capability of this new construct. Because an SF cutoff that is numerically the same as the currently used PF ratio cutoff would likely be easier to remember and because the results from previous studies yielded SF ratios that were close to that value, the SF ratio 300 was also tested as the cutoff in the automated tool [9–11].

Finally, we repeated this exercise using the cutoffs proposed by previous studies [9–11].

Statistical analysis was conducted using STATA 13 (StataCorp, College Station, TX). *P* values $< .05$ were considered to be statistically significant.

## 3. Results

We obtained 7544 measurements (matched $Pa_{O_2}$-$Sp_{O_2}$) from 3767 ICU admissions (Fig. 1). Patient demographics are shown in Table. The derivation data set consisted of 2225 ICU admissions and 4604 paired measurements, and the validation data set consisted of 1512 admissions and 2940 paired measurements.

Oxygen exchange dysfunction was a common problem in the included observations, with 88% having a PF ratio equal to or less than 300, 62% having to or less than 200, and 15% having to or less than 100 (Fig. 2). Applying the ALI Sniffer using the PF ratio, 51% of the all patients were identified as having ARDS. Of the former, 29% were identified as mild, 54% as moderate, and 17% as severe ARDS, as defined by the Berlin criteria [3].

The SF ratios calculated using the $Sp_{O_2}$ values were closely correlated with the ones calculated using oxygen saturations from blood gasometry (Spearman 0.95). Their relationship is represented in Fig. 3.

The correlation coefficient between SF and PF ratios was 0.72 (Fig. 4). The area under the curve on receiver operating characteristic analysis was 0.73, 0.84, and 0.95 for PF ratios less than 300, 200, and 100, respectively. The equation obtained from the mixed effects model that described the relationship between SF and PF ratios was Log10(PF

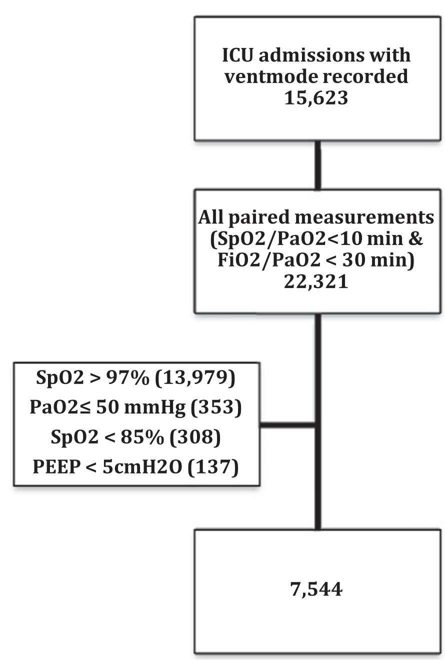


**Fig. 1.** Flow diagram of the measurements selection process.