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Original Article

SF Ratio as an Alternative Marker for PF Ratio in Paediatric Index of Mortality 3 Score at a Tertiary Care Centre

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Abstract

Introduction: Paediatric Index of Mortality 3 (PIM 3) score is a mortality prediction score used in paediatric intensive care units. The PF (PaO_2 / FiO_2) ratio is a component of the PIM 3 score. To obtain the ratio an arterial blood gas would be required. The SF (SpO_2 / FiO_2) ratio provides a less invasive method of monitoring. With this study, we aimed to see if SF ratio can replace the PF ratio component of the PIM 3 score.

Methods: It was a prospective study, where 101 critically ill children were included over a period of 18 months. Data was analyzed by mean, standard deviation (SD), frequency and percentages. Intra class comparison as well as ROC curve analysis was used to test the reliability of SF ratio. PIM 3 scores were obtained using PIM 3 calculators available on standard reference websites. Derived PIM 3 scores were obtained using SF ratio instead of the PF ratio. The two scores were compared.

Results: The mean age in the study was 4.5 years. The mean PF ratio was 281.7 ± 216.7 and mean SF ratio was 297.7 ± 115.8. Maximum mortality was seen in children with PIM 3 score between 10 and 30. The intraclass correlation coefficient was 0.997, interpreted as excellent agreement. The area under the ROC curve for mortality prediction using PIM 3 score was 0.814 and using PIM 3 with SF ratio was 0.819.

Conclusions: SF ratio can be used as a reliable, non-invasive, alternative marker for PF ratio in the paediatric index of mortality score.

Introduction

The Paediatric Index of Mortality 3 (PIM 3) score is one among the different risk scores which are used to rate the severity of medical illness in children admitted to the Paediatric Intensive Care Unit (PICU). It is designed to predict mortality in a systematic manner. It is assessed within one hour of admission. PF ratio is a component of the score. The PF ratio is the ratio of the partial pressure of oxygen in arterial blood to the fraction of inspired oxygen. It is measured from an arterial blood gas (ABG) analysis to quantify the degree of hypoxemia.[1] Non-invasive pulse oximetry is a widely used index of oxygenation in clinical settings. The non-invasive nature of pulse oximetry allows for a more affordable and rapid assessment of hypoxemia.[2] The SpO_2 / FiO_2 (SF) ratio, that is, the ratio of pulse oximetric oxygen saturation to the fraction of inspired oxygen, could improve our information regarding prediction of severity of hypoxemia. It is a more dynamic, simpler, non-invasive method of detection of hypoxemia. It can also be used for continuous monitoring of patients on ventilatory support and allows for a more affordable and rapid assessment.

At present, ABG monitoring lies superior while comparing all the modalities

available for diagnosing and monitoring children requiring oxygen support in the PICU. However, the ABG monitoring has its own limitations, the multiple arterial punctures being the most important of those. Further, ABG analysis facility and trained staff may not be available at all places.

Any reliable non-invasive method would be an ideal technique to monitor the child's condition's progression or worsening. In such a scenario, the SF ratio appears as a reasonable alternative and can be easily calculated under any clinical circumstance.[3] Many a times, a normal PF ratio is substituted in the mortality scores like Paediatric index of mortality 3 when an ABG is not done and PF ratio is not available.[2] SF ratio can be used instead of the PF ratio. However, very little data is available regarding the utility of SF ratio instead of PF ratio in the PIM 3 score. The SF ratio can be obtained without subjecting the child to multiple arterial pricks. Hence, we planned to do this study. Since we analysed a heterogeneous sample, it will allow for the generalization of our results to most paediatric patients in the ICU.

Methods

The study was conducted on one month to 18 years old children admitted to the PICU in a tertiary care centre, requiring oxygen support. It was an observational, descriptive study conducted over a period of 18 months. Ethics committee approval was obtained as per institutional guidelines (Ref no. FMIEC/CCM/725/2020). The minimum sample size was 90, as calculated by the formula -

$$n = \frac{2(Z\alpha + Z\beta)^2}{C^2} + 3$$

However, we included 101 patients. Purposive sampling was done. Written informed consent was obtained from the parents of the children who fulfill the inclusion criteria i.e., children aged between one month and 18 years admitted to the PICU and requiring oxygen support. Children with conditions like methemoglobinemia and in whom ABG was not done, were excluded. Patient details were noted. The ABG sample was drawn as per the protocol on requirement of oxygen support as a part of the management of the illness. SpO_2 and FiO_2 at the time of ABG sampling was noted and documented in a standard proforma. FiO_2 values were noted down from an FiO_2 analyzer, oxygen blenders or mechanical ventilator settings as applicable. The SF ratio was then calculated. The PF ratio was calculated from the ABG reports. The two ratios were then analysed. Data was analyzed by mean, standard deviation (SD), frequency and percentages. To evaluate the reliability, intraclass correlation coefficient (ICC) was used, which is a more desirable measure of reliability and should reflect both degree of correlation and agreement between measurements. Reliability value ranges between 0 and 1, with values closer to 1 representing stronger reliability. Based on the 95% confident interval of the ICC estimate, values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.90 are indicative of poor, moderate, good, and excellent reliability, respectively. Intra class comparison as well as ROC curve analysis was used to test the reliability of SF ratio to be used in place of PF ratio in PIM 3 score. PIM 3 scores were obtained using PIM 3 calculators available on standard reference websites.[4] Derived PIM 3 scores were obtained using SF ratio instead of the PF ratio. The two scores were compared.

Results

We included 101 children in the present study. The mean age of our study population was 4.5 years, the minimum age being 46 days and the maximum being 14 years. We categorised the children into four different age groups, highest number being in the age group of one to five years. Among the 101 children, 55 were males (54.45%) and 46 (45.54%) were females. Central nervous system (43.6%) and respiratory system (40.6%) were the predominant systems involved among these children. Forty one (40.6%) of the critically ill children required invasive ventilation. Of the 101 cases, 82 (81.18%) were discharged, six (5.94%) were discharged against medical advice and 13 (12.8%) died. The mean PF ratio in the study was 281.7 ± 216.7 and ranged from 77 to 863.28. The mean SF ratio in the study was 297.7 ± 115.8 and ranged from 60 to 807. 35.6% of all children had PIM 3 score less than 10, 37.6% children had PIM 3 score between 10 and 20, 11.89% had PIM 3 score ranging from 20 - 30, while another 14.8% children had PIM 3 score more than 30. Out of the 13 deaths, maximum mortality was seen among children with PIM 3 score between 10 and 30, at admission. The comparison of PIM 3 score using PF ratio and PIM 3 score using SF ratio was made using intraclass correlation coefficient as well as ROC curves. In our study, the intraclass correlation coefficient for mortality prediction using original PIM 3 score and PIM 3 score using SF ratio was 0.997 (95% CI 0.996 - 0.998) with a significant p value of < 0.001. This would mean that reliability of the PIM 3 score with SF ratio instead of PF ratio was excellent. The figures depict the ROC curves for the mortality prediction using original PIM 3 score and the PIM3 score using the SF ratio instead of the PF ratio (Figure 1 and Figure 2). Figure 1 depicts the ROC curve for the mortality prediction using original PIM 3 score where the area under the curve was 0.814, 95% CI 0.701 to 0.927.

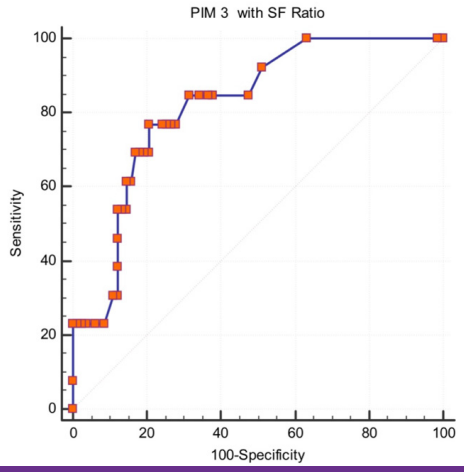

Figure 1: ROC curve for mortality prediction using PIM 3 score

The original PIM 3 at a cut-off of > 5.7 was found to be 76.92% sensitive and 78.05 % specific. This means that any value greater than 5.7 would be a predictor of increased risk of mortality based on the sensitivity and specificity. In case of 100 deaths, 76 can be predicted to have increased mortality risk if the value is more than 5.7 and 78 can be predicted to have a decreased risk of mortality if the score is less than 5.7 (Table 1).

Table 1: Youden index for measuring the effectiveness of the original PIM 3 score

Youden index J	0.5497
Associated criterion	> 5.7
Sensitivity	76.92
Specificity	78.05

Figure 2 depicts the ROC curve for the mortality prediction using PIM 3 with SF ratio instead of PF ratio where area under the curve was 0.819, 95% CI 0.709 to 0.930.

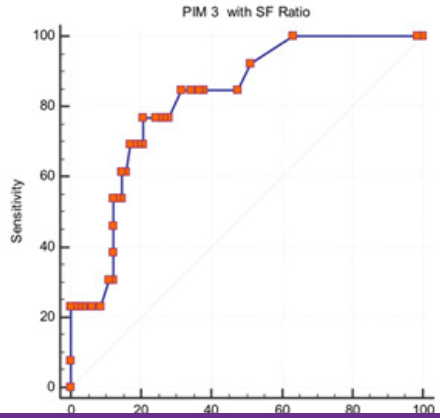

Figure 2: ROC curve for mortality prediction using PIM3 score with SF ratio

The PIM 3 with SF ratio at a cut-off of > 5.1 was found to be 76.92% sensitive and 79.27 % specific. This means that any value greater than 5.1 would be a predictor of increased risk of mortality based on the sensitivity and specificity. In case of 100 deaths, 76 can be predicted to have increased mortality risk if the value is more than 5.1 and 79 can be predicted to have a decreased risk of mortality if the score is less than 5.1 (Table 2).

Table 2: Youden index for measuring the effectiveness of derived PIM 3 score

Youden index J	0.5619
Associated criterion	> 5.1
Sensitivity	76.92
Specificity	79.27

The area under the ROC curve was not different for the two scores. This would mean that SF ratio can be used instead of PF in the score.

Discussion

Our study included 101 children in the age group of one month to 18 years who were admitted to the PICU and required oxygen support. The mean age of our study population was 4.5 years and composed predominantly of males (54.45%). Central nervous system (CNS) and respiratory systems (RS) were the predominant systems involved in the study. Children with CNS diseases formed the majority among the admissions who required oxygen support. The mean PF ratio in the study was 281.7 ± 216.7 and ranged from 77 to 863.28. The mean SF ratio in the study was 297.7 ± 115.8 and ranged from 60 to 807. Maximum number of cases in the study had a PIM 3 score between 10 and 20. 61.4% of the mortality cases had a PIM 3 score between 10 and 30.

Through our study, we wished to see if replacing the PF ratio in the PIM 3 score with SF ratio would significantly change the predicted mortality rate. There are very limited studies that have used the SF ratio instead of the PF ratio in the PIM 3 score. We compared predicted mortality as given by the original PIM 3 score and PIM 3 score using SF ratio instead of PF ratio. The agreement between the two parameters was found to be excellent. The intraclass correlation coefficient for mortality prediction using original PIM 3 score and PIM 3 score using SF ratio was 0.997 (95% CI 0.996 - 0.998) with a significant p value of < 0.001. This would mean that reliability of the PIM 3 score with SF ratio instead of PF ratio was excellent. The area under the ROC curves were also not different for the two scores. This would mean that SF ratio can be used instead of PF in the score.

In our study, we included a heterogeneous sample of children who were critically ill and required oxygen support. This does

not allow for the results to be generalised to other, less sick and non-oxygen dependent patients. However, on the other hand, it also validates the use of SF ratio instead of PF ratio in PIM 3 score in a more heterogeneous population of patients, not limiting its use to patients with ALI / ARDS alone as done in many previous studies. Also, we have looked at the direct utility of the SF ratio in the PIM 3 score, rather than PF ratios imputed from SF ratios.

Most of our study population had a CNS related diagnosis. This was in contrast to the Egyptian study done by Rady et al looking at the profile of PICU patients which showed pneumonia as the commonest cause.[7] Another large study done at Royal Children's Hospital (RCH), Melbourne, found congenital cardiac disease as the commonest cause for the PICU admission followed by respiratory disease.[8] Multiple factors including the geographical distribution, prevalence of epidemics and available healthcare system could be possible reasons for this. Several studies have previously established that SF ratio can be used as a surrogate marker for PF ratio. These include Khemani et al whose study found that SF ratio is a reliable non-invasive marker for PF ratio. However this was in order to identify children with ALI or ARDS.[10] Lobete et al conducted a study in a heterogeneous sample of 298 critically ill children and found that 1 / SF ratio had a strong linear association with 1 / PF ratio in both derivation and validation data sets and that oxygen saturation as measured by SpO_2 / FiO_2 ratio is an adequate non-invasive surrogate marker for PF ratio.[11] Multiple studies similar to these have corroborated that SF ratio can be reliably used as an alternative marker for PF ratio in several varied settings. We aimed to establish its reliable use instead of PF ratio in the PIM 3 score and found positive results.

Our results were consistent with similar studies conducted in other centres. Leteurte et al, in their prospective study in a French PICU suggested that SF ratio could be used in place of PF ratio for calculating Paediatric Index of Mortality 2.[6] Their study was conducted on 1043 patients and they arrived at the above conclusion using PF ratios imputed from SF ratios whereas in this study, we have directly utilized the SF ratio in the PIM 3 score. By directly utilizing the ratio directly, mortality score calculation becomes easier. When utilizing the SF ratios directly in the score, measurements made with SpO_2 above 97% can pose a problem as the slope of the relationship curve between SpO_2 and PaO_2 becomes almost zero and large changes in PaO_2 may result in very little change in SpO_2. This can be overcome by titrating the FiO_2 to maintain SpO_2 levels less than 97%. The statistical analysis used to validate the results were similar in both the studies.

Palaniappan et al in their prospective observational study done in Tamil Nadu in 2017 with sample size of 125 children concluded that SF ratio can be used as a reliable, non-invasive, surrogate marker for PF ratio.[5] However, they only included children with ALI / ARDS and therefore the results are less generalizable. The present study validates the use of SF ratio as an alternate marker to calculate the score, in a more heterogenous population, not limited to ALI / ARDS alone. Slater et al investigated if the performance of PIM 3 is improved by using PF values imputed from SF ratios and found that it improved the discrimination of PIM 3 even though the magnitude of increment was small.[13]

Similar results were found by Ray et al who concluded that SpO_2 based metrics perform no worse than arterial blood gas–based metrics in mortality prediction models.[12] They found that there was no significant difference between the predicted mortality using the original PIM 3 score and the derived score using PF ratio derived from SF ratio. This was a retrospective study in comparison to the prospective nature of the present study. Also, the authors first derived a linear regression equation correlating SF and PF ratios, subsequently imputed PF ratios from the SF ratio and then used it in the score where as we have directly utilized the SF ratio in the score. Due to the retrospective nature of the study, the ABG values and pulse oximetric values may not have been obtained simultaneously whereas this was ensured in the current study. This may contribute to some discrepancies as changes in SpO_2 and PaO_2 happen rather quickly.

Limitations of the study include the small sample size and hence the results cannot be generalized. Further, multicentred studies are required to generalize the results. The data was collected from a single PICU and variables that may affect the relationship between PF and SF like pH, hemoglobin, pCO_2, body temperature, ventilator setup etc were not considered and further studies are required to assess the effect of these variables. Also, the SpO_2 trace may not be reliable in conditions like methemoglobinemia, shock etc.

Conclusions

In conclusion, SpO_2 based metrics perform similar to blood gas based metrics in Paediatric Index of Mortality index 3 score and the SF ratio can be used as a reliable, non-invasive, alternative marker for PF ratio in the Paediatric Index of Mortality score. Even though the original PIM 3 score and PIM 3 score with SF ratio showed excellent agreement, this must nonetheless be confirmed by a larger prospective multicentre study.

Conflict of interest

None declared

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