SpO₂/FiO₂ as a predictor of non-invasive ventilation failure in children with hypoxemic respiratory insufficiency

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Abstract. Generally, monitoring of hypoxemia has been always based on partial pressure of arterial oxygen to fraction of inspired oxygen ratio; recently it was confirmed a good correlation between this ratio and a non-invasive alternative ratio of oxygen saturation to fraction of inspired oxygen (SF ratio = SpO₂/FiO₂). The SF ratio has been studied and validated, especially in the intubated patients, however studies monitoring patients treated with non-invasive ventilation (NIV) are lacking. The aim of the study was to determine if the SF ratio is a reliable predictive factor for failure of NIV in pediatric patients diagnosed with hypoxemic acute respiratory failure due to pneumonia. A five year retrospective study with consecutive sampling of patients diagnosed with hypoxemic acute respiratory failure due to pneumonia, admitted to the pediatric intensive care unit in a university hospital and treated with NIV was conducted. Physiological and ventilator variables were collected before starting NIV and at 2, 8 and 12 hours of treatment, and the corresponding SF ratios calculated. Thirty-four patients were studied. NIV failed in seven patients. Significant differences in SF ratio were observed between the successful and unsuccessful patients at the onset, 2 and 12 hours of treatment. Multivariable analysis revealed the SF ratio at two hours to be an independent predictor of NIV failure (odds ratio = 0.96, 95% confidence intervals 0.93–0.99; $P = 0.015$). Area Under Receiver Operating Characteristic curve = 0.90 (95% confidence interval = 0.79 to 1.000), optimal cut off value for SF at 2 hours ≤ 189 ; sensitivity = 86%, specificity = 74%. In conclusion, the SF ratio of 189 or less at 2 hours of NIV seems to be useful for predicting NIV failure in this cohort.

Keywords: Pneumonia, non-invasive ventilation, acute hypoxemic respiratory failure, acute respiratory distress syndrome, intensive care unit, child

1. Introduction

In children, non-invasive ventilation (NIV) has been proven useful for treating hypoxemia and avoiding intubation [1,2]. Research on adults with hypoxemic

acute respiratory failure (ARF) has revealed independent predictive factors for NIV failure, including a ratio of partial pressure of arterial oxygen to fraction of inspired oxygen (FiO₂) (PF ratio) [3]. To date, the following factors have been reported in pediatric patients as predictors of NIV success after one hour of treatment: significant decrease in heart rate (HR) and in respiratory rate (RR) [4]; marked improvement in the PF ratio [1]; and decrease in FiO₂ [5]. On the contrary,

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the following values and diseases have been described as predictors of NIV failure: average airway pressure greater than 11.5 cm H₂O and FiO₂ greater than 0.6 [6]; type I ARF [7]; acute respiratory distress syndrome (ARDS) [8]. Measurement of systemic oxygenation with pulse oximetry has become a standard of care, and has likely led to a decrease in arterial blood gas measurements. As a result, some children with moderate hypoxemia who meet criteria for ARDS based on documented partial pressure of arterial oxygen values may be under diagnosed and treated with NIV. According to available evidence, intubation should not be delayed for these patients [9]. The ratio of oxygen saturation (SpO₂) to fraction of inspired oxygen (SF ratio), was proposed as a non-invasive marker for identifying adult patients with acute lung injury or ARDS [10] and a simple predictor of NIV failure in critically ill adult patients [11]. Its role in identifying pediatric patients with acute lung injury or ARDS has been documented [9,12]. Recently, it has been proposed as a simple predictor of NIV failure in critically ill adult patients [11]. The aim of this study was to determine if the SF ratio within the initial few hours of treatment is a reliable predictive factor for NIV failure, and whether it is useful to identify ARDS in pediatric intensive care unit (PICU) patients with hypoxemic ARF due to pneumonia.

2. Materials and methods

With the approval of our institutional review board (Research Ethics Committee Fundació Sant Joan de Deu), consecutive sampling was conducted on all admitted patients diagnosed with hypoxemic ARF due to pneumonia who were treated between January 2005 and December 2009 with NIV in a 14-bed general PICU at Hospital Sant Joan de Deu (Barcelona, Spain). Based on Centers for Disease Control and Prevention criteria [13], pneumonia-type ARF was defined as the combination of clinical and laboratory signs, and parenchymal condensation on chest X-rays, with type I (hypoxemic) cases classified according to the modified criteria of Teague [14]. NIV comprised either continuous positive airway pressure (CPAP) or bilevel positive airway pressure (BLPAP) [15,16].

2.1. Inclusion criteria

Children with respiratory failure due to pneumonia that met at least one of the following conditions;

(a) Documented hypoxemia (defined as requiring FiO₂ > 35% to maintain SpO₂ > 95%) or severe dyspnea at rest, (b) RR > 2 SD of normal range for child's age [17].

2.2. Exclusion criteria

Exclusion criteria were as follows; (a) NIV given as palliative care or tracheostomized patients, (b) Conventional mechanical ventilation previously given during admission, (c) Low oxygen requirements (FiO₂ < 35% to maintain SpO₂ > 95%), (d) SpO₂ > 97% (because the oxyhemoglobin dissociation curve remains constant > 97%) [9], (e) Clinical data suggesting inaccuracy of pulse oximetric measurement (using vasoactive drugs), (f) Contraindications to NIV support were cardiorespiratory arrest, hemodynamic instability despite fluid load and vasoactive treatment, Glasgow coma scale score under 10, facial deformity, facial trauma or surgery, vocal cords palsy, bullous pneumopathy, pneumothorax, endotracheal intubation to manage secretions or airway protection and upper gastrointestinal tract active bleeding.

2.3. NIV equipment

The interface was chosen depending on the child's age; oral-nasal Performtrak (Respironics®) (preferred for children older than 18-month) or Mirage (Resmed®) (older than 6-year); nasal employed as oronasal Profile gel (Respironics®) (in infants younger than 18-month, since no age-specific oronasal interface was available for this group) or nasal (which was used as a second choice in patients for whom the oronasal interface proved unsuitable) [18]. The interface was first attached to the patient's face, and then fastened using pediatric headgear. Hydrocolloid dressings (Comfeel, Coloplast®; Peterborough, Cambridgeshire, UK.) were placed at the points of greatest pressure to prevent skin breakdown. From 2007 onwards, a heated humidifier (Fisher Paykel Healthcare, Auckland, New Zealand) was used in all cases. Ventilators used were BiPAP® Vision® (Respironics®, Pittsburg, PA) and Carina® (Dräger, Lübeck, Germany) since 2009.

2.4. Ventilation strategy

Ventilation was administered according to the protocol of the "Spanish Society of Pediatric Intensive Care" [18]. For CPAP, the startup parameters were

4–5 cmH₂O, and for BLPAP modes, an inspiratory positive airway pressure of 6–8 cmH₂O and an expiratory positive airway pressure of 4 cmH₂O were used and increased to an effective value within 5 min according to respiratory needs. BLPAP was selected for patients with higher respiratory rate and using accessory inspiratory muscles. If no improvement in SpO₂ was observed, then expiratory positive airway pressure was increased up to 10 cmH₂O. The pressure support (PS) was increased if the clinician considered the inspiratory volume to be inadequate, with a maximum inspiratory positive airway pressure of 22 cmH₂O. NIV was withdrawn and intubation performed when any of the following signs of treatment failure were observed: SpO₂ < 85%; venous pCO₂ > 65 mmHg despite maximum NIV settings; progressively worsening clinical signs of work of breathing. NIV was excluded if any of the exclusion criteria appeared.

2.5. Monitoring

All patients were continuously monitored by pulse oximetry (Siemens Sirecust 1280, North Rhine-Westphalia Germany), and for HR and RR. The measurements of the corresponding values were routinely recorded once they were stable. SF calculation was performed retrospectively with data collected prospectively. Arterial blood gas analysis was performed only when deemed necessary by the physician.

2.6. NIV results

NIV was considered successful if intubation was not required; contrariwise, failure was interpreted as the need for intubation. The efficacy of NIV was quantified by dividing the number of patients who avoided intubation by the number of patients treated with NIV.

2.7. Data collection

The following variables were collected for each patient: age, gender and underlying disease; length of stay in the PICU and in the hospital; Pediatric Risk of Mortality (PRISM II) score; duration of NIV (hours); pre-NIV pO₂, pCO₂ and pH when available; interface, ventilator and ventilation mode used. Physiological and ventilator variables were collected before starting NIV and at 2, 8 and 12 hours of treatment; and the

corresponding SF ratios calculated. NIV initial (SF at zero hour) is at the time of establishing NIV. The SF ratio values were correlated to respiratory conditions according to equivalent values of the PaO₂/fraction of inspired oxygen ratios published [9]. Thus, a SF ratio value of 201–263 at two hours indicated mild ARDS [10]; and a value below 201 at two hours, in patients with bilateral pulmonary infiltrates on their chest X-rays, indicated moderate or severe ARDS. The pre-NIV FiO₂ was estimated based on the following values for each oxygen delivery system: nasal prongs (1 lpm: 24%; 2 lpm: 28%; 3 lpm: 32%); Venturi mask (6–9 lpm): 24 to 50% (indicated on the mask itself) and reservoir mask (10 lpm or greater): 90% [19]. Complementary data comprised blood gas measurements and chest X-rays on admission (reviewed by three senior PICU physicians and classified according to Murray's index [20]).

2.8. Statistical analysis

Data were analyzed using SPSS version 17.0 (SPSS Inc, Chicago, IL). Before initiating NIV; age, gender, underlying diseases, RR, HR, SpO₂, FiO₂, SF ratio, pH, pCO₂, PRISM II were measured in the whole sample, and compared between the final successful and failed NIV groups. Qualitative variables were expressed in percentage and compared using the Chi-square test. Continuous variables were described with the mean ± SD or the median and interquartile range, and compared with the Student's *t*-test, or Mann-Whitney *U* test where appropriate. Survival time variables were described using median time and Kaplan-Meier graphs, and compared using the Log-Rank test. For all statistical analyses, a *P* value <0.05 was considered statistically significant, and 95% confidence intervals (CI) were calculated. SpPIN (specificity 100%, lowest value without NIV failure) and SnNOUT (sensitivity 100%, highest value with NIV failure) values for SF ratio at two hours were described. To identify independent predictors of NIV failure, a multivariate logistic regression model was adjusted using a forward stepwise procedure based on likelihood ratio (enter probability *P* < 0.05). Data obtained from measurements before NIV was started and at 2, 8 and 12 hours treatment was analyzed. Variables having *P* < 0.2 in the univariate analysis and/or those considered clinically important for controlling confusion were included at the beginning of the multivariate analysis. The effect of the variables included in the final model was estimated using the odds ratio (OR), with 95% CI. The calibration of the final model

was evaluated (Hosmer-Lemeshow test), and its diagnostic accuracy was assessed with Receiver Operating Characteristic curve analysis, using optimal cutoff values for computing the sensitivity, specificity and likelihood ratios for a positive (LR positive) and a negative (LR negative) value (with 95% CI) [21]. To confirm the results, a Cox regression was adjusted with the survival time variables, and the hazard ratios (HR) were computed at 95% CI, using forward stepwise analysis (enter $P < 0.05$).

3. Results

3.1. Descriptive study

The study period encompassed 491 episodes when NIV was used in the PICU registry. Valid cases included all hypoxemic episodes due to pneumonia, which received NIV at the onset of ARF. Twenty-eight patients were excluded due to having $\text{SpO}_2 > 97\%$ or low oxygen requirements (Fig. 1). The overall baseline characteristics of the final 34 patients are shown in Table 1. The evolution of clinical parameters is summarized in Table 2 and Fig. 2.

3.2. Ventilation modes, ventilators and interfaces

Among the ventilators, the most frequently used was the BiPAP Vision® (Respironics; Pittsburg, PA) (33 patients; 97%). One patient used Carina® Dräger; Lübeck). All of our patients received BLPAP. The most

widely applied ventilation mode was S/T (spontaneous/timed) (33 patients; 97%), two patients started respiratory support with CPAP but were switched to S/T. PS was used in one patient; (3.0%). All except one patient used oronasal interfaces.

3.3. Chest X-ray (evaluation)

Evaluation of the CXRs at admission revealed bilateral abnormalities in 20 patients but only five patients with abnormalities in all four-quadrants. The patients' Murray score showed no correlation with NIV failure. For diagnostic purposes, the combination of SF values at two hours and CXR findings resulted in the diagnosis of one severe, 17 moderate and eight mild ARDS cases.

3.4. Efficacy analysis

NIV was successful in 27 cases (79.41; 95% CI = 64.35 to 94.47) and failed in seven cases (six with worsening or increase in respiratory muscle load and one hypoxemic). Patients with CPAP or PS did not fail.

3.5. Predictive factors for NIV failure

The following variables were included at the beginning of the multivariate logistic regression analysis: age; PRISM II score, RR and SF at two hours NIV; and a binary variable identifying ARDS diagnosis. The final model ($-2LL = 20.76$; R squared = 0.33) was well

Fig. 1. Flow chart of patients and episodes included in the study and their classification into different groups.

Table 1

Baseline characteristics and outcome variables of the patients treated with NIV, plus clinical and laboratory variables for the successful and failed NIV groups (including pre-treatment values and *P* value)*

Variables	Whole Sample (n = 34)	Success group (n = 27)	Failure group (n = 7)	<i>P</i> value**
Males (%)	58	63	43	0.295
Age (months)	52 [18; 119]	59.6 [18.8; 120]	32.5 [14; 80]	0.320
Pediatric risk of mortality score	5.4 ± 3.7	4 ± 2.9	7 ± 5	0.015
Pre-NIV FiO ₂	50 [50; 68.75]	50 [40; 50]	50 [50; 100]	0.308
Pre-NIV SpO ₂	94 ± 4.1	93 ± 3.67	90 ± 4.5	0.359
Pre-NIV respiratory rate	44 ± 16.2	44 ± 16.3	50 ± 11.8	0.973
Pre-NIV heart rate	141 ± 24.6	140 ± 26.5	145 ± 17	0.516
Pre-NIV SF	182 ± 67	203.21 ± 81.18	172.3 ± 85.46	0.112
Pre-NIV venous pCO ₂	39 [35.5; 45]	42 [35; 46]	37 [36.5; 43.2]	0.290
Pre-NIV pH	7.37 [7.33; 7.4]	7.37 [7.33; 7.4]	7.44 [7.28; -]	0.329
Pediatric intensive care unit stay (days)	6 [3.75; 10.25]	5 [3; 8]	17 [5; 22]	0.019
Hospital stay (days)	12.5 [9; 21.5]	12 [9; 15]	23 [16; 31]	0.048
NIV time (h)	62 [32; 140]	88 [43; 144]	15 [2.5; 32]	0.001
Underlying disease				
Neuromuscular****	3 (8.8%)	2	1	0.760
Cancer*****	2 (5.8%)	2	0	
Others*****	12 (35.4%)	10	2	
None	17 (50%)	13	4	

*Age is expressed as median and [P25; P75]; sex as %; and the values of the remaining variables as mean ± SD or median value [P25; P75].

***P* value refers to the comparison between the successful and failed NIV groups.

***Due to the fact that there were only seven failure cases, p75 value is not shown by the statistical program

****Neuromuscular (one myasthenia gravis, two Duchenne muscular dystrophy)

*****Cancer (two hematologic malignancy).

*****Others (one congenital heart disease, two cerebral palsy, one cystic fibrosis, two Prader-Willi syndrome, one Di George's syndrome, one Down syndrome, four miscellaneous)

NIV = non-invasive ventilation; SF = SpO₂/FiO₂.

Table 2

Parameters whose values were significantly different between the successful and failed non-invasive ventilation groups (expressed as mean ± SD or median value [P25; P75])*

Variables	Success group (n = 27)	Failure group (n = 7)	<i>P</i> value
FiO ₂ start	50 [40; 60]	80 [67.5; 100]	0.002
FiO ₂ 2 h	45 ± 12.8	69.3 ± 18.1	0.001
FiO ₂ 12 h	45 ± 16	57 ± 3.6	0.042
FiO ₂ max	55 ± 18	83 ± 15	0.002
SpO ₂ start	97 [95; 99]	95 [89.5; 96]	0.045
SpO ₂ 2 h	97 [95; 98]	95 [92; 95]	0.031
Respiratory rate start	36 [29; 44]	49 [34.5; 56]	0.047
Respiratory rate 12 h	31 [26; 36]	43.5 [42; -]**	0.026
Heart rate 2 h	125 [110; 138]	144 [122; 169]	0.008
SF start	211 ± 70	117 ± 29	0.001
SF 2 h	215 [188; 280]	158 [108; 178]	0.0001
SF 12 h	271 [191; 284]	165 [158; -]**	0.047
Pediatric risk of mortality score	4 ± 2.9 (3.5 to 5.8)	7 ± 5 (3.8 to 13)	0.015
IPAP 2h	13 [12; 15]	17 [15; -]**	0.04

*FiO₂ and SpO₂ expressed in %; IPAP expressed in cmH₂O.

**Due to the fact that there were only seven failure cases, p75 value is not shown by the statistical program

Start = At the time of establishing non-invasive ventilation; Max = Maximum value achieved;

SF = SpO₂/FiO₂; IPAP = Inspiratory positive airway pressure.

Fig. 2. Change in median $\text{SpO}_2/\text{FiO}_2$ ratio for the successful and failed non-invasive ventilation groups. ($\text{SpO}_2/\text{FiO}_2$ ratio = ratio of oxygen saturation to fraction of inspired oxygen; NIV = non-invasive ventilation).

Fig. 3. Optimal cut off value was determined using the left upper corner of the ROC curve for computing the best sensitivity and specificity. The area under the ROC curve of the final model is 0.902 (95% confidence interval = 0.795 to 1.000). (ROC = Receiver Operating Characteristic)

calibrated (Hosmer-Lemeshow $P = 0.91$) and revealed that SF ratio at two hours NIV was the only independent predictive factor (OR for NIV failure = 0.96, 95% CI 0.93–0.99; $P = 0.01$). The area under the Receiver Operating Characteristic curve of the final model is 0.90 (95% CI = 0.79 to 1.00) (Fig. 3).

For SF ratio at two hours NIV, the optimal cutoff value is 189 or less; sensitivity = 86% (95% CI = 71 a 95%); and specificity = 74% (95% CI = 55% to 88%). These values yield an LR positive = 3.3 (95% CI = 1.48 to 3.43) and a negative LR 0.19 (95% CI = 0.07 to 0.48). With this final model accuracy, we can compute a SnNOUT value (sensitivity 100%) and a SpPIN value (specificity 100%): none of the patients who had an SF ratio greater than 191 or lower than 117 at two hours of NIV treatment required intubation or avoided intubation, respectively. Cox regression analysis ($-2LL = 19.19$) also confirmed these results, showing the SF ratio value at two hours of NIV as an independent factor which can be used to indicate the need for intubation for lower values (HR = 0.96; 95% CI = 0.93 to 0.98). The probability of avoiding intubation was evaluated by categorizing the cases according to the criteria for diagnosing categories of ARDS based on degree of hypoxemia with the SF ratio [22]. The results, summarized in Fig. 2, are illustrated in the Kaplan-Meier survival plot (Fig. 4). The difference between mild ARDS and moderate/severe ARDS was statistically significant ($P = 0.002$). Only 50% of moderate/severe ARDS children were intubated in our study.

4. Discussion

Given the ever-increasing number of factors proposed for predicting NIV success or failure, we propose that the SF ratio should be employed as one of primary markers to determine the outcome of patients on NIV. In fact, some authors have argued that the SF ratio should be used as the norm to characterize oxygen impairment, rather than a mere alternative to PF ratio [9]. Although a higher PRISM II score may be predictive factor of NIV failure as it was published by Lum et al. [23] and it was also suggested by our univariable analysis, multivariable analysis selected SF ratio at two hours as the most sensitive variable to identify NIV failure in this small and selected population among hypoxemic patients. Our results suggest that an SF ratio of 189 or less at two hours NIV is a reliable predictor for NIV failure in hypoxemic patients with pneumonia who develop ARDS. This value cannot be considered an immutable value; therefore, we suggest that it, along with other variables, may help physicians determine the need for intubation earlier during the treatment while avoiding routine blood gas sampling. Furthermore, patients should be monitored closely to avoid delays in intubation; some of

Fig. 4. Kaplan-Meier survival plot for the probability of avoiding intubation categorized by $\text{SpO}_2/\text{FiO}_2$ ratio at two hours NIV (moderate-severe ARDS versus mild-ARDS). Log Rank $P < 0.002$. Censored times represent those patients for whom NIV was removed because ARF was resolved. (NIV = Non-invasive ventilation; ARDS = Acute respiratory distress syndrome; ARF = Acute respiratory failure)

our patients in the failure group were very severely hypoxemic (SF under 100) at admission and probably should have treated with invasive ventilation. Although, adult literature supports a one hour NIV trial we believe that NIV should only be considered in PICUs with a wide experience in NIV techniques so that it can be safely administered in an adequately staffed and closely monitored unit [24]. Painful procedures tend to cause crying, which in turn increases patient-ventilator asynchrony, a phenomenon linked to NIV failure [25]. SF ratio at two hours could also be used to identify patients developing moderate and severe ARDS [26], a well-known factor for NIV failure. Patients with an SF ratio at two hours NIV between 117 (SnNOUT) and 191 (SpPIN) may benefit from a more aggressive recruitment strategy, under close monitoring, before deciding to intubate.

Nonetheless, these results are only valid for the study group reported here. Two important limitations of our study are the retrospective data collection and the small population size. In spite of all these limitations, the measurement of the SF ratio has arguably not been influenced. Homogeneity of the NIV treatment in this study was increased by excluding our initial six-year learning curve (126 patients) when a ventilator without oxygen blender (BiPAP S/T-D30 Respironics) was used in some patients. Additionally, it is well known that multivariate analysis depends on

the number of cases that failed, and our study has only seven failures of NIV, hence there is a small patient/variable disproportion in our study that makes 95% CI values more wide, so significance of the P value is reduced, but without changing the central estimator value. Otherwise, we believe that multivariable analysis can be maintained because we obtained the same results using two different multivariate analyses to avoid confusion and biases, which may strengthen our argument despite the small sample size.

Although ARDS has been identified as a predictive variable for failure of NIV in several studies, it didn't appear in our study. In our humble opinion, collinearity could explain for it; collinearity is a well known problem in multivariable analysis, SF ratio being a measurement of hypoxemic patient as ARDS is, it seems to identify better the sickest patients with ARDS that are going to fail. Actually, it makes sense that SF ratio is more sensitive variable than ARDS.

Factors, which could really alter the SF ratio reliability are changes in the hemoglobin dissociation curve (HDS) and the measurement of FiO_2 . HDS could be influenced by fetal hemoglobin, body temperature, pH and pCO_2 . Fetal hemoglobin is predominant after birth, but approximates adult values around six months of age. It shifts the HDS to the left and consequently, young infants exhibit a greater difference between SF and PF

ratios. However, only one patient was younger than six months old. Unfortunately, we could not obtain the latter data due to the scarce use of blood gas analysis in our patients. This should be considered the biggest limitation of our study because the influence of changes in body temperature, pH or PCO_2 on the HDS has not been controlled.

Moreover, the accuracy of SpO_2 measurement also depends on pulse oximeter algorithms [27], so it must be highlighted that different cutoff values could be obtained with different oximeter devices. Finally, it is conceivable that issues such as poor oximeter waveform and patient movement may have affected the accuracy of the measurement. However, as these patients were admitted to a large teaching PICU with a wide experience in oximetry, this is less likely to be a concern.

We must also acknowledge that FiO_2 calculation at admission can be inaccurate, so pre-NIV FiO_2 values could be less reliable than values obtained when breathing through an oronasal interface with a known FiO_2 delivered by the ventilator [28]. For this reason, moderate and severe ARDS diagnosis according to SF ratio criteria was made two hours after treatment with NIV. However, this limitation is also shared with previous NIV studies using PF ratio as a predictive factor for failure [1,3]. The use of NIV in ARDS or severe community-acquired pneumonia is controversial and not recommended routinely [29]. On the other hand, other studies suggest that in expert centers, NIV applied as first-line intervention in ARDS avoided intubation in 54% of treated patients [30]. Only 50% of moderate and severe ARDS children were intubated in our study. Among those patients with SF ratios values lower than 201 at two hours, there is a mixed population of severely hypoxemic patients with unilateral x-ray involvement, patients evolving to ARDS and patients already diagnosed with ARDS. It seems likely that moderate and severe ARDS patients with unilateral x-ray involvement at admission not responding to NIV could be identified earlier with the SF ratio at two hours than waiting for subsequent x-ray ARDS confirmation.

In conclusion, despite the aforementioned limitations about SF ratio measurement, we suggest that the SF ratio at two hours can be used to evaluate the response to NIV in patients with hypoxemic ARF (due to pneumonia) in the PICU. Furthermore, using SF ratio at two hours instead of PF ratio for moderate and severe ARDS diagnosis could be useful for minimizing invasive arterial blood work. This study may

serve as a starting point for further studies about the usefulness of SF ratio in NIV outcome.

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